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SUSTAINABLE DEVELOPMENT AND MULTISECTORAL APPROACHES

Kanchan Arsenic Filter Evaluation and Applicability to Cambodia

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Arsenic contamination of drinking water in rural Cambodia has driven the search for mitigation options. The Kanchan Arsenic Filter for household water treatment is being evaluated for its applicability as one potential solution to this crisis. In 2008, ten Kanchan filters, in 5 configurations, were tested over a 30 week period. Each filter treated 40 L/day. The ground water had arsenic and phosphate concentrations averaging 637 µg/L and 5.09 mg/L respectively, representing challenging source water. Arsenic removal averaged 95-97% for all configurations. After the first week of start up, all but 1 in 224 samples achieved the Cambodian standard of 50 µg/L. Arsenic removal was not significantly affected by the flow rate or the cleaning of the filter. There was no apparent depletion of arsenic adsorption capacity over the 30 weeks (8400 L filtered). Iron and turbidity removals were also very high, improving the user acceptability of this technology.

Introduction

Arsenic contamination in drinking water is a growing crisis in Cambodia especially in rural areas. A recent study that included testing 16,000+ tube wells for arsenic in 7 central provinces bordering the Mekong and Bassac rivers found that an estimated 320,000 rural population in 1600 villages are at risk (MRD and MoH, 2007). Arsenic concentration as high as 1300 µg/L (26 times higher than the Cambodian standard of 50 µg/L) is found south of Phnom Penh (MIME, 2004; Buschmann et al., 2007), where several arsenicosis cases have been confirmed by the Ministry of Health (MRD and MoH, 2007).

There is a strong demand among stakeholders to find effective solutions that are applicable to the rural context in Cambodia. The Kanchan Arsenic Filter (Kanchan filter) is one potential mitigation option.

This paper describes the field research carried out over a 30 week period, Feb 3rd to Aug 24th, 2008 to evaluate the performance and applicability of the Kanchan filter to treat groundwater from one location in Cambodia. The information provided here is part of an ongoing technology evaluation project and will be supplemented by further studies in additional communities plus social assessment for acceptability.

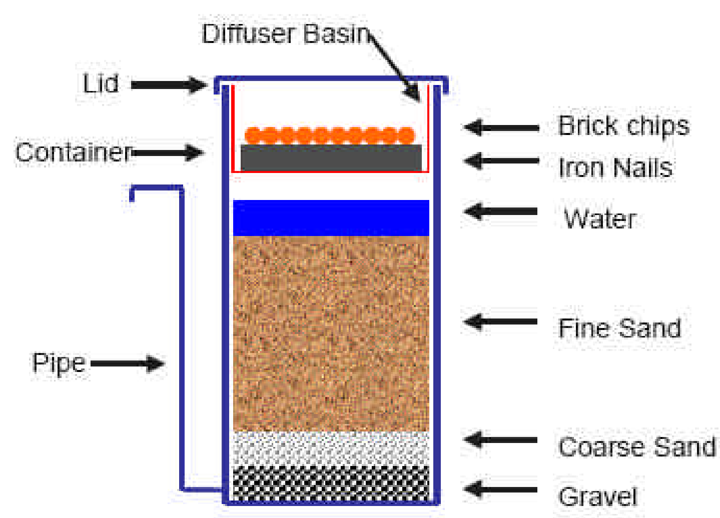

Figure 1. Components of the Kanchan Arsenic Filter

The Kanchan Arsenic Filter was developed by the Massachusetts Institute of Technology and a Nepali

NGO, Environment and Public Health Organization, based on 7 years of extensive inter-disciplinary laboratory and field studies in rural villages of Nepal (Ngai et al, 2007). This awards-winning filter is an open-content technology which requires no external energy or material input for operation and requires no replacement parts except for the small common nails (replaced approximately every three years). It is the natural rusting process of these nails that provides the iron oxide adsorption sites to remove the arsenic from the water. The fine sand filter media below the 5 or 6 kg of nails performs as an intermittently-operated slow sand filter (biosand filter). The rust particles that detach from the nails are strained out by the fine sand media then removed by cleaning the filter. The cleaning operation takes about 15 minutes and is the only maintenance required. Cleaning involves filling the filter with water, stirring the top 2 cm of sand to suspend the particles, and then scooping out the dirty water. Cleaning of the filter is done when the flow rate becomes unacceptably slow, normally every 1 to 3 months depending on the turbidity of the influent (raw) water. Refer to Figure 1 for a diagram of the filter showing its components.

Methodology

The raw water source was selected by first summarizing the water quality data in Cambodia from published studies to determine what would be representative of the general arsenic condition in contaminated areas. The ground water chemistry at the site chosen has worse conditions than average for phosphates and source water arsenic levels, but not too extreme.

A total of 10 Kanchan filters were installed in 5 different configurations, 2 filters for each configuration:

1. Original configuration - 5 kg of nails placed in the diffuser basin of an otherwise traditional biosand filter
2. Pre-rusted nails configuration - to evaluate if pre-rusting can give increased arsenic removal
3. Submerged nails configuration - nails are kept submerged under water at all times
4. Manual aeration configuration - by pouring water between 2 buckets 20 times before pouring in the filter
5. Mechanical aeration configuration - by bubbling air through the water prior to pouring in the filter.

Every day, for 30 weeks, 20 L of water was poured into each filter each morning and another 20 L was poured in each evening (Photograph 1). ITC and/or MRD staff visited the filters 3 times per week for inspection. Every week, raw and filtered water samples were collected and tested on site and at ITC's laboratory. A digital Wagtech Arsenator (Wagtech, UK), with a reported arsenic detection range of 2-100 μg/L was used to measure the arsenic concentration. Samples of raw water were generally diluted by a factor of 10 to stay within the digital readout range. Confirmation of arsenic results was done in part by shipping preserved samples (pH<2) to laboratories in France and USA. Iron was measured with the Jenway spectrometer, phosphate with the Wagtech Photometer 7100, pH with the Hanna HI 8424 pH meter, turbidity with the Wagtech digital turbidity meter, total coliform and *E. coli* with membrane filtration or Most Probable Number (MPN) method using Bio-rad media.

Photograph 1.
Filling the filters at 40 L/day

Results

Arsenic Removal

Arsenic removal ranged from 95-97% for all filter configurations regardless of wet or dry season. After the first week of start-up, only 1 in 224 samples (0.05%) exceeded the Cambodia standard; 50 µg/L. There was no observable trend of arsenic removal capacity exhaustion over the 30 weeks (8400 L filtered). Independent labs in France and USA confirmed the high arsenic levels in the raw water and that the filtered water met Cambodian standards.

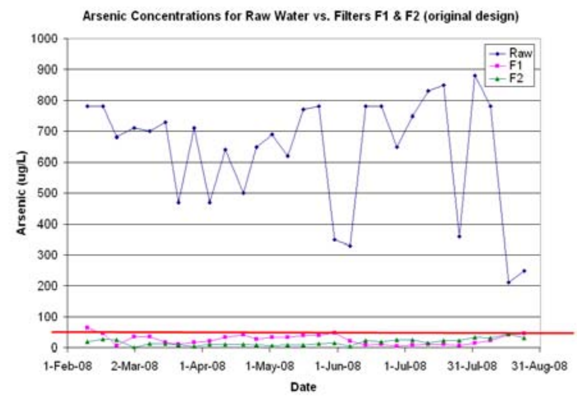

Figure 2. Arsenic Removal Effectiveness

Arsenic removal appeared not to be significantly affected by the flow rate of water through the filter nor by the frequency of cleaning the filters to restore flow rate (Figure 3). High arsenic removals were achieved despite the high raw water phosphate level (average of 5.09 mg/L as PO4), which is known to interfere with arsenic adsorption (Mahin et al, 2008).

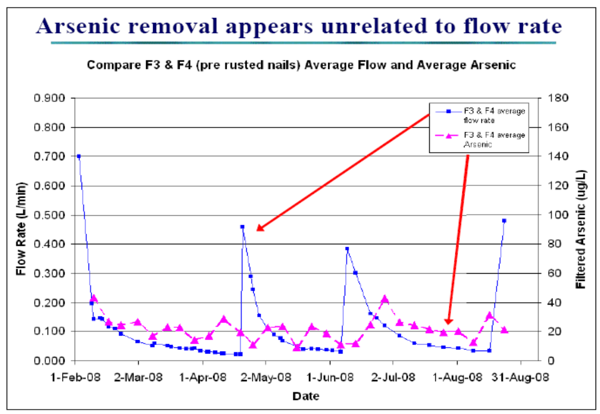

Figure 3. Flow Rate vs. Arsenic Removal

To test whether the nails (rusting) were critical to the % removal of arsenic achieved, the same raw water was run through the filters (original design configuration) without any nails. The results in Figure 4 indicate the importance of the rust that is generated from the 5 kg of small nails.

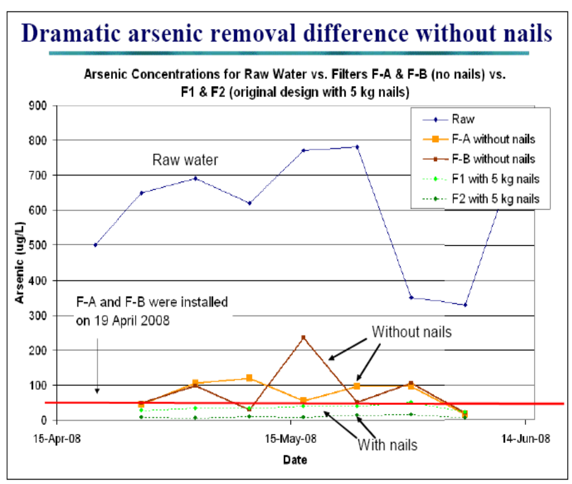

Figure 4. Arsenic Removal Difference without Nails

Iron and Turbidity Removal

Although not considered a health hazard, iron and turbidity removal are associated with high user acceptance and sustainability of the technology because of better appearance, taste, and smell. Iron removal in the Kanchan filter was consistently 99% for all configurations and filters, regardless of season (Figure 5). High turbidity removal for all filters was observed as well, recognizing that the % removal is a function of the low water turbidity typically found in groundwater (Figure 6).

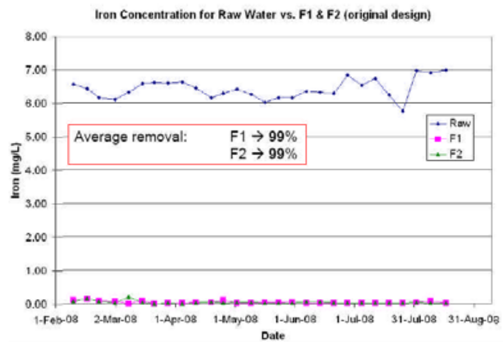

Figure 5. Iron Removal

E. coli Removal

For most filters configurations *E. coli* levels were very low and were not increasing through the filter. For the pre-rusted configuration the filtered water has higher *E. coli* in the initial 2-3 weeks after installation. It is believed that bacterial contamination may have been introduced to the water from the nails during pre-rusting procedure. This can presumably be avoided in the future by covering the pre-rusting container, or using a mild bleaching solution for pre-rusting. After the start-up period, all filters had zero *E. coli* in the filtered water.

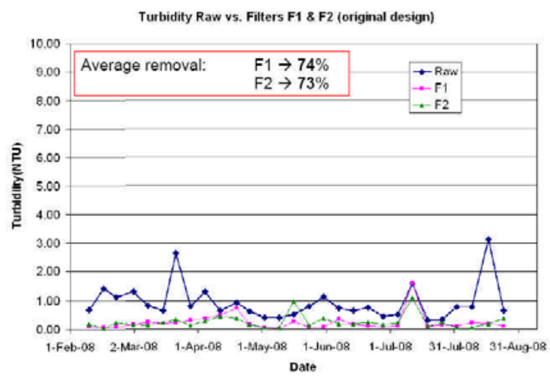

Figure 6. Turbidity Removal

pH Results

The pH of the filtered water from all 10 filters is within the Cambodian standard of between 6.5 and 8.5 (MIME, 2004). The filtered water pH increased by about 0.5 to 1.0 pH units. This increase is believed to be related to carbon dioxide equilibrium and from contact with the alkaline concrete materials.

Conclusions

The phase 1 field testing results have been encouraging. The raw water contains high arsenic and phosphate levels, which represents a challenging treatment condition. Nevertheless, the Kanchan Arsenic Filter was found to be highly effective. All of the 10 filters are consistently reducing arsenic levels from an average of 637 ppb to less than 50 ppb. The average removal is in the 95-97% range. Also, there is no observed trend of increasing arsenic concentration over 30 week period (8400 L water filtered), performance is consistent over the 30 week. These results are consistent with data from Nepal from over 1000 filters tested after one year of operation (Ngai et al., 2007).

In Phase 2 of this research project (September to December 2008), we will continue the on-going testing to determine whether arsenic capacity may be exhausted. In addition, we will explore the limitations of the filter by installing them at more challenging locations. We will also look into the issue of hardness levels (as $CaCO_3$) and pH of the raw water, water usage patterns and social assessment.

It is expected that this research project can fill an important gap in the delivery of safe drinking water for Cambodia. Although arsenic has been found, there is currently no suitable removal technology for Cambodia. A successful verification of the performance of the Kanchan Arsenic Filter can provide policy-makers and implementers a reliable mitigation option to arsenic affected households.

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