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Bio-Sand Filters for Removal of Pathogenic Bacteria and Arsenic from Drinking Water in Rural Areas of Developing Countries*

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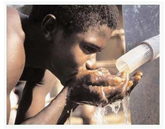
World Water Crisis

- Approximately 1.6 million people die each year due to lack of proper water sanitation.
- Contaminants often include bacterial pathogens, viral pathogens and dissolved arsenic in the form of arsenate and arsenite.
- This problem prevails in impoverished and under-developed areas, where two-thirds of the population earn less than two dollars a day.

"Therefore, the people in these countries require a water treatment system that is inexpensive, easy to construct, and most importantly very effective at providing large amounts of safe drinking water."

Health Effects Associated with Bacterial Contamination



Pathogenic Bacteria	Disease
Salmonella typhi	Typhoid fever
Salmonella paratyphi	Paratyphoid fever
Othe salmonella	Salmanellosis
Shigella spp.	Bacillary dysentery
Vibrio cholera	Cholera
Enteropathogenic *E. coli*	Gasteroenteritis
Yersinia enterocolitica	Gasteroenteritis
Caphylobacter jejuni	Gasteroenteritis
Legionella pneumophila	Acute respiratory illness
Leptospira spp.	Leptospirosis
Mycobacteria	Pulmonary illness
Opportunistic bacteria	Various diseases

Health Effects Associated with Arsenic Contamination

- Cancer: skin, lung, bladder, liver, and kidney
- Cardiovascular disease
- Peripheral vascular disease
- Developmental effects
- Neurologic & neurobehavioral effects
- Diabetes Mellitus
- Hearing loss
- Portal fibrosis of the liver
- Lung fibrosis
- Hematological effects (e.g., anemia)

Research Objectives

Examining the effectiveness of bio-sand filter for removing pathogenic microorganisms (using E. coli as model microorganisms)

Studying the mechanism of bacteria (E. coli) removal by the bio-layer (schmutzdecke)

Testing the efficiency of iron-oxide coated sand filter followed by bio-sand filter for achieving arsenic removals to levels well below prescribed drinking water standards

Experimental Methods for Bacteria Testing

The source water was obtained from Echo Park Lake. The water was inoculated with a known population of E. coli; the bacterial populations were counted before and after bio-sand filtration (see Figure 1).

Experimental Methods for Arsenic Testing

The source water from Echo Park Lake was spiked with 1000 mg/L of arsenic and passed through the iron coated sand filter. The water was then passed through the bio-sand filter for further arsenic removal (see Figure 1). Arsenic concentration was measured before and after the iron coated sand filter, using inductively coupled mass spectroscopy (ICP-MS) analytical technique.

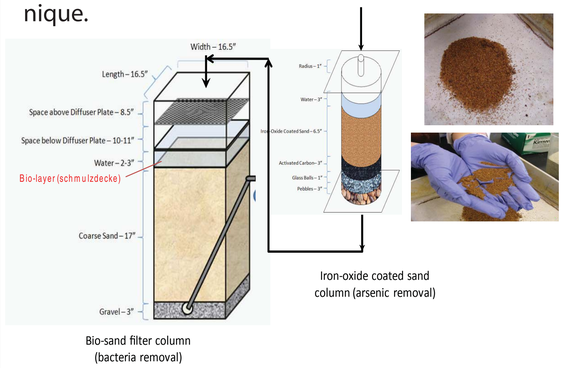


Figure 1. Schematic of the iron-oxide coated sand column and bio-sand filter used in this study. Notice the bio-layer (schmulzdecke) formation on the top of the sand layer

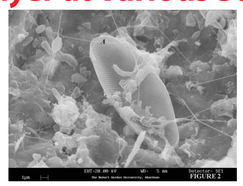
What a schmultzdecke (bio-layer) is and how it works

The schmutzdecke is a complex biological layer formed on the surface of a sand filter. The underlying sand provides the support medium for the biological layer that provides effective purification in water treatment.

- The schmutzdecke develops during continuous saturation by water containing high concentrations of microorganisms.
- This community of microorganisms consumes and adsorbs organic contamination in the influent water.

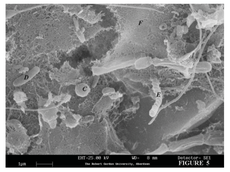
The microbial ecology of schmutzdecke is shown below:

Scanning Electron Micrographs of Bio-layer at Various Stages of Development



Stage 1: Freshly seeded sample showing diatom attachment

Stage 2: Freshly seeded sample showing coccoid bacteria, rod-shaped bacteria, and algae



Stage 3: Mature sample showing algae and adhesive mucilage

Key to the micrographs

A = diatom
B = coccoid shaped bacteria
C = rod shaped bacteria
D = algae
E = adhesive mucilage
F = gelatinous matrix

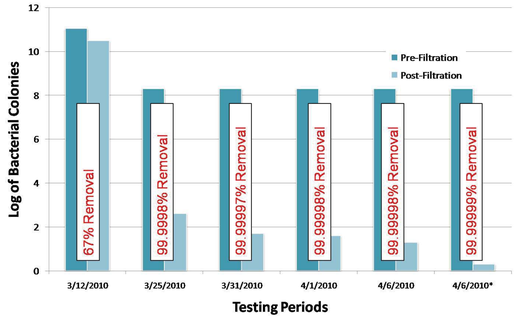


Figure 2. Comparison of Bacterial Levels Before and After Filtration Through the Bio-sand Filter during the Last Four Weeks of Schmulzdecke Formation

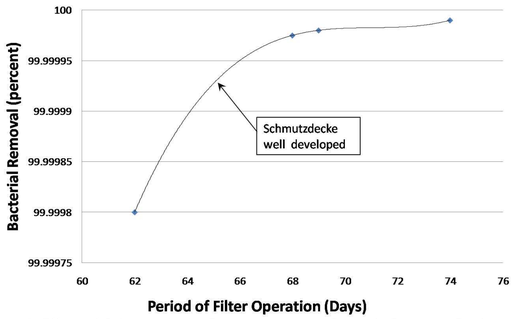


Figure 3. Effect of Schmulzdecke Development on Bacteria Removal During the Final Two Weeks

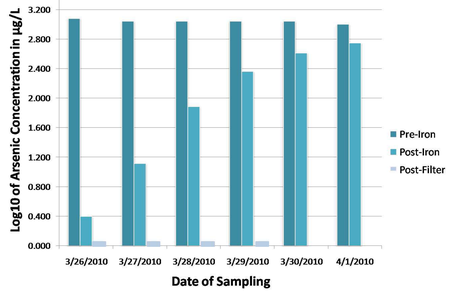


Figure 4. Arsenic Concentration After Treatment Using an Iron-oxide Coated Sand Column and a Bio-sand Filter

Conclusions

- The bio-sand filter was capable of achieving almost complete (> 99.99999 %) removal of bacteria
- The combination of iron-oxide coated sand filter and bio-sand filter was effective in reducing arsenic levels below the drinking water standard of 10 µg/L (>99.9 % removal)
- The bio-layer (schmutzdecke) alone achieved arsenic and bacteria removals below drinking water standards.

Future Recommendations

- The bio-sand filter must be optimized for bacteria removals at different influent flow rates and bacteria concentrations
- The combination of iron-oxide coated sand column and the bio-sand filter must be optimized for achieving high arsenic removals
- The system must be operated at various influent flow rates and arsenic concentrations for optimization
- The system must be tested and optimized for virus removal

Funding Source

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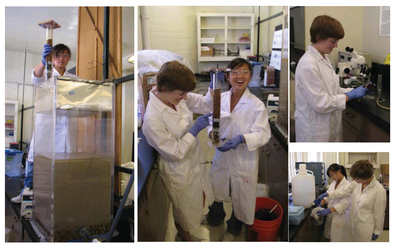

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