BIOSAND WATER FILTERS

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Abstract:

Biosand water filters are used in developing nations around the world to provide clean water. Clean quarry sand (the accepted standard) is not always readily available to those who need water filters. It is also difficult to maintain standard filters daily if the user must travel. The **goals** of this project are to:

- Determine the effectiveness of river sand as a substitute for clean quarry sand, with or without chlorine treatment
- Investigate the difference in effectiveness of smaller filter sizes (2 gal., 5 gal.) relative to traditional concrete filter size

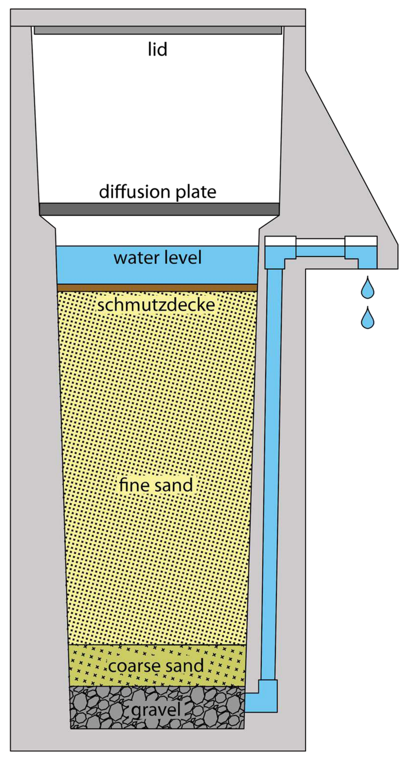
Background:

Biosand water filters are used by more than 500,000 people around the world and are contingent on the following process:

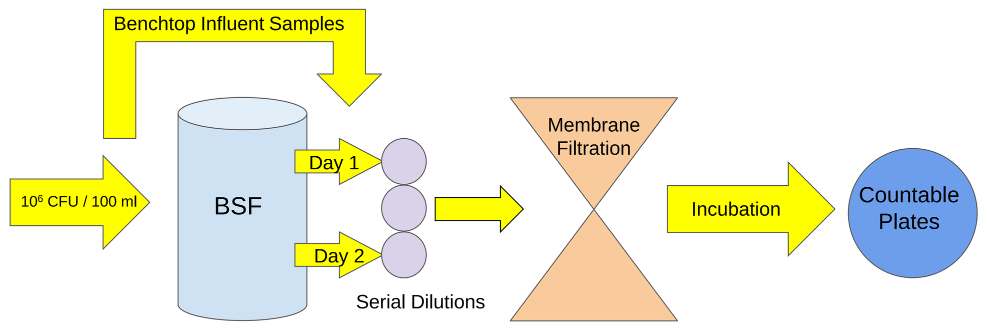
- As water flows through the sand and gravel, large particles in the water are caught, adsorbed, or otherwise removed.
- After approximately thirty days of operation, a biolayer of microorganisms develops.
- The microorganisms feed on bacteria and other impurities in the water, increasing the effectiveness of filtration.

Biosand filters are extremely effective but face a number of challenges related to transportation and upkeep:

- Standard filters are large and made of concrete; they are not easy to move to a location, nor easy to transplant after installation
- The bio-layer in standard filters breaks down over long periods of disuse, which greatly reduces the effectiveness of the filter
- Standard filters use clean quarry sand that is not always easily acquired



Methods:



Once per week, the influent water is spiked with ~10^6 CFU/100 ml of *E. coli* bacteria (CFU: Colony Forming Units). The filters are then filled with volumes of 12, 3.6, and 1.5 liters for the concrete, 5-gal, and 2-gal filters, respectively. Three 500-mL samples of influent water are saved on the benchtop as non-filtered controls; a portion from each sample of spiked water is diluted and processed by membrane filtration. The filtration paper incubates overnight and forms countable colonies. The controls are then stored in the dark and diluted and processed again the next day to track natural bacteria die-off. Samples of the effluent water are taken, diluted, and processed by membrane filtration over two days following the E. coli spike to track the removal of the bacteria due to filtration.

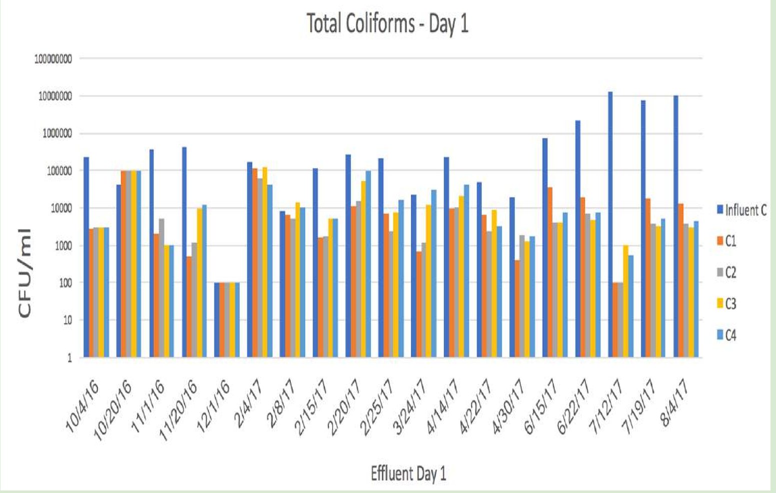


Figure 1

Figure 2

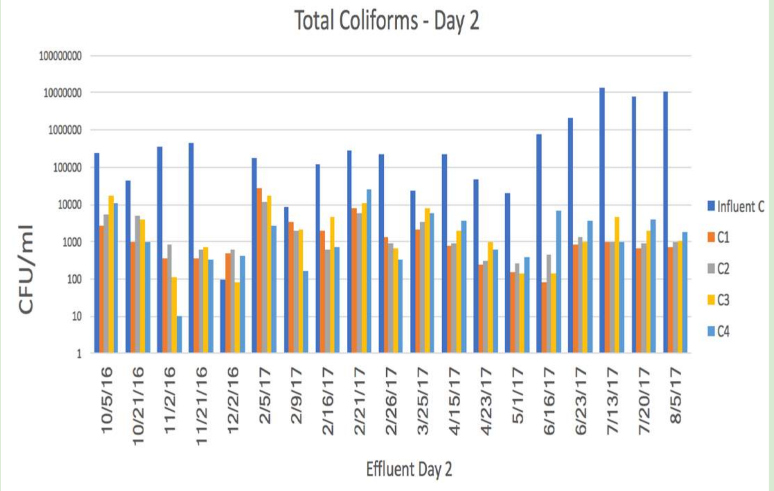


Figure 1 (Left) and 2 (Right):

Total coliforms from initial influent poured into the filters compared with the effluent samples from standard filter sizes.

C1 and C2: Control Filters
C3: Treated River Sand
C4: Untreated River Sand

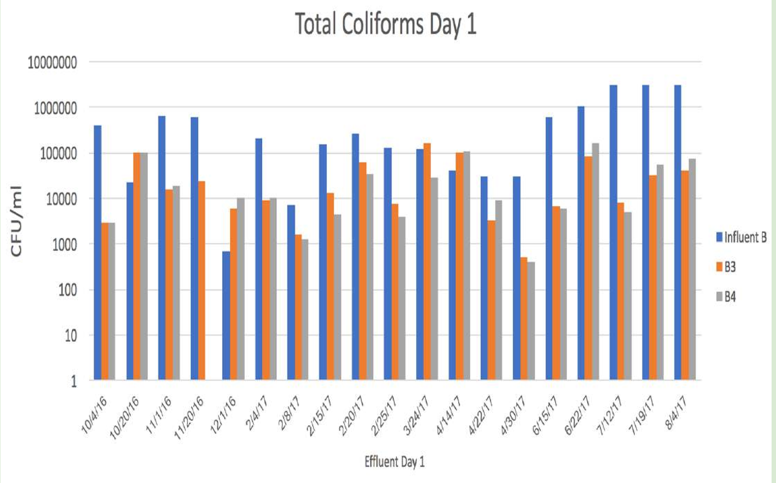


Figure 3

Figure 4

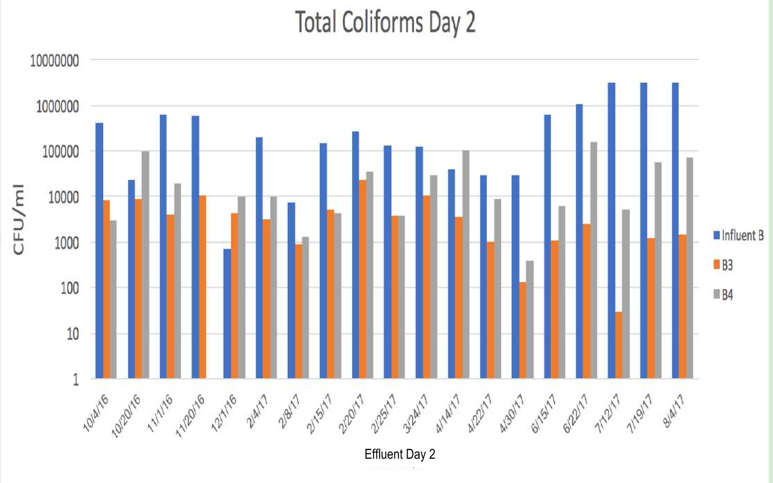


Figure 3 (Left) and 4 (Right):

Total coliforms from initial influent poured into the filters compared with the effluent samples from 5-gallon filter sizes.

B3: Treated River Sand
B4: Untreated River Sand

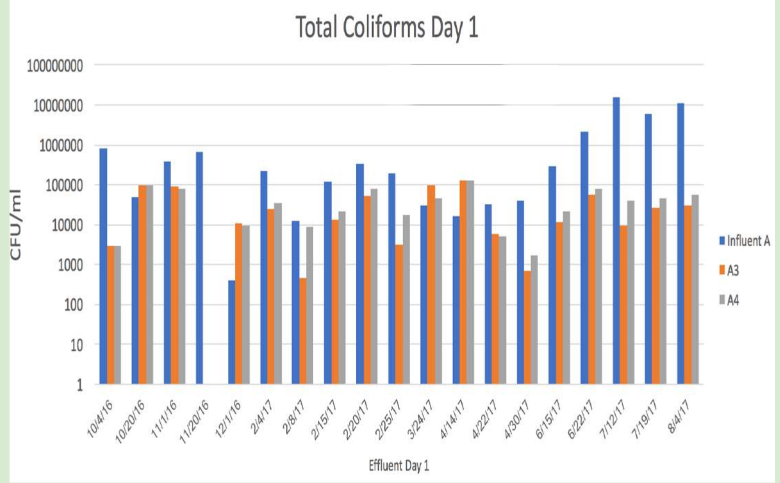


Figure 5

Figure 6

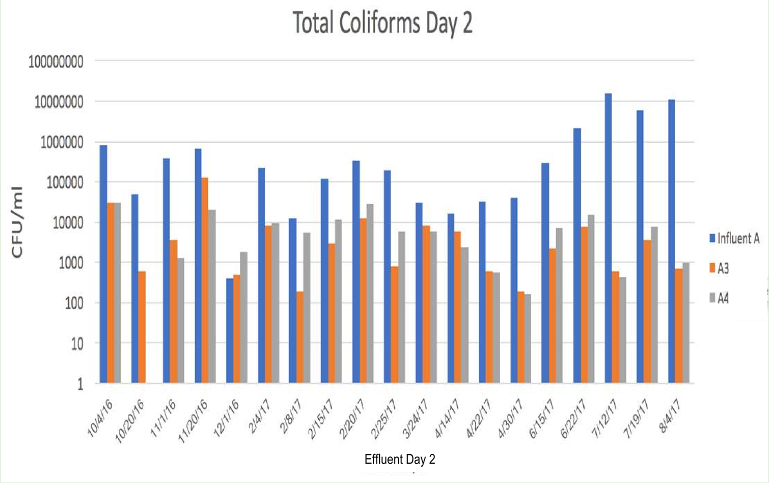


Figure 5 (Left) and 6 (Right):

Total coliforms from initial influent poured into the filters compared with the effluent samples from 2-gallon filter sizes.

A3: Treated River Sand
A4: Untreated River Sand

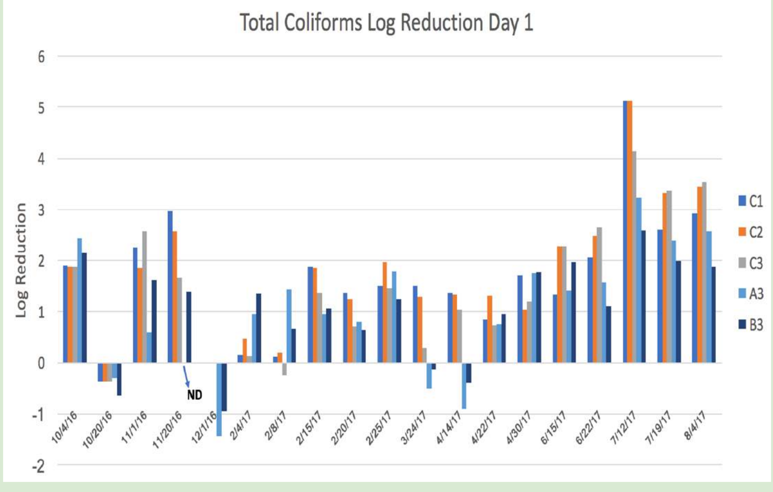


Figure 7

Figure 6

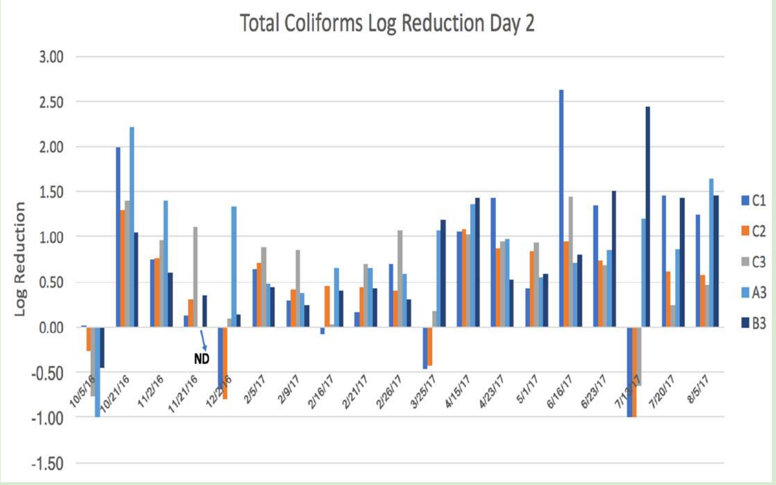


Figure 7 (Left) and 8 (Right):

Log reduction of coliforms. Shows the reduction in *E. coli* from initial spike concentration to the effluent concentration. Comparison among controls and treated river sand.

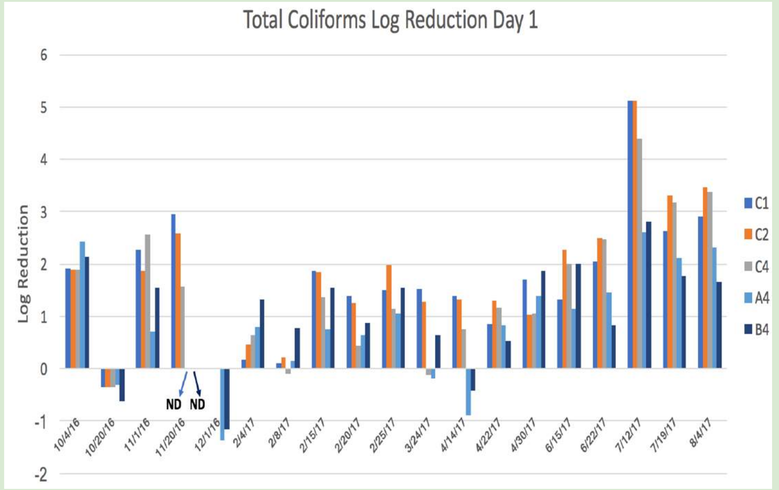


Figure 9

Figure 10

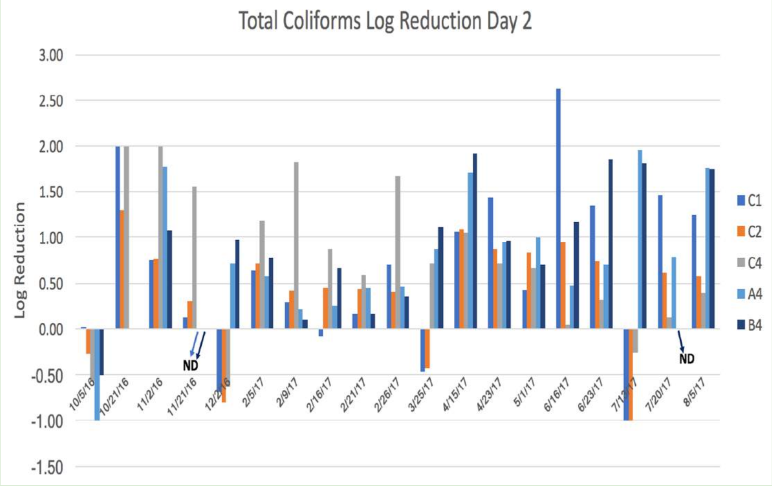


Figure 9 (Left) and 10 (Right):

Log reduction of coliforms. Shows the reduction in *E. coli* from initial spike concentration to the effluent concentration. Comparison among controls and untreated river sand.

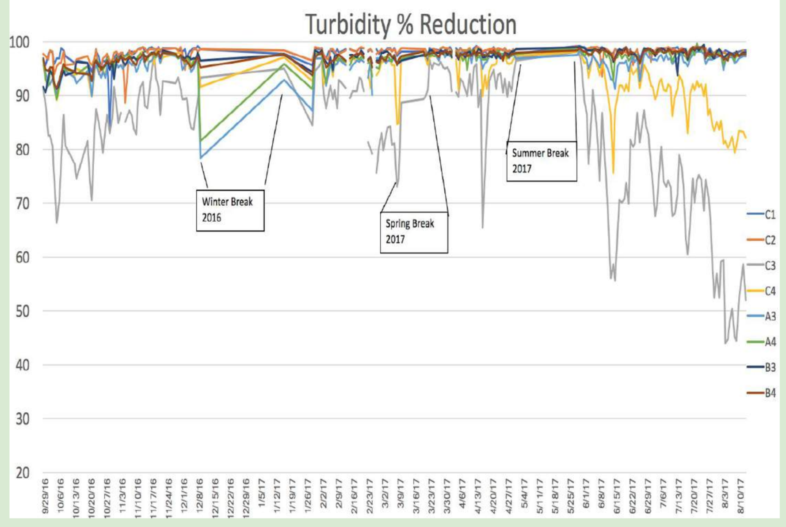


Figure 11

Figure 12

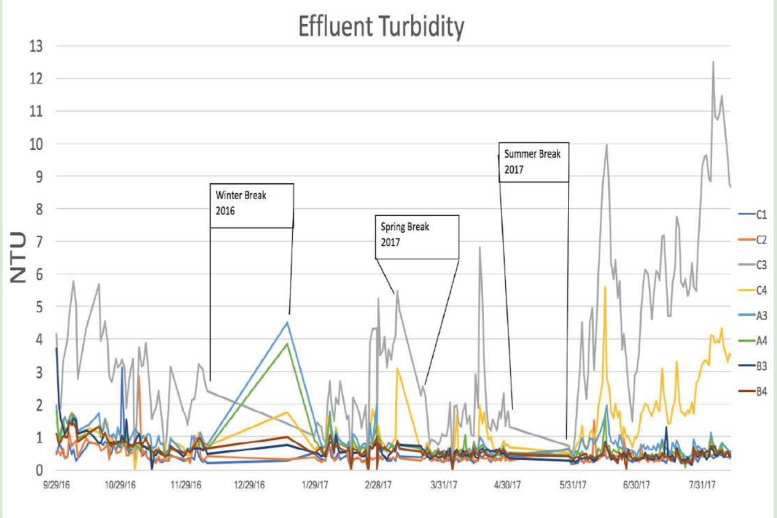


Figure 11 (Left) and 12 (Right):

Fg. 11: Graph showing the percent reduction in turbidity of river water after passing through the filters from its first fill in September 2016 to its final fill in August.

Fg. 12: Graph tracking the raw turbidity numbers of the effluent turbidites.

Discussion:

<u>Comparison of Sands in Standard Filters</u>

Referring to **Figures 9 and 10**, C1 and C2 (the controls filters) consistently have the highest log reduction, followed or matched by C4 (made with untreated river sand). Generally, the figures indicate that C4's bacteria reduction is comparable to that of C1 and C2. Looking at **Figures 7 and 8**, C3 (made with treated river sand) is comparable to the controls as well.

The EPA's standard for clean drinking water requires less than 1 NTU (NTU: Nephelometric Turbidity Unit). In **Figures 11 and 12**, C3 and C4 both exceed this standard, while C1 and C2 remain within the standard.

In terms of bacteria removal, filters C3 and C4 work nearly as well as the standard filter, but, in terms of turbidity removal, it appears that removal in these filters may deteriorate over time. When looking at **Figure 12** in terms of all the filters, the only filters that do not perform to standard are filters C3 and C4, making it more likely that river sand may still be comparable to quarry sand.

<u>Comparison of Disinfected Sand vs Untreated River Sand</u>

Figures 1 through 6 compare the concentration of bacteria in the initial influent water with the effluent water of the filters at one day, and then at two days after being spiked with *E. coli*. Each figure compares the results of disinfected and untreated sand by filter size. From these figures, we find that treated and untreated sand have comparable concentrations of bacteria. In terms of turbidity in **Figures 11 and 12**, only C3 and C4 varied from the cluster. All the other filter effluents remained under 1 NTU.

<u>Comparison of Filter Sizes</u>

Figures 7 through 10 compare the log reductions of different filter sizes. From the figures, it seems that the standard filters remove more bacteria than the smaller filters. These smaller filters flush more of the bacteria out into the effluent water after being spiked, making them not as efficient.

Future Work:

- Exploring the cause of increased turbidity in C3 and C4 filter effluents
- Obtain additional data points using new *E. coli* and a more consistent control (current *E. coli* is old and did not survive benchtop control tests)
- Investigate sand additives that could improve filter performance

Challenges:

The summer research faced some unexpected challenges:

- The budget did not allow for the creation of entirely new filters, so pre-existing filters were repurposed for this experiment.
- It was discovered that the temperature display for the lab incubator was not accurate, resulting in lower than optimum temperatures which hindered bacteria growth. The temperature was subsequently adjusted to compensate.
- The *E. coli* experienced rapid die off overnight on the benchtop. In all control tests, the bacteria died off significantly after 24 hours. Bacteria reduction by benchtop die-off was comparable to bacteria removal measured in filter effluents. The effectiveness of biosand water filters is well documented, and it is known that biosand filters remove bacteria. The significant bacteria die-off observed in this experiment makes it difficult to differentiate bacteria removal due to filtration versus bacteria reductions from natural die-off.
- The growth media was supposed to differentiate *E. coli* from total coliforms, but the color differentiation was not reliable. In many instances, colonies that appeared one color after 24 hrs would appear to change color after 48 hrs, creating uncertainty over the type of bacteria colonies growing on the plates.

Sources and Acknowlegements:

Sisson, Andrew J. et al. "Long-Term Field Performance of Biosand Filters in the Artibonite Valley, Haiti." *The American Journal of Tropical Medicine and Hygiene* 88.5 (2013): 862-867. PMC. Web. 7 Sep. 2017.

United States. Environmental Protection Agency. Drinking Water Requirements for States and Public Water Systems. Washington, D.C.: GPO, 2015. Web. 7 Sep. 2017.

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