Efficacy of Silver-Treated Ceramic Filters for Household Water Treatment

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INTRODUCTION

Ceramic filtration is one household water treatment option in current use in developing countries. The filters are manufactured by mixing combustible material with clay; the clay is then fired to create pore spaces through which water is filtered. The ceramic filters are designed to sit atop five-gallon buckets, which are used as the clean water receptacle. Treated water is collected from a spigot at the bottom of the clean water receptacle. Two variations of ceramic filters, flat-bottom and round-bottom, are currently manufactured.

Traditionally, colloidal silver has been applied to the ceramic filters after firing. Water flowing through the ceramic filter is thus treated by a combination of physical filtration and silver disinfection. Previous testing by others has shown that there is only a minimal loss of silver into the purified water from the system (Lantange 2001; van Halem 2006). Past work has shown, however, that application of the colloidal silver solution reduces the pore size and structure of the filter medium, which reduces flowrate and increases clogging (Fahlin, 2003; van Halem, 2006). In an attempt to maximize the pore structure of the filter, some manufacturers are now applying the silver solution to the filter media prior to firing; thus, the colloidal silver is incorporated throughout the ceramic matrix and the pore structure created during the firing process is not reduced by the application of the colloidal silver after the fact. It is unclear whether this new silver application method has an effect on the overall efficacy of the filter.

METHODS

In order to evaluate the impact of the physical design (round- versus flat-bottom) and the silver application method (before or after firing), a six-week study was performed. The filters used for the study included (i) two flat-bottom filters with silver applied before firing (filters A-1 and A-2), (ii) two flat-bottom filters with silver applied after firing (filters B-1 and B-2), and (iii) two round-bottom filters with silver applied before firing (filters C-1 and C-2).

The six filters were challenged with eight liters of local creek water every day, and testing of the influent and effluent waters was performed once per week for each filter (resulting in 6 total data points for each individual filter, and 12 total data points for each filter type). Filters A-1, B-1, and C-1 were analyzed on the first test day of each week (i.e., days 1, 4, 8, 11, 16, 18, 22, 25, 29, 32, 35, and 37 of the study). Filters A-2, B-2, and C-2 were analyzed on the second test day of each week (i.e., days 3, 5, 9, 12, 17, 19, 23, 26, 30, 33, 36, and 38 of the study).

Filter influent consisted of local creek water that had an approximate turbidity of 30 NTU and was spiked with *E. coli* to obtain 1.25 x 10^6 CFU/L. Filter influent and effluent were analyzed for total coliforms, *E. coli*, and turbidity. Total coliform and *E. coli* concentrations were determined by membrane filtration and direct plate counts on m-ColiBlue24 media (EPA Approved Hach Method 10029). Turbidity was measured with a Hach 2100AN turbidimeter. In addition, the flow rate of each filter was measured, using a stopwatch and a graduated cylinder, when the influent water level was at its maximum level.

RESULTS

Turbidity

All of the filters removed greater than 90% of the turbidity from the influent water (Figure 1). For all filters, influent turbidities were approximately 30NTU and effluent turbidities were ≤2 NTU on each test day.

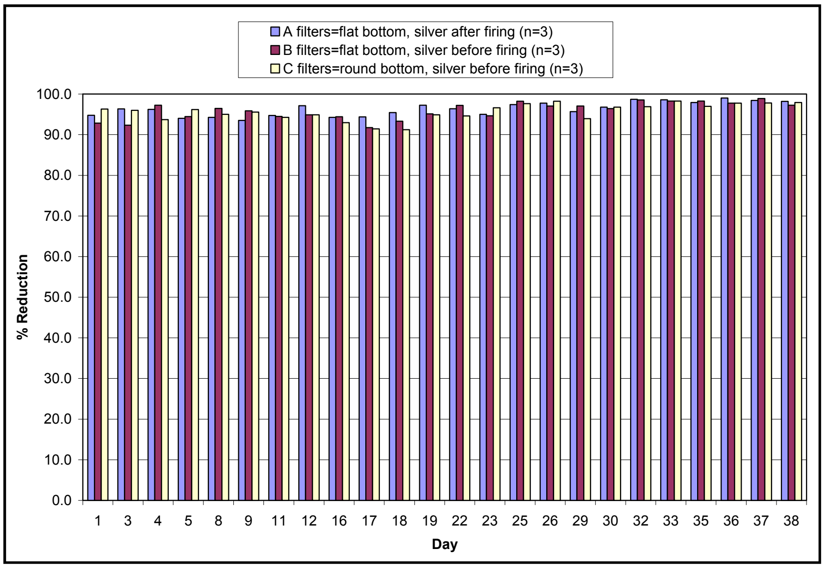

Figure 1. Percent reduction in turbidity by each filter. Filters A-1, B-1, and C-1 were analyzed on days 1, 4, 8, 11, 16, 18, 22, 25, 29, 32, 35, and 37. Filters A-2, B-2 and C-2 were analyzed on days 3, 5, 9, 12, 17, 19, 23, 26, 30, 33, 36, and 38.

Bacteria Removal

All of the filters successfully reduced both the *E. coli* and total coliform concentrations to zero (Figures 2-4).

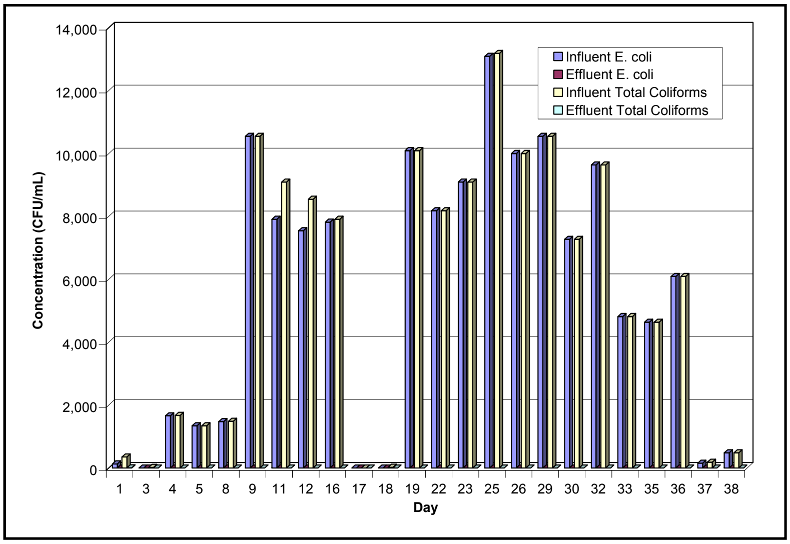

Figure 2. Bacteria removal achieved by the A filters. Filters A-1, B-1, and C-1 were analyzed on days 1, 4, 8, 11, 16, 18, 22, 25, 29, 32, 35, and 37. Filters A-2, B-2, and C-2 were analyzed on days 3, 5, 9, 12, 17, 19, 23, 26, 30, 33, 36, and 38.

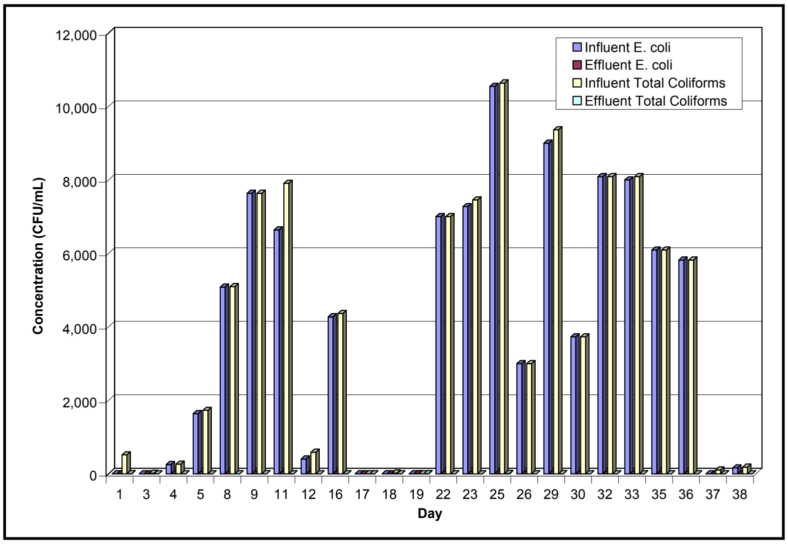

Figure 3. Bacteria removal achieved by the B filters. Filters A-1, B-1, and C-1 were analyzed on days 1, 4, 8, 11, 16, 18, 22, 25, 29, 32, 35, and 37. Filters A-2, B-2, and C-2 were analyzed on days 3, 5, 9, 12, 17, 19, 23, 26, 30, 33, 36, and 38.

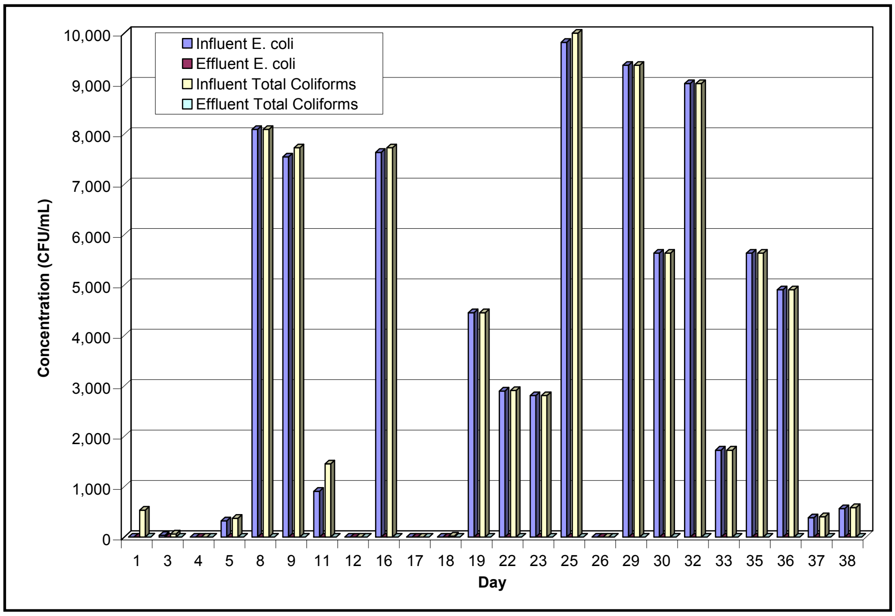

Figure 4. Bacteria removal achieved by the C filters. Filters A-1, B-1, and C-1 were analyzed on days 1, 4, 8, 11, 16, 18, 22, 25, 29, 32, 35, and 37. Filters A-2, B-2, and C-2 were analyzed on days 3, 5, 9, 12, 17, 19, 23, 26, 30, 33, 36, and 38.

The resulting log reductions of *E. coli* and total coliforms are depicted in Figures 5 and 6, respectively. Log reduction was calculated as follows:

Log reduction = Log [influent (CFUs) – effluent (CFUs)]

On several test days, the spiked influent water was tested and found to contain either less than the desired spike concentration (1.25 x 10^6 CFU/L) or no bacteria at all (Figures 2-4). On these occasions, there was either no log reduction reported (for zero influent concentrations) or the resultant log reduction was less than 6. For all days when the desired influent concentration of bacteria was obtained, a 6-log reduction in the bacteria concentration was achieved for all filters.

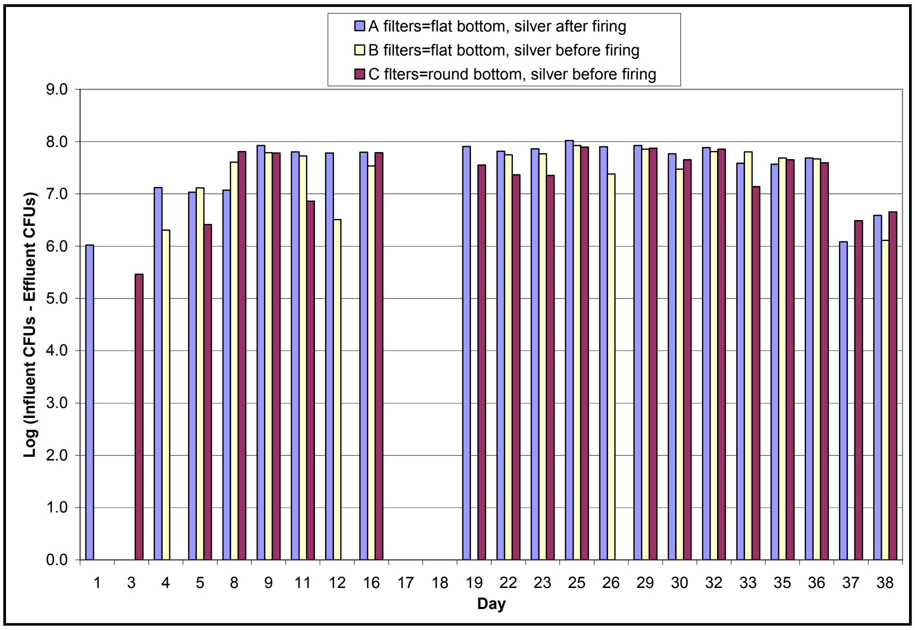

Figure 5. Log reduction of *E. coli*. Filters A-1, B-1, and C-1 were analyzed on days 1, 4, 8, 11, 16, 18, 22, 25, 29, 32, 35, and 37. Filters A-2, B-2, and C-2 were analyzed on days 3, 5, 9, 12, 17, 19, 23, 26, 30, 33, 36, and 38.

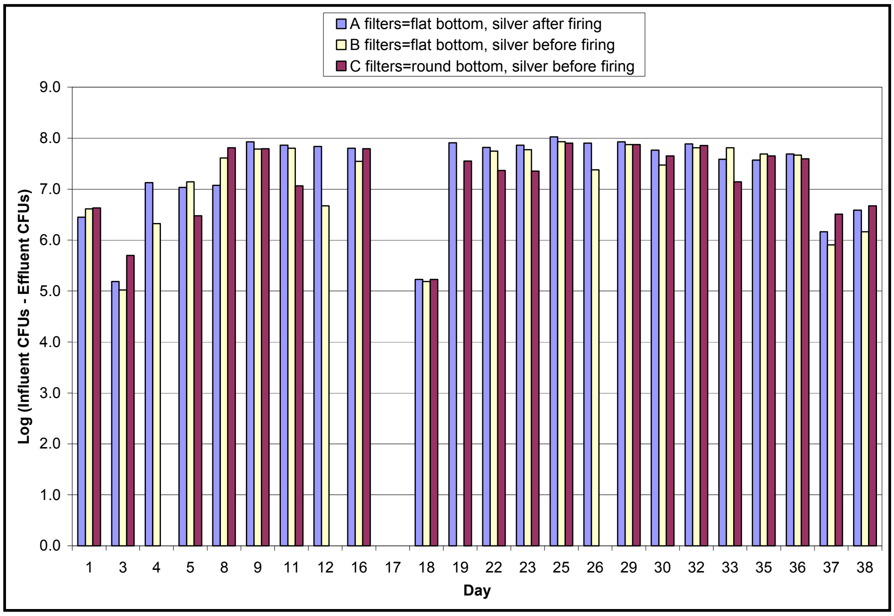

Figure 6. Log reduction of total coliforms. Filters A-1, B-1, and C-1 were analyzed on days 1, 4, 8, 11, 16, 18, 22, 25, 29, 32, 35, and 37. Filters A-2, B-2, and C-2 were analyzed on days 3, 5, 9, 12, 17, 19, 23, 26, 30, 33, 36, and 38.

Flow rate

While all of the filters performed well at removing both turbidity and bacterial contaminants, flow rates proved more variable. Influent water was added to each filter and allowed to begin to diffuse through the filter. After approximately 15-20 minutes, the filters were saturated and the flow rates were evaluated. Flow rates varied among each filter type (i.e., A, B, and C) as well as within each filter type (e.g., A-1 and A-2) (Figure 7). The typical flow rate for ceramic filters is between 2-4 L/hr. None of the filters achieved 2 L/hr, but filter A-2 consistently achieved the best flow rate.

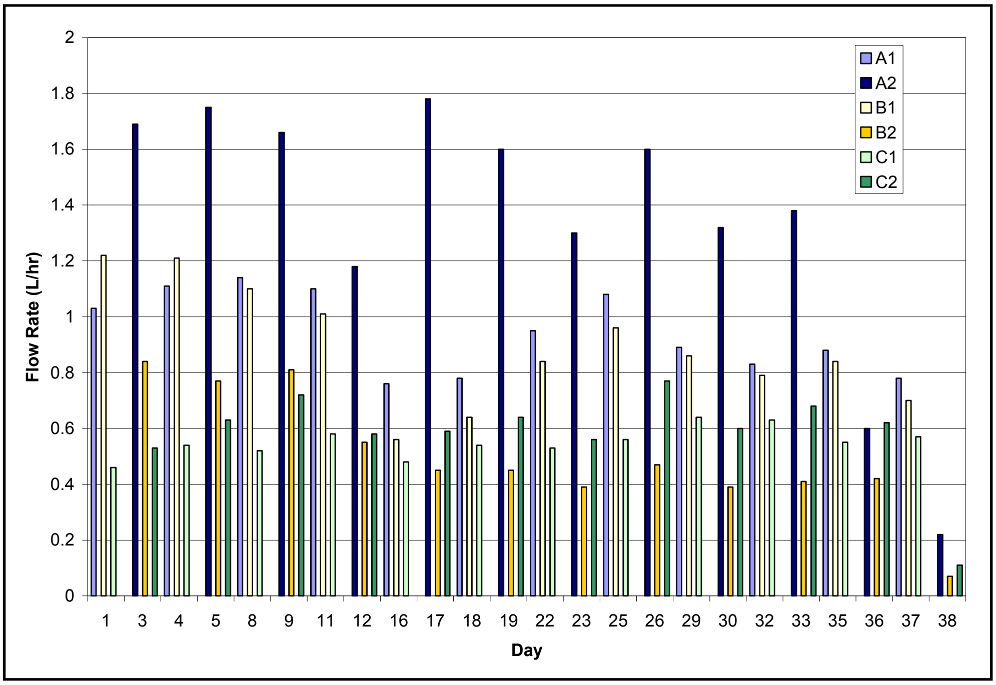

Figure 7. Filter Flow Rate

CONCLUSIONS

All three filter types (A, B, and C) were effective at reducing turbidity and removing bacterial contaminants. There was no indication that the shape of the filter (flat or round bottom) or the timing of the silver addition (before or after firing) had an effect on the resultant performance of the filter for the first six weeks of use. The low flow rates, and lack of consistency of the flow rates between the two filters of the same type, raise questions about whether the filters tested in this study were representative of those filters actually in use. Common practice is to test filter flow rates before distribution to end users, and any filter with a flow rate less than 2 L/hr is discarded. Low flow rates have been shown to limit end user acceptability. While the specific filters tested during this study performed well at removing the challenge contaminants, filters with a higher flow rate may

prove to perform differently. Future work should (i) test filters with flow rates that are representative of those being used in the field and (ii) address long-term filter performance (beyond six weeks of use).

KEYWORDS Ceramic filtration, colloidal silver, household water treatment, coliforms, *E. coli*, turbidity

REFERENCES

Fahlin, C.J. (2003). " Hydraulic Properties Investigation of the Potters for Peace Colloidal Silver Impregnated, Ceramic Filter." University of Colorado, 2003. www.pottersforpeace.org, accessed July 19, 2007

Lantagne, D. (2001). "Investigation of the Potters for Peace Colloidal Silver Impregnated Ceramic Filter, Report 1: Intrinsic Effectiveness." Alethia Environmental, 2001. www.pottersforpeace.org, accessed July 19, 2007.

Van Halem, D. (2006) "Ceramic Silver Impregnated Pot Filters for Household Drinking Water Treatment in Developing Countries." Delft University of Technology, 2006. www.pottersforpeace.org, accessed July 19, 2007.