The Extended Laboratory Use of Ceramic Water Filters with Antimicrobial Silver Ion Technology

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INTRODUCTION

Silver NanoParticle (AgNP) Technology

- The use of *silver nanoparticle (AgNP) technology* has shown promise in the WASH community to reduce waterborne disease in the household setting.
- Silver and AgNP have been shown to have antibacterial properties against Gram positive and Gram negative bacteria[1].
- There is currently no WHO guideline for silver in drinking water. US EPA Health Advisory is 100 µg/L and is generally used as the "guideline or allowable limit."[2]

Ceramic MadiDrop tablet (AgNP Technology)

- The MadiDrop is a ceramic tablet infused with silver.
- Recommended length of use is 6+ months.
- Treatment time is 24 hours for dirty water and 10 hours for clean water.
- Safe water storage treatment is recommended by leaving the treatment in a storage bucket over time.

Safe Water Storage Application

http://www.clean-water-for-laymen.com/household-water-filter.html

- *Biosand filters* have been widely tested and accepted for daily household use by removing pathogens through mechanical trapping and activity of the biolayer.
- Chlorine is recommended after filtration to remove residual contamination, particularly during the activation period of the filter or the reactivation period after long breaks of user inactivity.

RESEARCH QUESTIONS

1. How effective are MadiDrops under high levels of contamination typical of an *unprotected water source* over the course of a year?
2. Can the MadiDrop be used for longer than 6 months when it is used as a *safe water storage solution* with low levels of contamination?
3. Do *silver ion concentrations* remain at safe levels when a MadiDrop is left in a bucket for longer than 24 hours?

METHODS

Part I

- AgNP treatments were placed in 5 gallon buckets in source water and deionized water spiked with *E. coli* concentrations of 10^5 and 10^7 *E. coli* per 100 mL in 10 L at two, two and a half, seven, ten and twelve months. IDEXX Colilert Quanti-Tray/2000 and quantification methods based on the Standard Methods' Most Probable Number (MPN) were used to quantify total coliform and *E.coli* after 24 hours.

Part II

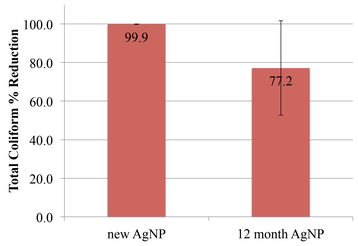
- MadiDrops were also tested in biosand effluent in 10 L after two, seven, ten and twelve months of use. IDEXX Colilert Quanti-Tray/2000 and quantification methods based on the Standard Methods' Most Probable Number (MPN) were used to quantify total coliform and *E.coli*.

Part III

- AgNP treatments remained in buckets after trials from Part I and II for up to 3 months. Samples were collected from source and deionized water treatments and silver ion concentrations were characterized using inductively coupled plasma mass spectrometry (ICP MS).

II. SAFE WATER STORAGE-BSF TRIALS

Mean Total Coliform Reduction in Biosand Effluent (+/- 1 SD)



New AgNP treatments (n = 12) showed complete reduction of total coliforms and *E.coli* after 24 hours of exposure in low levels of contamination (average 237.7 MPN/100 ml total coliform and 4.4 MPN/100 ml *E.coli*). Three twelve-month-old AgNP treatments (n = 9) under similar conditions had a total coliform reduction range of 26.8% to 100% (mean = 77.2%, p = <0.01).

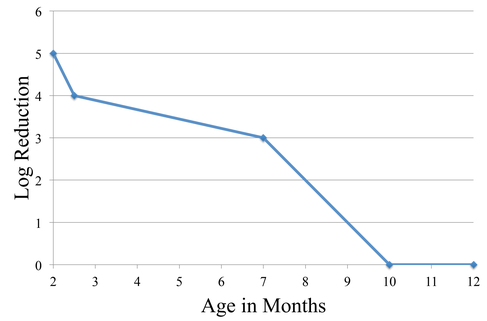
I. RESULTS: *E. COLI* SPIKED TRIALS

Effectiveness of AgNP Treatment over 12 months in Source and Deionized Water

Age AgNP in Months	*E. coli* concentration	% Reduction (Source)	% Reduction (DI water)
2	9.7 X 10^4	99.999	99.999
2.5	9.2 X 10^6	99.993	99.999
7	3.9 X 10^7	99.964	99.999
10	6.8 X 10^6	0	99.999
12	4.7 X 10^7	0	99.999

- After 24 hours in source water, a three to five log reduction was observed in the first seven months but dropped to 0 log reduction at ten and twelve months.
- In deionized water, a seven log reduction was observed in the first ten months which dropped to a six log reduction after twelve months.

Log Reduction of AgNP Treatments in Source Water Spiked with *E. coli*



CONCLUSIONS/RECOMENDATIONS

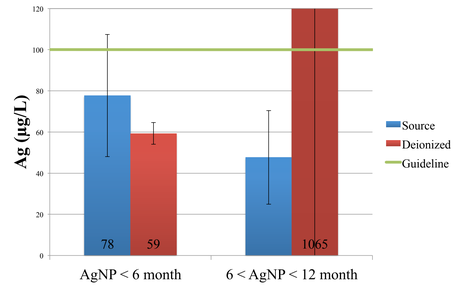
I. Preliminary results indicate that antimicrobial silver ion technology is effective during the first 6 months of use, regardless of contamination levels, but decreases in performance after ten to twelve months of use.

II. New AgNP treatments were effective in biosand effluent as a safe water storage option; twelve month later the effectiveness dropped to 77.2 %.

III. Mean silver ion concentrations in *source* water less than 12 months old were below 100 µg/L (mean = 59.2 ug/L; +/- 26.5 ug/L). However, silver ion concentrations in *deionized* water between 6 and 12 month old ranged from 21.8 ug/L after 24 hour exposure to 3086 ug/L with three month exposure. More research is needed on the biological and environmental effects of silver ion and AgNP concentrations.

III. RESULTS- AgNP CONCENTRATIONS

Mean Silver Ion Concentrations µg/L (+/- 1 S.D.) for Exposure >24 hours



- Silver concentrations in source water under varying conditions were below the guideline (<100 mg/L).
- Silver concentrations in deionized water in AgNP treatments older than 6 months were well above the guideline with an average of 1065 mg/L.
- Previous research has demonstrated an inversely proportional relationship between the size of the nanoparticle and the accumulation in the tissue with smaller AgNP particles (22-300 nm) accumulating more in tissues. - (Park et al., 2010)
- Particle size as well as solubility may influence the behaviour of the AgNPs, particularly in the deionized water and the "end of product life (> 6 months)"

AgNP in Source Water

AgNP in Deionized Water

FUTURE WORK

- Field testing in Haiti is currently underway to determine the effectiveness of AgNP as *a safe water storage solution* for elimination of residual contamination in effluent water from biosand filters during reactivation of the biolayer.
- Field testing in Honduras is also being conducted to determine the effectiveness in removing residual contamination in storage buckets in rural schools after biosand filtration.

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