MadiDrop®
RESEARCH DATA ANALYSIS

2025

Presented By
Snow Hill Water LLC

Data Provided By
Silivihere Technologies, Inc.

MadiDrop Research and Testing

Introduction

The MadiDrop is a novel, point-of-use (e.g. household-level) water treatment technology. It is a ceramic tablet infused with metallic silver. The tablet is placed in a water storage container and 10-20 liters of water is added to the container at night. The next morning, the water is safe to drink. When submerged in water, the MadiDrop releases silver ions to a level that is highly effective at disinfecting waterborne pathogens and mosquito larvae, but well below the drinking water standard for silver set by the U.S. Environmental Protection Agency and the World Health Organization. A single MadiDrop works the same way day after day for a total of 12 months, treating more than 7000 liters of water per year. The MadiDrop does not change the taste, odor, or appearance of the water. MadiDrops are now being used in more than 40 countries, providing safe water for more than 500,000 people.

The MadiDrop technology was developed and originally tested by Dr. James A. Smith and two of his doctoral students (Beeta Ehdaie and Carly Krause) in the Department of Civil and Environmental Engineering at the University of Virginia. Initial proof-of-concept experiments began in January, 2012. Research led by the University of Virginia on this technology includes five field studies involving school children and families in rural South Africa, Tanzania, and India. The MadiDrop is named after the Tshivenda word for water, "*madi.*" Tshivenda is spoken in the Venda region of South Africa and is the location of much of our early field testing of this technology. Venda was one of the South African Homelands under the apartheid regime.

Figure 1. The MadiDrop

This document provides an overview of MadiDrop performance data generated by the University of Virginia. The document is divided into two parts: (i) summary of federal funding that has supported this research; (ii) links to published studies of the MadiDrop technology and a synopsis of each archival publication.

The MadiDrop is manufactured and sold by Silivhere Technologies, Inc. The trade name "MadiDrop" is owned by the University of Virginia Licensing and Ventures Group and is licensed to Silivhere Technologies Inc. "*Silivhere*" is the Tshivenda word for silver.

This prior and ongoing research indicates that the MadiDrop is a highly effective technology for microbiological water purification. It produces silver levels in water that are below the USEPA and WHO drinking water guidelines, it does not change the taste of the water, it is simple to use and socially acceptable, it only releases ionic silver into the water, it is effective against viruses, bacteria, and protozoa, and it can treat 10-20 liters of water per day for 12 months.

Developmental Research Funding

This research has been supported financially by the following competitive research grants:

Formation of silver and copper nanopatches in ceramic porous media and application for point-of-use water treatment, 2014-2018, $382,796: National Science Foundation. Principal Investigator: J. Smith; co-PI: Lisa Colosi Peterson. (CBET 1438619).

The MadiDrop: a novel means to provide simple, safe & affordable drinking water, 2013-2015, $25,000: National Collegiate Inventors and Innovators Alliance. Principal Investigator: J. Smith

PureMadi – Metallic-ceramic technologies for global household water purification, 2013-2014, $50,000, Virginia Innovation Partnerships i6. Principal Investigator: J. Smith

I-Corps: PureMadi – Ceramic technologies for global household water purification, 2013, $50,000, National Science Foundation. Principal Investigator: J. Smith.

The Water and Health in Limpopo Innovations Fellowship Program, 2012-2018, $1.75 million, National Institutes of Health. Principal Investigator: R. Guerrant; Co-Investigators: R. Dillingham, J. Smith, P. Bessong, G. Louis, K. Firehock, M. Baernholdt, G. Learmonth, J. Richardson, R. Scharf, and A. Thompson-Heisterman.

REU Site: Water, Society, and Health, 2012-2016, $308,000. National Science Foundation. Principal Investigator: J. Smith, co-PI: G. Louis. (EEC 1156999)

Effectiveness of point-of-use water treatment technologies to prevent child stunting:, 2017-2019, $260,000, USAID PEER Cycle 6: P. Bessong, co-PIs: R Dillingham, E. Rogawski. (Parent NSF grant for PEER program is J. Smith's NSF CBET-1438619)

STTR Phase I: Development of the MadiDropCu+Chloramine: A Disruptive Point-of-Use Water Treatment Technology. 2021-2023, National Science Foundation. PI C. Conti; Co-PIs: R. Letteri and J. Smith, $254,000.

In addition, funding from sources internal to UVA, including the Jefferson Public Citizens (JPC) program, the Community-Based Undergraduate Research Grant (CBURG) program, and the Center for Global Health (CGH), also contributed to MadiDrop development research.

Published Research

Data on the performance of the MadiDrop technology is extensive. Below, references are provided to all published data on the MadiDrop technology to date. In addition, a brief synopsis of the most significant results of each published study are provided. With the exception of the dissertations of Drs. Ehdaie and Nunnelley, all of these published studies have gone through a rigorous and anonymous peer-review process prior to publication. Field studies have been reviewed and approved by the Health Sciences Institutional Review Boards of both the University of Virginia and the University of Venda (Thohoyandou, South Africa). Dr. Ehdaie's and Dr. Nunnelley's dissertations have been reviewed and approved by a five member dissertation committee at the University of Virginia.

1. Ehdaie, B., C. Krause and J. A. Smith, 2014, Porous ceramic tablet embedded with silver nanopatches for low-cost point-of-use water purification: Environmental Science & Technology: 10.1021/es503534c.

This is the first published study of the MadiDrop technology. All data and analyses are based on laboratory evaluation of the technology. There were multiple key findings in this publication. First, the ceramic matrix was characterized and the morphology of silver patches in the porous ceramic matrix was quantified. Disinfection rates were quantified, showing that *E. coli* concentrations could be reduced by 3-4 orders of magnitude (99.9 to 99.99% reduction) within 8 hours of contact time and by 6 orders of magnitude (99.9999% reduction) within 24 hours of contact time. Associated silver levels were able to be maintained at concentrations between 20 and 40 µg/L, which are less than half the USEPA and WHO drinking water standard of 100 µg/L. This study also demonstrated that silver released by the MadiDrop was essentially 100% in the form of ionic silver (Ag^{+1}). Finally, and perhaps most significantly, this study demonstrated that the MadiDrop worked identically, day after day, for at least 6 months.

2. Ehdaie B, Rento CT, Son V, Turner SS, Samie A, Dillingham RA, et al. (2017) Evaluation of a Silver-Embedded Ceramic Tablet as a Primary and Secondary Point-of-Use Water Purification Technology in Limpopo Province, S. Africa. PLOS ONE 12(1): e0169502. doi:10.1371/journal.pone.0169502

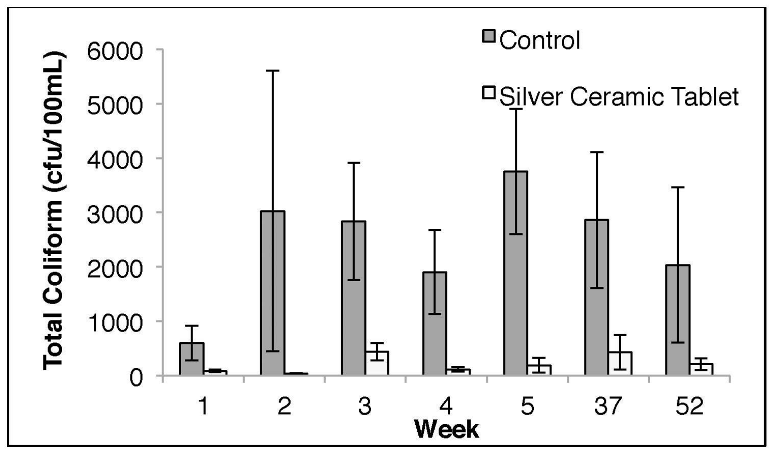

Figure 2. Total coliform bacteria in water storage containers with ceramic tablets. Control samples represent samples taken from the water storage container with the control ceramic tablet. Silver ceramic tablet samples represent samples taken from water storage containers with the silver-embedded ceramic tablet. Data points represent average total coliform levels among all households per week. Standard error was used to calculate error bars.

This is a field study of MadiDrop technological performance in the rural villages of Tshibvumo and Mashamba in Limpopo Province South Africa. The study involved 50 households. Each household was given two safe water storage containers (a 20-L plastic bucket with a cover and spigot) and two MadiDrops. One of the MadiDrops was a “placebo”. It had no silver and therefore had no water treatment capability. The household residents did not know which MadiDrop contained silver. They were told to use both water storage containers equally. Our team visited each home weekly at weeks 1, 2, 3, 4, 37, and 52 and measured the concentration of coliform bacteria in each household’s water storage container. The coliform bacteria levels in the placebo MadiDrop container were consistently high and at unsafe levels. By contrast, the concentration in the MadiDrop containers was zero or near-zero for each sampling visit. Figure 2 is a reprint of Figure 4 from this publication and shows the strong, long-term performance of the MadiDrop in these households. Although we knew the MadiDrop worked well for at least 6 months, this study demonstrated that the MadiDrop appears to continue to work well even after 52 weeks of real-world use. Also, the two villages studied had diverse water supplies, ranging from municipal standpipes, local groundwater wells, and river water, indicating that the MadiDrop works well for a range of water chemistries and turbidities. User acceptance was high and almost all study participants reported that the MadiDrop improved their water quality and was easy to use.

3. Kahler, D.M., Koermer, N.T., Reichl, A.R., Samie, A., and Smith, J.A., 2016, Performance and acceptance of novel silver-impregnated ceramic cubes for drinking water treatment in two field sites: Limpopo Province, South Africa and Dodoma region, Tanzania: Water, v. 8, no. 3, doi: 10.3390/w8030095.

In this study, we worked to increase the silver release and antimicrobial performance of the MadiDrop by changing its macroscopic surface area. We then evaluated the performance of this new form factor in a field study at two rural elementary schools in Limpopo Province, South Africa and the Dodoma region of Tanzania. The MadiDrops again performed exceptionally well, essentially eliminating coliform bacteria from the treated water. In addition, we collected user data and found that the technology was extremely well-received by the school children and teachers.

4. Ehdaie, B., Su, Y.-H., Swami, N.S., and Smith, J.A., 2020, Protozoa and virus disinfection by silver-and copper-embedded ceramic tablets for water purification: Journal of Environmental Engineering, v. 146, no. 4, https://doi.org/10.1061/(ASCE)EE.1943-7870.0001664.

This study shows that the MadiDrop technology is effective against protozoan pathogens (both *Cryptosporidium parvum* and *Giardia lambda*) and the MS2 virus. These results are consistent with other recent studies conducted at the University of Virginia on the effects of silver on protozoan pathogens (Su et al. 2013; Abebe et al. 2015).

5. **Hill, C.L., McCain, K.M., Nyathi, E., Edokpayi, J.N., Kahler, D.M., Operario, D.J., Taylor, D., Wright, N., Smith, J.A., Guerrant, R.L., Samie, A., Dillingham, R.A., Bessong, P.O., and Rogawski, E.T., 2020, Impact of low-cost point-of-use water treatment technologies on enteric infections and linear growth among children in Limpopo, South Africa: American Journal of Tropical Medicine and Hygiene, DOI: https://doi.org/10.4269/ajtmh.20-0228**

In the most extensive study to date, the University of Virginia is evaluating the technological performance and human health benefits of the MadiDrop. This investigation is led by Dr. Rebecca Dillingham, Director of the Center for Global Health and a faculty member of the School of Medicine at the University of Virginia. She has no affiliation or conflict of interest with Silivhere Technologies, Inc.

In partnership with the University of Venda, this randomized controlled study began in June 2016. Study team members enrolled residents of 400 households in rural villages in the Venda region of Limpopo Province, South Africa. The study is particularly focused on the effects the the MadiDrop intervention on children, and each enrolled household had at least one child under the age of three at the time of enrollment.

Study participants were randomly assigned to one of four groups of 100 households. The first group is the control. Families assigned to this group are instructed to use their usual procedures for managing their household drinking water (e.g. there is no intervention). The second group of 100 families received a plastic 20-liter safe water storage container that has a spigot and cover. The third group of 100 families received the safe water storage container and a MadiDrop. MadiDrops used in the study were obtained from inventory of the commercially available product. The MadiDrop is replaced by team members every 6 months. The fourth group received a safe water storage container and a silver-ceramic filter manufactured locally at the PureMadi Mukondeni Pottery Cooperative and Filter Production Facility. Silver-ceramic filters have been shown to significantly improve drinking-water quality and human health (Abebe et al., 2014). Silver-ceramic filters were chosen to provide comparison of the MadiDrop performance to a relatively established technology.

During the course of the study, community field workers visit households quarterly to collect water quality and health data. Water quality data includes measurement of total coliform bacteria of source water and intervention water and silver concentrations for households receiving a silver-based intervention (e.g. MadiDrop and ceramic water filters). Health data include measurement of child height and weight and collection of stool samples for PCR analyses of specific waterborne pathogens. Survey data on water use and health are also collected throughout the study.

Water quality data demonstrate that the MadiDrop technology is performing at a very high level. Figure

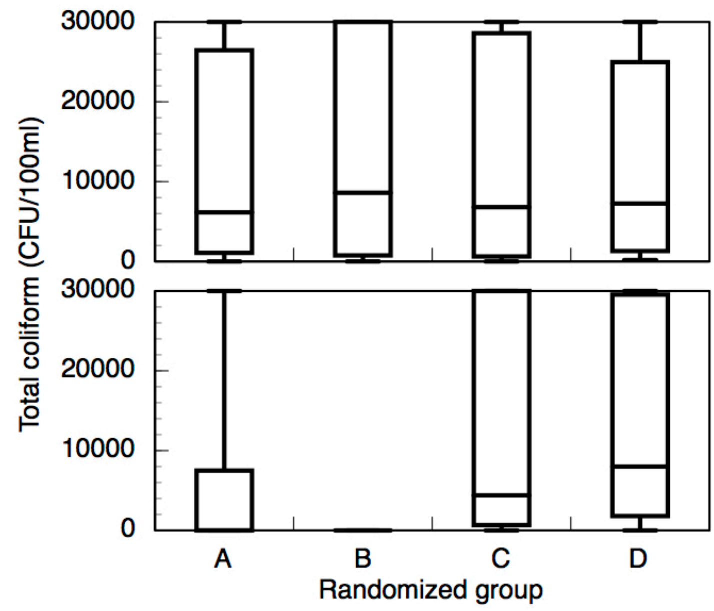

Figure 3. Box and whisker plots showing distribution of coliform bacteria in source water and household water for each study group of 100 households. The lower and upper bound of each box are the first and third quartiles. The horizontal band in the box is the median value. The ends of the whiskers are the minimum and maximum values observed. The upper graph is the source water, the lower graph is the household drinking water. Group A is the ceramic filter intervention, **Group B is the MadiDrop intervention**, Group C is the safe water storage container intervention, and Group D is the control. For the MadiDrop intervention, coliform bacteria concentrations are reduced from a median value of approximately 8000 cfu/100 mL to zero cfu/100 mL.

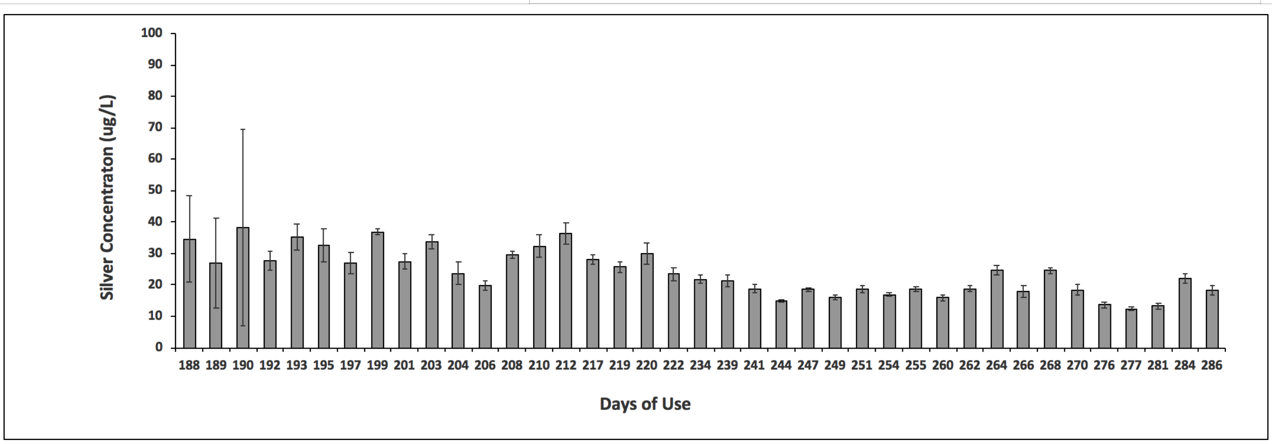

Figure 4. Silver concentration in water as a function of time for MadiDrops that have been used in the field for 6 consecutive months. Following field use, the MadiDrop were returned to the laboratory and placed in 20 liters of synthetic groundwater. The water was sampled after 24 hours and replaced. Silver levels consistently rose to concentrations between 20 and 40 μg/L showing the MadiDrop is still working consistently even after almost 300 days of use.

3 summarizes coliform bacteria data for the 400 households. The coliform data are presented as box-and-whisker plots to graphically describe the variation across households. The upper graphs show coliform data for the untreated source water for the four groups. The lower graphs show the post-intervention coliform data for the four groups. In the case of the control group (group D), there is no significant difference between the source water quality and the drinking water. For the group receiving a safe water storage container, there appears to only be marginal improvement in drinking water quality. Presumably, the safe water storage container helps to protect the water from additional contamination from, say, children reaching their hands in the container to scoop out some water. For the group receiving a MadiDrop and a safe water storage container (group B), there is a 100% reduction in coliform bacteria. This performance even exceeds the silver-ceramic filter (group D), although the filter still demonstrates very strong performance.

MadiDrops used during the first 6 months of this field trial were returned to the laboratory at the University of Virginia for additional testing. Four of the MadiDrops were randomly selected and placed in water storage containers with 20 liters of synthetic ground water. The water was replaced every 24 hours, and the silver concentration in the water was measured immediately before replacement. Figure 4 shows the results of these tests to date. The data show that the MadiDrops are still producing ideal silver concentrations for disinfection 24 days after the initial 6 months of field use. These data, coupled with the results from Figure 2, indicate that MadiDrop perform at a high level for 12 months or more.

Using early feedback from MadiTrial households, Silivhere Technologies, Inc. improved the silver application method used to produced the original MadiDrop and introduced the MadiDrop. The original MadiDrop could treat up to 10 liters of water per day for 6 months. The MadiDrop now treats up to 20 liters of water per day for 12 months, effectively quadrupling the cumulative amount of water treated relative to the original MadiDrop with only a small increase in price.

6. **Harris, J., Davis, J., Reese, M., Mannzhi, M., Tshidumo, N., Mhlarhi, R., Edokpayi, J., and Smith, J.A., 2023, Improving Antibacterial Performance of Household Water Filters with a Silver-Embedded Ceramic Tablet: Journal of Environmental Engineering, v. 149, no. 7; DOI: 10.1061/JOEEDU.EEENG-7264. EDITOR'S CHOICE AWARD PAPER (this is decided by the Editor-in-Chief and only one paper is selected monthly from the journal)**

This study evaluated the bacterial reduction of several water filters with and without a MadiDrop in both the laboratory and household settings. In laboratory tests, after 24 h, Kohler Clarity filters with MadiDrop halves split between upper and lower reservoirs removed 6.0 log E. coli, whereas filters alone removed 2.7 log E. coli. After 2 h, Rama Water carbon filters with MadiDrop halves split between reservoirs removed 3.3 log E. coli, whereas filters alone removed 1.7 log E. coli. After 2 h, ceramic pot filters with a MadiDrop in the lower reservoir removed 3.9 log total coliform bacteria (TCB), whereas filters alone removed 2.8 log TCB. In households, effluent TCB [colony-forming units per 100 mL] was between 0 and 12, 1 and 36, and 509 and 5,916 when the MadiDrop was in the lower reservoir, split between reservoirs, and not present in Kohler Clarity filters, respectively. Silver levels were ≤100 μg/L, the drinking water limit set by the USEPA. The addition of silver via a MadiDrop either wholly in the lower reservoir or split between upper and lower reservoirs of household water filters improved bacterial reduction in both laboratory and household settings.

7. **Juran, L., Wilcox, E., Albritton, M., Smith, J., Harris, J., Cohen, A., Sharma, L., and Gautam, Y., 2024, Effectiveness of the upscaled use of a silver-ceramic (silver ionization) technology to disinfect drinking water in tanks at schools in rural India: Journal of Water and Health, in review.**

This study deployed a silver-ceramic technology (MadiDrop) to disinfect drinking water in school storage tanks. While silver ionization is effective at the household scale, relatively little research has been conducted on its effectiveness at community scales. To address this gap, we assessed silver ionization disinfection via MadiDrop at three schools that serve vulnerable populations in rural India. Tank inflow and treated outflow were tested for total coliform (TC) and E. coli (EC). Silver concentrations were measured to ensure levels below the drinking water quality guideline. TC was significantly reduced in two of three tanks and overall. Reductions in TC and EC were significant compared to the baseline, and TC reduction was negatively corelated with silver concentration and tank residence time. Additionally, silver concentrations were maintained below the guideline. While the intervention could be considered successful, barriers and caveats are provided (e.g., monitoring silver concentrations in low-resource settings) as are study limitations and areas for future research.

Additional Third-Party Testing

The MadiDrop technology has been evaluated quantitatively by several of our international clients. These test results are uniformly positive and are available upon request.

Summary

Extensive research has been conducted by the University of Virginia to develop and test the performance of the MadiDrop technology. This work has been supported by significant federal funding. Results of this research demonstrate that the MadiDrop is a highly effective point-of-use water treatment technology for the developing world. It is effective agains waterborne pathogens, it is simple to use, it is socially acceptable, it is capable of treating 10-20 liters of water per day, and it has a lifespan of 12 months or more.