Baseline Testing of the Health Effects of the MadiDrop

in Limpopo Province, South Africa

By Kelly McCain, Amanda Gaylord, Evie Stinger & Catherine Reynolds

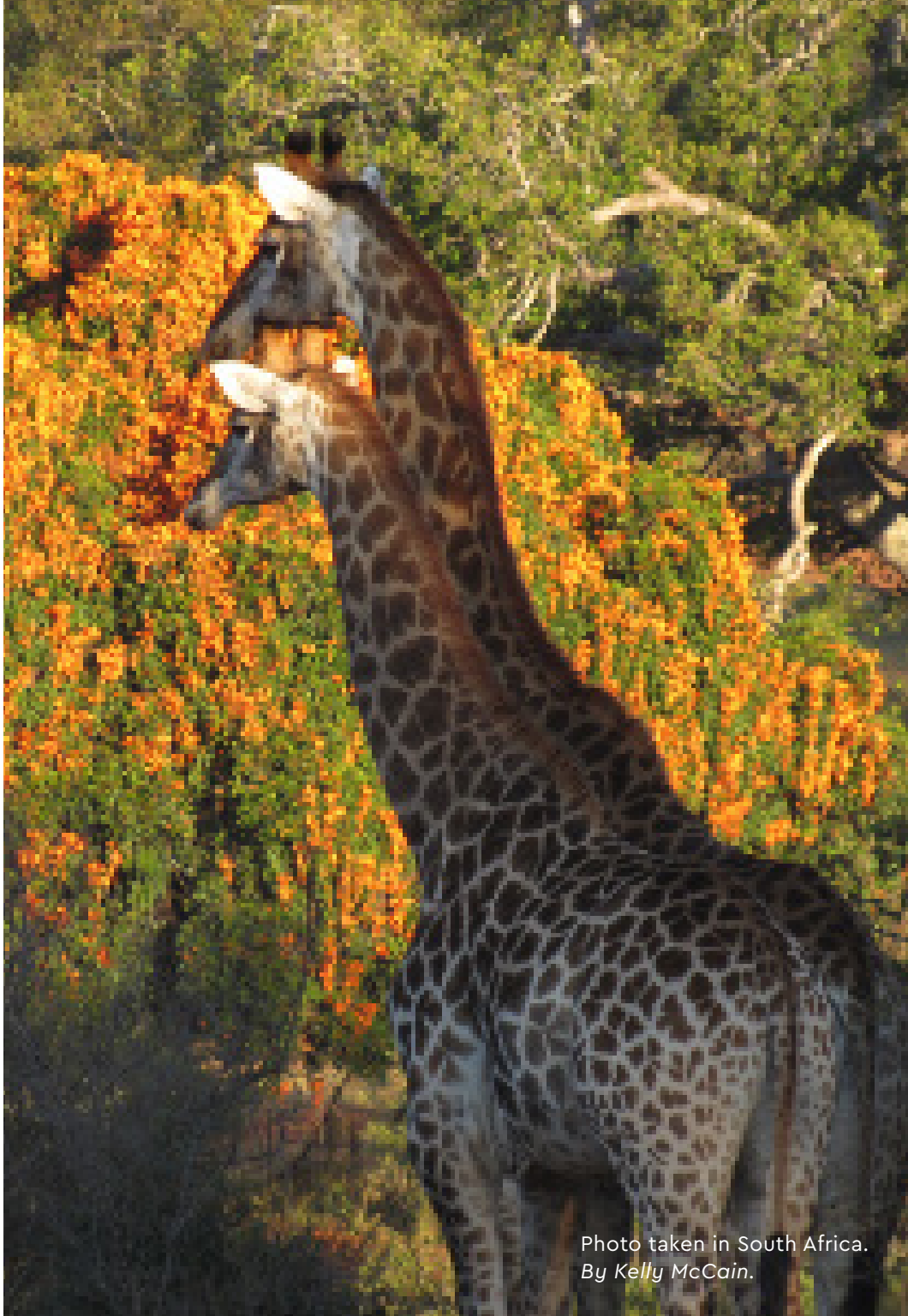

Photo taken in South Africa.
By Kelly McCain.

ABSTRACT

Access to clean water remains a pressing need in the rural Limpopo province of South Africa. Low cost point-of-use water purification methods have the potential to greatly improve the health of children in this area. This water purification research conducted was therefore divided into two focuses: first, an analysis of the effect of different water chemistries on the effectiveness of the MadiDrop, a small ceramic disk impregnated with silver nanoparticles that continually disinfects stored water in households. Second was a collection of baseline data and the installation of point-of-use water purification interventions for a two-year-long study on the impact of sustained intervention use on human health, specifically the growth of children. The consequent results suggest that the MadiDrop was effective at purifying water, except in situations with high turbidity. Data for the two-year-long study is still being collected and analyzed.

Photo taken in South Africa.
By Kelly McCain, et. al.

On the left is a MadiDrop. On the right is a ceramic filter with a bucket.

BACKGROUND

In the current global climate, clean, safe water is scarce. Contaminated water causes high rates of diarrhea, one of the leading causes of death worldwide. Early childhood diarrhea has also been associated with impaired cognitive function [1]. In addition, continuous exposure to enteropathogens in contaminated water causes high rates of enteric infections and also likely contributes to the development of environmental enteropathy, an inflammatory condition of the gut associated with increased intestinal permeability, impaired gut immune function, and low nutrient absorption [2]. The impact of environmental enteropathy in children will result in stunting and poor growth, which is an established marker of long-term morbidity and has been associated with cognitive impairment, poor school performance, low adult economic productivity, and increased risk of chronic disease later in life [3,4].

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Developing easy-to-use, effective, socially acceptable, and inexpensive methods to treat water is critical. Low-cost, point-of-use water treatments such as the MadiDrop, a silver-impregnated ceramic tablet, and ceramic water filters have the potential to vastly improve the health of millions of children worldwide in low-resource settings with unsafe water. Solutions like the MadiDrop can provide consistently clean drinking water in homes despite other external factors (e.g., runoff and pollution) that might reduce the quality of the water. These water treatment methods have been tested vigorously and have been proven to drastically reduce the amount of bacteria in the water by other researchers from the University of Virginia (UVA) [5]. However, the relationship

between human health and the use of these point-of-use water treatment methods has not yet been studied.

UVA has a long-standing relationship with the University of Venda (UNIVEN) in Thohoyandou, South Africa. The project team traveled to Dzimauli, a low-resource group of communities in a valley near Thohoyandou that has participated in previous studies involving the two universities. The water in Dzimauli is highly contaminated with E. coli and other bacteria. Despite regularly ingesting large amounts of bacteria, the children in these communities do not have high incidences of diarrhea. However, it is suspected that this lack of symptoms imparts a false feeling of safety, and that children may suffer from environmental enteropathy, and as a result, stunting and poor linear growth [2].

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The goal for this project was to collect baseline data for a larger two-year study that will analyze the effects of the MadiDrop, (alone and in combination with a silver-impregnated ceramic water filter), on linear growth (height and weight) of children in the Limpopo region of South Africa. As part of this investigation of water quality and the effectiveness of the MadiDrop on water with different chemistries, we attempted to examine existing household water storage and treatment systems to determine any impact these might have on water quality.

METHODOLOGY

Focus 1: Analysis of different water chemistries on MadiDrop effectiveness

The UVA JPC team worked with

Photo taken in South Africa.
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The photo is of a 20-liter bucket being filled at a water source.

UNIVEN students to collect 60 liters of water from 7 diverse water sources that in-field testing had shown to display noticeably different levels of dissolved oxygen, pH, turbidity, conductivity, and temperature. These tests were repeated at the UNIVEN lab with different equipment when the accuracy and dependability of the equipment used in situ was called into question.

The water samples were taken back to the UNIVEN lab and divided evenly among six buckets. Five buckets contained two MadiDrops each, and one bucket was a control bucket. The water in all of the buckets was left undisturbed for eight hours. At the end of that time period, a sample was taken from each bucket and analyzed for total coliform bacteria via membrane filtration. After filtration and a 24-hour incubation period, petri dishes were analyzed for bacterial growth and the number of colonies were recorded. Colonies were counted up to 300; in some dishes, colonies were indistinguishable from each other and were therefore recorded as 300+.

Researchers from UVA and UNIVEN analyzed samples for silver content. This was necessary to ensure that the silver levels were at a safe level for human ingestion.

Focus 2: Collection of baseline data and installation of point-of-use water purification interventions for the two-year-long Human Health study

After getting IRB (Institutional Review Board) approval for the human health focus of the research, the UVA JPC team worked with local community health workers and partners at UNIVEN to retrieve baseline data for a two-year-long study on the impact of sustained, continuous intervention use on human health, specifically the growth of children. Households were first visited by community health workers to be screened and deemed eligible for the study. Households were eligible for enrollment if there was a child under three years of age living in the home. Once enrolled, households were randomly assigned to one of four intervention groups:

1. A ceramic filter, a bucket with a spigot and lid, and two MadiDrops
2. A bucket with a spigot and lid and two MadiDrops
3. A bucket with a spigot and lid
4. No Intervention

A second visit to the household was then made by community health workers with UVA and UNIVEN student researchers to install the appropriate intervention, to give detailed instructions on how to use the intervention, and to collect baseline data. The baseline data collected was: the height and weight of all the children under the age of 16 living in the household; a stool sample from the youngest child (the primary study subject); and answers to a questionnaire concerning demographics, socioeconomic status, water sources, and sanitation and hygiene practices. A portable scale and height-measuring instrument were used to collect anthropometric data, with an infant length board used for children too young to stand. A plastic container with a screw lid, rubber gloves, and tongue depressors (in lieu of a spatula) were used for stool collection.

Photo taken in South Africa. *By Kelly McCain, et. al.*

UVA student researchers analyze petri dishes on-the-go.

Samples were placed in a cooler as soon as possible and were transported back to the UNIVEN lab that same day. A second visit was scheduled for the next day by UVA and UNIVEN students to collect inflow and outflow water samples of the interventions at every household, including the control households (no intervention). At the control households, an inflow sample was taken from the households' water storage container or pipe, and an outflow sample was taken from the primary drinking water source. Samples were collected in lab bags, placed in a cooler as soon as possible, and transported back to the UNIVEN lab that same day.

Inflow/outflow water samples collected from households were analyzed via membrane filtration and a turbidimeter by UVA and UNIVEN students. Analysis of the 24-hour incubated petri dishes was conducted as discussed above. Stool samples were tested by researchers at UNIVEN for myeloperoxidase (MPO) and characterizations of Cryptosporidia sp., Giardia lamblia, Entamoeba sp., and diarrheagenic E. coli.
After the completion of the baseline data collection, trained community health workers will visit enrolled households in 3-month intervals following the initial receival of the interventions. UNIVEN researchers will carry out data analysis.

RESULTS AND OUTCOMES

The testing site known as Lutsingeni was a standing pool of water into which a pipe flows. Farm workers use the water from this pipe as drinking water while working on the fields. We wanted to test the difference in water quality from the pipe to the standing pool. The pool was extremely shallow so when filling sample buckets, a lot of mud and silt was unavoidably gathered with the water. Although the team filtered out as much of the turbidity as they could, the extremely high turbidity likely clogged the pores of the MadiDrop, causing a failure in their ability to disinfect the water. We believe the turbidity caused this failure due to the

Figure 1: MadiDrop Disinfection Trials on Sites of Varying Water Chemistry

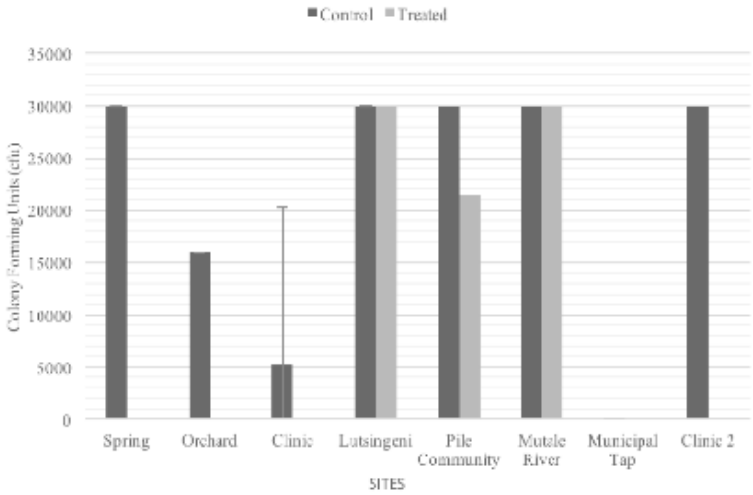

Figure 1, above, shows the averaged differences in bacterial levels in samples from water sources throughout Dzimauli both before and after treatment with the MadiDrop. For the majority of the water samples, there was a significant amount of colony forming units in the pre-treatment water. For the spring, orchard, and both clinic sources the level of bacteria in the water was reduced to almost zero colony-forming units after treatment with the MadiDrop. This translates to a 5-log bacterial reduction from pre- to post- treatment water.

fact that all of our other water samples, none of which were turbid, had vastly different water chemistries, but no other sample had this effect on the MadiDrop. With the pores clogged, it is possible that the silver was unable to diffuse out from the MadiDrop and effectively disinfect the water. We used the same MadiDrops for the next two samples, the Pile Community System and the Mutale River, and we did not see as large of a reduction in bacteria as we did with the samples tested before Lutsingeni. After the Mutale River sample, we decided to replace the MadiDrops, and once we had replaced them, we again saw a 5-log bacterial reduction.

DISCUSSION

As the human health study is to be conducted for another year, we are unable to release data gathered after the preliminary results. With these results, however, we may state that the use of ceramic filters and MadiDrops leads to a significant decrease of bacteria levels in drinking water. The

We witnessed no resistance to the use of the ceramic filters or the MadiDrops.

average drop of bacterium was a magnitude of 5-log. Besides the encouraging quantifiable evidence of the effectiveness of these technologies, we witnessed no resistance to the use of the ceramic filters or the MadiDrops. This suggests that both devices are perceived as socially acceptable within the Limpopo Region and, therefore, are more likely to be used.

In the analysis of collected data, as mentioned above, we hypothesized that an increase in turbidity causes a decrease in the effectiveness of the MadiDrop. These findings are valuable but further analysis and research must be conducted in order to determine the extent to which extreme variations in water quality can limit the MadiDrop. As of now, the MadiDrop can be

Figure 2: Preliminary Results of the Human Health Study

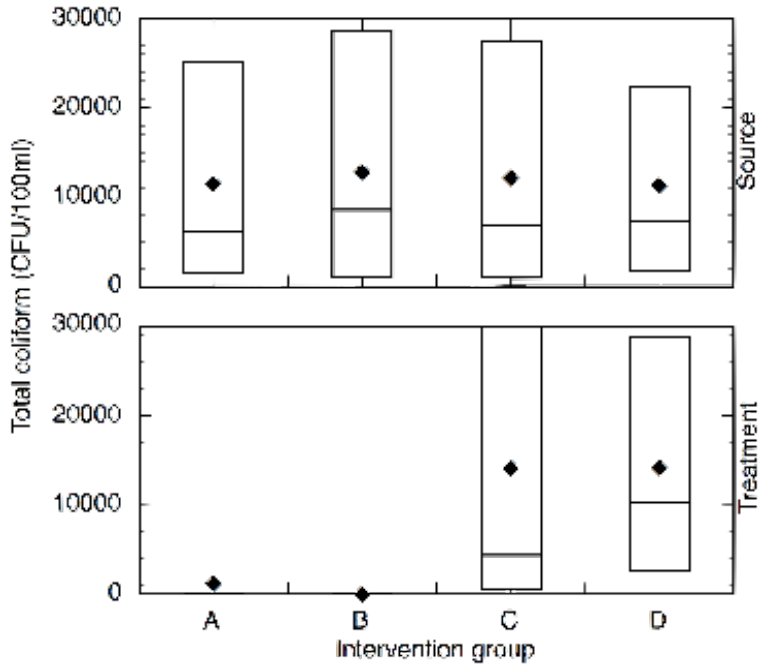

Figure 2 shows the changes in total coliform in household water samples before and after treatment with the four different intervention groups (A: Filter + MadiDrop, B: MadiDrop only, C: Bucket, D: no intervention). The inflow and outflow water samples taken the day after intervention installation are included in this figure. It clearly shows contaminated inflow water before treatment, with a range of about 1,000-28,000 colony forming units in 100 mL of water. For the outflow samples that had been treated with interventions A and B, the number of colony forming units in 100 mL of water decreased to almost zero, translating to a 5-log reduction. For interventions C and D, the number of colony forming units per 100 mL of water stayed about the same.

recommended for use with clear, non-turbid water only.

A limitation of the study was the relatively short time we were able to work on the project. The full human health study spans two years and we will not be present for the majority of it. Another team of students and postdoctoral researchers will return during the summer of 2017 to continue work on the project. There are community health workers administering follow-up surveys, conducting anthropometric measurements, and collecting stool samples on a regular schedule. Another limitation was the physical distance between our lab space and the field. For the planning stage of the project, we were in the US and the majority of the work done was in South Africa. It was sometimes difficult to transfer needed supplies and to communicate with community partners due to distance. As a group, however, we recognized that these were potential limitations and planned accordingly, packing supplies in our luggage, communicating with community partners via email, and making the most of our time.

Group photo taken in South Africa.
By Amanda Gaylord.

CONCLUSION

While much was accomplished in the short amount of time our team was able to spend in the field, more analysis must be done before the impacts on human health of the PureMadi filters and MadiDrop can be concluded. We are confident that these technologies will significantly reduce the presence of pathogens in drinking water. By the end of this ongoing study, we hope to report that these technologies positively impact human health.

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