Experiences with ceramic pot water filtration systems in Uganda: A case study of the health and social impacts of a market-based approach

by

Fantasia Williams

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Thesis Committee:
    Assistant Professor of Practice, Jose F. Alfaro, PhD
    Professor, Environmental Health Sciences, Marie S. O'Neill, PhD

Abstract:

Nearly half of the developing world lacks access to improved sanitation, and millions of individuals lack access to improved drinking water. Following trends of the rest of the developing world, diarrheal diseases are the number one cause of death among children under five years old in Uganda. Among all age groups, diarrhea can still be found among the top ten causes of death, continuously securing the sixth spot over the past ten years. In response, SPOUTS of Water, a Ugandan based NGO, began manufacturing and selling ceramic pot filters as an effective and affordable method of water treatment. Across various locations and over time, evidence has demonstrated that improving water and sanitation conditions can prevent a significant portion of diarrheal disease. The primary objective of this cross-sectional study is to investigate if the usage of the Purifaaya filter in two Ugandan communities is associated with a reduced prevalence of diarrheal disease. After adjustments for the total number of persons in a household, location (urban vs rural), water source, and toilet type, the study found that there was an association between filter use and the reduction in reported diarrheal disease. These results are a roadmap for understanding the potential for water filters to impact environmental and health outcomes in areas similar to that of rural Uganda.

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1. Introduction

Today, diarrheal diseases are a tremendous burden of illness in developing countries. In the last three decades, roughly 2 billion people around the world have gained access to both improved drinking water sources and improved sanitation (Centers for Disease Control and Prevention, 2014a). Still, nearly half of the developing world lacks access to improved sanitation, and millions of individuals lack access to improved drinking water (Centers for Disease Control and Prevention, 2014a; WHO/UNICEF, 2008). Most commonly, food and water contaminated with human or animal feces carry the pathogens that cause diarrhea (Centers for Disease Control and Prevention, 2014a). As a result, in developing countries, unsafe water, inadequate sanitation, and poor hygiene are responsible for approximately 88% of diarrheal related deaths (Centers for Disease Control and Prevention, 2014a). This has a profound impact on children. According to the Center for Disease Control and Prevention (CDC), “Diarrheal diseases kill more children than AIDS, malaria, and measles combined, making it the second leading cause of death among children under five (2014a)”. This number equates to about 525,000 children annually (World Health Organization, 2017). In addition to death, these types of diseases contribute to other conditions such as malnutrition and dehydration, which are both common when the nutrients are lost and not adequately replaced (World Health Organization, 2017).

1.1. *Diarrhea*

Diarrhea is defined as “the passage of three or more loose or liquid stools per day, or more frequently than normal for an individual” (World Health Organization, 2009). The cause of diarrhea can vary but it is most often a symptom of an infection in the intestinal tract caused by a variety of pathogens spread by fecal-oral transmission or contamination from both human and animal sources. (World Health Organization, 2017). These bowel movements can last extended periods and typically flush the body of water and salt until such time that the person can no longer survive unless they are provided with treatment to replenish the water and electrolytes (World Health Organization, 2017).

There are three types of diarrhea: acute watery, acute bloody, and persistent (World Health Organization, 2017). Acute watery diarrhea is “associated with significant fluid loss and rapid dehydration in an infected individual” (World Health Organization, 2009). *V. cholerae, Escherichia coli (E. coli),* and rotavirus are the pathogens most commonly responsible for this type of diarrhea (World Health Organization, 2009). Acute bloody diarrhea usually lasts from several hours to several days. It is also often referred to as dysentery and consists of “visible blood in the stools” (World Health Organization, 2009). This symptom is associated with severe intestinal damage and nutrient loss caused by an infection. The most severe cases of bloody diarrhea are typically caused by the bacteria Shigella (World Health Organization, 2009). Persistent diarrhea can consist of symptoms from either the acute watery or acute bloody types but last at least 14 days (World Health Organization, 2009).

1.2. *Diarrhea in Sub-Saharan Africa*

Sub-Saharan Africa is facing some of the world’s greatest water and sanitation challenges (WHO/UNICEF, 2008), and half of its population is expected to remain rural until at least 2030 (UN, 2007). Urban and rural areas share some of the same institutional and technical challenges in sustaining clean water. However, rural areas face additional challenges associated with a lack of roads, telecommunications, electricity, and the general absence of a formal small business sector (Montgomery, Bartram, and Elimelech, 2009).

1.3. Diarrhea in Uganda

Currently, 61 % of Ugandans lack access to safe water (Water.org, 2018). With Uganda's population of 42.8 million people, this equates to more than 26 million people based on 2017 population estimates by the Ugandan Population Reference Bureau (Centers for Disease Control and Prevention, 2017). Following trends of the rest of the developing world, diarrheal diseases are the number one cause of death among children under five years old in Uganda (Centers for Disease Control and Prevention, 2017). Among all age groups, diarrhea can still be found among the top ten causes of death, continuously securing the sixth spot over the past ten years (Institute for Health Metrics and Evaluation, 2017).

In rural Uganda, the five main types of water sources that are generally used include traditional water sources, improved point water sources, shallow wells, protected springs, and gravity-flow tap stands (Asingwire, 2011). Traditional water sources like ponds and open wells are considered unsafe, but oftentimes users must resort to using them when faced with barriers to safer sources such as long distances and lack of adequate transportation. Improved drinking water sources include sources that, "by nature of their construction or through active intervention, are protected from outside contamination, particularly fecal matter" (WHO/UNICEF, 2008). Although these supplies are protected from contamination, they are not necessarily free of pathogens (WHO/UNICEF, 2008). Point water sources in Uganda prompt rivalry between community members, as they are usually collectively owned, managed, and used (Poteete, Janssen, and Ostrom 2010). These communal arrangements make it hard to control for unauthorized users and combat against the tragedy of the commons. The most common pathogens responsible for severe diarrhea in low-income countries are Rotavirus and Escherichia coli (World Health Organization, 2017). In Uganda, the most common agent of diarrhea is Rotavirus (UNICEF, 2018).

1.4. *Purpose of Study*

Increasing access to and educating communities about the value of improved water sources and sanitation are important because these are essential to support healthy communities and positive health, economic, and social benefits overall (Bartram et al., 2005). Across various locations and over time, evidence has demonstrated that improving water and sanitation conditions can prevent a significant portion of diarrheal disease (World Health Organization, 2017). According to the Centers for Disease Control and Prevention, access to safe water and improved hygiene and sanitation "has the potential to prevent at least 9.1% of the global disease burden and 6.3% of all deaths" (2014a). Prevention and treatment are also significant in addressing this problem. Prevention efforts must involve education and behavioral changes, including simple practices such as hand washing and using water treatment methods. Treatment is also important and incorporating concepts such as rehydration must be integrated into response efforts. Keeping track of how prevention and treatment methods are used, how effective they are, and how they are evolving is important because they will help inform future responses to this problem.

The amassed information about the connection between improved drinking water and the reduction of diarrhea episodes has motivated the development and testing of numerous locally adapted water interventions and low-cost technologies to provide safe drinking water in developing countries. These introductions include the use of ceramic filtration devices (Arnold and Colford Jr, 2007). In an effort to address these issues, the non-profit organization, SPOUTS of Water (SPOUTS) was formed in 2011 (https://spouts.org/). The group has taken major steps towards providing effective and affordable methods of water treatment through the manufacturing and selling of a ceramic pot filter, the Purifaaya, that the company claims effectively eliminates 99.9% of water-borne bacteria without the need to boil. SPOUTS targets communities in Uganda that currently lack access to effective and affordable methods of water treatment.

The primary objective of this cross-sectional study is to investigate if the prevalence of diarrheal disease in a household is associated with the usage of the Purifaaya filter in two Ugandan communities. A secondary objective is to investigate if this association differs between rural and urban populations. We hope to have a better understanding of how the cumulative effects of exposures to environmental contaminants, such as water-borne pathogens, combine with social stressors to affect health, and even more specifically the distribution of diseases. The results of this study can help shape policy decisions and evidence-based practice by verifying a method to decrease risk factors for diarrheal disease and provide a new option for preventive healthcare. It may also prove to be a roadmap for understanding the potential for comparable water filters to impact environmental and health outcomes in regions similar to that of Uganda.

2. Methods

2.1. *Cross-sectional study*

This cross-sectional study was conducted over two weeks in August 2018 in two Ugandan communities: Kampala, the urban capital city of Uganda bordering Lake Victoria, and Namasagali, a rural community in Eastern Uganda along the Nile River (Figure 1). We collected baseline socio-demographic measurements and self-reported incidence of diarrheal disease among households that used the Purifaaya ceramic 20-liter pit filter. We compared the reported prevalence of diarrheal disease before and after filter usage, as well as explored the effect of community type on this prevalence.

2.2. *Study Population*

Communities were selected for sampling based on set criteria. In order to identify communities that had households using the Purifyaa and were suitable for comparison, we consulted with the SPOUTS of Water staff and client registration system. Communities were chosen based on the following criteria: a) a group of at least 20 households had received a Purifiyaa during May 2018 b) community type differed (i.e. urban vs rural), and c) filter acquisition methods differed, i.e. households in one community purchased the filters and households in the other received the filters through donations from an aid program. Namasagali is located about 160 kilometers north of Kampala, four hours when driving. Households sampled in Namasagali received the filters through an aid program run by SPOUTS Uganda, an NGO subsidiary of SPOUTS of Water with support from Korea International Cooperation Agency (KIOCA). Households sampled in Kampala purchased the filters themselves either through a payment plan with three installments or a one-time lump sum payment.

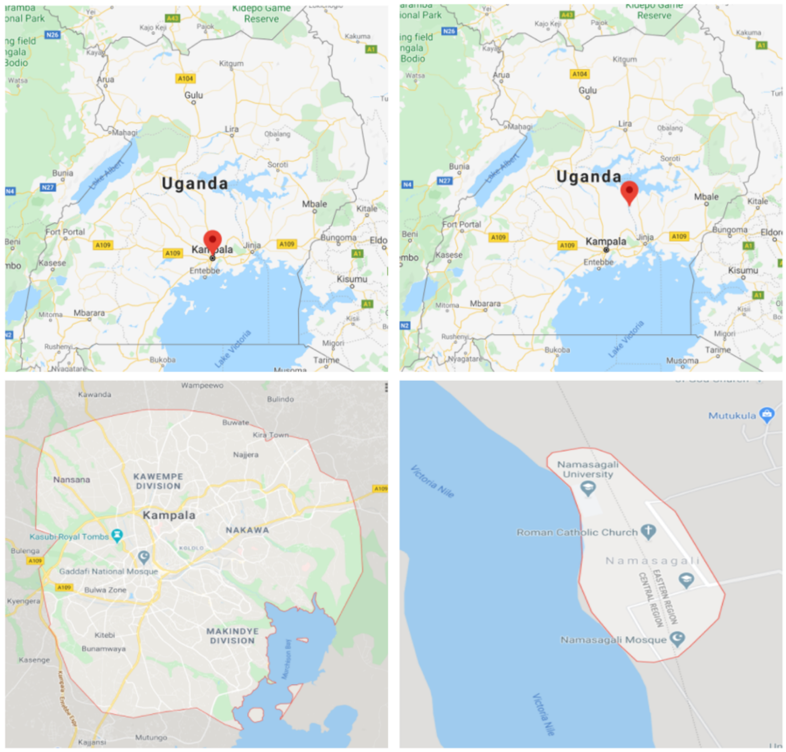

Figure 1. The geographical location of the Ugandan study sites. The visual on the top left shows the location of the country capital of Kampala relative to major cities in Uganda. The visual on the top right shows the location of Namasagali relative to Kampala and other major cities in Uganda. The visual on the bottom left shows the boundaries of Kampala, where most respondents resided. The visual on the bottom right shows the boundaries of Namasagali.

2.3. *Household Survey*

Enumerator-assisted questionnaires were administered to determine the effectiveness of the Purifaaya and collect information on a variety of social factors (including age, gender, location, and socioeconomic status). The questionnaires used in this study contained ten sections comprising 80 questions total. The ten sections collected information about Household Demographics, Health – Baseline, Health – Follow Up, Water Source, Drinking Water - Before Filter, Product Acquisition/ Filter Use, Livelihood, Filter Replacement, Poverty Indicators, and Sanitation. Diarrheal disease was self-reported by the household as any member of the household having three or more loose stools in a day (World Health Organization, 2009). The survey was written in English and piloted with students in Ann Arbor, Michigan, and SPOUTS Staff in Kampala, Uganda to check the clarity and context appropriateness of questions being asked. After each pilot, survey revisions were made. Two days were spent training three enumerators and two SPOUTS staff to impart a standardized understanding of the interview protocols. Paper questionnaires were chosen because of challenges faced in the field surrounding the ability to guarantee a reliable power supply for tablets or mobile devices. The cost of acquiring suitable devices also played a large factor.

2.4. *Statistical Analysis*

Reported diarrheal prevalence at the household level was compared between before and after filter usage and between urban and rural locations. If one or more household members had diarrhea in between February 2018 - April 2018, baseline, household diarrhea = 1, otherwise household diarrhea = 0. Similarly, if one or more household members had diarrhea in between May 2018 - August 2018, follow-up, household diarrhea = 1, otherwise household diarrhea = 0. We used logistic regression models to estimate odds ratios and 95% confidence intervals for the prevalence of diarrhea. The dependent variable for all models was household diarrhea and the primary exposure variable was a binary measure of filter usage, with 0 = pre-filter usage and 1 = post-filter usage. Potential confounding variables were decided a priori then individually added to the model to measure their effect on the association between filter usage and diarrheal disease. All analyses in this study were performed in R software, version 3.6.2.

2.5. *Human Subjects Approval*

The University of Michigan Institutional Review Board granted this study exempt status (HUM00148335). All participants gave oral, informed consent before participation.

3. Results

3.1. Household Survey

A total of 185 households were interviewed during a two-week period from August 6, 2018 to August 17, 2018. This included 135 urban households from Kampala and 35 rural households from Namasagali. The average household size was 6, 6, and 7 persons for the whole study population, urban, and rural households, respectively.

3.2. Prevalence of Diarrheal Disease

There were 28% households with at least one diarrheal case in the baseline period between February 2018 and April 2018; 21% urban households and 46% rural households (Table 1). Extra-large-sized households had the highest percentage of cases with 50%, followed by medium-sized households with 34%, large-sized households with 25%, and small-sized households with 20%. After using the Purifiyaa for a three-month period between May 2018 and July 2018, only four households reported a case of diarrheal disease, and all four cases occurred in urban households (3%).

Usage of a Purifiyaa was associated with lower odds of diarrheal disease after accounting for differences in household size and adjusting for potential confounders (Table 2). Crude analysis (Table 2, Crude) shows a significant 95% decrease (OR= .05, 95% CI: 0.02, 0.16) in the prevalence of diarrheal disease for households after using the filter. In the model adjusted for the total number of persons in a household, location (urban vs rural), water source, and toilet type, a 90% decrease (OR= .10, 95% CI: 0.03, 0.32) in the odds of at least one person in the household having diarrhea was observed after the filter was installed in the household, versus before it was installed (Table 2, Model 4). Additionally, a significantly lower prevalence of diarrheal disease was seen for urban households (OR= 0.04, 95% CI: 0.01, 0.40) compared to rural households.

The odds of a household having diarrhea increased almost tenfold when switching from piped water supplied by The National Water and Sewerage Corporation to retrieving water from an unprotected well or spring (OR= 9.28, 95% CI: 1.17, 73.36). By contrast, an 88% decrease in the odds of a household having diarrhea was observed when switching from piped water supplied by The National Water and Sewerage Corporation to using a borehole or handpump (OR= 0.11, 95% CI: 0.02, 0.96). Although, only marginally significant (p=.09), the data suggest that for each additional person in the household there was a 14% increase in the odds of at least one person in the household having diarrhea (OR= 1.14, 95% CI: .98, 1.31).

Table 1. Characteristics of Study Households at Baseline by Diarrheal Disease Status

	Diarrhea at Baseline		**Diarrhea at Follow-up**	
	Yes (*n* =52)	**No (*n* =133)**	**Yes (*n* =4)**	**No (*n=181*)**
Characteristics	N (%)	N (%)	N (%)	N (%)
Overall	52 (28)	133 (72)	4 (2)	181 (98)
Household Type				
Urban	29 (16)	106 (57)	4 (2)	131 (71)
Rural	23 (12)	27 (15)	0	50 (27)
Household Size				
Small (1-5)	17 (9)	65 (35)	2 (1)	80 (43)
Medium (6-10)	30 (16)	57 (31)	1 (1)	86 (46)
Large (11-15)	3 (2)	9 (5)	0	12 (6)
Extra-Large (16-20)	2 (1)	2 (1)	1 (1)	3 (2)
Water Source				
Piped (NWSC)	10 (5)	47 (25)	2(1)	56 (30)
Piped (Gravity)	4 (2)	8 (4)	0	13 (7)
Protected Well	13 (7)	35 (19)	1 (0.25)	49 (26)
Unprotected Well	5 (3)	3 (2)	1 (0.25)	6 (3)
Borehole	15 (8)	30 (16)	0	47 (25)
Stagnant Open	1 (1)	2 (1)	0	3 (2)
Moving Open	4 (2)	1 (1)	0	5 (3)
Rain Water	0	7 (7)	0	2 (1)
Toilet Type				
Uncovered Pit Latrine	14 (8)	39 (21)	2(1)	51 (28)
Covered Pit Latrine w/o Slab	12 (6)	1 (1)	0	13 (7)
Covered Pit Latrine w/ Slab	2(1)	24 (13)	1 (1)	25 (14)
Flush Toilet	2(1)	16 (9)	0	18 (10)
Missing	22 (12)	13 (7)	1 (1)	74 (40)

Table 2. Odds Ratios for the Prevalence of Diarrhea Post Filter Usage (n = 185)		
Model	**OR**	**95% CI**
Crude	0.05	(0.02, 0.16)
Model 1	0.05	(0.02, 0.15)
Model 2	0.05	(0.01, 0.15)
Model 3	0.04	(0.02, 0.13)
Model 4	0.1	(0.03, 0.40)
Abbreviations: CI, confidence interval; OR, odds ratio.		
Model 1 was adjusted for total number of persons in household.		
Model 2 was adjusted for total number of persons in household and location		
Model 3 was adjusted for total number of persons in household, location (urban vs rural), and water source.		
Model 4 was adjusted for total number of persons in household, location (urban vs rural), water source, and toilet type.		

3.3. Experiences with Water Treatment and Filter Use

One of the successes of SPOUTS Purifiaaya campaign and distribution system demonstrated through this study is ensuring its clients are adequately informed of correct filter usage and maintenance behaviors. All of the following responses were calculated based on response rates displayed in Table 3. When asked by enumerators to demonstrate how one would clean and retrieve water using the Purifiaaya 99% and 61% of households completed the task successfully, respectively. All the better, 90% of households were cleaning the filters as appropriate or greater frequency according to SPOUTS' recommendations.

Before receiving a Purifaaya 88% of households used at least one of ten treatment methods. The most common treatment method, boiling using charcoal as a fuel, was used by 49% of all households, 85% of these households were urban 15% rural households. The second most common treatment method, boiling using firewood as a fuel, was used by 41% all households, 78% of these households were urban 28% rural households. The two most common reasons households picked a specific treatment method was effectiveness (47%) and familiarity (27%). The majority of households, 95%, reported that they did not believe the water was safe to consume straight from their water source. Interestingly, 11% of this subgroup did not report some type of water treatment at baseline. Of the 160 households that reported using some type of treatment at baseline, all but one household completely replaced their previously preferred method with the Purifaaya. When it came to those responsible for treating drinking water 28% of households primarily relied on women, 25% of households primarily relied on men and boys, and in 47% of households, the tasks were completed by members of both genders.

100% of households that reported problems with appearance, taste, and/or smell of their drinking water reported an improvement with filter usage. 82% of households reported drinking more water after using the filter. Overall, 95% of households reported time saved treating water with the use of their ceramic pot filter compared to their previous method. The average time saved was 34 minutes per day.

Table 3. Water Treatment and Filter Usage Questions Response Rates

Question	Responded N(%)	Missing N(%)
How do you clean your filter? (Enumerator Observed)	179 (97%)	6 (3%)
How often do you clean your filter?	176 (95%)	9 (5%)
Can you show us how you get water out of the filter? (Enumerator Observed)	185 (100%)	0
Does anyone in the household treat water before drinking?	181 (98%)	4 (2%)
If someone in the house hold previously treated your drinking water how did you treat it?	181 (98%)	4 (2%)
Who in the household is responsible for treating the drinking water?	127 (69%)	58 (31%)
Why was this the preferred treatment option?	136 (74%)	49 (26%)
Do you think it is safe to drink straight from you water source?	182 (98%)	3 (2%)
Was the color of your previous drinking water clear?	182 (98%)	3 (2%)
Describe the taste of your previous drinking water.	184 (99%)	1 (1%)
Describe the smell of your previous drinking water.	184 (99%)	1 (1%)
Has your consumption of drinking water changed since your household received a filter?	181 (98%)	4 (2%)
How much time do you believe you save per day by using the Purifaaya?	185 (100%)	0

4. Discussion & Conclusion

The current cross-sectional study was conducted in two Ugandan communities. One community is rural, Namasagali, and the other is urban, Kampala, which is also the capital of the country. The study enrolled households from both communities that received a Purifaaya 20-liter ceramic water pot filter designed for household use in May of 2018 to investigate the association between the use of the filter and diarrheal disease. After adjustments for the total number of persons in a household, location (urban vs rural), water source, and toilet type, the study found that there was an association between filter use and the reduction in reported diarrheal disease.

The findings from our study are in line with previous research that has shown that ceramic filters similar to the Purifaaya to be effective and associated with the reduced prevalence of diarrhea disease (Clasen et al., 2004; Hagan et al., 2009). Though we were unable to test water quality in our study, it was repeatedly found that ceramic pot filters decreased the microbial content in filtered water (Van Halem et al., 2007; Simonis, & Basson, 2011). Prevailing research also indicates high levels of consumer satisfaction, acceptance, and adoption rates (Kallman, Oyanedel-Craver, & Smith, 2011), which is consistent with our study. One issue that did not arise in our study but might be realized in a follow-up or longitudinal study is the questionable ability of the product to provide sustained prevention of waterborne illness due to factors such as decreased flow rates and a decline in maintenance compliance (Van Halem et al., 2009; Salvinelli, & Elmore,2015; Salvinelli et al., 2017; Mellor et al., 2014). It should be noted that the dimensions, flow rate, and exact composition of the ceramic filters in all of the referenced studies were not identical to that of the filters used in this study, but they were all conducted in communities in developing countries similar to that of our study sites.

In addition to improved water quality, there are various other ways the Purifaaya could improve the overall quality of life and health of households. Some of those ways include time saved for other activities, reduction of carbon emissions, and reduction of respiratory illness due to household air pollution (Gordon et al., 2014; Okello, Devereux, & Semple, 2018). Though in our study females were not primarily responsible for water sourcing in the majority of households, in Uganda water sourcing is considered the burden of women and girls (Naiga, Penker, & Hogl, 2015). Those who lack access to clean water overwhelmingly must boil water over traditional cooking stoves. There is evidence of women who used wood, charcoal, or biomass for cooking being at increased risk of developing acute respiratory infections in sub-Saharan Africa and other developing world settings (Ezzati, & Kammen, 2001; Bautista et al., 2009; Salvi, & Barnes, 2010; Taylor, & Nakai, 2012; van Gemert et al., 2015). Charcoal is the primary fuel for cooking stoves used in urban areas in Uganda (Price, Roz, and K4D, 2017). In Uganda as a whole, charcoal is the second most commonly used cooking energy source after unprocessed biomass with approximately 13% and 85% of households using charcoal and biomass, respectively (Price, Roz, and K4D, 2017). A GACC study indicated that the price per household per year for cooking fuels in Uganda was highest for charcoal compared to all other fuel sources (2017). Charcoal production and use of firewood for fuel in Uganda are associated with deforestation and increased carbon emissions (Hofstad et al., 2009; Wurster, 2010; Ekeh, Fangmeier, & Müller, 2014; Sonter et al., 2015) which in turn exacerbates climate change. The results from our study suggest that after accounting for the initial cost the Purifiyya has the potential to lower water treatment costs while concurrently being environmentally sustainable (Ren, Colosi, & Smith, 2013). This, in turn, will free up money for households to use for other purposes, decrease household air pollution, especially in urban households, and aids efforts to slow deforestation and carbon emissions.

In rural areas, if biomass isn't used, the process of boiling water usually requires firewood collection, a time-consuming endeavor. As a result, the lack of clean water keeps women and girls from going to school and being otherwise economically productive. Improved water sources free up time for women to participate in "productive endeavors, adult education, empowerment activities, and leisure" (SIWI, 2005). These time-saving benefits were realized by households in our study. Further, the storage reservoir provided with the Puriffaya can also help to keep those responsible for securing water for the household safe. In a study conducted by Naiga et al., in the Isingiro District of Uganda, female users of community water sources reported having to travel long distances to the water source which had the tendency of being installed in isolated areas (2015). The risk of sexual harassment or assault while fetching water is greatly reduced as more coinvent access to water becomes available (SIWI, 2005). Access to improved water sources in rural areas of Uganda has begun to increase, but there are still issues relating to the operation and maintenance of these water sources challenging long-term access to safe water (Naiga, Penker, & Hogl, 2015). The Purifiaaya provides users an alternative to these unreliable sources as they operate and maintain the filter wholly on their own. Improved water sources while better than alternative options nevertheless do not grantee safe, clean, water, and may still require additional treatment before consumption (Ryder et al., 1985).

Strengths of this study include a) we worked directly with a company that is providing a market-based solution, and b) we considered the differences between urban and rural populations.

The present study has several limitations. The first limitation of our study is its small sample size. Second, is the lack of randomization. Third, cross-sectional studies gather all information at a single point and time and there is not an opportunity to establish a temporal relationship between filter usage and incidence of diarrhea. Cross-sectional studies, as opposed to longitudinal studies, are more prone to bias and mistaken inference. Fourth, to measure the prevalence of diarrhea households self-reported cases through an enumerator-assisted questionnaire. Therefore, there is much room for recall bias and misdiagnosis. Since health conditions are a sensitive topic, social desirability bias could also come into account. Fifth, the data were collected in a limited geographical area and does not have much external validity. Sixth, employees and affiliates of the company who sold the filters (including paid enumerators and volunteers) assisted in various stages of the data collection which could have also caused a social desirability bias. The respondents may not have wanted to negatively review the ceramic pot water filter in the presence of those perceived as representatives of the manufacturer. Finally, due to issues with confounding on location by purchase method (all urban households purchased the filter, while all rural households received the filter by donation) we were unable to address the second objective of this study. Further work will be done at a later date to address this issue.

The findings of this study support association, not causation. Thus, in the future longer longitudinal study should explore the findings of this study. Priorities for future research might focus on determining and addressing the filter flow rate, customer satisfaction, and sustained prevention of waterborne illness after extended use. Additionally, the relationship between Purifaaya usage and positive environmental and economic impacts might be explored in more detail.

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