# Monitoring and Evaluation of a Ceramic Water Filter and Hand-washing Intervention in Northern Ghana


by

Connie C. Lu

S.B. Environmental Engineering Science and Planning
Massachusetts Institute of Technology, 2011


Submitted to the Department of Civil and Environmental Engineering in Partial Fulfillment of the Requirements for the Degree of

Master of Engineering in Civil and Environmental Engineering
at the
Massachusetts Institute of Technology
June 2012



Signature of Author: ______________________________
Connie Lu
Department of Civil and Environmental Engineering
May 25, 2012

Certified by: ______________________________
Susan Murcott
Senior Lecturer of Civil and Environmental Engineering
Thesis Supervisor

Accepted by: ______________________________
Heidi M. Nepf
Chair, Departmental Committee for Graduate Students

Page intentionally left blank.

# Monitoring and Evaluation of a Ceramic Water Filter and Hand-washing Intervention in Northern Ghana

by
Connie Lu
Submitted to the Department of Civil and Environmental Engineering on May 25, 2012, in Partial Fulfillment of the Requirements for the Degree of Master of Engineering in Civil and Environmental Engineering

ABSTRACT

Through a Rotary Club contract, PHW will sell *Kosim* filters and install Tippy-Tap hand-washing stations in 1250 households in Northern Ghana. This thesis presents the following project monitoring and evaluation components: (1) three-part evaluation framework; (2) baseline results; and (3) recommendations for an objective measure of *Kosim* filter use.

The evaluation framework consists of a baseline survey, one-month follow-up survey, and six-month follow-up survey, and includes a staggered cross-sectional study that compares health outcome between purchasers and non-purchasers, and between purchasers from intervention households and purchasers from control households.

January 2012 baseline surveys collected information on household characteristics, water source, household water management, hand-washing practices, diarrheal disease prevalence, and respiratory disease prevalence. In total 429 households were sampled from 20 villages, and the results from 10 villages are reported in this thesis. Overall, 98.6% of the survey population uses surface water as a primary dry season drinking water source, and 79.9% uses unprotected water sources in the wet season. An estimated 52.6% of households use cloth filters to treat their drinking water at home. Only 5.0% of households practice hand-washing with soap, yet 99.2% of households have soap present in the home. The prevalence rate for diarrhea was 23% (95% CI 17% to 29%) for children under the age of five and 9% (95% CI 5% to 13%) for the general population. For cough and difficulty breathing, prevalence rates were 25% (95% CI 19% to 31%) for children under the age of five and 13% (95% CI 8% to 17%) for the general population.

Regarding an objective measure of *Kosim* filter use, the Camelbak® Flow Meter™ accurately measures flow of at least 0.8 L/min, and is therefore sufficient to measure most flow rates through the spigot of the *Kosim* filter. PHW should choose one of three options obtain an objective measure of *Kosim* filter use: (1) adapt and develop a method to retrieve data from the Camelbak® Flow Meter™; (2) adopt the SWEETSense™ monitoring and data retrieval system, or (3) develop a method to measure and retrieve data on total time that the spigot is in the "open" position.

Thesis Supervisor: Susan Murcott

Title: Senior Lecturer of Civil and Environmental Engineering

Page intentionally left blank.

**ACKNOWLEDGEMENTS**

Thank you mom, dad, grandma, grandpa and Danni for your constant love and tireless support, even as I wander all over the world. You have given me the invaluable opportunity to explore and learn—thank you.

Susan Murcott, my advisor and long-time mentor: I couldn't count on the fingers of all the Hindu deities the things for which I am grateful to you. But thank you in particular for sharing your energy and kindred spirit, building bridges to extraordinary opportunities and people, and pouring time into this thesis. Your devotion to your students, friends and life work is inspiring.

Matt, Adam, Winnie, Jon, Kellie and Emmanuel: Thank you for your company, conversation and hard work in Ghana and back home. I couldn't think of a hardier team than Ghana 4S.

I give my sincere gratitude to the many people and organizations that have put their energies into making this thesis possible:

- Emelia Ataya and Zainab Salifu, the dream team of survey fieldwork, for conducting all 429 baseline surveys and for your joy and charisma.
- Karim, Daniel, and the Ramchandani family for your warm friendship and hospitality.
- Mary Kay Jackson for your feedback on the survey tool, hospitality in Ghana, and for devoting time to this project, including digitizing the baseline surveys.
- Ezra Glenn, for patiently answering my numerous emergency statistical quandaries.
- Joe Brown, for your review of work in progress and your critical feedback on short notice.
- Jim Niquette for raising the bar, and then pushing us to reach it.
- Daniele Lantagne, for your sound advice on study design.
- Jill and Rachel for your willingness to provide feedback on short notice;

Pete Shanahan, Eric Adams, Lauren McLean, Kris Kipp and Patricia Dixon: Thank you for being the mind, hand, soul, and sanity of the M.Eng program.

Staff and supporters of the MIT Legatum Center and MIT Public Service Center: I am deeply grateful for your generous support and inspiration throughout this year.

To MIT D-Lab and the teachers at Lincoln-Sudbury Regional High School, thank you for opening my eyes to the world and seeding a desire to leave it slightly better.

Finally, a sincere thank-you to the people in the following groups, for your continuous injection of smiles and warm fuzzies: The River Roost, CEE M.Eng Class of 2012, Burton 1, Alpha Chi Omega, and pika.

Page intentionally left blank.

## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| ALRI | Acute Lower Respiratory Infection |
| CI | Confidence Interval |
| GDHS | Ghana Demographic and Health Survey |
| GHC | New Ghana Cedi |
| HCGI | Highly Credible Gastrointestinal Illness |
| HDW | Hand-Dug Well |
| HWTS | Household Water Treatment and Safe Storage |
| LRV | Log Removal Value |
| M.Eng | Master of Engineering |
| MIT | Massachusetts Institute of Technology |
| PHW | Pure Home Water |
| PPPHW | Global Public-Private Partnership for Hand-washing with Soap |
| Rotary FVGG | Rotary Future Vision Global Grant |
| WASH | Water, Sanitation and Hygiene |
| WATSAN | Water and Sanitation |
| WHO | World Health Organization |
| WTP | Willingness to Pay |

## COMMUNITY NAME ABBREVIATIONS

| | |
|---|---|
| DUF | Dufa |
| DUU | Duuyin |
| FUT | Futa |
| GBR | Gbruma |
| LAB | Labariga |
| LAH | Lahagu |
| TUG | Tugu |
| TYA | Tugu-Yapala |
| WUG | Wuvoguma |
| WUV | Wuvugu |

## TABLE OF CONTENTS

**TABLE AND FIGURES**

Page intentionally left blank.

# 1 Introduction

## 1.1 Research Goals and Motivation

Household water treatment and safe storage (HWTS) and hand-washing interventions can have a considerable positive impact on public health if water treatment devices and hand-washing practices are used correctly, consistently, and in a sustained manner. However, correct, consistent and sustained use is difficult to achieve, and as a result, HWTS and hand-washing interventions are not as effective as they could potentially be. Sustained use is often particularly low, so public health impacts achieved initially tend to decrease in the long-term (Arnold et al., 2009; Hunter 2009; Brown and Clasen, 2012). Organizations such as Pure Home Water (PHW) innovate and invest resources in hopes of increasing the short- and long-term public health benefit of water, sanitation and hygiene (WASH) projects. Monitoring and evaluation of HWTS and hand-washing interventions is critical to assessing and improving projects as PHW and other WASH organizations develop and learn.

*Monitoring* is the ongoing process by which stakeholders obtain regular feedback on progress made towards achieving objectives (UNDP, 2009). *Evaluation* is a rigorous and objective assessment of either completed or ongoing activities to determine the extent to which they are achieving stated objectives (UNDP, 2009).

This thesis contributes to the evaluation of a ceramic water filter and hand-washing intervention in Northern Ghana. Through a Rotary Future Vision Global Grant (Rotary FVGG), PHW will sell 1250 ceramic water filters at GHC 5 (US$ 3)[1] each and work with community members to install Tippy Tap hand-washing stations in each household that purchases a filter. PHW will take measures to train users and work with local committees to help maintain the technologies. This thesis had three goals, all of which contribute to the evaluation of the Rotary FVGG project:

1. Development of a three-part evaluation framework for Rotary FVGG, consisting of a baseline survey, one-month follow-up survey, and six-month follow-up survey.

2. Presentation of results from the baseline surveys conducted in January 2012.

3. Recommendations for an objective measure of ceramic water filter use.

---

[1] The monetary conversion rate used throughout this study is GHC 1.67 = US$ 1.00, which was the exchange rate at time that the Rotary Club of Malden and PHW wrote the Rotary FVGG project contract. The GHC 5 (US$ 3) price was set based on the preliminary results of a bidding-based willingness to pay (WTP) study conducted using *Kosim* filters in Northern Ghana. It should be noted that when the Rotary FVGG project contract was written, the final results from the WTP study were not available, and the contract price was determined based on a draft of the study. In the final published results of the WTP study, the results indicated that the price should be closer to GHC 2 (US$ 1.20) to reach approximately 75 percent of the study population (Berry *et al*. 2011).

## 1.2 Drinking Water in Ghana

In Ghana, 9 percent of the urban population and 20 percent of the rural population use unimproved drinking water sources (UNICEF/WHO, 2012). The 2008 Ghana Demographic and Health Survey (GDHS, 2008) found similar results: 7.0 percent of the urban population and 23.4 percent of the rural population were using unimproved drinking water sources (2008 GDHS). Unimproved sources used in Ghana include surface water; unprotected dug wells; unprotected springs; tanker trucks and carts with small tanks; and certain types of bottled/sachet water (2008 GDHS). Unimproved water sources are considered unsafe to drink. Improved water sources include piped water into dwelling, yard, or plot; public taps or standpipes; tubewells or boreholes; protected dug wells; protected springs; and rainwater collection (2008 GDHS).

However, the actual proportions of populations using unimproved drinking water sources may be significantly higher than the proportions reported in government sources. The WHO/UNICEF Joint Monitoring Program estimates that worldwide, 783 million people (11%) use unimproved sources. However, Onda et al. (2012) estimates that an additional 1.2 billion (18%) worldwide use water from "improved" sources or systems with significant sanitary risks. Such sanitary risks include pipe breaks, supply discontinuities, poor drainage, and proximity to latrines and animal waste (Onda et al., 2012).

The 2008 GDHS data may underestimate the proportions of the Ghanaian population that uses safe water for a number of reasons. In Northern Ghana, improved sources including protected dug wells, protected springs, and rainwater are available generally only during the 3- to 4-month wet season. People who report using these water sources would therefore need to use alternative sources in the 8- to 9-month dry season. Officially published data generally do not reflect this critical detail. In other cases, "improved" sources break down frequently, and users must resort to unimproved sources for many weeks at a time (Majuru *et al.*, 2011). From unstructured interviews in Tamale and the observations of the author and collaborators, it seems that many boreholes, hand-dug wells and sources of piped water in Northern Ghana do not produce water consistently or in ample quantities.

Importantly, many "improved" water sources are in fact contaminated. Patrick *et al.* (2011) sampled both unimproved and improved sources in Capiz Province in the Phillippines, and found that over 40 percent of the "improved" sources had significant levels of fecal contamination (> 10 CFU/100 mL). Even if water is uncontaminated at the source, it can become microbiologically unsafe by the time it reaches the consumer, due to recontamination during transport and storage (Mintz *et al.*, 1995).

## 1.3 Hand-washing in Ghana

Observed rates of hand washing with soap in Ghana are very low, even though soap is often used for laundry and bathing. A national survey of Ghanaian mothers found that 4 percent of mothers practiced hand-washing with soap after defecation, 2 percent practiced hand-washing with soap after cleaning a child's bottom, and only 1 percent practiced hand-washing with soap before feeding children (Scott *et al.,* 2007). A greater percentage of mothers practiced hand-washing with water only in each of these critical junctions: after own defecation (48%), after cleaning a child (27%) and before feeding a child (6%) (Scott *et al.,* 2007a). The survey method was structured observation of mothers in 531 from across rural and urban in five regions (Greater Accra, Ashanti, Eastern, Western and Northern), where trained fieldworkers spent from 6am to 9am discreetly sitting and observing compound activities in each household (Scott *et al.,* 2007a).

## 1.4 Diarrheal diseases and respiratory infections

Diarrheal diseases and respiratory infections are the top two causes of child mortality, and along with malaria are the top three causes of death in children under 5 years of age in Ghana. According to the World Health Organization (WHO), diarrheal diseases and pneumonia respectively cause 12 and 13 percent of child deaths in Ghana (WHO, 2011). Table 1-1 shows the prevalence rates of diarrhea by region in children under five estimated by the 2008 Ghana Demographic and Health Survey (GDHS, 2008). For reference, a map of the regions of Ghana is shown in Figure 1-1.

**Table 1-1: Prevalence rates of diarrhea and acute respiratory illness (ARI) in children under five (Data from GDHS, 2008). For diarrhea, 95% confidence intervals are included in this table. However, the GDHS did not calculated 95% confidence intervals for ARI.**

| Region | Sample size (number of children) | Diarrhea in the two weeks preceding the survey | Acute respiratory illness in the two weeks preceding the survey |
|---|---|---|---|
| Western | 260 | 15.3% (9.6% to 21.1%) | 3.8% |
| Central | 268 | 19.3% (12.1% to 26.5%) | 3.5% |
| Greater Accra | 329 | 12.4% (8.5% to 16.3%) | 6.3% |
| Volta | 237 | 5.1% (2.3% to 7.9%) | 3.4% |
| Eastern | 240 | 17.3% (11.8% to 22.7%) | 4.1% |
| Ashanti | 510 | 20.2% (15.2% to 25.3%) | 5.8% |
| Brong Ahafo | 260 | 28.4% (20.4% to 36.5%) | 5.7% |
| Northern | 413 | 32.5% (27.6% to 37.4%) | 9.3% |
| Upper East | 142 | 19.5% (11.6% to 27.4%) | 3.1% |
| Upper West | 72 | 23.6% (16.3% to 31.0%) | 7.7% |
| **Total** | **2731** | **19.8% (17.9% to 21.8%)** | **5.5%** |

**Figure 1-1: Map of regions of Ghana.**

From the 2008 GDHS values, we can see that under-five diarrhea is more prevalent in the north of Ghana, where PHW operates, than in the south. The Northern Region, where the PHW factory is located, has the highest prevalence of diarrhea in children under five, 32.5 percent. Similarly, the Northern Region also has the highest prevalence of acute respiratory illness in children under five, 9.3 percent.

A study of hospital health care in Northern Ghana found that the most common causes of hospital visits in children under five were malaria, diarrhea, and acute respiratory tract infections (ARIs). (Aikins et al., 2010). The estimated national cost of hospital treatment costs associated with under-five diarrhea ranged from US$ 907,116 to US$ 1,851,280 for outpatient clinic visits and from US$ 701,833 to US$ 4,581,213 for hospitalizations. This estimate does not include patient costs (i.e., household costs) for treatment. In addition, an estimated 80 percent of all cases of under-five diarrhea are treated at home, and the cost estimate does not include the cost of household treatment of diarrhea.

Human feces are the main source of pathogens that cause diarrhea and other common gastro-enteric infections, including *Salmonella spp*, *Shigella spp*, *Vibrio cholera* and rotavirus (Curtis and Caircross, 2003). A study of acute childhood diarrhea in northern Ghana found that rotavirus infection is the predominant cause of acute childhood diarrhea in urban northern Ghana (Reither *et al.,* 2007). In total, at least twenty viral, bacterial, and protozoan enteric pathogens multiply in human intestines, exit in feces, transit through the environment and cause diarrhea in new hosts (Curtis and Caircross, 2003).

Unimproved water sources and hands serve as major environmental vectors, transmitting diarrheal pathogens to the mouths of new hosts. Hands are also known to transport respiratory illness pathogens. Microbiological studies have identified respiratory pathogens on hands (Hendley *et al.*, 1973; Reed, 1975; Rabie and Curtis, 2006), confirming that hands carry respiratory micro-organisms shed from the nose, mouth or anus to the nasal mucosa, conjunctiva (Hendley *et al.*, 1973), or to the mouths of new hosts (Rabie and Curtis, 2006).

## 1.5 Household water treatment and safe storage (HWTS) Interventions

Interventions at the water source or collection point (such as protected wells, borehole, and communal tap stands) and at the household level or point-of-use can improve the quality of water used for drinking and cooking. Household drinking water and safe storage (HWTS) may be especially effective in many cases, because treatment and safe storage at the point of use can minimize recontamination during transport and in the home, which is a known cause of water quality degradation (Clasen *et al*., 2007). Chlorination, filtration using biosand or ceramic filters, solar disinfection and flocculation-disinfection, among others, are proven ways of improving water quality at the point of use (Clasen *et al.,* 2007).

## 1.6 Hand-washing Interventions

Hand-washing interventions, when implemented correctly, can be highly cost-effective investments of public and private resources, especially when compared to vaccines, which protect against individual illnesses (PPPHW). Hand-washing with soap (both plain and antibacterial) cleanses hands of viruses and bacteria (Faix 1987; Rabie and Curtis 2006), and when used at critical times, can reduce the incidence of diarrheal and respiratory diseases (Global Public-Private Partnership for Hand-washing with Soap (PPPHW)). Critical times for hand-washing include: (1) after defecation or using the toilet, (2) after cleaning up a child or handling diapers, (3) before eating, (4) before preparing or handling food (Curtis and Cairncross, 2003).

## 1.7 Pure Home Water (PHW)

Pure Home Water (PHW) is a non-profit social enterprise that was founded by Susan Murcott and local partners in 2005, and is registered in Tamale in Northern Ghana. The goals of PHW are "to provide safe drinking water to those most in need in Northern Ghana, and to become locally and financially self-sustaining." PHW manufactures and distributes ceramic water filters, locally known as *Kosim* filters. Ceramic filters are a proven HWTS technology for improving water quality at the point of use (Clasen *et al*., 2007). Moreover, ceramic filters can be manufactured at low cost and with local materials in Ghana. The filters are discussed in greater detail in the section describing technologies to be distributed via Rotary FVGG. PHW has already reached over 100,000 people directly with its *Kosim* water filter, and also provides education, training and emergency relief. In addition, PHW is expanding its services in the region to include some aspects of sanitation and hygiene education.

## 1.8 Rotary Foundation Future Vision Global Grant 25252 (Rotary FVGG)

Beginning in June 2012, PHW will undertake a Rotary Foundation Future Vision Global Grant project, which is the subject of this evaluation. Through the Rotary FVGG, Pure Home Water will sell *Kosim* filters to 1250 households in rural communities near Tamale at a price of GHC 5 (US$ 3) each. PHW employees will also assist community workers in installing hand-washing stations known as Tippy Taps at no extra cost in each household that purchases a filter. Tippy Taps are discussed further in the technology section to follow. A draft of the contract between PHW and the purchasers in the Rotary FVGG is included as Appendix D. To implement the Rotary FVGG project, PHW will help select, train and work with WATSAN[2] Committees in each community. According to the Rotary FVGG proposal, the WATSAN Committees will be responsible for several critical components of the project, including local governance of the project, oversight of cost-sharing, accounting, education of the community on the benefit of the water filters and hand-washing at critical times, and distribution of replacement filters as needed (FVGG Application Questions, 2011).

The Sunyani Central Rotary Club is the Host Sponsor for FVGG 25252, and the Rotary Club of Tamale is designated as the advisor to Pure Home Water. Joanne Cohn of the Rotary Club of Malden spearheaded the project proposal, and worked with Susan Murcott and other members of the PHW Board to plan the implementation of the Rotary FVGG project (FVGG Application Questions, 2011).

[2] WATSAN = Water and Sanitation

## 1.9 Technologies to be distributed via Rotary FVGG

Through the Rotary FVGG, PHW will sell *Kosim* filters to 1250 households. PHW will also provide the materials for and assist community workers in installing Tippy-Tap hand-washing stations in all households that purchase *Kosim* filters at no extra cost to the households.

### 1.9.1 *Kosim* Ceramic Filter System

Pure Home Water will sell its newly re-designed high rate *Kosim* ceramic filter system in the Rotary FVGG project. The *Kosim* filter is a type of ceramic pot filter, which is a proven HWTS technology for improving water quality at the point of use (Clasen *et al*., 2007). Ceramic water filters are capable of filtering and chemically inactivating bacteria and protozoans, two of the three classes of pathogens that occur widely in drinking water and are associated with enteric diseases. Ceramic water filters therefore are considered "interim" technologies based on the WHO 2011 household water treatment performance targets. Interim technologies may be recommended for use if supported by epidemiological evidence of positive health impacts (WHO, 2011).

The ceramic pot filter system consists of a porous ceramic pot that is suspended over a clean storage container. The ceramic pot is produced by pressing and firing a mixture of clay and sieved combustible material, such as saw dust or rice husks, in a pre-determined ratio. When the mixture is fired, the combustible material burns out, leaving pores and tortuous pathways in the hardened clay. The resulting porous ceramic mechanically filters dirty water. In addition, the fired ceramic pot is impregnated with colloidal silver, which inactivates waterborne pathogens and prevents the build-up of a biofilm (Bloem, 2009). Ceramic pot filter technology was first developed and tested by Fernando Mazriegos in Guatemala in 1982. The design was then standardized and disseminated by Ron Rivera, Manny Hernandez and others, through the non-profit organization Potters For Peace. As of 2009, at least 35 factories are currently producing ceramic pot filters globally (Rayner, 2009). The PHW factory is the 36$^{th}$.

Pure Home Water built its factory from 2010 to 2012 with the help from many, especially Manny Hernadez and Curt and Cathy Bradner of Thirst Aid. Since the founding of PHW in 2005, numerous MIT students have worked with Susan Murcott, Mary Kay Jackson and PHW staff to develop and disseminate the *Kosim* ceramic filter and to monitor its performance, uptake and sustained use. Miller (2012) discusses the history of the *Kosim* filter in greater detail. In addition, PHW has worked hard to continuously upgrade and expand the production capacity and quality control of its factory in Northern Ghana. The latest design of the *Kosim* filter, credited to Manny Hernandez and the Curt and Cathy Bradner of Thirst Aid, is a hemispheric ceramic pot filter with a composition of 60 percent Gbalahi[3] clay, 20 percent Wayamba clay, and 20 percent rice husk by weight (Miller, 2012). The hemispheric filter to be sold in the Rotary FVGG has a

[3] Gbalahi and Wayamba refer to two communities in the Northern Region from which the clay is sourced.

flow rate of 6 to 9 L/hr[4], a total coliform removal of 99.8 percent (2.7 LRV[5]) and a turbidity removal of 92 percent (Miller, 2012).

**Figure 1-2: Left, Hemispheric ceramic water filters on cooling racks after firing process at PHW; Right, PHW employee and MIT graduate student painting filters with colloidal silver solution**

**Figure 1-3: Left, S. Murcott and PHW employees packing first hemispheric filters and safe storage containers for first commercial distribution of new design; Right, women in Tamale region learning how to use and maintain ceramic pot filters (Credit: Susan Murcott)**

[4] The flow rate of 6 to 9 L/hr is significantly higher than the typical flow rate in ceramic pot filters of 1 to 3 L/hr. The higher flow rate if preferable, but previously has been thought to correlate with lower microbiological efficacy. Miller and PHW employees have identified a ceramic composition and firing process that results in a high flow rate while maintaining a comparable bacterial reduction to that of other ceramic pot factories' products. Miller (2012) discusses the technical aspects of the high rate *Kosim* filter in detail.

[5] LRV = Log removal value

### 1.9.2 Tippy Tap hand-washing stations

The Tippy Tap is a simple and hygienic device that enables hand-washing with running water where there is no piped water. The device consists of a small plastic container (approximately 5 L capacity), with a handle and a hole to allow water flow. The plastic container is suspended on its handle on a horizontal straight stick, which in turn is suspended at the two ends on vertical notched posts or sticks. A rope or wire connects the top of the container to another straight stick, which serves as a foot pedal. Soap is suspended using another rope or wire that is attached to the top stick. A gravel pit catches the runoff from the device to prevent formation of open puddles. Figure 1-4 shows a Tippy Tap built near the PHW factory.

To operate the Tippy Tap, the user lightly steps on the foot pedal, which tips the container and releases running water so that she can wet her hands. She then uses the attached soap and rinses in running water.  The Tippy Tap is hygienic because users only touch the soap with their hands. In addition, since branches are readily available in rural Ghana, one need only to purchase a plastic container, string or wire, and gravel to build a Tippy Tap.

Dr. Jim Watt of the Salvation Army in Zimbabwe designed the original Tippy Tap. Numerous organizations, including UNICEF, WaterAid, USAID, MIT D-Lab and now Pure Home Water have promoted the technology. In January 2012, we installed a demonstration Tippy Tap at the PHW factory.

Appendix E is a set of instructions, published online (n.d.) by Technology for Development (Werkgroep OntwikkelingsTechnieken, WOT), for building a Tippy Tap. In the Rotary FVGG project, PHW employees will work with WATSAN committees and community members to install Tippy Taps at no extra cost to all households that purchase a *Kosim* filter. The Rotary Club is currently seeking a corporate partner to provide bar soap free of cost for use on the Tippy Taps.

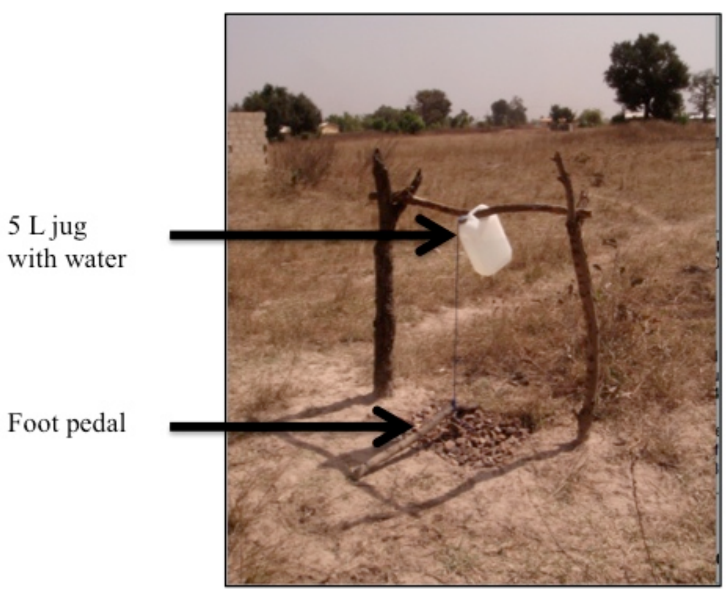



**Figure 1-4: Tippy Tap on PHW factory grounds**

## 1.10 Efficacy of and Adherence in HWTS and Hand-washing Interventions

Numerous studies have been conducted to assess the impact of HWTS and hand-washing interventions on public health. In particular, many studies assess the impact of HWTS interventions on reducing diarrheal illness incidence. A smaller number of studies assess the impact of hand-washing interventions on reducing diarrheal illness incidence, and a very limited number of studies assess the impact of hand-washing interventions on reducing respiratory illness incidence.

To grapple with the considerable heterogeneity in the results from these studies, a number of research groups have conducted meta-analyses to obtain pooled estimates on the effect sizes of HWTS and hand-washing interventions.

Meta-analysis is a formal statistical technique for combining results over more than one study of the same research question. The technique maximizes precision in estimating parameters as well as power for testing hypotheses for particular research questions (Rosner, 2006). Meta-analyses produce pooled estimates, which are calculated from results quoted in the component studies or directly from the data provided in the studies.

This section discusses the efficacy, with respect to improvement of public health, of HWTS and hand-washing interventions. It also covers the importance of user adherence in these interventions.

### 1.10.1 Efficacy of HWTS interventions

There have been a number of efforts in the last three decades to evaluate the effect of water quality interventions on preventing diarrhea, and more recent attention has included water treatment at the household level or point of use.

Using meta-analysis, Clasen *et al*. (2007) confirmed previous studies' conclusions that interventions to improve water quality, including household water treatment, are effective in reducing the occurrence of diarrheal disease in all ages and in children under five. Clasen *et al.* included data and/or conclusions from 33 reports on water quality interventions in 21 countries collectively. These trials measured rate ratios, risk ratios (relative risk), longitudinal prevalence and odds ratios[6]. The pooled estimate on the effect of household level water treatment from 8 studies reporting rate ratios was 0.62 (95% confidence interval (CI) 0.47 to 0.82). The pooled estimates for the 7 studies reporting risk ratios and the 10 studies reporting odds ratios on household water treatment were 0.49 (95% CI 0.36 to 0.65) and 0.65 (95% CI 0.58 to 0.76) respectively. These results suggest that household water treatment can reduce the occurrence of diarrhea by 35 to 51 percent. A similar analysis that included only those studies on household

[6] A risk ratio, relative risk, or odds ratio of 1.0 indicates that the intervention had no effect, and a lower ratio indicates a stronger effect.

water filtration resulted in similar and statistically significant levels of disease reduction (Clasen *et al.*, 2007). Another group of researchers conducted an earlier comparative study of the relative effectiveness of hygiene, sanitation, water supply and water quality interventions on diarrhea reduction (Fewtrell *et al.*, 2005). The study by Fewtrell *et al.* produced a relative risk estimate of 0.61 (95% CI 0.46 to 0.81) for household treatment studies excluding those that the authors considered to be of poor quality.

However, other research challenges the notion that point-of-use water quality interventions are the most effective interventions, especially in the long-term. Waddington *et al.* (2009) found that while household-level water quality interventions are seen to be effective in the short term, their impact decreases significantly over time. Specifically, shorter studies of water quality interventions (those under 12 months) had a pooled effect size of 0.56 (95% CI 0.47 to 0.66), suggesting that the interventions reduced diarrheal rates by 34 to 53 percent in the short term. However, longer studies (12 months or more) had a pooled effect size of 0.81 (95 percent CI 0.67 to 0.97), suggesting that the diarrheal rate reduction was only 3 to 33 percent in the longer term.

Schmidt and Cairncross (2008) discuss the possibility of bias in the current evidence of diarrhea reduction by HWTS interventions, and warn that implementation of household water treatment should not be scaled up before more rigorous evidence is collected. Schmidt and Cairncross found that the observed diarrhea reductions in existing studies might be largely or entirely due to bias, especially bias due to inadequate blinding[7]. In addition to inadequate blinding, trials in the field of water and hygiene are not subjected to a strong regulatory process and therefore may carry selective reporting, participant selection bias and publication bias (Schmidt and Cairncross. 2008).

Other researchers and practitioners have responded with anecdotal reasoning and empirical evidence that certain household water treatment methods do make positive impact on public health, despite the effect of bias in many trials. Hunter conducted a meta-regression of published trials, and found that the overall effect size of household water treatment technologies on diarrheal disease was lower, but still significant, after adjusting for bias due to lack of blinding (Hunter, 2009). Hunter included a total of 28 randomized controlled trials with 39 intervention arms, comprised of studies used in the previous meta-analysis (Clasen *et al*., 2007) as well as more recently published trials. To estimate the potential contribution bias towards the estimated impact of HWTS, Hunter referred to a study by Wood *et al.* that gave two estimates of potential bias in unblinded studies, one due to unclear allocation concealment[8] and one due to lack of blinding.

---

[7] Blinded studies follow procedures to prevent study participants and outcome assessors from knowing which intervention was received. Even when blinding of participants is not feasible, it may still be possible to blind assessment of outcomes. In unblinded studies, the knowledge of the intervention received, rather than the intervention itself, may affect the outcome or outcome measurements (Wood *et al.* 2008).

[8] Inadequate allocation concealment implies that the study did not follow procedures to prevent foreknowledge of forthcoming allocations by study participants or by those recruiting them to the trial. As a result, the selection of participants into intervention groups may be biased (Wood *et al*. 2008).

Wood *et al.* examined a wide range of interventions and outcomes, and estimated the effect of unclear allocation concealment and lack of blinding in subjective and objective outcomes[9]. In trials with subjective outcomes, the ratio of odds ratios from trials with inadequate allocation concealment estimates to odds ratios from trials with adequate allocation concealment was 0.69 (95% CI 0.59 to 0.82) (Wood *et al*., 2008). The ratio of odds ratios from non-blinded trials to odds ratios from blinded trials was 0.75 (95% CI 0.61 to 0.82) (Wood *et al*., 2008). In other words, trials with inadequate allocation concealment overestimate the benefit of the intervention by 31 percent on average, and non-blinded trials overestimate the benefit of the intervention by 25 percent on average (Wood *et al*., 2008).

Hunter used a Monte Carlo approach to adjust the effect estimates of HWTS interventions based on the estimates of bias from Wood *et al*., and estimated that the adjusted effect size is a relative risk of 0.85 (95% CI 0.76 to 0.97), which is still statistically significant (Hunter, 2009). In other words, even after adjusting for potential bias due to inadequate blinding, HWTS interventions reduce the risk of diarrheal illness by 15 percent on average. It is essential to note that ceramic water filter interventions were found to be overall more beneficial to public health than disinfection interventions. In fact, while the ceramic filters were clearly effective even after adjusting for bias, the estimated effect sizes of disinfection interventions were less than the mean effect of bias derived from the study by Wood *et al.* (Hunter, 2009). The disinfection interventions therefore lowered the HWTS effect estimate. After adjusting for the potential bias due to inadequate blinding, then, ceramic filter interventions on average reduce the risk of diarrhea by *over* 15 percent (Hunter, 2009).

Based on his results, Hunter made three critical conclusions on HWTS. First, Hunter recommended that large double-blinded placebo-controlled studies be conducted to improve the effectiveness of disinfection interventions—chlorination, coagulation-chlorination, and SODIS—before implementation of such interventions is continued in developing countries. For Biosand filters, Hunter recommended one or more large, preferably blinded, randomized trials with a follow-up duration of at least 52 weeks. On the other hand, ceramic filters were clearly effective, and Hunter recommended that research for ceramic filters should focus primarily on how to increase uptake and sustainability of these interventions.

### 1.10.2 Adherence in HWTS interventions

Despite the lack of consensus on the efficacy and scalability of household water treatment, one fact that is widely known is that household based interventions require effort on the part of users to treat water correctly, consistently and in a sustained manner, to avoid recontamination, and to refrain from using other untreated sources. Evidence from Clasen *et al.* (2007) suggests that non-adherence in any of these essential links can reduce effectiveness. However, most investigators acknowledge that it is difficult to document the extent to which household members consume treated water (Clasen *et al*., 2007). Two indicators, developed by the WHO International

[9] In medicine, objective and subjective outcomes are based on the extent to which the outcome assessment could be influenced by the investigators' judgment (Wood *et al*. 2008).

Network through the USAID Hygiene Improvement Project (USAID HIP) to quantify the sustainability of HWTS (USAID HIP, 2010), are especially useful for discussing the topic of adherence:

> *Indicator WA8, or " % of households practicing correct use of recommended household water treatment technologies"*
>
> *Indicator WA9, or " % of households practicing sustained use of recommended household water treatment technologies."*[10]

In the soon-to-be-published Toolkit for Monitoring and Evaluating Household Water Treatment and Safe Storage, the WHO/UNICEF Joint Monitoring Programme builds on the USAID HIP indicators. The toolkit organizes indicators into three tiers for monitoring and evaluation of HWTS:

1. First tier indicators, for inclusion in surveys where only 2 questions can be asked at the household level, such as in national level surveys, rapid assessments or multi-sectoral surveys;

2. Second tier indicators, for inclusion in surveys where there is the capacity to ask approximately 10-15 questions; and

3. Third tier indicators, for comprehensive monitoring and/or evaluation of HWTS. (WHO/UNICEF, 2012)

Table 1-2 summarizes the indicators from the first, second and third tiers that the author highlights as the most relevant to monitoring and evaluation of the Rotary FVGG project.

---

[10] Here, sustained use is defined as households practicing recommended household treatment of drinking water during two measures separated in time. The indicator requires a longitudinal study, where data is collected from the same study participants at two different points in time.

**Table 1-2: Selected indicators from the WHO/UNICEF Joint Monitoring Programme's Toolkit for Monitoring and Evaluating Household Water Treatment and Safe Storage (2012). The authors selected these indicators as the most relevant to monitoring and evaluating the Rotary FVGG project.**

| Tier | Indicator |
|---|---|
| First | *% of households that self-report treating water at survey visit* |
| | *% of households self-reporting treated water that are confirmed to be treating drinking water on day of survey* |
| | *% of households storing water safely* |
| Second | *% of households who can demonstrate correct use of recommended water treatment technologies* |
| | *% of households removing water safely from storage container* |
| | *% of adults (male & female) and children reporting drinking ONLY treated water* |
| Third | *% of households with negative test for pathogens or pathogen indicators in drinking water* |

The rate of sustained use is low in many HWTS interventions. Clopeck (2009) surveyed 309 customers who had purchased *Kosim* ceramic pot filters from Pure Home Water between 2005 and 2008, and found that only 46 percent of respondents were still using the filters at the time of interview. Arnold *et al*. (2009) found that a three-year household water treatment and hand-washing intervention in rural Guatemala led to modest gains in water treatment in the intervention households compared to control households, as evidenced by self-reported activity (33.3 percent in intervention households vs. 21.0 percent in control households) and observed water treatment activity (8.7 in intervention households vs. 3.3 percent in control households). However, the proportion of participating families in intervention villages reporting water treatment dropped from 70 percent immediately after the intervention to approximately 37 percent six months later (Arnold *et al.* 2009).

### 1.10.3 Efficacy of Hand-washing interventions

#### 1.10.3.1 Diarrheal incidence and mortality

In a systematic review, Curtis and Cairncross (2003) found that hand-washing with soap reduces diarrheal disease incidence by 42 to 44 percent. Hand-washing with soap also seems to reduce the risk of severe intestinal infections and of shigellosis by 48 and 59 percent respectively (Curtis and Cairncross, 2003). Curtis and Cairncross reviewed all studies that were relevant to the analysis and available at the time, and included 17 observational and intervention studies in their final meta-analysis. The studies reported a variety of hand-washing occasions, including: after defecation or after using the toilet, after cleaning up a child or handling diapers, before eating, and before preparing or handling food. Health outcomes measured in the studies included diarrhea, dysentery, typhoid, cholera and shigellosis in both children and adults. Curtis and Cairncross calculated the diarrheal reduction rate from a pooled estimate of relative risk, which is the excess risk of diarrheal disease associated with not washing hands. The pooled estimate was calculated from results quoted in the studies (reported as relative risks or odds ratios) or directly from the data provided in the studies (Curtis and Cairncross, 2003). The Curtis and Cairncross review showed that diarrheal disease reduction by hand-washing is likely more significant than previously thought. An earlier review that included five studies reported a median reduction in diarrhea incidence by 35 percent. (Huttly, 1997).

Significantly, Curtis and Cairncross note that there has been mounting evidence that interventions to reduce diarrheal disease may reduce diarrheal *mortality* to the same or to an even greater extent than they reduce diarrheal *incidence*. There are three primary pieces of evidence to support this hypothesis. First, Victora *et al.* (1988) found that environmental risk factors for diarrheal incidence are also risk factors for diarrheal mortality. Second, Esrey *et al*. (1991) suggested that reducing the rate of pathogen ingestion reduces the incidence of severe infections before reducing the rate of mild infections. Third, most diarrhea deaths are associated with *persistent* diarrhea and dysentery (Curtis and Cairncross, 2003). Specifically, Morris *et al.* (1996) found that a 5 percent decrease in the proportion of days in which a child suffered from diarrhea was associated with a 17 percent decrease in the risk of mortality.

#### 1.10.3.2 Respiratory infection incidence

In another systematic review, Rabie and Curtis (2006) found that hand-washing reduces the risk of respiratory infections by 6 to 44 percent, giving a pooled estimate of 24 percent. The reduction rate was calculated from a pooled estimate of relative risk, which is the ratio of the risk/rate of developing or having a respiratory infection in the non-hand-washer group to the risk/rate of developing or having a respiratory infection in the hand-washer group. Rabie and Curtis included all 8 suitable studies that were available at the time of review, noting the poor geographical distribution of current studies on the effect of hand-washing on respiratory infection risk. While developing countries carry the major burden of acute respiratory infections, all of the suitable studies were in developed countries. Relatedly, the Rabie and Curtis study concerned primarily upper respiratory infections such as colds and influenza, rather than more serious illnesses, which are more likely to cause mortality. Despite the shortcomings due to lack of research in developing countries, the Rabie and Curtis study adds to the already substantial evidence that hand-washing interventions are highly relevant to reducing major disease burdens in the developing world.

### 1.10.4 Adherence in hand-washing interventions

Like household water interventions, hand-washing interventions require effort by household members to wash hands correctly and consistently. Since existing rates of hand-washing with soap in Ghana and many other low-income countries are low, significant behavior change is required for hand-washing interventions to be effective. In order to change long-held habits, one must have a firm understanding of the factors that drive and facilitate hand-washing. However, many past efforts to promote hand-washing have not engendered mass behavior change because they often treat hygiene as a side issue. These efforts therefore do not focus sufficient resources to understanding drivers and local environmental factors of hand-washing (PPPHW). While the three-year household water treatment and hand-washing intervention evaluated by Arnold and colleagues resulted in modest gains in water treatment rates, it resulted in no significant differences between intervention and control villages in self-reported hand-washing behavior. The presence of soap was also similar in intervention and control villages. The combination of no change in hand-washing behavior and only modest changes in water treatment rates is likely the reason that the intervention showed no significant effect on child diarrheal prevalence, child ARI prevalence and child growth (Arnold *et al.*, 2009).

## 1.11 Measuring adherence, user adoption and sustained use

### 1.11.1 Self-reported measures

Most studies on adherence, user adoption and sustained use in household water treatment and hand-washing interventions rely on self-reported data, often gathered through household surveys (Curtis and Cairncross, 2006; Rabie and Curtis, 2006; Peletz, 2006; Clasen *et al.*, 2007; Johnson *et al.*, 2007; UNICEF-PHW, 2009; Clopeck, 2009; Arnold *et al.*, 2009). The advantage of using self-reporting is that it is generally more cost- and time- effective than structured observation for measuring rates of habitual behaviors such as water treatment and hand-washing. However, there is evidence and a general consensus that self-reported information, especially via oral reports, often poorly reflects reality (Curtis and Cairncross, 2006; Arnold *et al.*, 2009; Fowler, 2009). When surveys are used, respondents may report events inaccurately because: 1) they not understand the survey question, 2) they do not know the answer, 3) they cannot recall the answer, although they do know it, or 4), they do not want to report the answer in the interview context (Fowler, 2009). A common reason for inaccurate reporting due to the interview context is that the respondents are giving a courtesy response because they sense that the surveyor is seeking a certain answer. Hand-washing behavior in particular is very difficult to assess reliably, since people often fear that they will be judged for admitting to poor hygiene practices (PPPHW). In fact, self-reported measures of hand-washing behavior consistently overestimate actual behavior (PPPHW).

### 1.11.2 Structured observation

Given the weaknesses of self-reported measures, many argue that obtaining reliable measures of water treatment and hand-washing practices requires direct observation of daily practices in the home and/or specific objective measures. While objective measurements such as flow monitoring may gage use of particular water treatment devices, they cannot show whether household members are exclusively using the specific treatment device or are also using other sources of water. According to the Global Public-Private Partnership for Hand-washing with Soap (PPPHW), direct structured observation is the only feasible and reliable way to measure hand-washing practice. Direct structured observation requires an observer to spend several hours in each home being evaluated, observing and recording events of interest in a standard format. To obtain consistent and valid results, the observers must be well-trained and supervised. For structured observation of hand-washing behavior, observers arrive early in the morning, sit quietly and observe the domestic behaviors of mothers and children, and record, for example, what happens during and after child defecation (PPPHW). While structured behavior can be intrusive and likely changes household behavior, it is possible to minimize the behavior change due to observation by giving a different reason for observation, such as child health assessment (PPPHW). Structured observation is known to be a more reliable measure than self-reporting, but is used less frequently because it is expensive and time-consuming (PPPHW). Of the 17 studies reviewed by Curtis and Cairncross, for example, only two used actual observations of hand-washing to provide data.

More frequently, brief direct observations are used in combination with self-reported measures. Arnold *et al.* (2009) provides measures of self-reported water treatment as well as "confirmed" water treatment based on brief direct observations. Water treatment was classified as "confirmed" for a given family if they (1) reported treating their water in the previous seven days, (2) had treated water at the time of the interview, and (3) could show the materials they used to treat water (Arnold *et al.*, 2009). An evaluation of ceramic filter use after a flood distribution by Pure Home Water and UNICEF included self-reported measures, but also asked household members to demonstrate filter-cleaning practices and show the level of water in the filter at the time of the interview (UNICEF-PHW, 2009). Direct observation of whether soap is present in the home has been used to supplement self-reported hand-washing information. However, presence of soap is common even in the absence of hand-washing behavior, since soap is used for laundry and bathing (PPPHW; Arnold *et al.*, 2007).

# 2 Rotary FVGG Evaluation Framework

## 2.1 Research Objectives

The purpose of the Rotary FVGG evaluation is to assess the user adoption, sustained use, and health impact of the Rotary FVGG project. It was critical that the evaluation be designed to assess these factors with reasonable certainty. However, Rotary allocated only a very minimal budget to carry out the evaluation aspect of the contract. It is our hope that this thesis, together with on-going MIT M.Eng team involvement, can fill this gap and contribute to a thorough follow-up evaluation. The overarching aims of the evaluation are to help PHW and by extension, Rotary, to assess and improve its dissemination practices, and to provide useful monitoring and evaluation feedback for the Future Vision Global Grant program. Therefore, we sought to develop an evaluation framework that maximally fulfills the following criteria: (1) Addresses the evaluation needs stated in the Rotary FVGG proposal; (2) Provides information that is useful to the short- and long-term work of PHW; and (3) Utilizes the time and resources of PHW and the Rotary Club efficiently.

This section discusses the original Rotary FVGG evaluation needs, the process of developing the evaluation framework, and the final evaluation framework.

## 2.2 Rotary FVGG Evaluation Needs

The Future Vision Global Grant proposes the following evaluation measures:

> "Community workers from PHW will conduct a brief oral survey with each household receiving a Kosim water filter and handwashing station to determine the incidence of diarrheal illness and respiratory illness among household members
>
> - At the time the filters and Tippy Taps are distributed and approximately 1/3 of households will be resurveyed 4-6 months later.
>
> The information to be collected to measure success will include:
>
> - Water source(s);
> - Person responsible for filtering water, maintaining filter;
> - Understanding of filter use, cleaning procedure;
> - Condition of safe storage container;
> - Person responsible for maintenance of Tippy Tap;
> - Problems with filter or Tippy Tap;

- Incidence of severe diarrhea or respiratory illnesses prior to use of filter and Tippy Tap; and
- Any observed change in health status after using filter and Tippy Tap.

The information collected will not be sufficiently detailed for scientific study. The survey results are intended to demonstrate the benefits of using Kosim filters and Tippy Taps with reasonable certainty" (FVGG 25252 Application Questions, 2011).

With the overarching goal of measuring the benefits of the ceramic filters and Tippy Taps in mind, the author and her thesis advisor interpreted the FVGG project evaluation needs as the following:

- Measure user adoption, effective use, and sustained use of ceramic filters and Tippy Taps
- Collect the following use-related information:
    - Water source(s);
    - Person responsible for filtering water, maintaining filter;
    - Understanding of filter use, cleaning procedure;
    - Condition of safe storage container;
    - Person responsible for maintenance of Tippy Tap; and
    - Problems with filter or Tippy Tap.
- Measure the prevalence of diarrheal and respiratory illnesses prior to use of ceramic filters and Tippy Taps
- With reasonable certainty, assess impact of ceramic filters and Tippy Taps on the incidence of diarrheal and respiratory illnesses

## 2.3 Development of the Evaluation Framework

The three-part structure proposed by the Future Vision Global Grant, consisting of a baseline survey, a one-month follow-up survey and a six-month follow-up survey, was adopted for the evaluation framework.

Use-related information is collected in all three of the surveys. The baseline survey gathers information on water source(s) and current practices of household water treatment, water dispensing, and hand-washing. The one-month follow-up survey measures adoption and correct use of ceramic filters and Tippy Taps, and gathers information on maintenance of and problems with these technologies. The six-month follow-up measures sustained and effective use of the ceramic filters.

Health-related information is collected in the baseline survey and in the six-month survey. Initially, the health impact evaluation was planned as a longitudinal prospective cohort study. A longitudinal study is a type of epidemiological study that involves repeated observations of the same variables over a period of time. Longitudinal studies track the same people in each of the repeated observations, and thus look at changes over time. A prospective cohort study is a type of longitudinal study that follows a group of similar individuals who differ with respect to a certain factor or factors being studied, in order to determine how the factors affect the rates of a certain outcome.

As a longitudinal study, this evaluation would have aimed to follow approximately 429 rural households in the Tamale Region of Ghana with respect to the use or non-use of ceramic water filters and hand-washing stations via the 2012 Rotary FVGG, in order to determine whether the Rotary FVGG project affects rates of diarrheal and respiratory illness. Approximately 215 of these households would have been in intervention communities, where Rotary project sales take place, and the remaining 215 households would have been in control communities, which do not participate in Rotary project sales. The same households would be surveyed again at the six-month follow-up, in order to determine the relative reduction of diarrheal and respiratory illness prevalence rates in intervention and control households. If we found that the health of the intervention households improved significantly more than the health of the control households, we could conclude that the Rotary FVGG may have made a positive health impact.

However, as we proceeded to realize that it was possible that of the households surveyed during the baseline in the intervention communities, a considerable number may not choose to purchase ceramic filters when the Rotary project is implemented. These households would effectively be lost from the sample cohort, since they cannot be considered intervention households and cannot be considered control households[11].

To better use the baseline data, a cross-sectional component was added to the health impact evaluation. In a cross-sectional study, information on intervention and disease is *simultaneously* assessed (Hennekens and Buring 1987), and relative risks can be calculated to understand the connection between intervention (ceramic filter and Tippy Tap usage) and outcomes (diarrheal and respiratory illnesses.) For an example of a cross-sectional study that was conducted by PHW and M.Eng students, see Peletz (2006) and Johnson (2007). The final design of the study is a staggered cross-sectional study, which is introduced in the following section.

## 2.4 Staggered Cross-Sectional Study

As suggested by Joe Brown of the London School of Hygiene and Tropical Medicine, this evaluation will be conducted as a hybrid of a longitudinal study and a cross-sectional study, which Brown has termed a staggered cross-sectional study (Brown, personal com., 2012). The staggered cross-sectional study developed by Brown consists of four primary components:

[11] While such households would not possess ceramic filters or Tippy Taps, other households in their communities would be participating in the Rotary project, and their water management and hygiene practices could influence the behavior and health of others in the community. We could imagine for example that members of non-participating households could make use of participating neighbors' Tippy Taps or even drink their filtered water.

1. Collection of baseline data from intervention and control communities selected randomly from within the communities eligible for the Rotary FVGG (January and April 2012)[12];

2. Implementation of filter sales and Tippy Tap construction in the intervention communities selected at baseline (June 2012);

3. Six-month follow-up with all households surveyed from intervention communities selected at baseline, including filter purchasers and others (January 2013); and

4. Concurrent with component 3, follow-up surveys with all households from control communities surveyed at baseline AND implementation of filter sales and Tippy Tap construction in the control communities (January 2013).

Lu and Murcott decided to apply Brown's framework to the Rotary FVGG project evaluation An annotated schematic of the final evaluation framework is shown in Figure 2-1. Using Brown's framework, we will have diarrheal and respiratory illness data from two points in time, for all households. Health outcome can therefore be calculated as a ratio of prevalence rate at follow-up (in January 2013) to prevalence rate at baseline (in January and April 2012). Lower ratios represent better health outcomes.

The staggered cross-sectional study will enable three comparisons of health outcome:

1. Between "purchasers" (those who choose to purchase filters) from intervention communities (where filter sales occurred in June 2012) and "non-purchasers" (those who choose not to purchase filters) from intervention communities;

2. Between purchasers from control communities (where filter sales occurred in January 2013) and non-purchasers from control communities; and

3. Between purchasers from intervention communities and purchasers from control communities.

The first comparison measures how choice to purchase a filter AND six months of filter use affect the health outcome. The second comparison measures how choice to purchase a filter, alone, affects the health outcome. The third comparison measures how six months of filter use, alone, affects the health outcome. The second and third comparisons are critical because they account for the systematic differences between households who choose to purchase filters and households who choose not to purchase filters (i.e., households that choose to purchase filters may be wealthier, better educated, or otherwise systematically different from households that choose not to purchase filters).

The advantages of using this staggered cross-sectional study design are:

1. We eliminate the confounding effect of purchaser vs. non-purchaser from our study;

---

[12] This portion of the evaluation has already been conducted, although the selection of villages was not completely random. See Community Selection (Section 3.4.5).

2. We will obtain three complementary measures of health impact without collecting significantly more data than if we only used one type of comparison;

3. All of the households sampled in the baseline, regardless of whether or not they choose to participate in the Rotary FVGG project, will be included in useful analyses of health impact—whereas using only a longitudinal prospective cohort format would mean that households that abstain from the Rotary FVGG project would be lost from the sample cohort;

4. We will also have the ability to obtain two additional measures that may be of interest to PHW and the Rotary Club:

    a. A direct measurement of the uptake "rate" (percentage who choose to purchase filters) in the control and intervention groups (Brown, personal com., 2012); and

    b. A nested study of drivers of demand for purchase, since we have data from two time points on both purchasers and non-purchasers, and could look for associations (wealth, education, water sources, etc.) (Brown, personal com., 2012).

## 2.5 Final Evaluation Framework

The evaluation consists of a baseline, a one-month follow-up survey, and a six-month follow-up survey. Each of these three parts is discussed within this section. An annotated schematic of the final evaluation framework is shown in Figure 2-1.

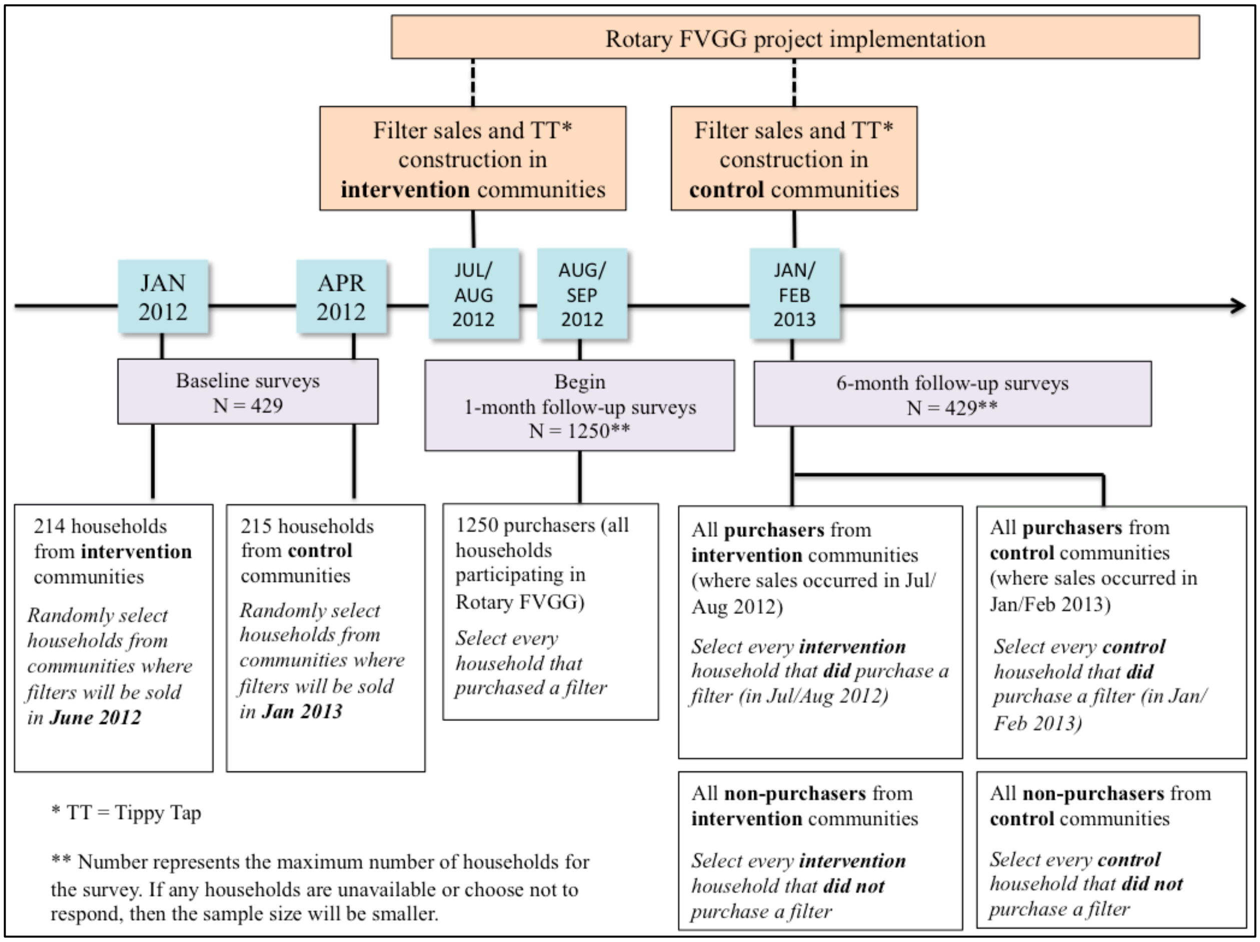



**Figure 2-1: Schematic of the final evaluation framework for the Rotary FVGG project.** ***Text in italics indicates method for selecting survey households.***

### 2.5.1 Baseline

The purpose of the baseline study is to obtain information on household water management, hand-washing practices, and the incidence of diarrheal and respiratory illnesses prior to the use of the ceramic water filters and Tippy Taps. In the baseline study, a household survey, attached as Appendix A, was administered in communities where the Rotary FVGG sales and Tippy Tap construction will occur before the follow-up—intervention communities—and in similar communities where the Rotary FVGG sales and Tippy Tap construction will be concurrent with the follow-up—control communities. The latter are considered control communities because all health data collection is *retrospective*, so all health data collected households in the control communities is representative of the conditions *without* filter use and Tippy Tap implementation.

In total, the baseline survey includes 214 intervention households and 215 control households. This thesis presents only the results from the 214 intervention households.

### 2.5.2 One-month follow-up

A first follow-up survey will be administered in the intervention communities one month after the Rotary project sales of ceramic water filters and installation of hand-washing stations, to measure user adoption of the technologies and practices, and to guide follow-up monitoring and training as needed. All households (approximately 1250 in total) that purchased ceramic filters in the Rotary FVGG project will be recruited for this follow-up.

It may be possible to reduce the fieldwork requirements of the one-month follow-up by creating a shorter version of the one-month follow-up with only monitoring questions to assist with re-training and maintenance of filters and Tippy Taps. This thesis refers to the shorter version as a "re-train-and-maintain survey". During the one-month follow-up, the full monitoring and evaluation survey may be administered in a smaller subset of the 1250 total households, and the shorter re-train-and-maintain survey will be administered in all 1250 households. The author recommends that PHW consult an expert on HWTS monitoring and evaluation to determine the sample size and sampling strategy for the subset of households where the full-length one-month follow-up will be administered.

In the full-length one-month follow-up survey, the following user adoption-related information should be collected to measure the success of the project:

- Person responsible for filtering water and maintaining filter
- Understanding of filter use and cleaning procedure
- Condition of safe storage container
- Person responsible for maintenance of Tippy Tap
- Problems with filter or Tippy Tap

In order to facilitate a systematic survey process, a first draft of the full-length one-month follow-up survey is included in this thesis, as Appendix B. The survey should be pre-tested in Tamale and revised as necessary before use.

To write re-train-and-maintain survey, PHW should shorten full-length survey (Appendix B) to include only questions that are essential for identifying which households need re-training and maintenance. More detailed recommendations on implementing the one-month follow-up are included in the Discussion and Conclusions section.

### 2.5.3 Six-month follow-up

A second follow-up survey will then be administered in January 2013, six months after the filter sales and Tippy Tap construction in the intervention communities in June 2012. This survey will be administered in all households surveyed at the baseline, in both the intervention and control communities, and will obtain information on filter usage, water quality of filtered and unfiltered household water, Tippy Tap usage, diarrheal illnesses, and respiratory illnesses.

In the intervention communities, all households that were surveyed at the baseline, regardless of whether they chose to purchase filters in June 2012, will be surveyed. Along with the information on usage and health mentioned above, the follow-up surveys in intervention communities will take note of which households chose to purchase filters and which households did not choose to purchase.

During the same time frame (approximately January 2013), PHW will implement filter sales and Tippy Tap construction in the control communities. Concurrent with the filter sales, PHW will also survey all control households surveyed at the baseline, regardless of whether they chose to purchase filters. Surveys of purchasers will take place at the time of sale, and surveys of non-purchasers will take place shortly thereafter. More detailed recommendations on implementing the six-month follow-up are included in the Discussion and Conclusions section. The italic text in the evaluation framework schematic in Figure 2-1 gives specific instructions for household recruitment in each of three parts of the survey framework.

# 3 Baseline Survey Methodology

## 3.1 Research Objectives

The primary purpose of this portion of the study is to obtain baseline data on drinking water sources and management, hand washing practices, and prevalence of diarrheal and respiratory illnesses in households in rural villages of Tamale, Northern Region, Ghana.

The baseline survey directly assesses two of the stated evaluation needs of the Rotary FVGG: water source(s) and prevalence of diarrheal and respiratory illnesses prior to use of ceramic filters and Tippy Taps. In addition, it provides information on hand-washing and household water management practices that will help PHW to successfully implement the Rotary FVGG and other local dissemination and scale-up efforts. The Results (Section 4) of this thesis present baseline data from 214 households from 10 villages. The author will summarize data from approximately 215 additional households from 10 villages in summer 2012. Thus, in total, the baseline data is derived from 429 households in 20 villages, comprising the most extensive survey specific to the topic of water, hygiene and health in the location of rural Tamale that PHW has conducted to date. The information therefore should significantly augment and update PHW's understanding of the characteristics of the local population, as well as water sources, filter and Tippy Tap use and maintenance behaviors, sustained use, and diarrheal and respiratory health status.

The baseline is also part of a long-term effort to assess the user adoption, sustained use and health impact associated with the 2012 Rotary Future Vision Global Grant project. The overall evaluation framework is comprised of this baseline and two follow-up surveys, and has been described in the Evaluation Framework (Section 2). The diarrheal and respiratory illness prevalence rates estimated using the baseline survey will be compared to the prevalence rates estimated at the six-month follow-up survey, contributing to the health impact assessment of the Rotary FVGG project.

This section describes the baseline survey methodology, including the process of developing the survey and an overview of the final baseline survey tool. The Baseline Results (Section 4) presents the baseline data on the 214 households sampled in the intervention communities. The baseline data on both intervention and control communities—429 total—will be available to PHW staff, future MIT students and others who will continue the Rotary FVGG project evaluation and other PHW monitoring and evaluation work in Ghana.

### 3.2 Baseline survey Development

A household survey was developed to obtain information on drinking water management, hand-washing practices, and diarrheal and respiratory illness rates. For other surveys by PHW, MIT, or Innovations for Poverty Action (IPA) to which this one might be compared, see: Peletz, 2006; Johnson, 2007; Clopeck, 2009; Desmyster 2009; and Berry *et al*., 2012.

Many existing surveys were studied to inform the development of this survey, which itself evolved through many iterations both before and during pre-testing in Tamale. Basic guidelines on survey design, format and question wording were taken from Survey Research Methods (Fowler, 2009). The pretest survey and final survey format was based on the Pure Home Water Flood Emergency Relief Project survey tool developed by UNICEF in collaboration with PHW in 2007 (UNICEF-PHW, 2009), which we found to be the most concise and easiest to use in the field.

Since this monitoring and evaluation study seeks to gain insight into a range of household information both on WASH practices and health status, the survey has drawn questions from multiple sources. Questions for obtaining information on household characteristics and water management practices were modified from the UNICEF Baseline Household Survey: Household-Based Drinking Water Treatment (UNCIEF, 2005), the final survey used by Rachel Peletz for her cross-sectional epidemiological study on water and sanitation practices in Northern Region of Ghana (Peletz, 2006), as well as the Flood Emergency survey tool (UNICEF-PHW, 2009). The original questions on hand-washing practices were obtained from the Hand-washing Handbook (PPPHW), and the Peletz survey (Peletz, 2006). Questions on diarrheal and respiratory disease prevalence are an expansion of similar questions in the Peletz survey (Peletz, 2006), with clarified definitions of diarrheal and respiratory from a number of published studies and reports (Gove 1997; Baqui, 1991; Arnold *et al*., 2009; Majuru 2011). In the survey applied in the pre-test, we used a modification of the *Smilie Diary* (Gundry and Wright, 2004). Using the modified *Smilie Diary*, participants record weekly diarrhea and respiratory illness episodes using an image-based form.

The baseline survey was modified several times before travel to Ghana, with the help of thesis advisor Susan Murcott, Joanne Cohn of the Rotary Club of Malden, and Jim Niquette of the PHW board. The dual objectives considered during the initial modification process were to meet the evaluation requirements in the Rotary Global Grant proposal and to maximize time- and cost-effectiveness. In the interest of shortening the survey, a number of questions in the initial questionnaire were omitted, including those on cultural beliefs (such as understanding of diarrheal and respiratory illness causes), although they would have likely obtained interesting information.

## 3.3 Baseline Survey Overview

A copy of the final survey used in Tamale is presented in Appendix A, which includes the main two-page survey plus three annexes referred to as Forms A, B and C (further described below). The following is an overview of the survey tool structure:

### 3.3.1 Household Information

- Respondent relationship to the youngest child in household
- Number of people in household
- Number of children under five in the household

In each household, respondents were asked to identify their relationship to the youngest children in the household. Possible responses were: mother, grandmother, or other primary caretaker. The total numbers of people and the number of children under five in each household were also recorded.

Much of the population in rural Tamale is polygamous, so defining households for this survey was a challenging task. One husband has one or more wives, and is the head of a compound, which includes wives, children and sometimes other relatives. The husband typically lives in a separate dwelling from his wives. Each wife is the head her household—her own children and sometimes other relatives—and each household has a dwelling in the compound. For this study, the enumerators initially defined a household unit as all persons who regularly obtained his or her drinking water from the same water storage container(s). However, this definition proved to be impractical as all residents of a compound typically shared the water container(s). Most respondents, instead, defined their households as one wife, her children, any other immediate relatives living with her, and her husband. Approximately fourteen respondents counted all members of their polygamous compounds as members of their households. Households are discussed in greater detail in the Results section.

There are usually multiple one-room household dwellings contained within a roughly circular compound wall. The open courtyard in the center of the compound is used for cooking, cleaning and other activities. A photograph and annotated schematic diagram of a typical compound are shown in the Figure 3-1 and Figure 3-2 respectively.

**Figure 3-1: Typical compound in rural communities surrounding Tamale (Credit: Jonathan Lau).**

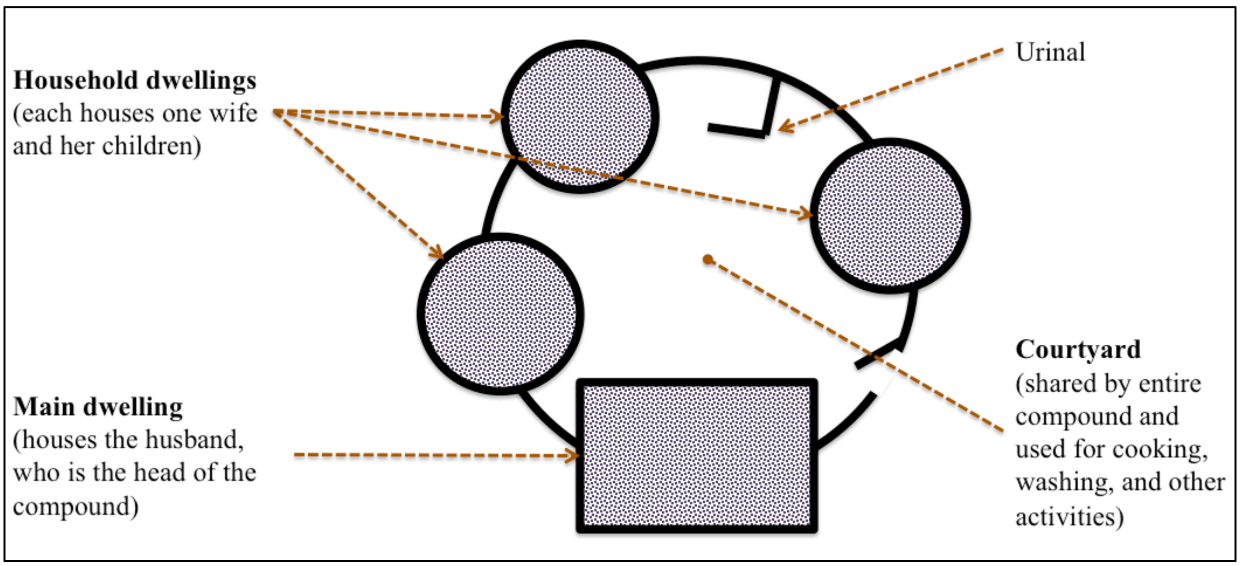



**Figure 3-2: Schematic diagram of a typical compound in rural communities near Tamale.**

### 3.3.2 Household Water Management Practices

- Sources of drinking water: wet season and dry season
- Treatment method (if any)
- Dispensing method of household water (pathways for water contamination in home)

Participants were asked about household drinking water management practices. For all water management questions, the enumerators did not prompt any specific responses, but instead used open-ended wording and then coded the respondents' answers into pre-determined possible responses.

Data on the collection sources for drinking water were recorded as separate responses for the wet and dry seasons. Responses for collection sources were coded as: surface water, hand-dug well (HDW) unprotected, HDW protected, borehole, community water treatment, piped supply, rainwater, or other. Data on water treatment methods were also collected, and answers were coded as: boil, alum, chlorine tablets/liquid, ceramic filter, cloth filter, none, or other. Participants were also asked to describe the dispensing method for taking water out of the storage containers. Responses were coded as: pour directly, draw with cup or scoop with a handle, draw with a cup or scoop without a handle, spigot, or other. Many previous surveys included an additional question on water storage method. In this study, the water storage question was omitted, because households in peri-urban villages of Tamale nearly ubiquitously use traditional ceramic urns as their primary water storage container, shown in Figure 4-11 in Baseline Results (Section 4).

For the water management questions, if households had more than one response per question, all responses were included. The author chose to use a conservative approach in synthesizing the household water management data. The household drinking water sources are presented as a "primary source" and a "secondary source" for each season. If households used more than one source, and one of these sources was unimproved and the other(s) were improved, the unimproved source was counted as the primary source. The other source(s) were counted as secondary. This was done for two reasons. First, since all household water is typically stored in traditional ceramic urns, it seemed that water from improved sources would be mixed in the storage container with any pre-existing supply. Once households have contaminated the water in the storage container, it would remain contaminated until it is properly emptied and cleaned. It appears that the large urns would be difficult to fully empty and clean. Therefore, if the household uses an unimproved source in addition to an improved source, the storage container would likely be contaminated. Second, improved sources such as boreholes, piped supply, and rainwater, may not provide water consistently and in ample quantity. Unstructured interviews and personal observation by PHW employees Josh Hester and John Adams, and the survey enumerators suggested that most of the improved sources in the villages included in this survey did not produce water consistently and in ample quantity. See Appendix G for a rapid assessment report by Josh Hester and John Adams of the boreholes in Tugu and Duuyin, two of the villages surveyed during January 2012. Similarly, if households used a cup or scoop without a handle along with another method of dispensing water, they were counted as using a cup or scoop without a handle.

### 3.3.3 Hygiene Practices

- Handwashing with soap
- Presence of soap in household

Two methods were used to measure the rate of handwashing with soap at critical times. In the eight pre-test surveys and the first 54 surveys included in the study, participants were asked the direct question as to whether they washed their hands at each of four critical times: "Do you wash your hands (1) after toilet use, (2) after wiping a child's behind or disposing of stools, (3) before eating, and (4) before handling food or water." They were then asked whether they used soap when washing their hands.

When it became clear that this method severely overestimated the rate of handwashing with soap, the direct question was replaced with an indirect question. Participants were asked "What type of soap do you use in the home?" followed by "What do you use this soap for?" For both of these questions, enumerators did not prompt any specific responses, but again used open-ended wording. The first question was purely a lead-in to the second question, so responses to the first question were not recorded. Responses to the second question were coded as: washing dishes/utensils, laundry, bathing, hand-washing, and other. If households had more than one response, all responses were marked. The enumerators pushed to obtain all responses possible by asking, "What else do you use the soap for?" until the respondents indicated that they had already stated all uses.

For both methods, approximately half of the participants were also asked to show their soap to the enumerators in order to confirm presence of soap in the household.

The 2003 Ghana Demographic and Health Survey (GDHS) confirmed hand-washing rates by checking for hand-washing materials in a designated area within the dwelling, yard, or plot. We opted to not use this method, as households share compound houses where washing areas may be shared among several households, and personal items such as soap may not be kept in any designated area (2003 GDHS).

### 3.3.4 Diarrheal and Respiratory Illness Prevalence Rates

- Prevalence of diarrhea in last 48 hours
- Prevalence of severe or watery diarrhea in last 48 hours
- Prevalence of highly credible gastrointestinal illness (HCGI) in last 48 hours
- Prevalence of respiratory illness in last 48 hours
- Prevalence of severe respiratory illness in last 48 hours

Data were collected on the incidence of diarrhea, highly credible gastrointestinal illness (HCGI), respiratory illness and severe respiratory illness in all members of the household, and in children under five specifically. The time frame of concern in the final survey was defined as the 48 hours prior to the interview, since Arnold *et a*l. (2009) identified underreporting of symptoms when participants were asked to recall events occurring in longer time spans.

The general structure of the health status questions is a series of "yes/no" questions on health status, with nested question sets on health of children under five, symptoms of adults with gastrointestinal illnesses and symptoms of adults with respiratory illnesses. Due to resource limitations, it was unfeasible to ask about the health status of every member of each household individually. However, it was particularly important to obtain accurate data on the disease incidence in children under five and on other family members manifesting the symptoms in question. Thus, participants with children under five in the household were prompted to describe the health status of each such child individually, using Form A. Forms A, B and C are included with the baseline survey in Appendix A. For households without children under five, Form A was left blank. They were then asked whether *any other* members of the household presented any of the following symptoms: diarrhea, abdominal, blood or mucus in the stool, nausea, or vomiting. If any of these symptoms were present in at least one such individual, Form B was used to complete the symptom information. Similarly, participants were then also asked whether *any other* members (aged five or above) of the household had cough or difficulty breathing. If either of these symptoms were present in any additional individual, Form C was used to complete the respiratory illness symptom information. The clinical definitions of the illnesses under study, as well as the adapted definitions used in this study, are discussed next.

The clinical definition of diarrhea is: three or more loose or watery stools in 24 hours, or a single stool with blood or mucus (Baqui *et al.*, 1991; Arnold *et al.*, 2009). Due to the large household sizes in the participating villages however, the respondent would likely not be able to recall the number of loose or watery stools for each member of the household. It was therefore decided that it would be more accurate to simplify the functional definition to presence of one of the following symptoms: "diarrhea", or "blood or mucus in the stool", with the terms in quotations translated directly into Dagbani. If the respondent responded that one or more members of the household had diarrhea, he or she was then asked whether the diarrhea was "severe or watery", translated directly into Dagbani, in each case. Here and throughout the survey, the meaning of the term "severe" was left to the interpretation of the respondent.

Highly credible gastrointestinal illness (HCGI) includes any of the following conditions: vomiting, watery diarrhea, soft diarrhea and abdominal cramps, or nausea and abdominal cramps. Compared to diarrhea or severe diarrhea alone, HCGI is more inclusive of symptoms that may result from consumption of waterborne pathogens. The author chose to assess HCGI as a health measure in this thesis because of its inclusivity. The flow charts in Figure 3-3 and Figure 3-4 show how HCGI was assessed in children under five and other individuals respectively. If a child under five was indicated to have at least one of the relevant symptoms ("diarrhea", "vomiting", and "blood or mucus in the stool", with terms in quotations translated directly into Dagbani), respondents were asked to complete the symptom information for each child.[13] If the child was reported to have any of the following symptoms or symptom combinations, they were counted as having HCGI: "vomiting", or "diarrhea" that was further reported to be "severe or watery", again with terms in quotation marks translated directly into Dagbani. If at least one adult or child aged five or above was indicated to have at least one of the relevant symptoms ("diarrhea", "abdominal pain", "vomiting", "nausea", and "blood or mucus in the stool", with terms in quotations translated directly into Dagbani), respondents were then asked to complete the symptom information for each individual. If the individual was reported to have any of the following symptoms or symptom combinations, they were counted as having HCGI: "vomiting", "diarrhea" that was further reported to be "severe or watery", "diarrhea" and "abdominal pain", or "nausea" and "abdominal cramps", again with terms in quotation marks translated directly into Dagbani.

[13] Data on nausea and abdominal cramps were not collected for children under five, as it seemed that caretakers would not be able to accurately assess whether the young children were suffering from these symptoms or other symptoms that were not outwardly apparent.

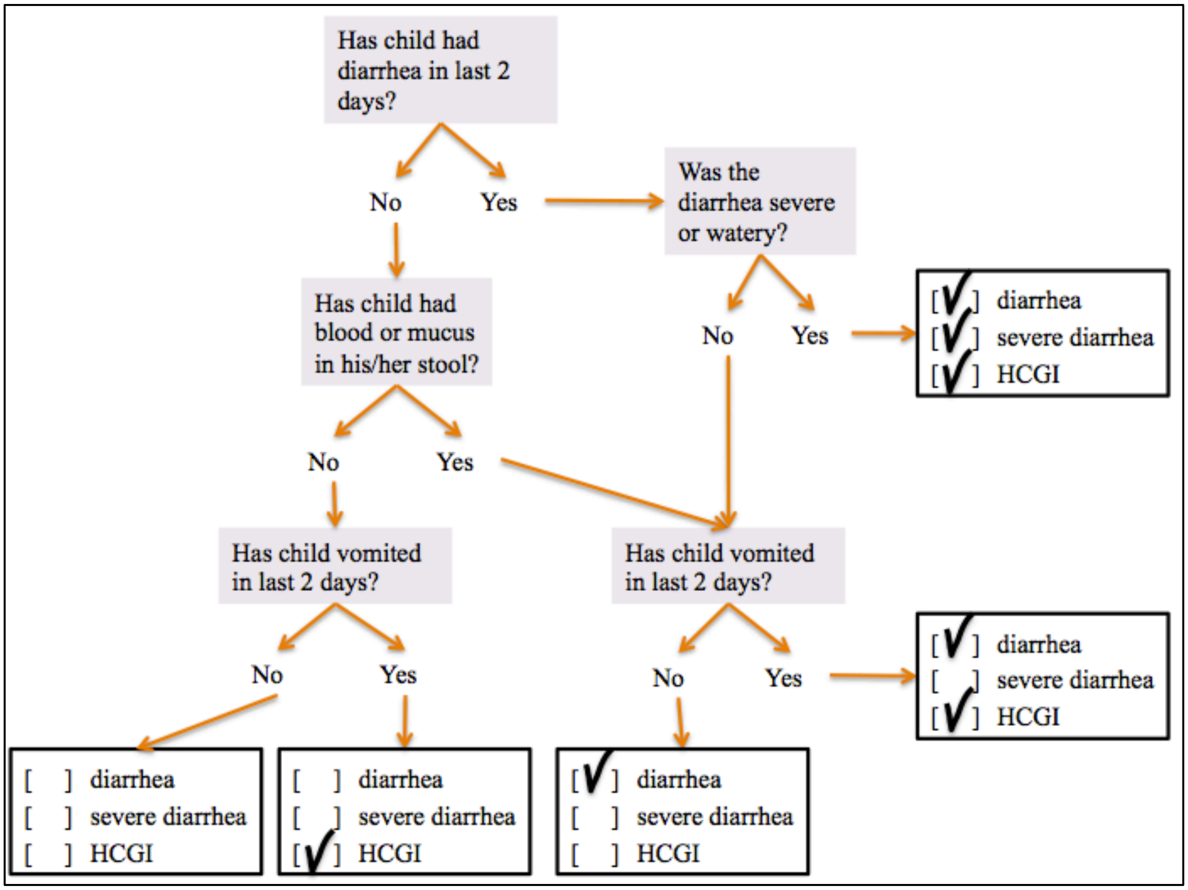



**Figure 3-3: Flow chart for determining diarrheal illness status for children under five. All questions were translated to Dagbani directly, and the definitions for "diarrhea", "severe", "blood or mucus in the stool" and "vomit" were left to the discrepancy of the respondent.**

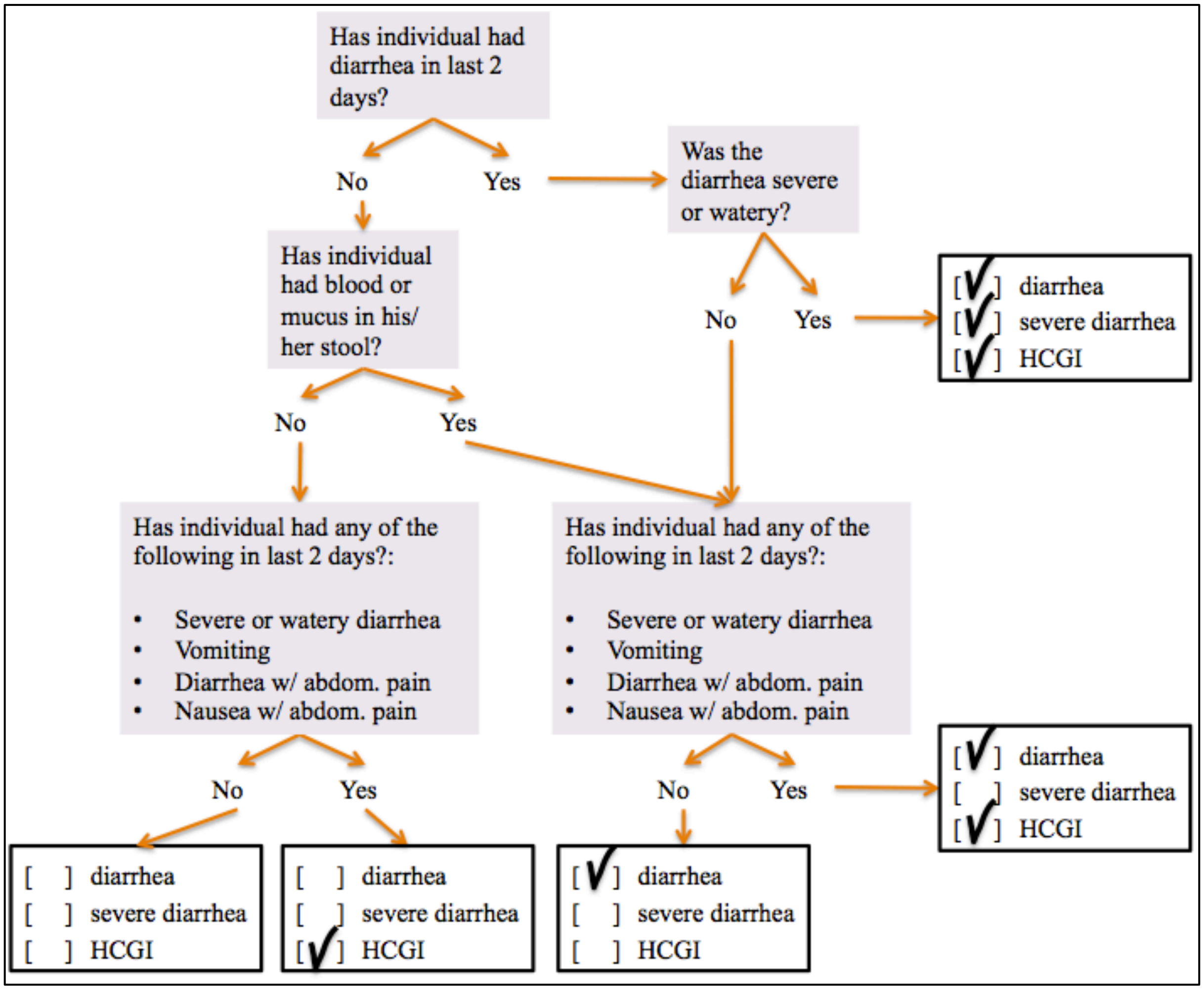



**Figure 3-4: Flow chart for determining diarrheal illness status for adults and children ages five and over. All questions were translated to Dagbani directly, and the definitions for "diarrhea", "severe", "blood or mucus in the stool", "vomiting", and "abdominal pain" were left to the discrepancy of the respondent.**

Data on incidence of respiratory illness was also collected, based on a definition adapted from the World Health Organization (WHO) clinical definition of acute lower respiratory-tract infection (ALRI). The WHO definition is: cough or difficulty breathing with a raised respiratory rate measured with a wristwatch (more than 60 breaths/min in children <60 days old, more than 50 breaths/min for children aged 60-364 days, and more than 40 breaths/min for children aged 1-5 years) (Gove 1997; Arnold *et al.* 2009). However, since not all members of each household would be present during the interview and those present would not likely be representative of the entire household, this study omitted the respiratory rate condition. To assess the incidence of respiratory illness and severe respiratory illness in children under five, participants were asked whether each child had "cough or difficulty breathing", and whether these symptoms were "severe", with terms in quotation marks translated directly into Dagbani. The survey tool was intended to include lower respiratory-tract infections and exclude upper respiratory-tract infections, since upper respiratory-tract infections (such as the common cold) tend to be less severe and almost ubiquitous among children under five during the dry season. If the participant indicated that at least one adult or child aged five or above had "cough or difficulty breathing", he or she was further were asked if these symptoms were "severe" in each case identified, again with terms in quotation marks translated directly into Dagbani. The meaning of the term “severe” was left to the interpretation of the respondent.

## 3.4 Baseline survey Implementation

Following a one-day survey pre-test and modifications, survey enumerators implemented the baseline survey in peri-urban communities in Tamale. During January, data was collected from 214 households from a total of 10 villages. During April, data was collected from an additional 215 households from 10 other villages. Both January and April are dry season months in Northern Ghana. This section describes the critical components of the baseline survey implementation: the survey team, pre-test, modifications, and the methodology used to select communities, households and respondents for data collection.

### 3.4.1 Survey Team

The survey was conducted by two survey teams, including one MIT graduate student and two Ghanaian enumerators, and supervised by the principal investigator Susan Murcott. Finding and hiring highly effective survey enumerators was critical to the success of this study. Essential qualities for the Ghanaian enumerators included: ability to speak English and Dagbani fluently and translate between the two languages, familiarity with Pure Home Water’s mission and/or other water-related projects, excellent communication abilities, and familiarity with local customs.

Emelia Ataya and Zainab Salifu were hired to form the enumerator team. Emelia Ataya is a university-educated Ghanaian businesswoman from the Upper East region. She did outstanding community work for the Guinea Worm Eradication Program and was highly recommended by Jim Niquette when Susan Murcott reached out to find candidates. Salifu is a secondary school-educated Ghanaian from Tamale, and a native speaker of the local language, Dagbani. Prior to this study, Salifu had worked with PHW in various capacities for many years, and aims to become a primary school teacher. Both Ataya and Salifu possess excellent communication skills and the ability to create a sense of understanding and trust with survey respondents.

**Figure 3-5: Left, Emelia Ataya; Right, Zainab Salifu, Connie Lu and a survey respondent.**

Murcott and Lu took time to discuss the research goals with Ataya and Salifu in order to align the objectives of the entire team and increase survey efficiency. Ataya was already highly experienced with survey enumeration at the beginning this study, and helped to train Salifu to translate and enumerate. Throughout the January fieldwork, Ataya conducted surveys alone while Salifu and Lu worked as a team. Towards the end of the January fieldwork period, Salifu began to conduct surveys on her own. Two-way feedback between Lu and the survey enumerators was critical to improving and controlling the quality of the survey work throughout the period of survey implementation. During the April fieldwork, Ataya and Salifu each conducted surveys alone, and periodically checked in with each other as well as with Lu and Murcott for quality control.

### 3.4.2 Baseline Survey Modification and Pre-test

The survey was modified six times in Tamale with the help of Emelia Ataya and Susan Murcott. A number of questions were omitted or modified before the initial pretest based on Ataya's cultural understanding. Other questions were modified before the initial pretest, based on Murcott's understanding of local water management practices.

One day of fieldwork was devoted to pre-testing the survey in Jerigu, a community that will not participate in the Rotary FVGG project. Pre-testing the survey greatly increased the clarity of the survey, alignment of survey enumerator's goals, and overall quality of the data collected. The aims of the pre-test were to: (1) Identify questions that seemed to be confusing to respondents, as well as questions that seemed to prompt answers that were unclear or difficult to record, (2) For closed multiple-choice questions, to identify any missing options associated with local practices (such as rainwater harvesting as a wet season water source), (3) Take note of logistics needs for the survey implementation, and (4) Train survey enumerators to administer the survey smoothly and consistently. Eight households were interviewed in total during the pre-test, and all areas for survey tool improvement were noted in the process of interviewing.

After survey pretest, the *Smilie Diary* was replaced with a series of "yes/no" questions on health status, with nested question sets on health of children under five, symptoms of adults with gastrointestinal illnesses and symptoms of adults with respiratory illnesses. The *Smilie Diary* seemed to be culturally inappropriate for Northern Ghana, for reasons that are unknown to the author. More importantly, it was logistically difficult to complete a *Smilie Diary* for each member of the household. The process of completing a *Smilie Diary* is time-consuming, and survey fatigue on the part of the respondent was apparent. Other minor changes were also made after the survey pretest. The nested health questions enabled enumerators to consistently record all health symptoms relevant to diarrhea, other highly credible gastrointestinal illnesses, and respiratory illnesses, while minimizing repetition and survey fatigue.

After the implementation of the first 54 surveys, it was obvious that the direct hand-washing questions led to drastic over-reporting. These questions were therefore re-developed during the survey implementation to better accommodate local cultural values. The final handwashing practices data are therefore based off a sample size of 160 households, rather than the full 214 households interviewed. Hand-washing practices are addressed in greater detail in the Baseline Survey Overview (Section 3.3) and in Results (Section 4).

### 3.4.3 Survey Instrument Translation

All household surveys were conducted in or translated on-site into the local language, Dagbani. Because Dagbani is predominantly an oral, not a written language, the survey tool was written in English and each enumerator translated the questions and interpreted the responses in the field. Lu and Murcott chose not to devote time to completing a translation and back-translation of the written survey instruments. Based on the experience of past MIT students, the task of translation and back-translation is complicated and time-consuming for a number of reasons. First, Dagbani is a simple language with only 6,000 documented words (Mahama, 2003). In addition, Dagbani is typically not expressed in written form. Dagbani is one of many local languages in a country where English is the official language. Since English is used in professional and academic settings, local languages are rarely used in writing. As a result, it is difficult to find individuals who are able to translate and write documents in Dagbani, and equally difficult to find another individual to back-translate the Dagbani document into English. Once individuals agree to translate and back-translate, Green (2008) found that the translators struggled with water management questions, since most people use idiomatic expressions to describe water sources and household water management. Both Ghanaian enumerators, as individuals who are familiar with water management, were able to orally translate and interpret responses to the survey in the field without hesitation. In addition, the enumerators, even Salifu, who is a native Dagbani speaker, found the English version of the survey easy to follow and use for recording responses, as they are both accustomed to reading English, not Dagbani. Lu and Murcott decided that instead of investing time to translate the written tool in the Dagbani, it would be more useful to improve the structure of the survey tool and increase the quality and quantity of data collection.

### 3.4.4 Sample Size Determination

Sample size calculation for studies with dichotomous outcomes (e.g. healthy vs. ill with diarrhea) requires four input components: (1) type I error (alpha), (2) power (1-beta), (3) event rate in the control group, and (4) treatment or intervention effect of interest (Schulz and Grimes, 2005). Type I error is the probability of detecting a statistically significant difference when the treatments are in reality equally effective, i.e., the chance of a false-positive result. Power (1-beta) is the probability of detecting a statistically difference when a difference of a given magnitude really exists, i.e. the complement of the chance of a false-negative result (Schulz and Grimes, 2005).

In order to calculate the sample size required for a statistically significant result, all four input components must be predicted. Different assumptions about error and power change sample sizes considerably, and these assumptions are often quite subjective (Schulz and Grimes, 2005). In this study, two different types of event rates—diarrheal illness rates and respiratory illness rates—and two different interventions—filter use and Tippy Tap use—are considered. By using different but reasonable values for power and error, we calculated a large range of sample sizes, from 150 households to 600 households. As a result of this wide range, the author decided to conduct as many surveys as possible within the time and funding limitations. Altogether, 429 surveys were conducted, 214 during January 2012 and 215 during April 2012. The delay between the January surveys and the April surveys was due to funding constraints.

### 3.4.5 Community selection

Since this study aims specifically to evaluate the Future Vision Global Grant project, PHW Board members and the Rotary Club completed community selection during the process of planning for the project. Prior to arrival in Ghana, PHW Board members developed a list of 77 peri-urban communities that could potentially participate in the Rotary project. Jim Niquette, one of the PHW Board members, then developed a list of eleven communities for the January fieldwork. The eleven communities were selected because: (1) they were in rural areas near Tamale, (2) there was high use of unimproved water, and (3) they were formerly endemic guinea worm communities (Niquette, personal com., 2012). In addition, the enumerators could reach the chosen villages by reliable roads. Niquette and Ataya had already established trust with the formerly endemic guinea worm communities during the Guinea Worm Eradication Program. As a result, the survey enumeration team would be more likely to collect accurate responses and would be less likely to encounter barriers to working in these communities. The communities were therefore not randomly selected, due to financial and logistical constraints.

The pre-test was conducted in one of the eleven communities selected by Niquette, and survey results presented in this paper were calculated from the remaining ten communities. The baseline sample size was approximately doubled through additional survey work in April 2012. Ataya selected the communities surveyed in April using the same criteria that Niquette used to select the January communities.

### 3.4.6 Community Engagement

Prior to undertaking the surveys of households in each community, the enumerator team completed a formal introduction process that is the cultural norm in traditional rural communities. Ataya first entered the community to find an individual who could facilitate the formal introduction with the chief of the community. Usually, this individual was the health volunteer who Ataya had worked with during the Guinea Worm Eradication Program. The enumerator team then met briefly with the chief to explain the purpose of the visit and obtain approval for the research. Once approval was obtained, the enumerators planned the sampling strategy based on the approximate number of households in the community, and split into two independent enumerator teams.

### 3.4.7 Household selection

The enumerators aimed to randomly sample households within the chosen communities. Since written or electronic records of the households and compounds did not exist, it was not possible to draw a simple random sample. The enumerators used systematic sampling, where they targeted every house, every other house, or every third house to generate a random sample that was spatially representative of the entire community. For efficiency, the enumerators worked in only one community each day, and surveyed as many households as possible in each community within time limitations. In the smaller villages, such as Futa, all households were targeted, so every household with a person present in the home was surveyed. In the largest village, Tugu, the enumerators targeted one of every three households. In the villages of intermediate size, every other household was targeted.

Whenever the enumerators reached a household where no caretaker was present and available to participate, they continued sampling at the immediately neighboring household. Due to limited time, it was not possible to schedule survey times with most households that were not immediately available. There was therefore sampling bias towards households where primary caretakers were more likely to be present and available in the mornings, when all surveys were conducted.

The rate of non-response is insignificant. Only one household chose not to participate in the survey, and in this household, the caretaker indicated that they were too busy to be interviewed.

### 3.4.8 Interview strategy

Upon reaching each compound, the enumerators briefly explained the purpose of the visit and asked to speak with a primary caretaker of the family, preferably a mother or grandmother. If a respondent was present and available to be interviewed, the enumerators gave more information about the purpose of the survey and asked if the potential respondent was willing to participate. Once voluntary and informed consent was obtained, the enumerators conducted the survey following the structure of the survey tool. The enumerators translated survey questions and interpreted responses in as consistent a manner as possible.

Most surveys were conducted in the central courtyard of the compound. A smaller number of surveys were conducted inside one of the dwellings within the compound, and a few surveys were conducted outside of the compounds, in gathering areas where respondents were resting, working, or eating meals with their neighbors. The enumerators attempted to conduct the surveys in privacy and to obtain household responses from only one respondent. However, it was difficult to achieve privacy and exclusive response with some households, as they tended to be highly social. In most households, more than one family member was present, and in many households, neighbors and friends were present as well. People tended to gather around the respondent and listen to the survey proceedings. In some cases, the enumerators would obtain combined responses from multiple of the people present. Respondents likely felt pressured to give particular responses based on the presence of relatives, neighbors and friends in a number of cases. No responses were disqualified based on the identity of the respondent(s) or the social context of the survey.

### 3.4.8 Number of interviews conducted per day

On average, the enumerators collectively surveyed 22.5 households per day. Each enumerator or enumerator team surveyed between 8 and 18 households per day. In addition to the shortening the survey tool prior to implementation, the enumerators brought water sachets and took breaks during fieldwork to avoid survey fatigue.

### 3.4.9 Data Entry

Enumerators recorded responses on hard-copy survey tools during the household surveys. The responses were then entered into an Excel spreadsheet manually. Each item in the data was double-checked at initial time of entry. Digitized data were then randomly spot-checked with the responses recorded on the printed survey tools throughout the process of data analysis, in order to catch inadvertent data corruption or deletion. All surveys were numbered and identifying information was removed before the data was presented in this thesis.

# 4 Results

## 4.1 Communities

The baseline consists of interview data from ten communities, which are listed in Table 4-1. The communities are small, rural, traditional villages located 30 to 90 minutes by vehicle from the city of Tamale, with populations between 200 and 1500 individuals. The exact population of each village is not shown, as it was difficult to obtain updated information after the end of the Guinea Worm Eradication Program. Table 4-1 also indicates the number of households that were surveyed in each community.

**Table 4-1: Number of households sampled in communities surveyed during January 2012**

| Village | Number of households sampled |
|---|---|
| Dufaa | 16 |
| Lahagu | 10 |
| Duuyin | 28 |
| Labariga | 17 |
| Tugu | 32 |
| Tugu-Yapala | 20 |
| Futa | 13 |
| Gbruma | 26 |
| Wuvoguma | 36 |
| Wuvugu | 16 |
| **Total** | **214** |

## 4.2 Summary of baseline survey results

Table 4-2 is a summary of the baseline survey results, including key variables pooled across all communities. The rest of the results subsections present the key variables in greater detail and include community-specific estimates.

**Table 4-2: Summary of key variables (pooled across communities).**

| Pooled estimates (95% CI, if applicable) | | |
|---|---|---|
| **Average number of individuals per household (n = 214)** | | 8.0 |
| **Average number of children <5 per household (n = 214)** | | 1.6 |
| **Respondent (n = 208)** | **Mother** | 75.5% |
| | **Grandmother** | 8.7% |
| | **Other primary caretaker** | 15.9% |
| **Primary dry season water source (n = 214)** | **Surface water** | 98.6% |
| | **HDW unprotected** | 0.9% |
| | **HDW protected** | 0.0% |
| | **Borehole** | 0.5% |
| | **Piped** | 0.0% |
| | **Community** | 0.0% |
| **Secondary dry season water source (n = 47)** | **Surface water** | 0.0% |
| | **HDW unprotected** | 20.7% |
| | **HDW protected** | 0.0% |
| | **Borehole** | 24.1% |
| | **Piped** | 25.9% |
| | **Community** | 29.3% |
| **Primary wet season water source (n = 214)** | **Surface water** | 55.6% |
| | **HDW unprotected** | 24.3% |
| | **HDW protected** | 0.0% |
| | **Borehole** | 15.0% |
| | **Piped** | 0.0% |
| | **Community** | 1.4% |
| | **Rainwater** | 0.5% |
| | **Spring** | 3.3% |
| **Secondary wet season water source (n = 110)** | **Surface water** | 0.0% |
| | **HDW unprotected** | 15.4% |
| | **HDW protected** | 0.0% |
| | **Borehole** | 4.2% |
| | **Piped** | 9.8% |
| | **Community** | 11.9% |
| | **Rainwater** | 57.3% |
| | **Spring** | 1.4% |
| **Household water treatment method (n = 213)** | **None** | 43.7% |
| | **Cloth filter** | 52.6% |
| | **Ceramic filter** | 1.9% |
| | **Boil** | 0.0% |
| | **Alum** | 1.9% |
| | **Chlorine** | 0.0% |
| **Method for dispensing drinking water (n = 213)** | **Cup or scoop w/o handle** | 83.6% |
| | **Cup or scoop w/ handle** | 14.6% |
| | **Spigot** | 1.9% |
| | **Other** | 0.0% |
| **Hand-washing with soap (n = 160)** | **No** | 95.0% |
| | **Yes** | 5.0% |
| **Soap present in household (n = 126)** | **No** | 0.8% |
| | **Yes** | 99.2% |
| **Interest in purchasing water filter (n = 209)** | **No** | 0.5% |
| | **Yes** | 99.5% |
| **Under-five prevalence of illness in 48 hours preceeding survey (n = 200)** | **Diarrhea** | 23% (17% to 29%) |
| | **Severe diarrhea** | 11% (7% to 16%) |
| | **HCGI** | 18% (13% to 23%) |
| | **Cough or difficulty breathing** | 25% (19% to 31%) |
| | **Severe cough or difficulty breathing** | 18% (13% to 24%) |
| **General population prevalence of illness in 48 hours preceeding survey (n = 200)** | **Diarrhea** | 9% (5% to 13%) |
| | **Severe diarrhea** | 5% (2% to 8%) |
| | **HCGI** | 8% (4% to 12%) |
| | **Cough or difficulty breathing** | 13% (8% to 17%) |
| | **Severe cough or difficulty breathing** | 10% (5% to 14%) |

## 4.3 Basic household information

General information on the number of individuals in each household was recorded. In each household, there were a mean of 8.0 individuals and a median of 7.0 individuals. There were a mean of 1.6 children under five and a median of 1.0 child under five.

In traditional, rural communities in Northern Ghana, families tend to be polygamous. Communities are therefore made up of compounds, each of which consists of a husband, one or more wives, their children, and sometimes other family members. Within each compound, there are one or more households, each of which consists of a wife, her children, and sometimes the wife's other immediate family members. The physical organization of compound homes in rural Tamale reflects the social organization of the household, and has been discussed in the Baseline Survey Overview (Section 3-3).

Throughout the survey work, there was confusion surrounding the definition of the household. Since a primary purpose of this survey is to assess current water management practices and the prevalence of waterborne diseases, the functional unit of "household" was initially defined as a group of individuals who share the same water storage container. In practice, this definition was generally not ideal, as all compound members typically shared the water container(s) within the compound. For the majority of the fieldwork, the enumerators referred to the "household" as the respondent, her husband, and their children. The latter practical definition of household seemed more reflective of the actual situation. However, a small number of respondents initially counted all members of their compounds as members of their household. In this case, where possible, the enumerators encouraged the respondents to limit the count to only her specific household. However, this was not possible when the respondent was the father in the compound, in which case the respondent's compound was considered to be the household.

Another source of confusion was that approximately fourteen respondents counted all members of their polygamous compounds as members of their households. Many compounds had numerous wives and children, so some respondents were unsure of the exact number of individuals in the larger compounds. In these cases, a best estimate was recorded. Fourteen of the households consisted of more than 15 individuals, and these increased the mean values of the number individuals per household and number of children under the age of five per household. To provide two alternate perspectives on household size, mean and median values were calculated, and are included in the Table 4-3.

**Table 4-3: Mean and median numbers of individuals per household and numbers of children under five per household (by community).**

| Village | Sample size (households) | Number of individuals | Number of children <5 | Number of individuals per household | | Number of children <5 per household | |
|---|---|---|---|---|---|---|---|
| | | | | Mean | Median | Mean | Median |
| Dufaa | n = 16 | 137 | 21 | 8.6 | 9.0 | 1.3 | 1.0 |
| Lahagu | n = 10 | 68 | 14 | 6.8 | 7.0 | 1.4 | 1.5 |
| Duuyin | n = 28 | 264 | 36 | 9.4 | 8.0 | 1.3 | 1.0 |
| Labariga | n = 17 | 133 | 19 | 7.8 | 7.0 | 1.1 | 1.0 |
| Tugu | n = 32 | 257 | 49 | 8.0 | 6.5 | 1.5 | 1.0 |
| Tugu-Yapala | n = 20 | 177 | 46 | 8.9 | 8.0 | 2.3 | 1.0 |
| Futa | n = 13 | 101 | 24 | 7.8 | 6.0 | 1.8 | 2.0 |
| Gbruma | n = 26 | 156 | 38 | 6.0 | 5.0 | 1.5 | 1.5 |
| Wuvoguma | n = 36 | 277 | 71 | 7.7 | 6.0 | 2.0 | 2.0 |
| Wuvugu | n = 16 | 134 | 25 | 8.4 | 7.5 | 1.6 | 1.0 |
| **Total** | **n = 214** | **1704** | **343** | **8.0** | **7.0** | **1.6** | **1.0** |

In each household, the relationship of the respondent to the youngest member of the household was recorded. Often, more than one member of the household participated in the interview, and in these cases, the primary respondent was identified as the person who initially and formally agreed to participate. Approximately 75.5 percent of respondents were mothers, 8.7 percent were grandmothers, and 15.9 percent were other primary caretakers.

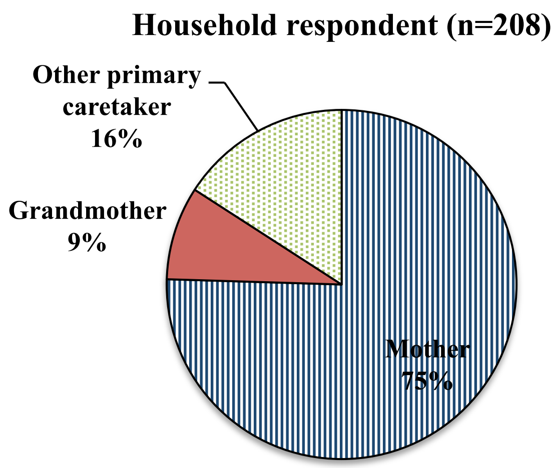



**Figure 4-1: Relationship of respondent to youngest member of household (all communities combined).**

**Table 4-4: Relationship of respondent to youngest member of the household (by community).**

| Village | Sample size (households) | Mother | Grandmother | Other primary caretaker |
|---|---|---|---|---|
| Dufaa | n = 16 | 75.0% | 18.8% | 6.3% |
| Lahagu | n = 10 | 80.0% | 20.0% | 0.0% |
| Duuyin | n = 28 | 82.1% | 10.7% | 7.1% |
| Labariga | n = 17 | 94.1% | 5.9% | 0.0% |
| Tugu | n = 32 | 65.6% | 9.4% | 25.0% |
| Tugu-Yapala | n = 20 | 75.0% | 0.0% | 25.0% |
| Futa | n = 13 | 69.2% | 0.0% | 30.8% |
| Gbruma | n = 26 | 76.9% | 15.4% | 7.7% |
| Wuvoguma | n = 32 | 81.3% | 3.1% | 15.6% |
| Wuvugu | n = 14 | 50.0% | 7.1% | 42.9% |
| **Total** | **n = 208** | **75.5%** | **8.7%** | **15.9%** |

## 4.4 Household water management

The most common water sources used by the households surveyed were surface water, unprotected hand-dug wells, boreholes, community water treatment, and rainwater. Figures 4-2 and 4-3 show examples of each of these sources.

**Figure 4-2: Unimproved water sources used by households in peri-urban Tamale. Top, Surface water, known as dugouts or dams (Credit: Susan Murcott); Bottom, unprotected hand-dug wells (Credit: Jenny VanCalcar).**

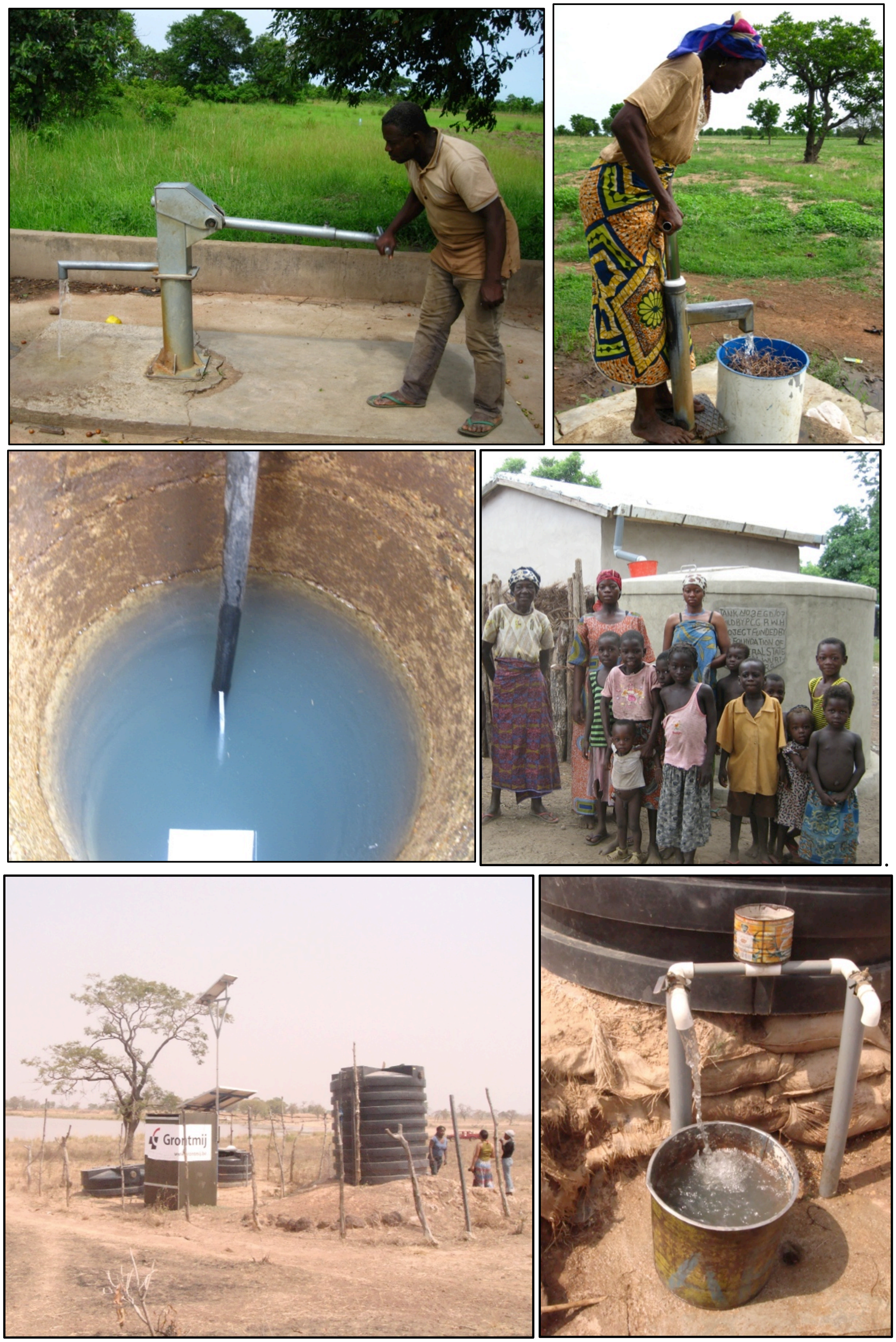



**Figure 4-3: Improved drinking water sources used in per-urban Tamale. Top, boreholes in Tugu (left) and Duuyin (right) (Credit: Josh Hester); Middle left, turbid water in a Duuyin borehold (Credit: Josh Hester); Middle right, rainwater catchment system (Credit: Susan Murcott); Bottom, community water treatment and close-up of that system's water outlet.**

### 4.4.1 Dry Season Drinking Water Source

The baseline survey was conducted in January and April, months which both fall within the 8- to 9-month dry season in Ghana. Overall, 98.6 percent of households surveyed (n=214) used surface water as a dry season drinking water source, and 77.5 percent of households surveyed used surface water as the only source of drinking water during the dry season. Only 1.4 percent of households surveyed did not use surface water for drinking water during the dry season, and for that fraction, 0.9 percent use unprotected hand-dug wells[14] and 0.5 percent use boreholes. In other words, 99.5 percent of households use unimproved drinking water sources during the dry season.

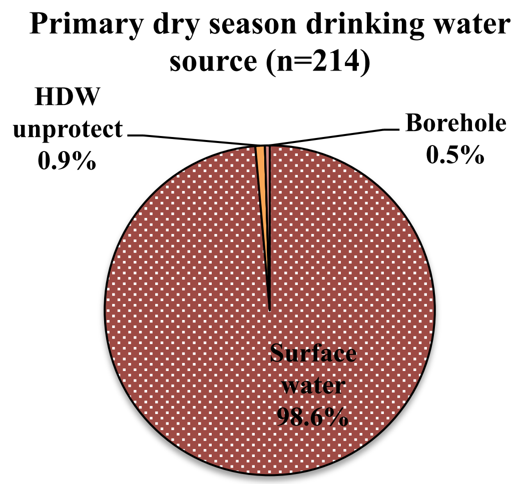



**Figure 4-4: Primary dry season drinking water sources (all communities combined).**

[14] One hand-dug well in the communities surveyed was directly observed to be unprotected, and photographs taken by Jenny VanCalcar, a past M.Eng student, in 2009 showed that other hand-dug wells observed in Northern Ghana were also unprotected. During the baseline study, we were unable to confirm whether all of wells in the communities we surveyed were protected or unprotected. However, all hand-dug wells were assumed to be unprotected based on unprotected status of the wells we were able to observe.

**Table 4-5: Primary dry season drinking water sources (by community).**

| Village | Sample size (households) | Surface water | HDW unprotect. | HDW protected | Borehole | Piped | Community |
|---|---|---|---|---|---|---|---|
| Dufaa | n = 16 | 87.5% | 12.5% | 0.0% | 0.0% | 0.0% | 0.0% |
| Lahagu | n = 10 | 100.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Duuyin | n = 28 | 100.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Labariga | n = 17 | 100.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Tugu | n = 32 | 96.9% | 0.0% | 0.0% | 3.1% | 0.0% | 0.0% |
| Tugu-Yapala | n = 20 | 100.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Futa | n = 13 | 100.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Gbruma | n = 26 | 100.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Wuvoguma | n = 36 | 100.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Wuvugu | n = 16 | 100.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| **Total** | **n = 214** | **98.6%** | **0.9%** | **0.0%** | **0.5%** | **0.0%** | **0.0%** |

Of the 214 households surveyed, 47 households had more than one dry season drinking water source. Secondary sources during the dry season (n = 47) were: community treatment (29.3 percent), piped water (25.9 percent), borehole (24.1 percent), and unprotected hand-dug well (20.7%). Thus, 79.3 percent secondary dry season drinking water sources are improved, while 20.7 percent are unimproved.

Considering that only 47 of 214 households had secondary dry season water sources, one can conclude that 82.1 percent of households do not have any access, even intermittent, to an improved water source during the dry season.

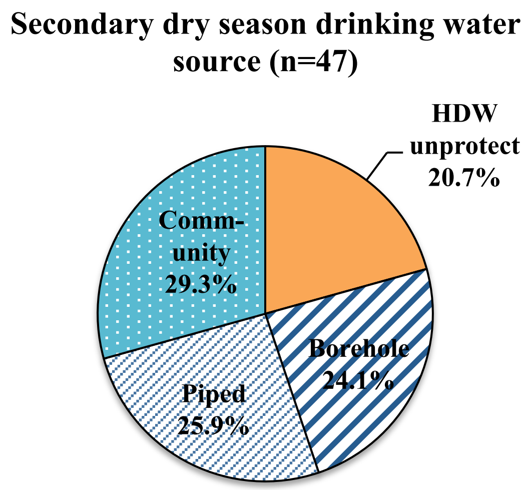



**Figure 4-5: Secondary dry season drinking water sources (all communities combined).**

**Table 4-6: Secondary dry season drinking water sources (by community).**

| Village | Sample size (households) | Surface water | HDW unprotect. | HDW protected | Borehole | Piped | Community |
|---|---|---|---|---|---|---|---|
| Dufaa | n = 16 | 0.0% | 44.4% | 0.0% | 0.0% | 55.6% | 0.0% |
| Lahagu | n = 0 | n/a | n/a | n/a | n/a | n/a | n/a |
| Duuyin | n = 6 | 0.0% | 0.0% | 0.0% | 100.0% | 0.0% | 0.0% |
| Labariga | n = 0 | n/a | n/a | n/a | n/a | n/a | n/a |
| Tugu | n = 8 | 0.0% | 0.0% | 0.0% | 100.0% | 0.0% | 0.0% |
| Tugu-Yapala | n = 0 | n/a | n/a | n/a | n/a | n/a | n/a |
| Futa | n = 0 | n/a | n/a | n/a | n/a | n/a | n/a |
| Gbruma | n = 0 | n/a | n/a | n/a | n/a | n/a | n/a |
| Wuvoguma | n = 17 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% |
| Wuvugu | n = 0 | n/a | n/a | n/a | n/a | n/a | n/a |
| **Total** | **n = 47** | **0.0%** | **20.7%** | **0.0%** | **24.1%** | **25.9%** | **29.3%** |

### 4.4.2 Wet Season Drinking Water Source

During the 3- to 4-month long wet season, household drinking water sources were more varied than during the dry season. Primary wet season drinking water sources (n = 214) were: surface water (55.6 percent), unprotected hand-dug well (24.3 percent), borehole (15.0 percent), spring (3.3 percent), community treatment (1.4 percent), and rainwater (0.5 percent). In other words, 83.2 percent of the survey population was using unimproved water sources, even in the wet season.[15]

[15] Springs were assumed to be unprotected, and were therefore considered to be unimproved sources.

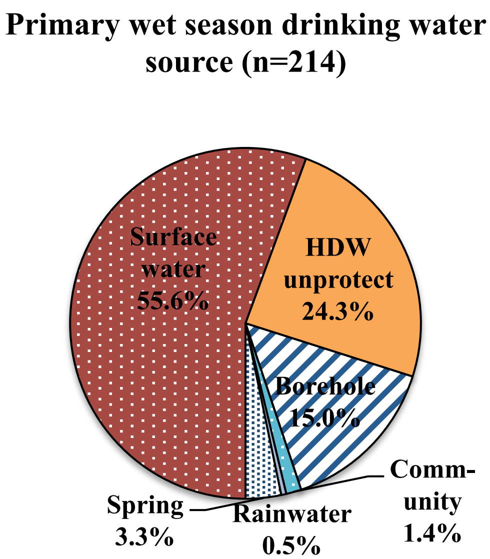



**Figure 4-6: Primary wet season drinking water sources (all communities combined).**

**Table 4-7: Primary wet season drinking water sources (by community).**

| Village | Sample size (households) | Surface water | HDW unprotect. | HDW protected | Borehole | Piped | Community | Rainwater | Spring |
|---|---|---|---|---|---|---|---|---|---|
| Dufaa | n = 16 | 81.3% | 18.8% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Lahagu | n = 10 | 30.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 70.0% |
| Duuyin | n = 28 | 3.6% | 0.0% | 0.0% | 96.4% | 0.0% | 0.0% | 0.0% | 0.0% |
| Labariga | n = 17 | 17.6% | 82.4% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Tugu | n = 32 | 84.4% | 0.0% | 0.0% | 15.6% | 0.0% | 0.0% | 0.0% | 0.0% |
| Tugu-Yapala | n = 20 | 100.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Futa | n = 13 | 61.5% | 38.5% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Gbruma | n = 26 | 3.8% | 96.2% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Wuvoguma | n = 36 | 88.9% | 0.0% | 0.0% | 0.0% | 0.0% | 8.3% | 2.8% | 0.0% |
| Wuvugu | n = 16 | 68.8% | 31.3% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| **Total** | **n = 214** | **55.6%** | **24.3%** | **0.0%** | **15.0%** | **0.0%** | **1.4%** | **0.5%** | **3.3%** |

Of the 214 households surveyed, 110 households had a secondary wet season drinking water source. Secondary sources during the wet season (n = 110) were: rainwater (57.3 percent), unprotected hand-dug well (15.4 percent), community treatment (11.9 percent), borehole (4.2 percent), and spring (1.4 percent).

Therefore, 35.8 percent of all households surveyed do not have any access to improved water sources, even intermittent, during the wet season.

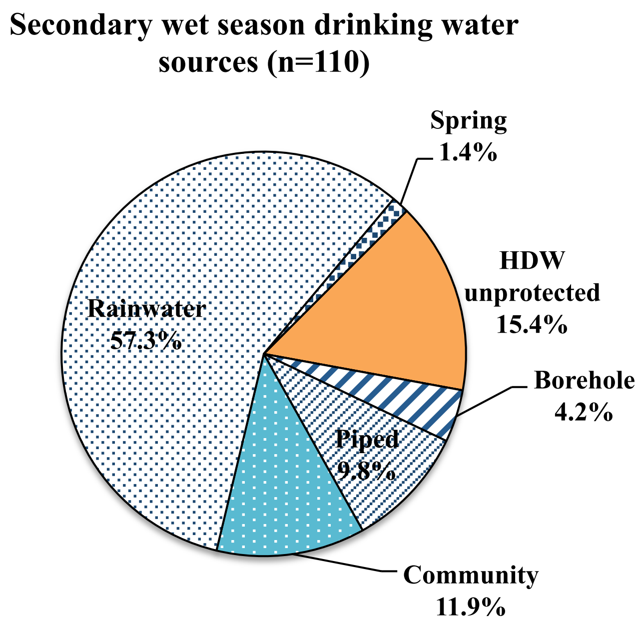



**Figure 4-7: Secondary wet season drinking water sources (all communities combined).**

**Table 4-8: Secondary wet season drinking water sources (by community).**

| Village | Sample size (households) | Surface water | HDW unprotect. | HDW protected | Borehole | Piped | Community | Rainwater | Spring |
|---|---|---|---|---|---|---|---|---|---|
| Dufaa | n = 15 | 0.0% | 33.3% | 0.0% | 0.0% | 42.4% | 0.0% | 24.2% | 0.0% |
| Lahagu | n = 10 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% | 0.0% |
| Duuyin | n = 16 | 0.0% | 0.0% | 0.0% | 6.3% | 0.0% | 0.0% | 93.8% | 0.0% |
| Labariga | n = 5 | 0.0% | 60.0% | 0.0% | 0.0% | 0.0% | 0.0% | 40.0% | 0.0% |
| Tugu | n = 13 | 0.0% | 0.0% | 0.0% | 33.3% | 0.0% | 0.0% | 66.7% | 0.0% |
| Tugu-Yapala | n = 5 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 60.0% | 40.0% |
| Futa | n = 7 | 0.0% | 60.0% | 0.0% | 0.0% | 0.0% | 0.0% | 40.0% | 0.0% |
| Gbruma | n = 12 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% | 0.0% |
| Wuvoguma | n = 18 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 50.0% | 50.0% | 0.0% |
| Wuvugu | n = 9 | 0.0% | 22.2% | 0.0% | 0.0% | 0.0% | 0.0% | 77.8% | 0.0% |
| **Total** | **n = 110** | **0.0%** | **15.4%** | **0.0%** | **4.2%** | **9.8%** | **11.9%** | **57.3%** | **1.4%** |

### 4.4.3 Household Water Treatment

Just over half of the 213 households surveyed (52.6 percent) reported using cloth filters for water treatment. The cloth filters used by households in the Tamale region were either headscarves or specialized filters retained after the end of the Guinea Worm Eradication Program in August

2011. Figure 4-9 shows cloth filters that were specially made by Vestergaard Frandsen and distributed by the Guinea Worm Eradication program. After guinea worm was eradicated from Ghana, households were instructed to use headscarves as replacements for the specially made and widely distributed guinea worm filters. In some interviews, the respondents specified whether they used guinea worm filters or headscarves without prompt from the enumerators. It seems that many households followed these instructions, or were at least aware of the instructions, because most households that specified filter types were using headscarves. It is probable that the guinea worm filters distributed through the program wore out over time, and some women began to use headscarves.

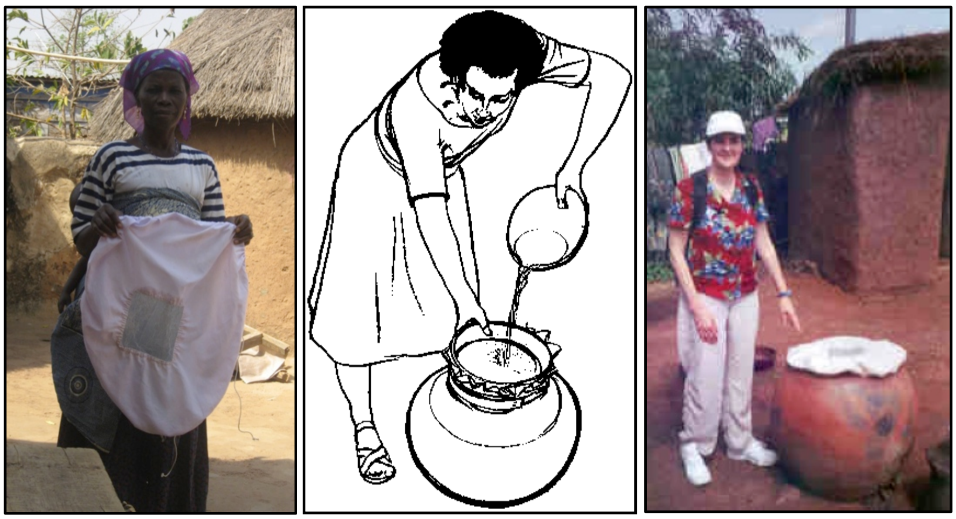


**Figure 4-8: Cloth filters made and distributed widely by the Guinea Worm Eradication Program (Credit: Susan Murcott).**

A small number of households surveyed (1.9 percent) were using ceramic water filters from Pure Home Water via a study by Innovations for Poverty Action. These ceramic filters were sold via a bidding game or take-it-or-leave-it offer by a group of researchers (Berry *et al.* 2011). A few households mentioned that they were using ceramic filters in the past, but had not been able to replace them after they were broken.

Another 1.9 percent of households surveyed reported using alum for household water treatment. The remaining 43.7 percent of households did not use any form of household water treatment.

**Figure 4-9: Right, alum balls (Credit: Melinda Foran); Left top, water being treated with alum (Credit: Melinda Foran); Left bottom, Water after treatment with alum (Credit: Melinda Foran)**

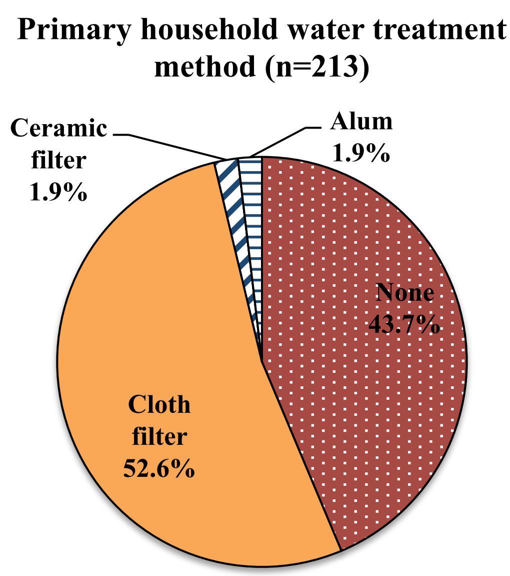



**Figure 4-10: Primary household water treatment method (all communities combined).**

**Table 4-9: Primary household water treatment method (by community).**

| Village | Sample size (households) | None | Cloth filter | Ceramic filter | Boil | Alum | Chlorine |
|---|---|---|---|---|---|---|---|
| Dufaa | n = 16 | 56.3% | 43.8% | 0.0% | 0.0% | 0.0% | 0.0% |
| Lahagu | n = 10 | 20.0% | 60.0% | 10.0% | 0.0% | 10.0% | 0.0% |
| Duuyin | n = 28 | 28.6% | 60.7% | 10.7% | 0.0% | 0.0% | 0.0% |
| Labariga | n = 17 | 41.2% | 58.8% | 0.0% | 0.0% | 0.0% | 0.0% |
| Tugu | n = 32 | 37.5% | 53.1% | 0.0% | 0.0% | 9.4% | 0.0% |
| Tugu-Yapala | n = 20 | 20.0% | 80.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Futa | n = 13 | 84.6% | 15.4% | 0.0% | 0.0% | 0.0% | 0.0% |
| Gbruma | n = 26 | 42.3% | 57.7% | 0.0% | 0.0% | 0.0% | 0.0% |
| Wuvoguma | n = 36 | 66.7% | 33.3% | 0.0% | 0.0% | 0.0% | 0.0% |
| Wuvugu | n = 15 | 33.3% | 66.7% | 0.0% | 0.0% | 0.0% | 0.0% |
| **Total** | **n = 213** | **43.7%** | **52.6%** | **1.9%** | **0.0%** | **1.9%** | **0.0%** |

### 4.4.4 Drinking Water Storage

The use of traditional ceramic water containers for drinking water storage was ubiquitous for all of the households surveyed. Therefore, in the interest of saving time, data on household water storage methods were not recorded, although storage is a potential source of drinking water contamination. Figure 4-11 shows typical water urns.

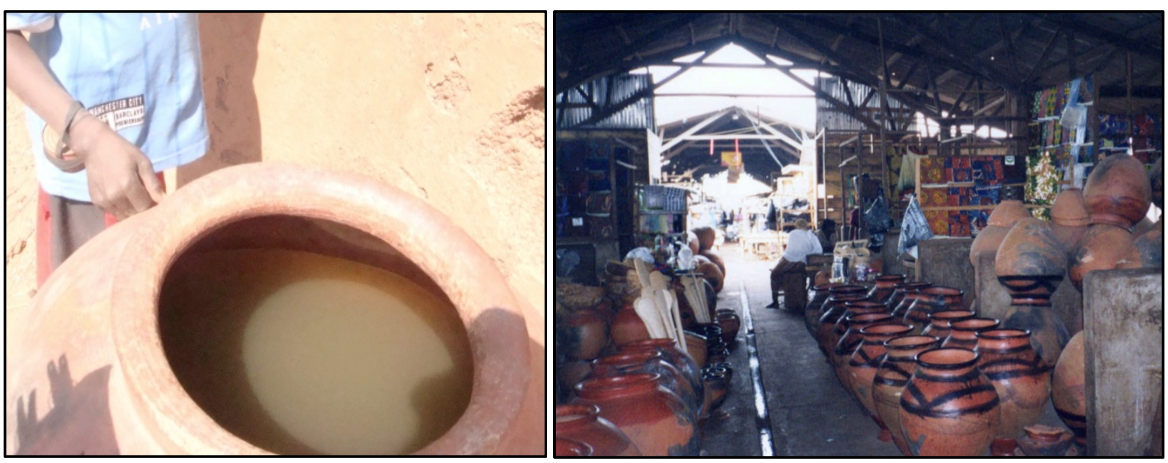


**Figure 4-11: Left, close-up of water storage urns used for household water storage; Right, Water storage urns for sale in the downtown Tamale marketplace (Credit: Susan Murcott).**

### 4.4.5 Method of Dispensing Drinking Water

Data on another potential source for drinking water contamination, the method of dispensing water from storage containers, were, however, recorded. Overall, 83.6 percent of 213 households surveyed used a cup or scoop without a handle to dispense drinking water from storage containers. The majority of these households used re-purposed aluminum cans as water-dispensing containers. Another 14.6 percent used a cup or scoop with a handle, exclusively, to dispense drinking water from storage containers. The remaining 1.9 percent of households, corresponding to households using ceramic water filters, used a spigot to dispense water from the ceramic filter's storage container.

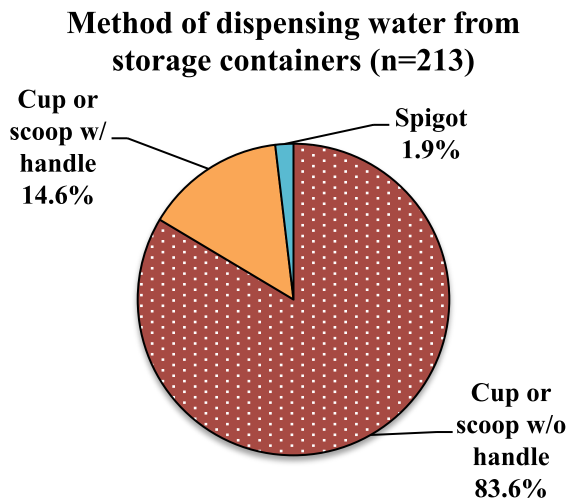



**Figure 4-12: Method of dispensing water from storage containers (all communities combined).**

**Table 4-10: Method of dispensing water from storage containers (by community).**

| Village | Sample size (households) | Cup or scoop w/o handle | Cup or scoop w/ handle | Spigot | Other |
|---|---|---|---|---|---|
| Dufaa | n = 16 | 62.5% | 37.5% | 0.0% | 0.0% |
| Lahagu | n = 10 | 50.0% | 40.0% | 10.0% | 0.0% |
| Duuyin | n = 28 | 82.1% | 7.1% | 10.7% | 0.0% |
| Labariga | n = 17 | 94.1% | 5.9% | 0.0% | 0.0% |
| Tugu | n = 32 | 93.8% | 6.3% | 0.0% | 0.0% |
| Tugu-Yapala | n = 20 | 85.0% | 15.0% | 0.0% | 0.0% |
| Futa | n = 13 | 92.3% | 7.7% | 0.0% | 0.0% |
| Gbruma | n = 26 | 80.8% | 19.2% | 0.0% | 0.0% |
| Wuvoguma | n = 36 | 86.1% | 13.9% | 0.0% | 0.0% |
| Wuvugu | n = 15 | 86.7% | 13.3% | 0.0% | 0.0% |
| **Total** | **n = 213** | 83.6% | 14.6% | 1.9% | 0.0% |

## 4.5 Hand-washing practices

In total, 54 households were surveyed using the direct question, “Do you wash your hands (1) after toilet use, (2) after wiping a child’s behind or disposing of stools, (3) before eating, and (4) before handling food or water.” Of these 54 households, 94.4 percent reported practicing hand-washing with soap at all critical times.

However, 160 households were surveyed using the paired indirect questions, “What kind of soap do you use?” and “What do you use the soap for?” Of these 160 households only 5.0 percent reported hand-washing as one of the uses for soap, even when the enumerators asked “What else do you use the soap for?” repeatedly. While the indirect question does not assess hand-washing at critical times, it does give information on whether soap is used for hand-washing. Table 4-11 below shows only the results from the indirect question.

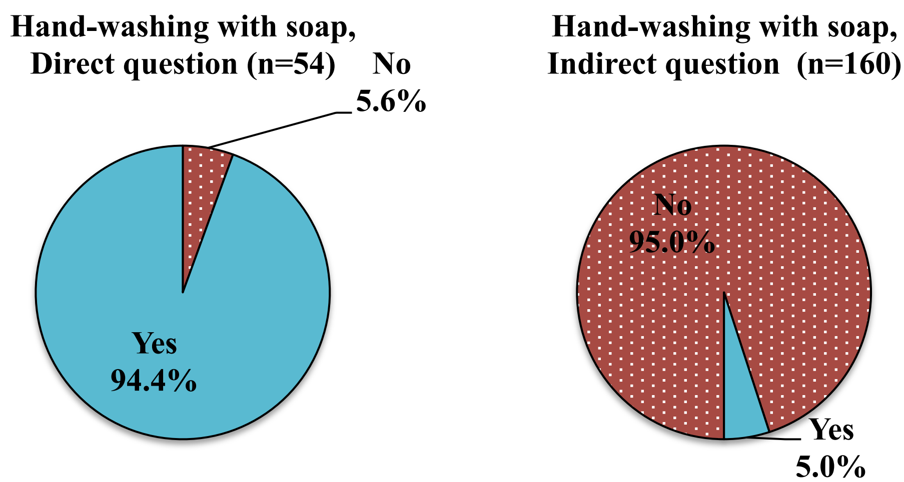



**Figure 4-13 : Left, hand-washing with soap (for all communities surveyed using direct question combined); Right, hand-washing with soap (for all communities surveyed using indirect question combined).**

**Table 4-11: Hand-washing with soap (by community, for all those surveyd using indirect question).**

| Village | Sample size (households) | No | Yes |
|---|---|---|---|
| Dufaa | n = 0 | n/a | n/a |
| Lahagu | n = 0 | n/a | n/a |
| Duuyin | n = 0 | n/a | n/a |
| Labariga | n = 17 | 100.0% | 0.0% |
| Tugu | n = 32 | 100.0% | 0.0% |
| Tugu-Yapala | n = 20 | 95.0% | 5.0% |
| Futa | n = 13 | 100.0% | 0.0% |
| Gbruma | n = 26 | 88.5% | 11.5% |
| Wuvoguma | n = 36 | 97.2% | 2.8% |
| Wuvugu | n = 16 | 81.3% | 18.8% |
| **Total** | n = 160 | 95.0% | 5.0% |

The enumerators requested approximately half of the households (n = 126) to show confirmed presence of soap. Overall, 99.2 percent of households surveyed were able to show the soap that they used. Only one household that was asked to present the soap was unable to do so.

One of the households with soap present produced their own soap, made of ash and other locally available materials, and sold this soap within the community. The vast majority of households used one of three varieties of bar soap. Two of these varieties—known as “Key soap” and “Duck soap” after the logos imprinted on the soap—are manufactured in long bars and sold by lengths specified by the customer. The other popular variety is a round bar soap known as “banku” after a local staple food made of fermented corn and cassava. A number of the households dissolved bar soap in water to make a liquid soap. One household used “Sunlight”, a powdered laundry detergent made by Unilever. It seemed that “Sunlight” is considered by some rural Ghanaian households to be high-status product. Figure 4-14 shows these common soap products.


**Figure 4-14: Soaps commonly used in peri-urban Tamale. Top left, Key soap (Credit: Stephen Buchan); Top right, Duck soap (Credit: PZ Cussons); Bottom left, banku soap (Credit: Kiva Fellows); Bottom right, Sunlight detergent (Credit: KenyaBuy.com).**

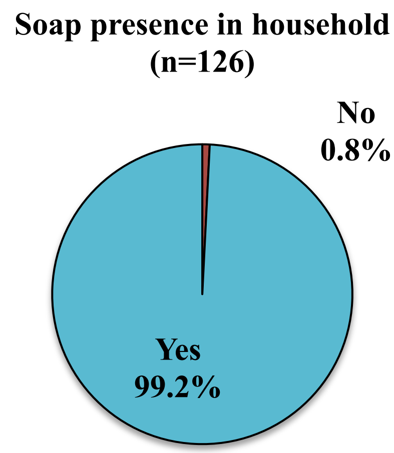



**Figure 4-15: Soap presence in household (all communities combined).**

**Table 4-12: Soap presence in household (by household).**

| Village | Sample size (households) | No | Yes |
|---|---|---|---|
| Dufaa | n = 16 | 6.3% | 93.8% |
| Lahagu | n = 10 | 0.0% | 100.0% |
| Duuyin | n = 23 | 0.0% | 100.0% |
| Labariga | n = 11 | 0.0% | 100.0% |
| Tugu | n = 21 | 0.0% | 100.0% |
| Tugu-Yapala | n = 7 | 0.0% | 100.0% |
| Futa | n = 6 | 0.0% | 100.0% |
| Gbruma | n = 10 | 0.0% | 100.0% |
| Wuvoguma | n = 13 | 0.0% | 100.0% |
| Wuvugu | n = 9 | 0.0% | 100.0% |
| **Total** | n = 126 | 0.8% | 99.2% |

## 4.6 Interest in purchasing filter

Households were asked whether they would be interested in purchasing a ceramic water filter for GHC 5 (US$ 3) in the future. Of 209 households asked this question, 208 responded "yes" and one responded "no." While many of the "yes" answers were enthusiastic responses, some households noted that they were interested in purchasing the filter, but would only do so if they had the funds to do so when the opportunity arose. Once the actual sales of these filters begin in June 2012, PHW will know whether these were courtesy responses or not.

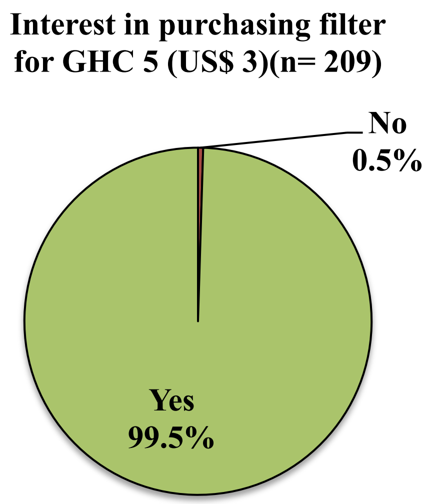



**Figure 4-16: Interest in purchasing filter for GHC 5 (US$ 3) (all communities combined).**

**Table 4-13: Interest in purchasing filter for GHC 5 (US$ 3) (by household).**

| Village | Sample size (households) | No | Yes |
|---|---|---|---|
| Dufaa | n = 16 | 0.0% | 100.0% |
| Lahagu | n = 10 | 0.0% | 100.0% |
| Duuyin | n = 24 | 0.0% | 100.0% |
| Labariga | n = 17 | 0.0% | 100.0% |
| Tugu | n = 32 | 3.1% | 96.9% |
| Tugu-Yapala | n = 20 | 0.0% | 100.0% |
| Futa | n = 13 | 0.0% | 100.0% |
| Gbruma | n = 25 | 0.0% | 100.0% |
| Wuvoguma | n = 36 | 0.0% | 100.0% |
| Wuvugu | n = 16 | 0.0% | 100.0% |
| **Total** | **n = 209** | **0.5%** | **99.5%** |

## 4.7 Household health

In this study, the prevalence of a disease is defined as the percentage of people that were suffering from that disease within 48 hours of the time of survey. Using data on reported symptoms, prevalence in children under five and total population were calculated for: diarrhea, severe diarrhea, highly credible gastrointestinal illness, cough and difficulty breathing, and severe cough and difficulty breathing.

$$\text{Prevalence} = \frac{\text{Number of individuals with disease within 48 hours of interview}}{\text{Total number of individuals in population}}$$

For each disease, 22 prevalence rates were calculated:

- 10 community-specific prevalence rates of the disease in children under five
- 1 overall prevalence rate of the disease in children under five
- 10 community-specific prevalence rates of the disease in the general population
- 1 overall prevalence rate of the disease in the general population

For example, each community-specific prevalence rate in children under five was calculated by dividing the number of children under five suffering from diarrhea within the community by the total number of children under five within the community. The overall prevalence of diarrhea of children under five was calculated by dividing the total number of children under five suffering from diarrhea by the total number of children under five in all households surveyed. Similarly, each community-specific prevalence rate of diarrhea of the total population was calculated by dividing the number of those suffering from diarrhea within the community by the total number of people within that community. The overall prevalence of diarrhea of the total population was calculated by dividing the total number of those suffering from diarrhea by the total number of people in all households surveyed.

Prevalence rates of each of the health conditions were calculated for the population of children under five in each of the communities included in the survey, as well as for the total population of children under five from all communities. The prevalence of a health condition in children under age five from all communities is equivalent to the weighted average of the community-specific prevalence rates for children under age five. Similarly, prevalence of each of the health conditions were calculated for the total population in each of the communities included in the survey, as well as for the total study population. The prevalence of a health condition in the total population is equivalent to the weighted average of the community-specific prevalence rates.

However, for all health-related analyses, households consisting of more than fifteen individuals were excluded, as the accuracy of responses on health status seemed to decline considerably beyond this point. The reported prevalence of diarrheal and respiratory illness was consistently lower in households with more than fifteen individuals than in households with fifteen individuals or fewer. There appears to be considerable underreporting of symptoms by respondents whose households have more than fifteen individuals. A possible explanation for this underreporting is that in large households, respondents are unlikely to interact closely with all individuals on a regular basis. They would therefore not be aware of the actual health status of each and every member of the family.

All estimates of prevalence rates are accompanied by 95 percent confidence intervals, which are calculated using the method described in Appendix F.

### 4.7.1 Prevalence of Diarrheal Illnesses

#### 4.7.1.1 Diarrhea

The prevalence of diarrhea is defined in this study as the percentage of people that were suffering from diarrhea within 48 hours of the time of the survey. For this survey, the functional definition of diarrhea was the presence of either of the following symptoms: "diarrhea", or "blood or mucus in the stool", with the terms in quotations translated directly into Dagbani.

$$\text{Overall prevalence of diarrhea in children under 5} = \frac{\text{Total number of children under 5 with diarrhea within 48 hours of time of survey}}{\text{Total number of children under 5 in all surveyed households}}$$

$$\text{Community-specific prevalence of diarrhea in children under 5} = \frac{\text{Number of children under 5 in community with diarrhea within 48 hours of time of survey}}{\text{Total number of children under 5 in all surveyed households in community}}$$

$$\text{Overall prevalence of diarrhea in general population} = \frac{\text{Total number of people with diarrhea within 48 hours of time of survey}}{\text{Total number of people in all surveyed households}}$$

$$\text{Community-specific prevalence of diarrhea in general population} = \frac{\text{Number of people in community with diarrhea within 48 hours of time of survey}}{\text{Total number of people all surveyed households in community}}$$

The overall prevalence of diarrhea in children under the age of five was **23 percent, with a 95% CI of 17 to 29 percent** (n = 200). The community-specific prevalence rates of under-five diarrhea are **not statistically different** from each other. Figure 4-17 shows community-specific prevalence rates of diarrhea in children under five, with error bars depicting the 95% CI for each community. Appendix F describes the method used to calculate confidence intervals for this and all other prevalence rate estimates in this thesis.

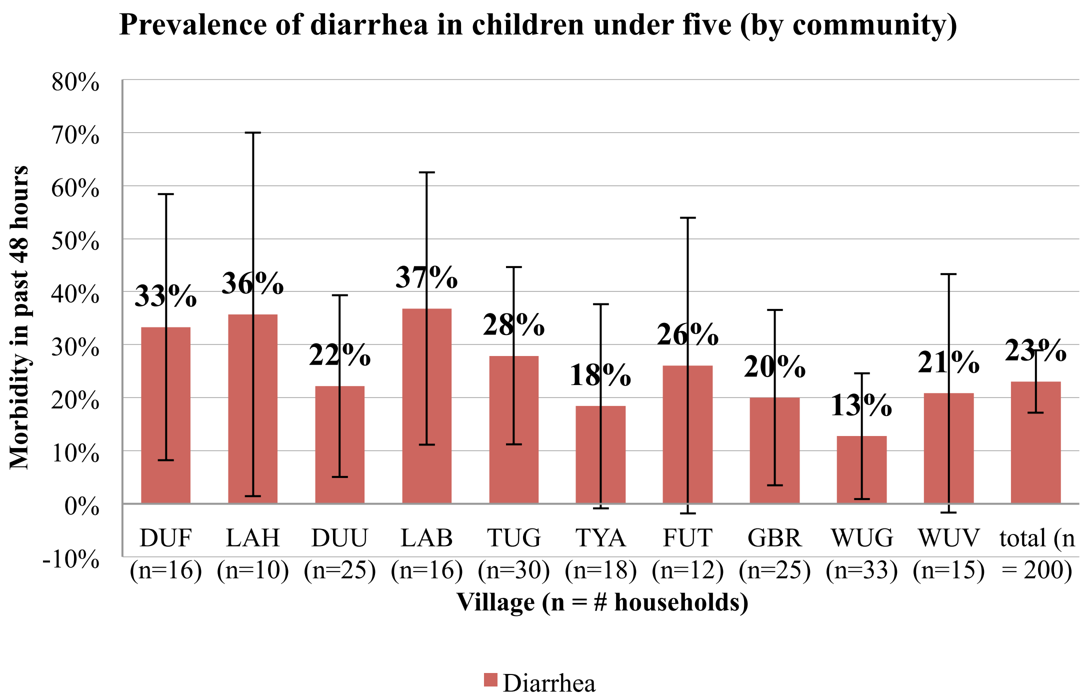



**Figure 4-17: Prevalence of diarrhea in children under five (by community).**

The overall prevalence of diarrhea in the general population was **9 percent, with a 95% CI of 5 to 13 percent** (n = 200). Figure 4-18 shows community-specific prevalence rates of diarrhea in the general population. The community-specific prevalence rates of diarrhea in the general population are **not statistically different** from each other.

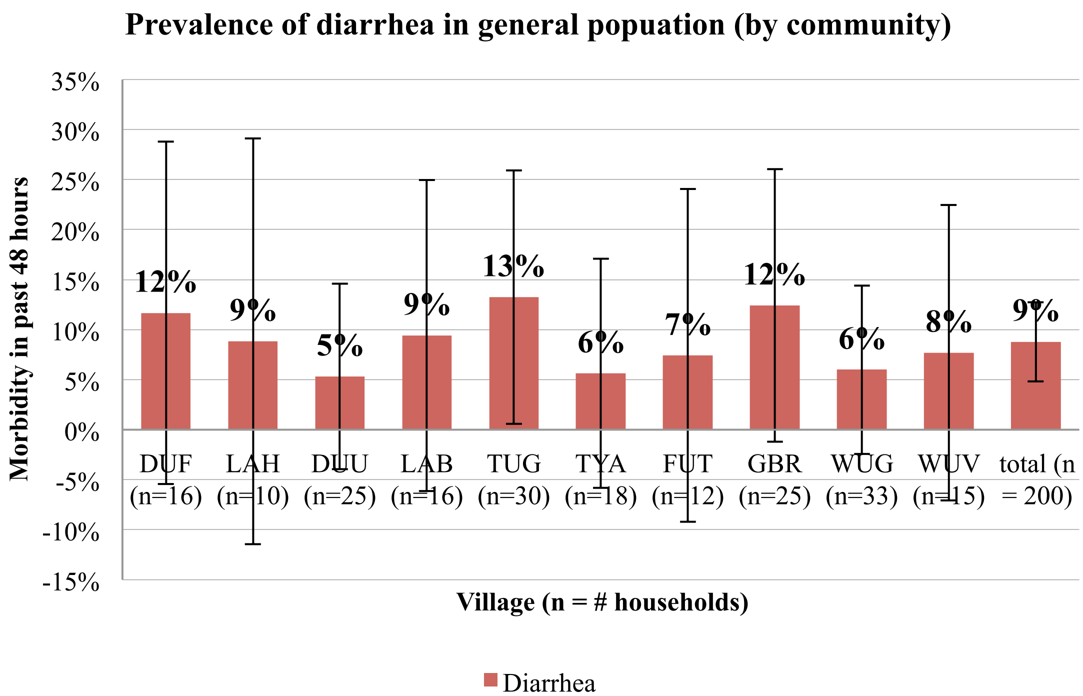



**Figure 4-18: Prevalence of diarrhea in general population (by community).**

### 4.7.1.2 Severe Diarrhea

The prevalence of severe diarrhea is defined in this study as the percentage of people that were suffering from severe or watery diarrhea within 48 hours of the time of the survey. For this survey, diarrhea that was reported to be "severe or watery", translated directly into Dagbani, was counted as severe diarrhea. The meaning of the term "severe" was left to the interpretation of the respondent.

$$\text{Overall prevalence of severe diarrhea in children under 5} = \frac{\text{Total number of children under 5 with severe diarrhea within 48 hours of time of survey}}{\text{Total number of children under 5 in all surveyed households}}$$

$$\text{Community-specific prevalence of severe diarrhea in children under 5} = \frac{\text{Number of children under 5 in community with severe diarrhea within 48 hours of time of survey}}{\text{Total number of children under 5 in all surveyed households in community}}$$

$$\text{Overall prevalence of severe diarrhea in general population} = \frac{\text{Total number of people with severe diarrhea within 48 hours of time of survey}}{\text{Total number of people in all surveyed households}}$$

$$\text{Community-specific prevalence of severe diarrhea in general population} = \frac{\text{Number of people in community with severe diarrhea within 48 hours of time of survey}}{\text{Total number of people all surveyed households in community}}$$

Many of the cases of diarrheal illness in children under the age of five were severe, although the proportions of severe diarrhea to all cases of diarrhea varied across communities. The overall prevalence of severe diarrhea in children under the age of five was **11 percent, with a 95% CI of 7 to 16 percent** (n = 200). The community-specific prevalence rates of under-five severe diarrhea are **not statistically different** from each other. Figure 4-19 shows community-specific under-five prevalence rates of severe diarrhea, with error bars depicting the 95% CI for each community. Figure 4-20 shows community-specific prevalence rates of severe diarrhea relative to the prevalence rates of total diarrhea, for children under five.

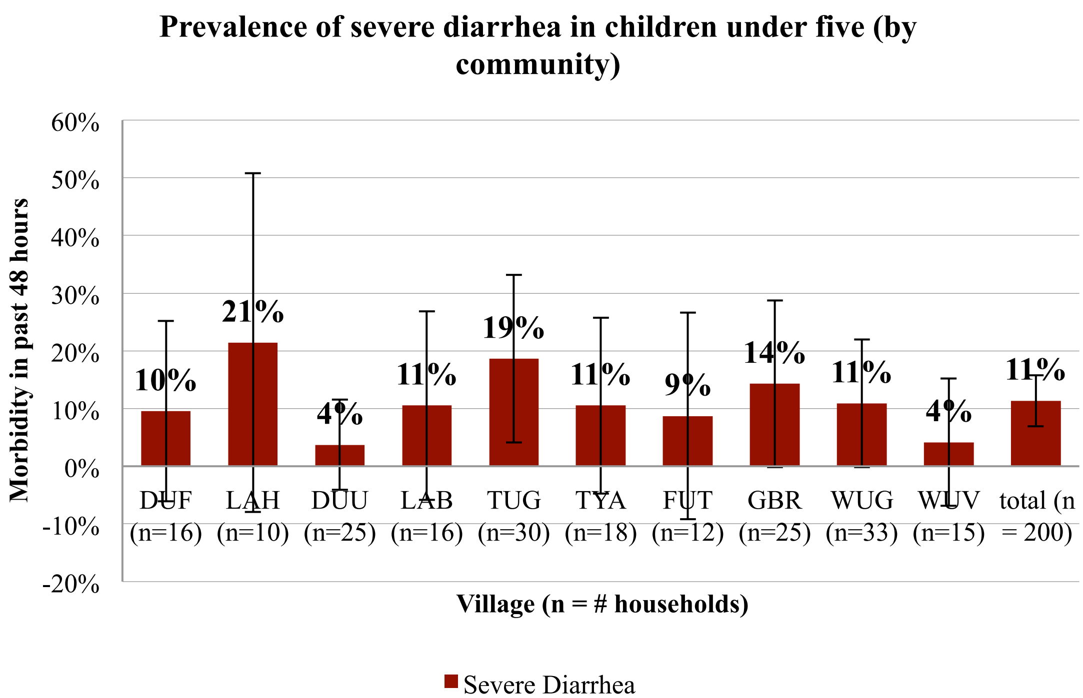



**Figure 4-19: Prevalence of severe diarrhea in children under five (by community).**

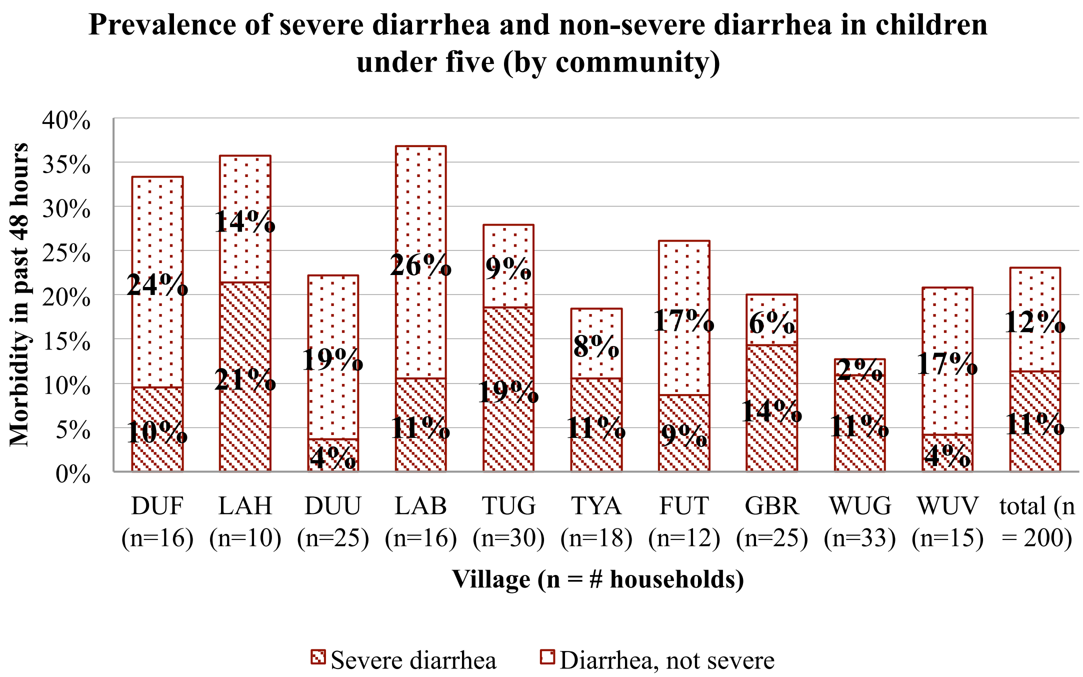



**Figure 4-20: Prevalence of severe diarrhea and non-severe diarrhea in children under five (by community).**

Just over half of the cases of diarrheal illness in the general population were severe. The overall prevalence of severe diarrhea in the general population was **5 percent, with a 95% CI of 2 to 8 percent** (n = 200). The community-specific prevalence rates of severe diarrhea in the general population are **not statistically different** from each other. Figure 4-21 shows community-specific prevalence rates of severe diarrhea in the general population, with error bars depicting the 95% CI for each community. Figure 4-22 shows community-specific prevalence rates of severe diarrhea relative to the prevalence rates of total diarrhea, for the general population.

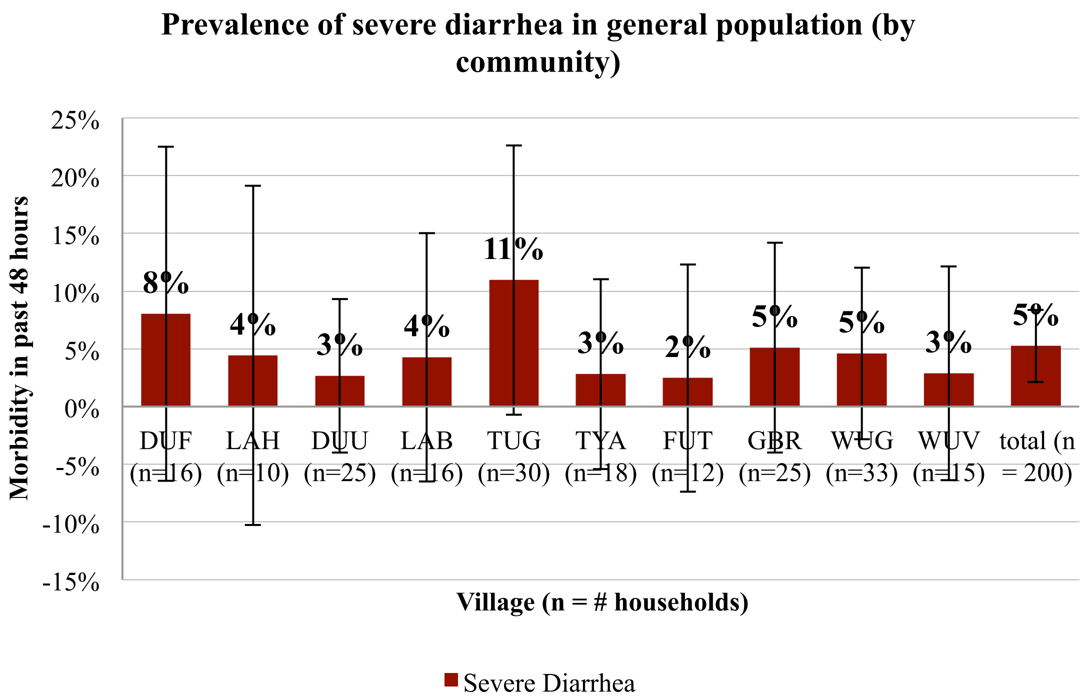



**Figure 4-21: Prevalence of severe diarrhea in general population (by community).**

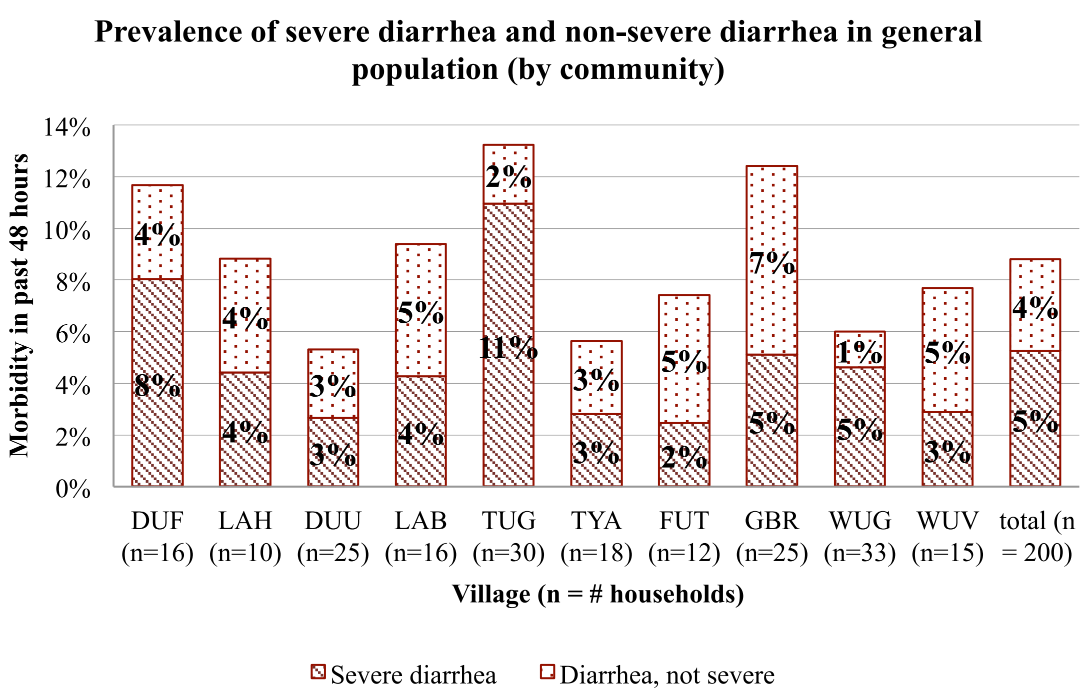



**Figure 4-22: Prevalence of severe diarrhea and non-severe diarrhea in general population (by community).**

#### 4.7.1.3 Highly Credible Gastrointestinal Illness (HCGI)

The prevalence of highly credible gastrointestinal illness (HCGI) is defined in this study as the percentage of people that were suffering from HCGI within 48 hours of the time of the survey. Presence of one or more of the following symptoms or combinations of symptoms is interpreted as HCGI: severe or watery diarrhea, vomiting, diarrhea with abdominal pain, and nausea with abdominal pain. The author assessed the prevalence of HCGI, because it seemed that, compared to diarrhea and severe diarrhea alone, HCGI could be a more inclusive measure of waterborne illness. For an explanation of how HCGI was assessed in this survey, see Figures 3-3 and 3-4, along with the accompanying narrative in Baseline Survey Overview (Section 3-3).

The enumerators consistently collected information on severe or watery diarrhea and vomiting. However, information on nausea and abdominal pain was not collected for children under five, with the exception of the two households where respondents volunteered this information without prompt. The rationale for not collecting nausea and abdominal pain is that it is difficult for respondents to gauge whether their young children have nausea and abdominal pain, since these are not always visible conditions. Data on all of the HCGI symptoms, nausea and abdominal pain included, were gathered for adults and children age five and older.

$$\text{Overall prevalence of HCGI in children under 5} = \frac{\text{Total number of children under 5 with HCGI within 48 hours of time of survey}}{\text{Total number of children under 5 in all surveyed households}}$$

$$\text{Community-specific prevalence of HCGI in children under 5} = \frac{\text{Number of children under 5 in community with HCGI within 48 hours of time of survey}}{\text{Total number of children under 5 in all surveyed households in community}}$$

$$\text{Overall prevalence of HCGI in general population} = \frac{\text{Total number of people with HCGI within 48 hours of time of survey}}{\text{Total number of people in all surveyed households}}$$

$$\text{Community-specific prevalence of HCGI in general population} = \frac{\text{Number of people in community with HCGI within 48 hours of time of survey}}{\text{Total number of people all surveyed households in community}}$$

The overall prevalence of HCGI in children under the age of five was **18 percent, with a 95% CI of 13 to 23 percent** (n = 200). The community-specific prevalence rates of under-five HCGI are **not statistically different** from each other.

In Figure 4-23, under-five HCGI prevalence is juxtaposed with under-five diarrhea prevalence to facilitate analysis of whether HCGI may be a better proxy than diarrhea for waterborne and hand-borne disease. For every community and for the pooled population (all households), the prevalence of HCGI is **not statistically different** from the prevalence of diarrhea.

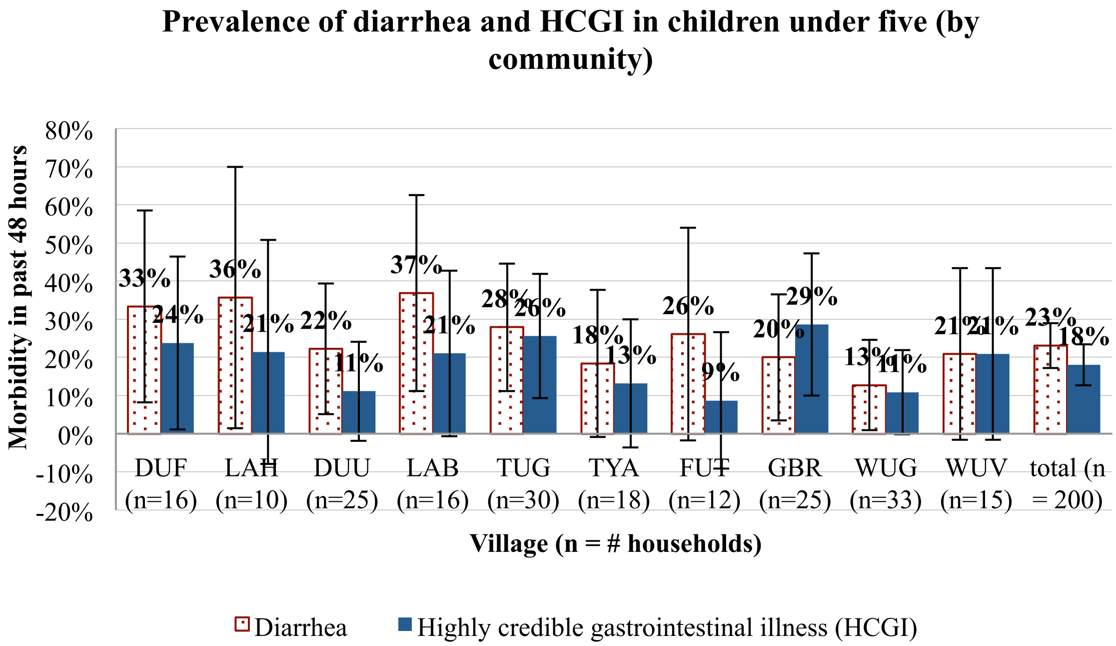



**Figure 4-23: Prevalence of diarrhea and HCGI in children under five (by community).**

The overall prevalence of HCGI in the general population was **8 percent, with a 95% CI of 4 to 12 percent** (n = 200). The community-specific prevalence rates of HCGI in the general population are **not statistically different** from each other.

In Figure 4-24, HCGI prevalence in the general population is juxtaposed with diarrhea prevalence in the general population, again to facilitate analysis of whether HCGI may be a better proxy than diarrhea for waterborne and hand-borne disease. Again, for every community and for the pooled population (all households), the prevalence of HCGI is **not statistically different** from the prevalence of diarrhea. Therefore, this study cannot conclude that HCGI is a better proxy than diarrhea for waterborne and hand-borne disease, nor does it rule out this possibility.

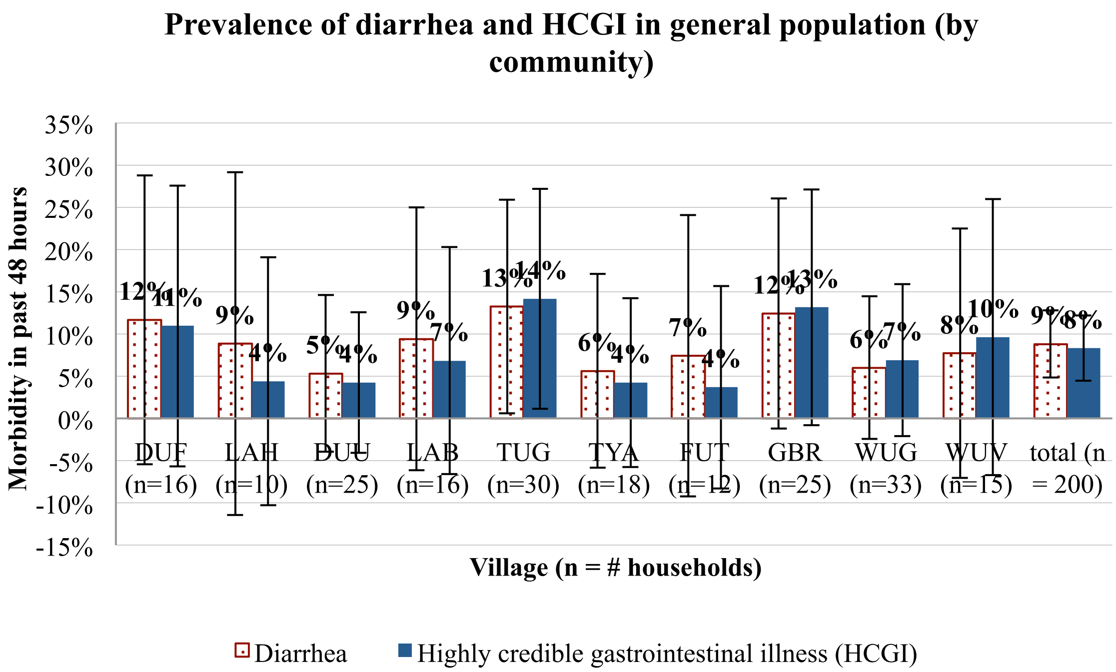



**Figure 4-24: Prevalence of diarrhea and HCGI in general population (by community).**

### 4.7.1.4 Diarrheal illnesses: Summary tables

**Table 4-14: Prevalence rates of diarrhea, severe diarrhea and HCGI in children under five (by community).**

| Village | Sample size (households) | Diarrhea (95% CI) | Severe diarrhea (95% CI) | HCGI (95% CI) |
|---|---|---|---|---|
| Dufaa | n = 16 | 33% ( 8% to 58% ) | 10% ( -6% to 25% ) | 24% ( 1% to 47% ) |
| Lahagu | n = 10 | 36% ( 1% to 70% ) | 21% ( -8% to 51% ) | 21% ( -8% to 51% ) |
| Duuyin | n = 25 | 22% ( 5% to 39% ) | 4% ( -4% to 11% ) | 11% ( -2% to 24% ) |
| Labariga | n = 16 | 37% ( 11% to 63% ) | 11% ( -6% to 27% ) | 21% ( -1% to 43% ) |
| Tugu | n = 30 | 28% ( 11% to 45% ) | 19% ( 4% to 33% ) | 26% ( 9% to 42% ) |
| Tugu-Yapala | n = 18 | 18% ( -1% to 38% ) | 11% ( -5% to 26% ) | 13% ( -4% to 30% ) |
| Futa | n = 12 | 26% ( -2% to 54% ) | 9% ( -9% to 27% ) | 9% ( -9% to 27% ) |
| Gbruma | n = 25 | 20% ( 3% to 37% ) | 14% ( 0% to 29% ) | 29% ( 10% to 47% ) |
| Wuvoguma | n = 33 | 13% ( 1% to 25% ) | 11% ( 0% to 22% ) | 11% ( 0% to 22% ) |
| Wuvugu | n = 15 | 21% ( -2% to 43% ) | 4% ( -7% to 15% ) | 21% ( -2% to 43% ) |
| **Total** | **n = 200** | **23% ( 17% to 29% )** | **11% ( 7% to 16% )** | **18% ( 13% to 23% )** |

**Table 4-15: Prevalence of diarrhea, severe diarrhea and HCGI in general population (by community).**

| Village | Sample size (households) | Diarrhea (95% CI) | Severe diarrhea (95% CI) | HCGI (95% CI) |
|---|---|---|---|---|
| Dufaa | n = 16 | 12% ( -5% to 29% ) | 8% ( -6% to 23% ) | 11% ( -6% to 28% ) |
| Lahagu | n = 10 | 9% ( -11% to 29% ) | 4% ( -10% to 19% ) | 4% ( -10% to 19% ) |
| Duuyin | n = 25 | 5% ( -4% to 15% ) | 3% ( -4% to 9% ) | 4% ( -4% to 13% ) |
| Labariga | n = 16 | 9% ( -6% to 25% ) | 4% ( -7% to 15% ) | 7% ( -7% to 20% ) |
| Tugu | n = 30 | 13% ( 1% to 26% ) | 11% ( -1% to 23% ) | 14% ( 1% to 27% ) |
| Tugu-Yapala | n = 18 | 6% ( -6% to 17% ) | 3% ( -5% to 11% ) | 4% ( -6% to 14% ) |
| Futa | n = 12 | 7% ( -9% to 24% ) | 2% ( -7% to 12% ) | 4% ( -8% to 16% ) |
| Gbruma | n = 25 | 12% ( -1% to 26% ) | 5% ( -4% to 14% ) | 13% ( -1% to 27% ) |
| Wuvoguma | n = 33 | 6% ( -2% to 14% ) | 5% ( -3% to 12% ) | 7% ( -2% to 16% ) |
| Wuvugu | n = 15 | 8% ( -7% to 22% ) | 3% ( -6% to 12% ) | 10% ( -7% to 26% ) |
| **Total** | **n = 200** | **9% ( 5% to 13% )** | **5% ( 2% to 8% )** | **8% ( 4% to 12% )** |

### 4.7.2 Prevalence of Respiratory Illnesses

#### 4.7.2.1 Cough and Difficulty Breathing

The prevalence of cough and difficulty breathing is defined in this study as the percentage of people that were suffering from cough or difficulty breathing within 48 hours of the time of the survey.

$$\text{Overall prevalence of cough and difficulty breathing in children under 5} = \frac{\text{Total number of children under 5 with cough and difficulty breathing within 48 hours of time of survey}}{\text{Total number of children under 5 in all surveyed households}}$$

$$\text{Community-specific prevalence of cough and difficulty breathing in children under 5} = \frac{\text{Number of children under 5 in community with cough and difficulty breathing within 48 hours of time of survey}}{\text{Total number of children under 5 in all surveyed households in community}}$$

$$\text{Overall prevalence of cough and difficulty breathing in general population} = \frac{\text{Total number of people with cough and difficulty breathing within 48 hours of time of survey}}{\text{Total number of people in all surveyed households}}$$

$$\text{Community-specific prevalence of cough and difficulty breathing in general population} = \frac{\text{Number of people in community with cough and difficulty breathing within 48 hours of time of survey}}{\text{Total number of people all surveyed households in community}}$$

The overall prevalence of cough and difficulty breathing in children under the age of five was **25 percent, with a 95% CI of 19 to 31 percent** (n = 200). The community-specific under-five prevalence rates of cough and difficulty breathing are **not statistically different** from each other, with one exception. Tugu-Yapala and Lahagu appear to have significantly lower rates of under-five cough and difficulty breathing, and of under-five severe cough and difficulty breathing, than Gbruma and Wuvugu. However, given the small sample size from each community, survey-derived estimates of small proportions (such as prevalence rates of under-five cough and difficulty breathing Tugu-Yapala and Lahagu) may have confidence intervals that are larger than those calculated using our chosen method. Calculation of a more realistic confidence interval would require statistical methods that are out of the scope of this thesis.

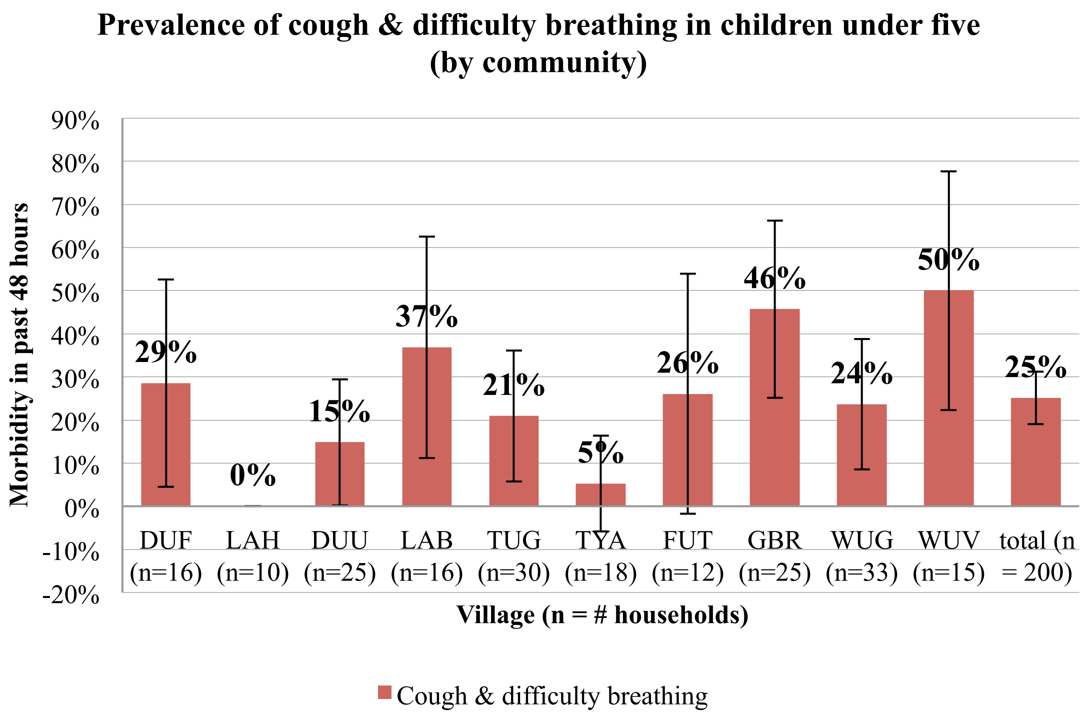



**Figure 4-25: Prevalence of cough and difficulty breathing in children under five (by community).**

The overall prevalence of cough and difficulty breathing in the general population was **13 percent, with a 95% CI of 8 to 17 percent** (n = 200). The community-specific prevalence rates of cough and difficulty breathing for the general population are **not statistically different** from each other.

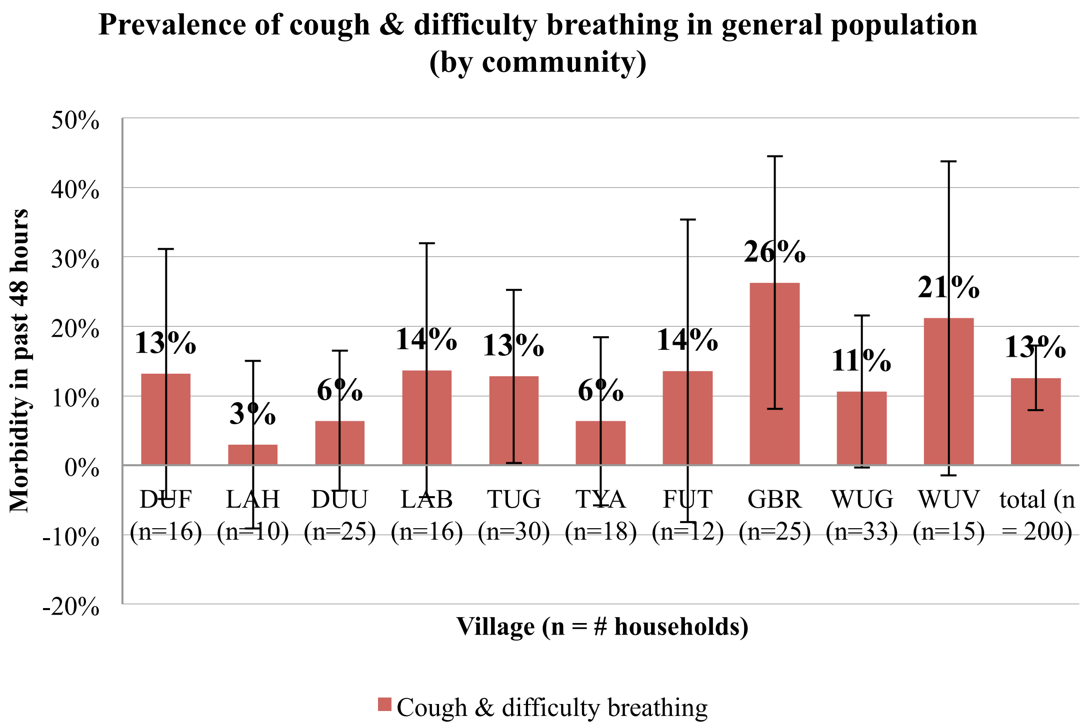



**Figure 4-26: Prevalence of cough and difficulty breathing in general population (by community).**

### 4.7.2.2 Severe Cough and Difficulty Breathing

The prevalence of severe cough and difficulty breathing is defined in this study as the percentage of people that were suffering from severe cough or difficulty breathing within 48 hours of the time of the survey. Throughout this survey, the enumerators left the meaning of "severe" to the interpretation of the respondents. Many respondents described a "severe" cough as a cough that interrupted sleep for the individual presenting the symptoms.

$$\text{Overall prevalence of severe cough and difficulty breathing in children under 5} = \frac{\text{Total number of children under 5 with severe cough and difficulty breathing within 48 hours of time of survey}}{\text{Total number of children under 5 in all surveyed households}}$$

$$\text{Community-specific prevalence of severe cough and difficulty breathing in children under 5} = \frac{\text{Number of children under 5 in community with severe cough and difficulty breathing within 48 hours of time of survey}}{\text{Total number of children under 5 in all surveyed households in community}}$$

$$\text{Overall prevalence of severe cough and difficulty breathing in general population} = \frac{\text{Total number of people with severe cough and difficulty breathing within 48 hours of time of survey}}{\text{Total number of people in all surveyed households}}$$

$$\text{Community-specific prevalence of severe cough and difficulty breathing in general population} = \frac{\text{Number of people in community with severe cough and difficulty breathing within 48 hours of time of survey}}{\text{Total number of people all surveyed households in community}}$$

With the exception of one community, the majority of all cases of cough and difficulty breathing in children under the age of five were considered to be severe by the respondents. The overall prevalence of severe cough and difficulty breathing in children under the age of five was **18 percent, with a 95% CI of 13 to 24 percent** (n = 200). The community-specific under-five prevalence rates of severe cough and difficulty breathing are **not statistically different** from each other, with the same exception as in the under-five prevalence rates of total cough and difficult breathing. Figure 4-27 shows community-specific under-five prevalence rates of severe cough and difficulty breathing, with error bars depicting the 95% CI for each community. Figure 4-28 shows community-specific prevalence rates of severe cough and difficulty breathing relative to the prevalence rates of total cough and difficulty breathing, for children under five.

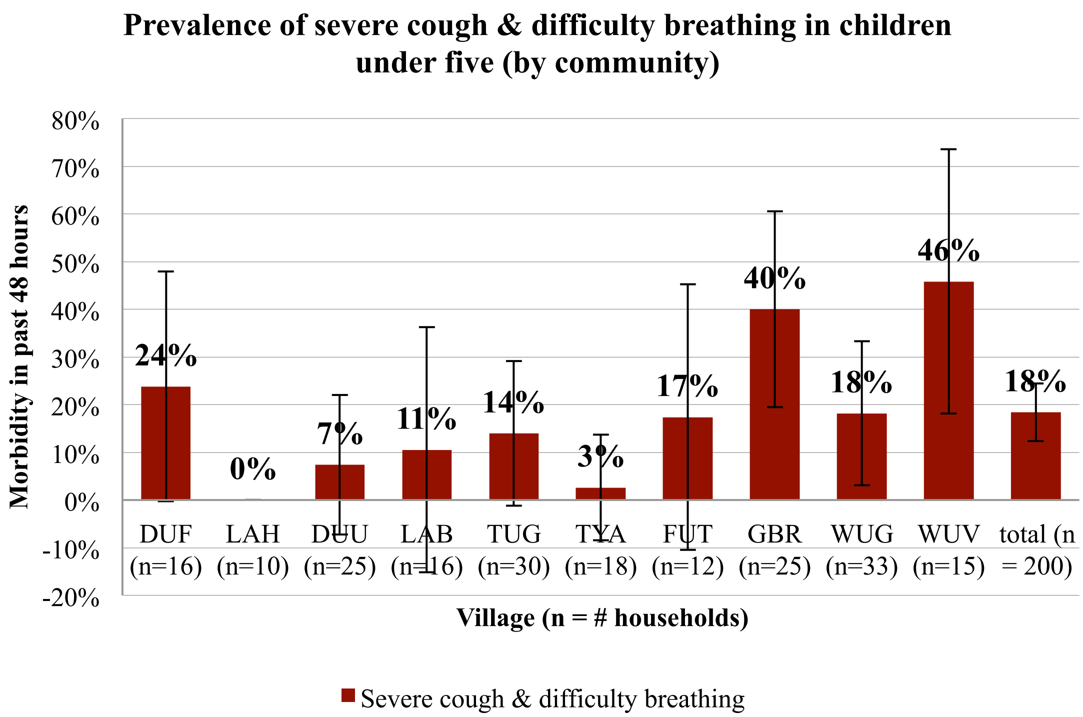



**Figure 4-27: Prevalence of severe cough and difficulty breathing in children under five (by community).**

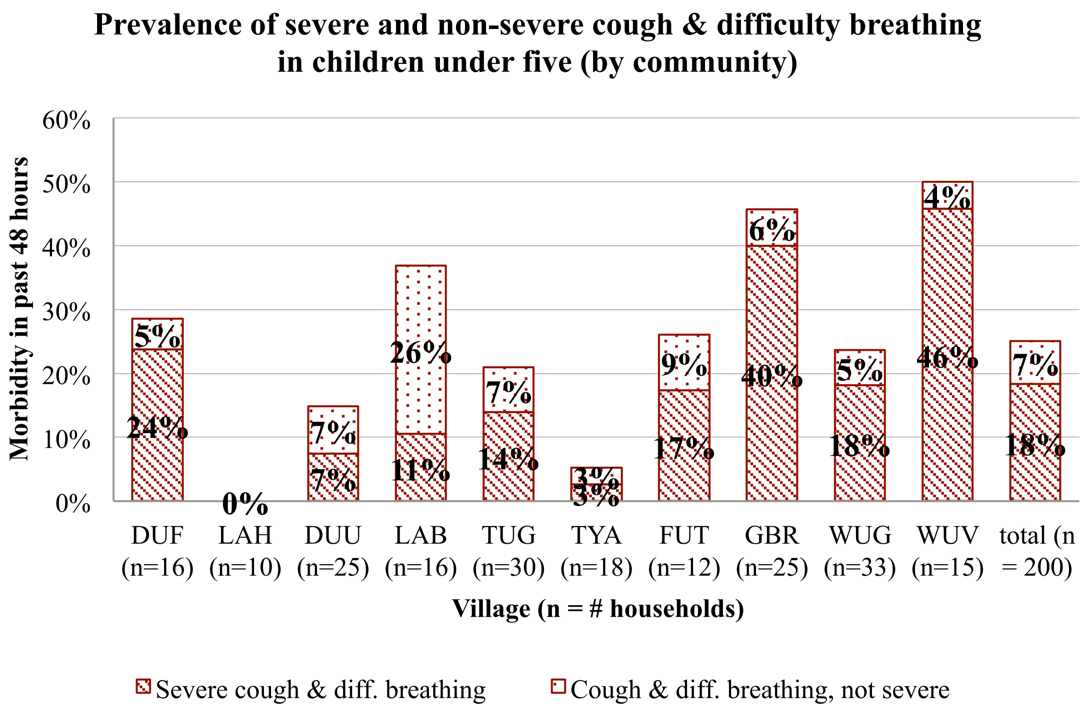



**Figure 4-28: Prevalence of severe and non-severe cough and difficulty breathing in children under five (by community).**

For all communities, at least half of all cases of cough and difficulty breathing in the general population were considered to be severe by the respondents. The overall prevalence of severe cough and difficulty breathing the general population was **10 percent, with a 95% CI of 5 to 14 percent** (n = 200). The community-specific prevalence rates of severe cough and difficulty breathing in the general population are **not statistically different** from each other. Figure 4-29 shows community-specific prevalence rates of severe cough and difficulty breathing in the general population, with error bars depicting the 95% CI for each community. Figure 4-30 shows community-specific prevalence rates of severe cough and difficulty breathing relative to the prevalence rates of total cough and difficulty breathing, in the general population.

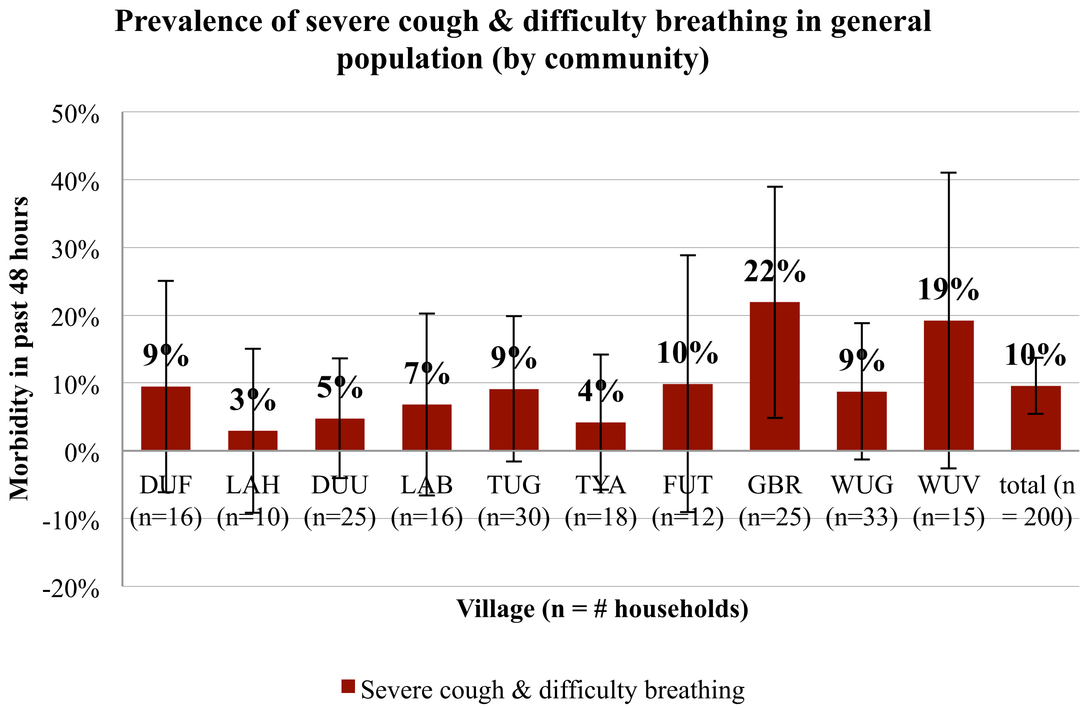



**Figure 4-29: Prevalence of severe cough and difficulty breathing in general population (by community).**

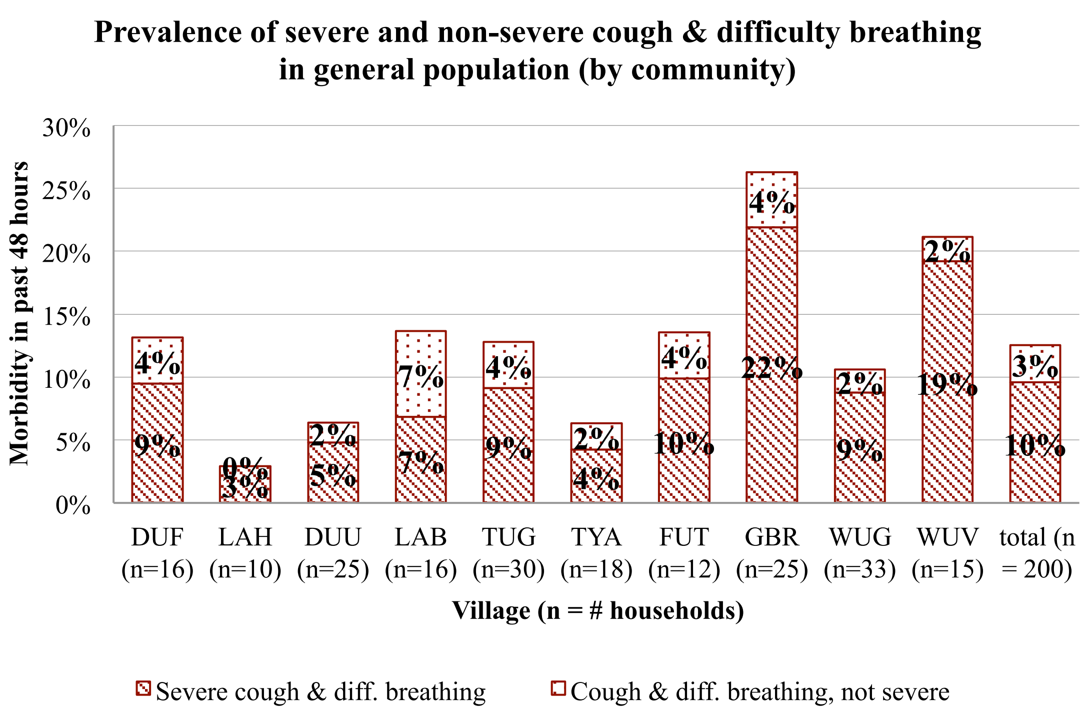



**Figure 4-30: Prevalence of severe and non-severe cough and difficulty breathing in general population (by community).**

### 4.7.2.3 Respiratory Illnesses: Summary tables

**Table 4-16: Prevalence rates of cough and difficulty breathing in children under five (by community).**

| Village | Sample size (households) | Cough and difficulty breathing (95% CI) | Severe cough and difficulty breathing (95% CI) |
|---|---|---|---|
| Dufaa | n = 16 | 29% ( 5% to 53% ) | 24% ( 1% to 47% ) |
| Lahagu | n = 10 | 0% ( 0% to 0% ) | 0% ( 0% to 0% ) |
| Duuyin | n = 25 | 15% ( 0% to 29% ) | 7% ( -3% to 18% ) |
| Labariga | n = 16 | 37% ( 11% to 63% ) | 11% ( -6% to 27% ) |
| Tugu | n = 30 | 21% ( 6% to 36% ) | 14% ( 1% to 27% ) |
| Tugu-Yapala | n = 18 | 5% ( -6% to 16% ) | 3% ( -5% to 11% ) |
| Futa | n = 12 | 26% ( -2% to 54% ) | 17% ( -7% to 41% ) |
| Gbruma | n = 25 | 46% ( 25% to 66% ) | 40% ( 20% to 60% ) |
| Wuvoguma | n = 33 | 24% ( 9% to 39% ) | 18% ( 4% to 32% ) |
| Wuvugu | n = 15 | 50% ( 22% to 78% ) | 46% ( 18% to 73% ) |
| **Total** | **n = 200** | **25% ( 19% to 31% )** | **18% ( 13% to 24% )** |

**Table 4-17: Prevalence rates of cough and difficulty in general population (by community).**

| Village | Sample size (households) | Cough and difficulty breathing (95% CI) | Severe cough and difficulty breathing (95% CI) |
|---|---|---|---|
| Dufaa | n = 16 | 13% ( -5% to 31% ) | 9% ( -6% to 25% ) |
| Lahagu | n = 10 | 3% ( -9% to 15% ) | 3% ( -9% to 15% ) |
| Duuyin | n = 25 | 6% ( -4% to 16% ) | 5% ( -4% to 14% ) |
| Labariga | n = 16 | 14% ( -5% to 32% ) | 7% ( -7% to 20% ) |
| Tugu | n = 30 | 13% ( 0% to 25% ) | 9% ( -2% to 20% ) |
| Tugu-Yapala | n = 18 | 6% ( -6% to 18% ) | 4% ( -6% to 14% ) |
| Futa | n = 12 | 14% ( -8% to 35% ) | 10% ( -9% to 29% ) |
| Gbruma | n = 25 | 26% ( 8% to 44% ) | 22% ( 5% to 39% ) |
| Wuvoguma | n = 33 | 11% ( 0% to 22% ) | 9% ( -1% to 19% ) |
| Wuvugu | n = 15 | 21% ( -1% to 44% ) | 19% ( -3% to 41% ) |
| **Total** | **n = 200** | **13% ( 8% to 17% )** | **10% ( 5% to 14% )** |

# 5 Limitations of Baseline Study

## 5.1 Error in household interviews

While household surveys are relatively efficient tools for gathering information from data-poor regions, survey responses can be inaccurate for a number of reasons. In this survey, respondents may have given inaccurate answers if they misinterpreted survey questions or could not clearly recall certain events. Respondents may also have deliberately changed certain responses to be polite, withhold sensitive information or demonstrate need for assistance. In addition, for this study, while one of the two enumerators had six years of field experience with the Guinea Worm Eradication Program, none of the enumerators had formal academic training from epidemiology or survey methods, so enumerator behavior may be a source of error and inconsistency.

### 5.1.1 Misinterpretation of survey questions

For consistency, all data on health status were collected based on respondents' answers rather than enumerators' observations. The latter would depend on the number and health status of the individuals present in the home at the time of the interview, which may not be representative of the entire household. From informal observations, there seems to be considerable underreporting of cough and difficulty breathing due to cultural interpretation of the survey question. In Northern Ghana, a large proportion of the population suffers from persistent cough during the dry season. The local belief is that the dry weather and dust causes the coughing. It seems that many have become accustomed to this cough, as some respondents did not report this symptom even when they or other members of the household were visibly coughing during the interview. As a result, this study is likely to underestimate the morbidity rates for cough and difficulty breathing.

Respondents' interpretations of the indirect question on hand-washing may have led to underestimation of the rate of hand-washing with soap. While the enumerators pushed to solicit all uses of household soap, it is possible that hand-washing is considered too minor of a use to report. In other words, it is possible that respondents sometimes use soap to wash hands, but do not consider hand-washing to be one of the main uses of soap.  Culturally, the soaps that most households used are marketed for use on laundry. Nevertheless, if hand-washing is not considered by respondents to be an important use of household soap, it is unlikely that hand-washing with soap is practiced on a regular basis and at critical times.

### 5.1.2 Lack of knowledge or recall of solicited events

Morbidity rates may have been underestimated because respondents did not know of or recall all cases of illness in the households. Underreporting was particularly apparent in households (fourteen total) with more than fifteen members, and the data from these fourteen households were removed from the morbidity rate estimates. However, it is probable that some underreporting also occurred in mid-sized and even smaller households, particularly for illness in adults and children over the age of five. This is evidenced by the enumerators' observation that respondents seemed to report their own health conditions and the health conditions of those present at the time of the interview than the health conditions of household members who were outside of the home during the interview. It is probable that respondents sometimes did not know that other members of the household were ill, especially with diarrhea or HCGI, since adults and older children would not necessarily complain of illness and would be defecating outside of the home. It is also feasible that, during the window of response time within the interview, respondents did not recall some cases of illness of which they did have knowledge.

Respondents may also misestimate whether recent illnesses occurred within the 48-hour window prior to the interview, especially when family members are frequently ill or the household is large in number. Depending on the respondents' personal or cultural perception of time, she or he could either over-report or under-report illnesses in the household.

### 5.1.3 Politeness

Particularly for household water treatment and willingness to purchase filters, respondents may have given inaccurate responses in the interest of being polite to the enumerators. In this study, it is probable that politeness resulted in overestimation of the proportion of households that use cloth filters for household water treatment and the proportion of households that were interested in purchasing ceramic water filters for GHC 5. Because Ataya was a community liaison for the Guinea Worm Eradication Program, many households recognized her and may have associated the Pure Home Water survey group with the Guinea Worm Eradication Program. One of Ataya's responsibilities in the Guinea Worm Eradication Program was to ensure that all households were using the cloth filters. Therefore, it is likely that some respondents were eager to show the PHW enumerators that they were continuing to use the cloth filters, even if they no longer used them on a regular basis. The household water treatment results may be more representative of knowledge rather than practice of water treatment methods. Similarly, when asked whether they would be interested in purchasing a filter from Pure Home Water, some respondents may have given positive responses out of politeness. In other words, had they been asked to commit to the purchase, the respondents may have given more realistic answers. We will know the reality of this once we return to sell filters in summer 2012 and the months following.

### 5.1.4 Withholding of sensitive information

Some respondents may have underreported illnesses because they felt uncomfortable disclosing sensitive health information. Illness can reflect on the hygiene practices, nutrition, and socioeconomic status of the family. The enumerators were careful to withhold judgment or any indication thereof and, as women, were able to develop some connection with many of the respondents as caretakers of the family. Nevertheless, the enumerators were visitors to the homes of the respondents, and as a result, many respondents may not have wanted the family to appear infirm or unhygienic.

### 5.1.5 Demonstrate need for assistance

On the other hand, other respondents may have over-reported illnesses because they felt they could demonstrate the need for monetary or medical assistance. The enumerators attempted to mitigate this opportunity for error by stating that the survey was being conducted as part of a household water treatment intervention. However, a number of households requested medicines during the interview, and seemed to be under the impression that the enumerators could provide direct assistance on treating the prevalent illnesses. It is impossible to conclude whether the overall morbidity rate was underestimated or overestimated.

### 5.1.6 Enumerator inconsistency

Due to limited time in the field, it was not feasible to go through a several-day training process for enumerators, although a pre-test was conducted and learning from that was brought forward into the actual survey itself. The survey work was distributed between one enumerator, Ataya, and one enumerator team, Salifu and Lu. Since interviewing is a communication-intensive and highly social process, it is likely that there is inconsistency between the manner in which Ataya conducted surveys on her own and the manner in which Salifu and Lu conducted surveys as a team. While formal training helps to decrease error and inconsistency, enumerator behavior may affect responses in any study. In the fieldwork period for this study, the enumerators communicated regularly with each other about interviewing methodologies to increase accuracy and precision in the absence of formal training.

## 5.2 Error in translation

Translation from English to Dagbani and vice-versa is another potential source of error in this study. The survey was designed and revised to be easily and accurately translated into Dagbani. However, accurate translation depends on the enumerators' translation skills and proficiencies in the two languages. Salifu and Ataya are both highly qualified on the basis of language proficiency and communication skills. However, there were a number of instances where translation was challenging. In particular, the collection of data on household water management requires some specialized language, especially regarding water sources. There was initial confusion over the distinction among protected hand-dug wells, unprotected hand-dug wells, and boreholes, which was clarified among the enumerators during the fieldwork period by reviewing definitions of these water sources. Specifically, Ataya had interpreted the term “protected” to mean that the water source was protected from users standing in the source and transmitting guinea worm, and Salifu assigned the terms “protected hand-dug wells”, “unprotected hand-dug wells”, and “boreholes” to different colloquial descriptions of actual water sources. When this inconsistency was discovered, Lu and Murcott clarified that the term “protected” referred to water sources that were protected from microbiological contamination.

## 5.3 Limitations of interpretation of results

### 5.3.1 Improved sources not necessarily safe sources

This study ultimately groups drinking water sources into improved and unimproved water sources, based on WHO definitions of drinking water categories. Improved sources are generally considered to be better for public health than unimproved sources. However, improved sources are not necessarily microbiologically safe and cannot be considered to be safe unless water quality is regularly monitored and confirmed to be acceptable for human consumption. It is not uncommon to find ‘improved’ water sources that are microbiologically contaminated (Patrick *et al.* 2011).

### 5.3.2 Household data versus compound data

There was inconsistency in how the household was defined in the baseline survey. By and large, the household was defined as the respondent (usually a mother) and her husband, children, and extended family members. However, many of the respondents were members of polygamous compounds, and approximately fourteen of these respondents counted all members of the compound as members of their household. There may be additional nuances in how respondents that are members of polygamous compounds counted members of their households, and the author is unable to discuss such nuances with any confidence. Many respondents were members of households of non-polygamous household at the time of the baseline survey. However, it is possible that between the baseline and the follow-up, the husband may marry another wife, and the structure of the compound will change. This would introduce additional complexity to our survey. The survey tool was not designed to record whether respondents’ households were polygamous and how respondents counted their households, so the author’s knowledge relating to household definition is largely anecdotal.

### 5.3.2 Community heterogeneity

Community-specific illness prevalence rates should be interpreted and used critically, as the 95% confidence intervals for these values are very large. Where possible, overall prevalence rates should be used instead of community-specific rates.

# 6 Objective Measurement of *Kosim* Use

## 6.1 Research Objectives

The third goal of this thesis is to provide recommendations on methods to objectively measure household use of the *Kosim* ceramic water filter. Specifically, this portion of the study seeks an objective measurement of *how much* a given household *normally* uses its *Kosim* filter, rather than of *whether* the household appears to be using the filter *at the time of observation*. The overarching aims of the objective measurement of water filter use, identical to those of the household surveys, are to help PHW assess and improve its dissemination practices, and to provide useful monitoring and evaluation feedback for the Rotary FVGG project and similar small- or large-scale distributions in the future.

If the objective measure presented in this study were to be further developed and used for the Rotary FVGG project, it would be administered in a small subset (50 to 100 households) within the intervention communities only. This objective measure of water filter use is meant to provide information on the accuracy of the self-reported measure, which will be assessed in a larger sample size of households, during follow-up surveys. In other words, the objectively measured use would be compared to the self-reported use in the same households, to determine how much of self-reported measures tend to over-report ceramic filter use.

## 6.2 Measurements of ceramic water filter use

### 6.2.1 Prior Art

Self-reported measures are the most common method to assess use of ceramic water filters and other HWTS, since such measures are low-cost, can be combined with other survey questions, and can shed light on user knowledge and beliefs regarding water treatment.

However, at least three previous evaluations have included objective measures of ceramic water filter use, along with self-reported measures. The level of water in the plastic safe storage container, which is distributed with the ceramic filter, was included as an objective measure in the Pure Home Water Flood Emergency Relief Project survey (UNICEF-PHW, 2009). In her thesis, Clopeck defined "sustained use" based on three objective observations: (1) *Kosim* filter is correctly installed in the storage unit, (2) Water is currently in the *Kosim* pot filter, and (3) Clear water is currently in the *Kosim* storage unit (Clopeck, 2009). Brown and Sobsey verified self-reported filter use by visual inspection of three criteria: (1) Filter is damp from recent use, (2) Filter not being used for another purpose, and (3) Filter is in good working order at time of visit

(Brown and Sobsey, 2006). These objective measures provide information on *whether* the filters are being used at the time of observation, but not on *how much* use the filters received. In addition, the measures described above do not necessarily measure normal use during the period between the household's purchase or receipt of the filter and the enumerator's observation. That is, the percentage of households that appear to be using their filters at the time of observation may not be representative of the percentage of households that use their filters consistently. Once an enumerator team begins interviewing in a given community, word of the visit often spreads through the community and some households would have the opportunity to put their previously unused filters into use before the enumerators reach their home.

### 6.2.2 Evaluation criteria

The recommendation for the objective measure of *Kosim* filter use is made based on the following criteria:

1. *Quantitative and representative:* Measures *how much* a household *normally* uses its Kosim filter.

2. *Easy to implement:* All tasks needed to implement the measurement method must be within the abilities of PHW staff and other contributors (e.g. MIT students). Because of the limited electrical engineering, manufacturing knowledge, and time of the author, this criterion necessitated that the measurement device was one that could be easily adapted from an existing commercially available product.

3. *Low-cost*: The cost of measurement method, including device and data-retrieval, should not exceed the cost of the filter (GHC 45, or US$ 27). Ideally, its cost should be on the order of evaluation costs per filter (less than GHC 10, or approximately US$ 6).

4. *Discreet:* The measurement objective should not be apparent to the user of the filter.

5. *Robust:* The measurement device should be able to function through 6-12 months or more of normal filter use.

6. *Zero-power requirement (or battery-powered):* The measurement method must run without an external source of electricity.

### 6.2.3 Quantitative and representative measure

With José Gomez-Marquez and Jacqueline Linnes of MIT's D-Lab: Health, the author brainstormed three types of methods to objectively measure *how much* a household *normally* uses its *Kosim* filters, which in this study is referred to as a quantitative and representative measure. Thesis advisor Susan Murcott and Peter Shanahan of the MIT M.Eng Program provided additional input during the initial brainstorming process. We reasoned that a quantitative and representative objective measure of *Kosim* filter use could potentially be inferred from measurement of one of three physical parameters: (1) Total flow volume (during period of assessment, e.g. 6 months) of water through the spigot of the filter, (2) Total time that the spigot is in the "open" position, or (3) Total volume or mass change (as absolute value of negative and positive change) of the water stored in the plastic container.

Of these, the first seemed to be the most direct measurement. Measurement of the time that the spigot is in the "open" position would be simple to implement. However, this measure would not distinguish between use of the spigot to dispense water and storage of an empty plastic container with the spigot in the "open" position. Measurement of total volume or mass change would be a relatively straightforward application of a water level or force sensor. However, the measure would not distinguish between normal filling/dispensing of drinking water and changes due to cleaning or transport.

### 6.3 Selection and evaluation of Camelbak® Flow Meter™

The search narrowed to commercially available devices that could measure total water flow over a period of 6-12 months and function without external sources of electricity. A basic web search was conducted to identify product options, and household water flow meters dominated the search results. Gomez-Marquez suggested the Camelbak® Flow Meter™ as a possible solution or design inspiration.

Table 6-1 shows the scoring matrix used for selecting the Camelbak® Flow Meter™ for further testing. Among the product options identified, the Flow Meter™ was the only one that met all key selection criteria. Figure 6-1 shows an image of this device and its intended use.

**Table 6-1: Decision matrix for selecting Camelbak® Flow Meter™ for further evaluation.**

| PRODUCT: | Tom Aquatics Flow Meter | GPI ® Flowmeter for water | Futurelec Flow Meter & Sensor | Residential Flow Meter | Camelbak ® Flow Meter ™ |
|---|---|---|---|---|---|
| |  |  |   |  |  |
| Commercially available | 1 | 1 | 1 | 1 | 1 |
| Records cumulative water flow (Volume) | 0 | 1 | 1 | 1 | 1 |
| Functions w/o external electricity | 1 | 1 | 1 | 1 | 1 |
| Low-cost (Cost per unit*) | 1 (US$ 7) | 0 (US$ 166) | 1 (US$ 18.90) | 0 (US$76.88) | 1 (US$ 15) |
| Discreet | 1 | 1 | 0 | 0 | 1 |
| TOTAL | 4 | 4 | 4 | 3 | 5 |

*Current lowest price from online sources.


**Figure 6-1: Left, Camelbak® Flow Meter™ (Credit: [http://www.scalerchelis.com/)](http://www.scalerchelis.com/); Right, intended use of Camelbak® Flow Meter ™ is to measure personal hydration during exercise by gaging flow from Camelbak® hydration packs (Credit: [http://gearjunkie.com/](http://gearjunkie.com/)).**

With the help of Gomez-Marquez, it was determined that the Camelbak® Flow Meter™ sensor operation consists of three connected mechanisms:

1. Fluid flow (at proper range of rates) causes impellor to rotate.

2. Magnet in impellor trips a reed switch with each rotation.

3. Voltage from reed switch takes the form of a square wave, where the frequency of the wave is proportional to the impellor angular velocity, and thus also to the fluid flow rate.

An image of the reed switch within the Camelbak® Flow Meter™ is shown in Figure 6-2.

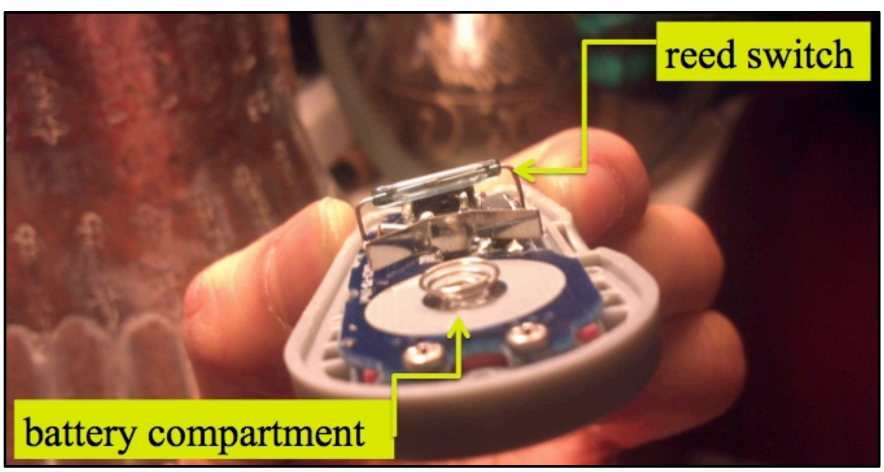



**Figure 6-2: Reed switch and battery compartment within Camelbak® Flow Meter™ device.**

The search for flow-measuring devices that fit the study criteria was not exhaustive. However, within this study, no other pre-existing devices that could potentially fit all of the criteria were found. Designed to measure athletes' water intake through a small tube connected to a hydration pack, the Camelbak® Flow Meter™ is battery-powered and robust, as it would be expected to withstand physical force, a wide temperature range, and exposure to dirt and water spills. While device's retail price is US$ 30, online prices are as low as US$ 15, which meets the maximum cost criteria of US$ 27 per unit, though is not within the ideal cost range of less than US$ 6 per unit. PHW may be able to work with Camelbak® to bring the cost closer to or within the ideal range. Since the Flow Meter™ is designed to measure personal hydration, it seemed liked it would be sensitive to relatively low flow rates, unlike flow sensors for home water and water treatment systems. This supposition was tested in the field, as described below.

## 6.4 Testing the Camelbak® Flow Meter™ on the *Kosim* filter system

A simple experiment was conducted to determine whether, and within what range of storage water levels of, the Camelbak® Flow Meter™ could accurately measure the total flow volume from the Kosim filter storage container.

Consumer reviews generally showed that the Flow Meter™ product adequately measures drinking rates from Camelbak® hydration packs. However, Camelbak® does not specify a range of flow rates for which the Flow Meter™ is effective. In addition, while previous MIT M.Eng students and other researchers have measured and published flow rates from the ceramic filter portion of the *Kosim* system, they have not looked specifically at flow rates through the plastic storage container.

The height of stored water above the center of the outlet (at the spigot) corresponds to the hydraulic head, which determines the flow rate of water through the spigot. Therefore, the independent variable tested was the hydraulic head of water in the *Kosim* storage container.

### 6.4.1 Experimental set-up

Both ends of the Camelbak® Flow Meter™ were plugged into short sections of flexible plastic tubing (Figure 6-3, top and bottom left), similar to that used in Camelbak® Hydration Packs (Figure 6-1, right). The free end of the plastic tubing at the inlet side of the Flow Meter™ was then held by hand onto the spigot outlet of the *Kosim* storage container. The free end of the plastic tubing at the outlet side of the Flow Meter™ was left unconnected, directly over an empty 1000-mL graduated cylinder (Figure 6-3, bottom right). The *Kosim* storage container contained a known amount of tap water, and was held in place by a metal stand designed specifically for use with the storage container (Figure 6-3, bottom right). The distance from ground level to the center of the spigot (base of the hydraulic head measurement) was 57.5 cm. Figure 6-3 shows the adapted Flow Meter™, the *Kosim* spigot, and the experimental set-up.


**Figure 6-3: Top, Flow Meter™ plugged into flexible plastic tubing; Bottom, experimental set-up and close-up of experimental set-up (Credit: Jonathan Thibault).**

### 6.4.2 Testing procedure

1. Fill storage container to set up the maximum hydraulic head (water level nearly high enough to contact the bottom of the ceramic pot filter, which is marked on the *Kosim* instruction sheet with a ---STOP--- line).

2. Record initial head (height from center of spigot to top of water).

3. Check that Flow Meter™ reads 0.0 L, graduated cylinder is empty, and timer is reset.

4. Simultaneously flip spigot to start flow and start timer.

5. Watch Flow Meter™ reading closely. As soon as Flow Meter™ reads 5.0L, simultaneously stop the timer and flip spigot to stop flow.

6. Record final head.

7. Record volume of water in graduated cylinder and time elapsed.

8. Reset Flow Meter™, empty graduated cylinder, and reset timer.

9. Release a small quantity of water from the Kosim filter, to lower head by 1-4 cm.

10. Repeat steps 2 through 9 until the flow rate is too low for the Flow Meter™ to sense. At that threshold, increase initial head by 0.5 cm and repeat steps 2 through 9 until the flow rate is high enough for the Flow Meter™ to sense.

### 6.4.3 Results

The Camelbak® Flow Meter™ was sensitive to the flow from the *Kosim* storage container when the initial head in the container was at least 4.0 cm, and accurately measured total flow when the initial head was at least 6.0 cm.

The results from applying the Camelbak® Flow Meter™ to the *Kosim* filter system are shown in Table 6-2. From each experiment run, a flow rate was calculated from the actual flow volume (that was measured in the graduated cylinder) and the flow rate. The flow rate of water from the spigot of the *Kosim* storage container varies from <0.7 L/min to 1.6 L/min, depending on the level of water stored within. Additionally, the Flow Meter™ was sensitive to flow when it is at least 0.7 L/min, and accurately measures flow when it is at least 0.8 L/min.

**Table 6-2: Results from Camelbak® Flow Meter™ testing on *Kosim* filter system.**

| Initial head | Final head | Measured volume | Actual volume | Time elapsed | Flow rate |
|---|---|---|---|---|---|
| *cm* | *cm* | *L* | *L* | *s* | *L/min* |
| 34.0 | 33.5 | 0.5 | 0.50 | 18.7 | 1.6 |
| 30.0 | 29.5 | 0.5 | 0.51 | 29.6 | 1.0 |
| 25.5 | 25.0 | 0.5 | 0.56 | 23.4 | 1.4 |
| 22.5 | 22.0 | 0.5 | 0.56 | 24.9 | 1.3 |
| 18.5 | 18.0 | 0.5 | 0.53 | 32.5 | 1.0 |
| 16.0 | 15.5 | 0.5 | 0.56 | 30.0 | 1.1 |
| 14.0 | 13.0 | 0.5 | 0.53 | 30.6 | 1.0 |
| 12.0 | 11.5 | 0.5 | 0.47 | 28.1 | 1.0 |
| 10.5 | 10.0 | 0.5 | 0.54 | 34.8 | 0.9 |
| 8.0 | 7.5 | 0.5 | 0.50 | 33.6 | 0.9 |
| 7.0 | 6.5 | 0.5 | 0.48 | 34.8 | 0.8 |
| 6.0 | 5.5 | 0.5 | 0.46 | 36.2 | 0.8 |
| 5.0 | 4.5 | 0.5 | 0.60 | 48.5 | 0.7 |
| 4.0 | 3.5 | 0.5 | 0.72 | 60.1 | 0.7 |
| 3.5 | -- No sensitivity -- | | | | |

## 6.5 Objective Measure Implementation

The Camelbak ® Flow Meter ™ can be adapted for use as a front-end device to measure and record flow through the *Kosim* filter system. Implementation would require adaptation of the spigot on the filters on which the flow meter is installed, design of an anti-tamper mechanism, and a system for retrieving data collected by the Camelbak ® Flow Meter ™.

PHW uses spigots that are manufactured by Tomlinson Industries. The spigot model, Tomlinson HFSG, has a white polypropylene body with 3/4"-16 UNF threads, and comes with two washers and a jam nut. PHW purchased thousands of these spigots at a price US$ 0.77 per unit, before distributing *Kosim* filters during the 2007 flood emergency in Ghana. Figure 5-3 shows the spigot installed on the *Kosim* filter safe storage container—a jam nut and two washers secure and seal the spigot to the container.

**Figure 6-4: Left, Jam nut and washer, which attach the Tomlinson Industries spigot to the inside of the *Kosim* safe storage container; Right, Tomlinson Industries spigot and washer attached to the outside of the *Kosim* safe storage container.**

In order to implement the objective measure, either the Camelbak ® Flow Meter ™ or the Tomlinson must be altered. The design constraints are:

- Flow through the spigot must drive the impellor mechanism of the flow meter;
- Flow meter impellor must be close enough to the electrical circuit to trip the reed switch;
- Measurement mechanism cannot block normal flow through the spigot, even over the course of 6 to 12 months; and
- Device is hidden to maximum extent possible to deter tampering by users.

An engineer or mechanic will likely be able to think of a number of ways to implement the objective measure. However, one potential design would be to alter the Camelbak ® Flow Meter

™ so that the blue plastic portion containing the impellor (shown in the image at the left in Figure 6-1) is secured inside of the Tomlinson spigot, and the gray plastic portion containing the electronics (Figure 6-2) is attached securely to the outside of the spigot. The hybrid flow meter and spigot would require testing before implementation, to determine whether the reed switch is still sensitive to impellor rotation in the new configuration. If the reed switch is no longer sensitive to impellor rotation, an engineer may need to find an impellor with a stronger magnet or a more sensitive reed switch.

In addition, measures to prevent tampering of the Flow Meter ™ should be taken, to ensure that the device measures true usage of the filter system. One method to discourage tampering would be to inactivate the mode change and reset buttons, and enclose the entire device within a small view-blocking box. Still, it would be impossible to fully hide the flow measurement device. Users may feel inclined to remove the device if it appears to impede water flow or does not seem useful to the function of the filter system. If users are advised to leave the device alone, they may be suspicious of its purpose and may affect their use of the filter system as a result.

Once we succeed in designing a hybrid flow meter and spigot that can satisfactorily collect flow data, we must also determine how to retrieve data from the device. Unless the data can be digitally transmitted somehow, this will require periodic visits to households being monitored, in order to manually read and record the data on total flow volume through spigot. If the device is enclosed with a box, the PHW employee will need to temporarily remove the box in order to obtain the reading. Regardless of whether the users are initially aware of the purpose of the flow meter, these periodic visits are likely to indicate to households that the filter use is being monitored, and would therefore be likely to change their use of the filter system as a result. This behavior change may bias the measurement, but brings up the question of whether it may worthwhile to introduce objective monitoring in a more widespread manner in order to increase filter use.

The author also suggests that PHW consider two other objective measurement methods as alternatives to the hybrid flow meter and spigot:

1. *Adopt SWEETSense™ flow monitoring and data retrieval system*:

   A monitoring system developed by Portland State University's SWEETLab™ provides a potential alternative to manual data collection using Camelbak ® Flow Meter™. SWEETLab™ has developed SWEETSense™, which monitors flow and continuously sends the data to the Internet via cellular networks or Wi-Fi. The data can then be viewed immediately online, using SWEETData.org™. The advantages of using the SWEETLab™ approach are that (1) it eliminates the need for periodic household visits to record monitoring data, and (2) it does not require further development. The disadvantages are that: (1) the system is costly, at a minimum of $100 per filter system monitored, and (2) the SWEETSense™ control board is large and highly visible. It would be worthwhile to explore the possibility of partnering with SWEETLab™, as the cost and design of the SWEETSense™ system may change in the future.

2. *Develop method to measure and retrieve data on total time that the spigot is in the "open" position:*

   As discussed in Quantitative and Representative Measure (Section 5.2.3), a quantitative and representative objective measure of *Kosim* filter use could potentially be inferred from measurement of any of three physical parameters, including the total flow volume through the spigot, and the total time that the spigot is in the "open" position. The latter measure would be easiest implement, but was dropped early in the design process because it would not distinguish between use of the spigot to dispense water and storage of an empty plastic container with the spigot in the "open" position. After more detailed design of the method to measure total flow volume, it seems that implementability is a much more important factor than we initially considered it to be. The author is particularly concerned about clogging over time using the hybrid flow meter and spigot.

   The advantages of measuring total time that the spigot is in the "open" position are that: (1) it does not affect the flow through the spigot, so clogging is not a concern; and (2) it should be relatively simple and inexpensive to implement, compared to measuring flow through the spigot. The disadvantage is that it would not distinguish between use of the spigot to dispense water and storage of an empty plastic container with the spigot in the "open" position. However, astute data analysis may mitigate this concern, since storage of an empty plastic container with the spigot in the "open" position would likely result in a total time measurement that is significantly higher than what one would expect from typical use.

# 7 Discussion and Conclusions

## 7.1 Comparison of results to other studies

Selected results from this study are compared to those of other studies. The author was able to find recent data on hand-washing rates in Ghana and under-five prevalence of diarrhea and acute respiratory illnesses in Ghana and specifically to the Northern Region. The following sub-sections discuss the how our data on hand-washing with soap, under-five prevalence of diarrhea, and under-five prevalence of respiratory illnesses compare to existing data.

### 7.1.1 Hand-washing rates in Ghana

The 5 percent rate of hand-washing rate with soap, measured using the indirect question method in this study, is comparable to the rate measured by structured observation in a national survey of Ghanaian mothers by Scott *et al.* (2007a). Scott *et al.* found that 4 percent of mothers practiced hand-washing with soap after defecation, 2 percent practiced hand-washing with soap after cleaning a child's bottom, and only 1 percent practiced hand-washing with soap before feeding children (Scott *et al.,* 2007a).

Scott *et al.* also found that a greater percentage of mothers practiced hand-washing with water only at each of these critical junctures: after own defecation (48%), after cleaning a child (27%) and before feeding a child (6%) (Scott *et al.,* 2007a). The higher rate of hand-washing with water only was echoed in this study. In this study, a number of respondents explained that washing hands with water after defecation is required as an act of religious ablution in Islam. A smaller number of respondents also mentioned practicing hand-washing with water as an act of ablution after handling a child's feces. Indeed, when the enumerators requested to use households' urinals during fieldwork, they were given a small container of water to wash their hands.

### 7.1.2 Under-five prevalence of diarrhea in Northern Region

The under-five diarrheal prevalence rate measured by the baseline survey seems to be reasonable, compared to the Northern Region under-five diarrheal prevalence rate measured by the 2008 Ghana Demographic and Health Survey. This study found that 23 percent of children under five had diarrhea in the *48 hours* prior to the survey, with a 95% CI of 17 percent to 29 percent (n = 200 households). The 2008 GDHS found that 32.5 percent of children under 5 had diarrhea in the *2 weeks* prior to the survey, with a 95% CI of 27.6 percent to 37.3 percent (n = 413 children). These prevalence rate estimates are not statistically different, although the overlap of the 95% confidence intervals between the two prevalence rate estimates is small. However, since the comparison is between a 48-hour prevalence rate and a 2-week prevalence rate, if we consider this difference in recall period, the GDHS estimate of diarrhea prevalence is lower than the estimate in this study. There are three possible reasons for this: (1) this study has overestimated the prevalence of diarrhea; (2) the GDHS underestimated the prevalence of diarrhea, perhaps due to under-reporting because of their longer recall period; (3) diarrheal prevalence has changed between the time of data collection for the 2008 GDHS and for this study and/or (4) the populations studied by this study and the GDHS are in fact different. While the GDHS prevalence rate estimate is specific to the Northern Region, it includes both urban and rural areas. On the other hand, this study includes only rural areas. Urban areas tend to have lower diarrhea prevalence rates than rural areas (2008 GHDS), so this could explain why the GDHS estimate of diarrheal prevalence rate is lower than that of this study.

### 7.1.3 Under-five prevalence of respiratory illness in Northern Region

The 2008 GDHS found that 9.3 percent of children under five had acute respiratory illness (ARI) in the 2 weeks prior to survey (n = 413 children). The 95% confidence intervals for ARI are not published. Since our study measured the prevalence rate of cough and difficulty breathing instead of ARI, which has more stringent definition, it is not possible to make a direct comparison. This study found that 25 percent of children under five had cough and difficulty breathing in the 48 hours prior to the survey, with a 95% CI of 19 percent to 31 percent (n =200 households), and 18 percent of children under five had severe cough and difficulty breathing in the 48 hours prior to the survey, with a 95% CI of 13 percent to 24 percent (n = 200 households). The 2008 GDHS prevalence of ARI is significantly lower than both the prevalence of cough and difficulty breathing and the prevalence of severe cough and difficulty breathing estimated by this study, even though the recall period in this study was shorter than the recall period used by the GDHS. There are a number of possible reasons for this difference: (1) this study overestimated the prevalence of respiratory illnesses; (2) the GDHS underestimated the prevalence of ARI, perhaps due to under-reporting because of their longer recall period; (3) respiratory prevalence has changed between the time of data collection for the 2008 GDHS and for this study; (4) the definition of ARI is more stringent than the definitions of (severe) cough and difficulty breathing; (5) this study measured respiratory illness during the dry season, and there is widespread anecdotal evidence that respiratory illness is more prevalent in the dry season. It seems unlikely that our study overestimated the prevalence of respiratory illnesses, because some respondents did not report conditions even though they were visibly coughing during the interview.

## 7.2 Baseline study conclusions

There is a great need and potential for improved water treatment in the peri-urban villages of Tamale. Overall, 98.6 percent of the survey population is using surface water as a primary drinking water source in the dry season, and 79.9 percent of the survey population is using unprotected water sources in the wet season. The potential for ceramic water filter dissemination is demonstrated by the fact that 99.5 percent of households surveyed expressed interest in purchasing the filter for the sale price of GHC 5 (US$ 3). The success of the Guinea Worm

Eradication Program in establishing the habit of water treatment with cloth filters demonstrates that it is possible to change household water management practices given adequate motivation, training and follow-up. Even two years after the last Guinea Worm Eradication Program follow-up, 52.6 percent of households surveyed were still using cloth filters to treat their drinking water. While the Guinea Worm program was extremely intensive and well funded, it may be possible to borrow some of the key strategies and even hire unemployed personnel for Pure Home Water dissemination practices.

In addition, safe storage and dispensing is a considerable need, as almost all households use open clay pots for drinking water storage, and 83.6 percent of households dispense drinking water by dipping cups or scoops without handles directly into the pots. Storage containers and dispensing mechanisms that prevent recontamination of drinking water would be significant improvements in rural communities in Tamale.

There is also a great potential for improved hand-washing practices. Only 5.0 percent of the households surveyed currently practice hand-washing with soap, yet 99.2 percent of households have soap present in the home. The great majority of households used bar soaps, which are appropriate for attaching to the Tippy Tap hand-washing stations.

The other piece of evidence for the need for improved water treatment is the high prevalence rates for diarrhea and respiratory illnesses. The prevalence rates for diarrhea were 23 percent (95% CI 17 to 20 percent) for children under the age of five and 9 percent (95% CI 5 to 13 percent) for the general population. For cough and difficulty breathing, prevalence rates were 25 percent (95% CI 19 to 31 percent) for children under the age of five and 13 percent (95% CI 8 to 17 percent) for the general population. Hands ("fingers") and drinking water ("fluids") are two of the five exposure pathways for diarrheal illnesses, and hands are also exposure pathways for respiratory illnesses. Therefore, while other exposure pathways exist, clean drinking water and improved hand-washing practices are two important elements of improving public health in rural Tamale communities.

## 7.3 Guidance and Recommendations for Rotary FVGG Follow-up

### 7.3.1 One-month follow-up survey

The first follow-up survey should be conducted approximately one month after the sales of ceramic water filters and installations of Tippy Taps in a given community. The original purpose of the one-month follow-up is to (1) assess user adoption and (2) to identify any need for re-training and maintenance in all households that purchased ceramic water filters. However, since approximately 1250 households will purchase filters, implementing a full-length survey (survey tool in Appendix B) would require extensive fieldwork. While it is critical to identify any need for re-training and maintenance in all households that purchased filters, the sample size of 1250 is much larger than needed to assess the rate of user adoption (Brown, personal com., 2012).

PHW and Rotary can greatly reduce the fieldwork requirements of the one-month follow-up by creating a re-train-and-maintain survey, which is a shorter version of the full-length one-month follow-up (Appendix B). The author recommends that PHW administer the full-length one-month follow-up in a smaller subset of the 1250 purchaser households. The shorter re-train-and-maintain survey should be administered in all 1250 purchaser households. The author recommends that PHW consult an expert on HWTS monitoring and evaluation to determine the sample size and sampling strategy for the subset of households where the full-length survey will be administered.

The author further recommends that PHW staff pre-test the full-length and shortened versions of the one-month follow-up survey in Tamale, and revise them as necessary, before use.

Since household surveys are time-consuming, it would be infeasible for the baseline enumerator team to administer the re-train-and-maintain survey in all 1250 purchaser households. If possible, the responsibility of gathering this information should be assigned to the WATSAN committee in each village. The PHW employee hired to manage the Rotary project would then be responsible for providing guidance on the monitoring, along with printed forms and writing implements for recording responses from each household. The additional advantage of assigning the WATSAN committees the responsibility of gathering the user adoption-related information is that the committees will be able to identify households that require filter replacement or maintenance, Tippy Tap maintenance, or better instructions on the use and cleaning of filters and Tippy Taps. In other words, conducting the one-month follow-up survey will assist the committees in fulfilling their responsibilities. Pure Home Water will request access to the collected information for the purposes of measuring project success and monitoring the activity of the WATSAN committees.

The full-length one-month survey, on the other hand, can be administered by either the baseline survey enumerators or the community WATSAN committees. PHW should determine which of these options is more practical given budgetary and logistical constraints, after determining the sample size for the full-length one-month survey.

### 7.3.2 Six-month follow-up survey

The second follow-up should be conducted in January 2013, approximately six months after the June 2012 filter sales and Tippy Tap construction in the intervention communities. Data on filter usage, quality of filtered and unfiltered water, Tippy Tap usage, diarrheal illness, and respiratory illness should be collected.

In addition, data on potentially confounding factors should be collected in the six-month follow-up. Potentially confounding factors are those that (1) may affect the intervention uptake in the study population (e.g. household income may be correlated with sustained use of ceramic water filter) or (2) may be risk factors for one of the outcomes (e.g. use of improved sanitation may reduce risk of diarrhea). In this study, potentially confounding factors would include, at minimum, socioeconomic factors and sanitation practices. Statistical analyses should be conducted to determine whether these factors are confounders.

A draft of the six-month follow-up survey tool is included as Appendix C. Currently it does not include a method to collect data on potentially confounding factors. The author recommends that PHW identify potentially confounding factors, and add questions to gather these data to the survey tool in Appendix C. Peletz (2006) and Johnson (2007) collected data on potentially confounding factors in their survey work, and may be a useful resource.

The six-month follow-up survey tool may be shortened to include only questions on diarrheal and respiratory illness and potentially confounding factors in the following types of households. The shortened version can be used in the following types of households: non-purchasers in intervention communities, and purchasers and non-purchasers in control communities.

Both the full-length six-month survey tool (draft in Appendix C), and the shortened version must be pre-tested by the enumerators and revised as necessary before use for data collection.

The six-month follow-up surveys should be conducted by enumerators who meet the criteria described in Survey Team (Section 3.4.1), preferably Ataya and Salifu if they are available and willing. This round of follow-up surveys should concurrently, or in as small a time frame as is logistically feasible, in both intervention and control communities.

Procedures for conducting the six-month surveys differ for the intervention and control communities, and are described below:

#### 7.3.2.1 Intervention Communities

PHW should survey all households that were surveyed at the baseline, regardless of whether they chose to purchase filters in June 2012, as long as they are available and give informed consent to be interviewed. In addition to the information on diarrheal and respiratory illness and potentially confounding factors, the enumerators should take note of which households chose to purchase filters and which households did not choose to purchase filters.

In the households that did purchase filters, PHW should collect information on filter and Tippy Tap usage (as outlined in survey tool in Appendix C), and collects samples of the treated and untreated water. The water quality data should be used in combination with survey responses to determine effective use of ceramic water filter. Relative risk analyses should then be conducted using the water quality data and survey data to understand the connections between interventions (filter and Tippy Tap usage) and outcomes (diarrheal and respiratory illnesses.) Peletz (2006) and Johnson (2007) provide methodologies for collecting and testing household water samples, along with methodologies for the associated relative risk analyses.

In the households that did not purchase filters, PHW need only to collect information on diarrheal and respiratory illness and potentially confounding factors. The shortened version of the survey tool can be used.

#### 7.3.2.2 Control communities

PHW should implement filter sales and Tippy Tap construction in control communities around January 2013. Concurrent with the filter sales, or in as small a time frame as logistically possible, PHW should survey all households that were surveyed at the baseline, as long as they are available and give informed consent to be interviewed. In the six-month follow-up in control communities, PHW need only to collect information on diarrheal and respiratory illness and potentially confounding factors.

At the time of sale to every purchaser in the control communities, PHW should ask each purchaser whether Ataya and Salifu interviewed their household during the baseline survey April 2012. If they were part of the baseline survey, PHW should request to interview them again, using the shortened version of the six-month survey tool that collects only information on diarrheal and respiratory illness and potentially confounding factors.

Immediately after sales are completed in a given control community, PHW will conduct the same shortened six-month follow-up in all households that were surveyed at the baseline and did not choose to purchase filters. For these non-purchaser households, PHW should again the shortened version of the six-month survey tool that collects only information on diarrheal and respiratory illness and potentially confounding factors.

#### 7.3.2.3 Data analysis

The author recommends that PHW consult with an expert on monitoring and evaluation of HWTS to improve the implementation plan for the six-month follow-up, and to develop a data analysis plan. Literature review is also a critical step. Methodology for measuring socioeconomic status via household surveys can be found in Peletz (2006) and Johnson (2007). Methodology for statistical analyses to identify confounders can be found in Brown and Sobsey (2006). An excellent resource for analysis of cross-sectional data is "Ecological and Cross-Sectional Studies" (Chapter 9) in Epidemiology: Concepts and Methods by William A. Oleckno. Updated versions of this work are reported in Chuang et al. (2010), Patrick (2011) and O'Keefe (2012)[16].

### 7.3.3 Challenge of measuring the effects of a two-part intervention

The evaluation recommended in this thesis treats ceramic filter usage and Tippy Tap usage as a single entity. In reality, households may choose to use one or the other, and not necessary both. For this reason, it is challenging assess the effect of a two-part intervention, especially if the evaluator wants to resolve the effects of each of the two parts. The author recommends that PHW consult an expert on monitoring and evaluation of HWTS to explore possible methods for evaluating ceramic filter usage and Tippy Tap usage as two separate entities. However, this may be outside the scope of the Rotary FVGG monitoring and evaluation study.

---

[16] All MIT M.Eng theses that were supervised by Murcott are available at web.mit.edu/watsan >> click "Thesis" >> click "Ghana".

## 7.4 Other recommendations on Rotary FVGG implementation

The author recommends two additional measures that may make the Rotary FVGG project more successful. These recommendations are by no means exhaustive.

- PHW should conduct a brief literature review on factors that are associated with higher rates of water treatment in HWTS interventions. Deep Springs International (DSI), a non-profit working in Haiti, has found that the most critical factor that has determined the success of DSI's clean water program to date is how often health workers visit households. DSI found that households that received health worker visits were 50 percent more likely to treat their water (Greenemeier, 2011). An extensive literature review to compare this finding to those of other organizations and researchers is out of the scope of this thesis. However, conducting such a review to inform the Rotary FVGG implementation strategy may greatly increase the correct and sustained use rate of the Rotary FVGG.

- Since the Rotary FVGG includes Tippy Tap construction, which is a significant time and resource investment, it is worthwhile to develop a sound plan for motivating households to use the Tippy Taps correctly. To this end, the author suggests two particularly useful resources:

    - A study of the factors motivating hand-washing with soap in Ghana (Scott et al., 2007b); and

    - The Handwashing Handbook (PPPHW).

## 7.5 Guidance and Recommendations for Future PHW Surveys

### 7.5.1 Measurement of diarrheal and respiratory illness

In this study, the author chose to measure three types of diarrheal illnesses (diarrhea, severe diarrhea, and HCGI) and two types of respiratory illnesses (cough and difficulty breathing, and severe cough and difficulty breathing). The results provide an interesting perspective on how rural households in Northern Ghana think about severity of illnesses and the collection of data on multiple types of each illness (as opposed to only one type of each illness) did not greatly lengthen the survey. However, the digitization and analysis of data on multiple types of diarrheal illness and multiple types of respiratory illness introduces additional complexity that would be unnecessary for PHW's future health impact evaluations.

The prevalence rates of diarrhea and of HCGI, in both children under five and the general population, **are not statistically different** from one another. The prevalence rates of diarrhea and severe diarrhea **are statistically different** from one another, but only in the pooled estimate (all households, n = 200) of children under five.

**Recommendation:** For future measures of diarrheal illness, the author therefore advises that PHW measure diarrhea and severe diarrhea for surveys that have: (1) sample sizes of at least 200 households AND (2) are particularly concerned with diarrhea in children under five. For all other surveys, PHW should only measure diarrhea OR HCGI. A measurement of the prevalence of diarrhea is more comparable than a measurement of the prevalence of HCGI to data from sources such as the Ghana Demographic and Health Survey, so it is recommended that PHW should measure diarrhea for surveys that do not fit the two criteria above.

The prevalence rates of cough and difficulty breathing and of severe cough and difficulty breathing, in both children under five and the general population, **are not statistically different** from one another.

**Recommendation:** For future measures of respiratory illness, the author recommends that PHW measure the rate of cough and difficulty breathing only.

### 7.5.2 Pre-test the survey tool

**Recommendation:** All survey tools should be pre-tested for at least one full day before implementation for actual data collection. During and after the pre-test, survey enumerators should discuss the strengths and weaknesses of the survey tool, and modify the tool as appropriate. Baseline Survey Modification and Pre-test (Section 3.4.2) discusses the motivations for and benefit of pre-testing the survey tool for the baseline survey.

**Recommendation:** Include the data digitization and mock analysis process when conducting the pre-test, in order to ensure that the survey team can collect data that can be digitized and analyzed in a straightforward manner. This will save a considerable amount of time during data digitization and analysis.

### 7.5.3 Survey tool format

A survey tool that looks concise on paper is not necessarily easy to implement as an interview. In oral surveys, for example, it may be difficult for enumerators to record data in complex tables.

**Recommendation:** In developing the survey tool, use the following formats whenever possible:

- Yes /no questions;
- Multiple choice questions; and/or
- Questions that require writing a single numerical response (e.g. Number of children: __).

### 7.5.4 Account for data digitization and analysis time

In this study, the author underestimated the time that would be required to do office work related to the survey implementation. Data digitization and analysis, and reflection to improve on the efficiency and accuracy of survey implementation, can take many times the amount of time spent actually collecting data.

**Recommendation:** When designing the evaluation, plan time for data digitization and analysis, and other office work, along with time for fieldwork.

### 7.5.5 Future research goals

Hunter (2009) concluded that ceramic filters are effective for improving health, at least in the short-term. However, for HWTS technologies, sustained use is often particularly low, so public health impacts achieved initially tend to decrease in the long-term (Arnold et al., 2009; Hunter 2009). Hunter recommends that future research on ceramic water filters should focus primarily on how to increase uptake and sustainability.

**Recommendation**: PHW should continue to seek practices that increase uptake and sustainability, and should consider testing the local applicability and impact of promising practices. Rigorous documentation of what practices are used in what interventions, with a parallel assessment of intervention success, may help to test local applicability and impact of promising practices.

**Recommendation**: PHW should continue to work with others in the HWTS network to identify or develop a measure of intervention success that is less complex and less time-consuming to implement than traditional monitoring and evaluation studies.

## 7.6 Objective use conclusions

The Camelbak ® Flow Meter ™ can be adapted for use as a front-end device to measure and record flow through the *Kosim* filter system. Implementation would require adaptation of the spigot on the filters on which the flow meter is installed, design of a anti-tamper mechanism, and a system for retrieving data collected by the Camelbak ® Flow Meter ™. If these steps are taken, the objective measurement device will be a hybrid flow meter and spigot that is attached directly to the *Kosim* safe storage container as the current Tomlinson spigots are attached. Unless a digital data transmission system is adopted or developed, a PHW employee will make periodic visits to each monitored household to manually read and record data from the hybrid device. However, these steps required to implement the hybrid flow meter and spigot may prove to be challenging, and the installation of an impellor in the spigot may cause clogging over time. The implementation of the hybrid flow meter and spigot is discussed in Objective Measure Implementation (Section 5.5).

The author therefore suggests that PHW consider two other objective measurement methods as alternatives to the hybrid flow meter and spigot:

1. *Adopt SWEETSense™ flow monitoring and data retrieval system*

2. *Develop method to measure and retrieve data on total time that the spigot is in the "open" position:*

These alternatives and their respective advantages and disadvantages are also discussed in Objective Measure Implementation (Section 5.5).

# 8 References


Albert, Jeff, Jill Luoto, and David Levine. "End-User Preferences for and Performance of Competing POU Water Treatment Technologies among the Rural Poor of Kenya." Environmental Science and Technology 44 (2010): 4426-32. .

Arnold, Benjamin, et al. "Evaluation of a Pre-Existing, 3-Year Household Water Treatment and Handwashing Intervention in Rural Guatemala." International Journal of Epidemiology 38 (2009): 1651-61.

Baqui, Abdullah H., et al. "Methodological Issues in Diearrhoeal Diseases Epidemiology: Defintion of Diarrhoeal Episodes." International Journal of Epidemiology 20.4 (1991): 1057-63.

Berry, James, Greg Fischer, and Raymond Guiteras. Eliciting and Utilizing Willingness to Pay: Evidence from Field Trials in Northern Ghana., 2011.

Brown, Joe. Personal communication. Ed. Connie Lu. Email on 20 May. 2012.

Brown, Joe and Thomas Clasen. “High adherence is necessary to realize health gains from water quality interventions.” PLoS One 7.5 (2012): e36735.

Brown, Joe, and Mark Sobsey. Independent Appraisal of Ceramic Water Filtration Interventions in Cambodia: Final Report. UNICEF, 2006.

Clasen, Thomas, et al. "Interventions to Improve Water Quality for Preventing Diarrhoea: Systematic Review and Meta-Analysis." BMJ (2007) <bmj.com>.

Clopeck, Katherine L. Monitoring and Evaluation of Household Water Treatment and Safe Storage Technologies: The Sustained use of the KOSIM Ceramic Water Filter in Northern Ghana. Master of Science in Technology and Policy Massachusetts Institute of Technology, 2009.

Cohn, Joanne, and Rotary Club of Malden, Massachusetts. Response to 7/18/2011 Checklist Questions, Global Grant 25252: A Safe Water and Handwashing Program in the Northern Region of Ghana., 2011.

Curtis, Val, and Sandy Cairncross. "Effect of Washing Hands with Soap on Diarrhoea Risk in the Community: A Systematic Review " The Lancet Infectious Diseases 3 (2003): 275-81. <http://infection.thelancet.com>.

Desymter, Davy, et al. "Monitoring and Evaluation of 1,000 Households Receiving Ceramic Pot (*Kosim*) Filters After an Emergency Flood Mass Distribution in Northern Ghana." International Ceramic Pot Filter Workshop. Atlanta, GA, February 8, 2009.

Esrey, S.A, et al. "Effects of Improved Water Supply and Sanitation on Ascariasis, Diarrhoea, Dracunculiasis, Hookworm Infection, Schistosomiasis, and Trachoma." The Bulletin of the World Health Organization 69 (1991): 609-21.

Faix, R. G. "Comparative Efficacy of Handwashing Agents Against Cytomegalovirus." Infection Control 8 (1987): 158-62.

Fowler Jr., Floyd J. Survey Research Methods. 4th ed. Thousand Oaks, California: SAGE Publications, Inc., 2009.

Ghana Statistical Service (GSS), Ghana Health Service (GHS), and ICF Macro. Ghana Demographic and Health Survey. Accra, Ghana: GSS; GHS; ICE Macro, 2008.

Global Public-Private Partnership for Handwashing With Soap (PPPHW). The Handwashing Handbook: A Guide for Developing a Hygiene Promotion Program to Increase Handwashing with Soap.

Gove, S. "Integrated Management of Childhood Illness by Outpatient Health Workers: Technical Basis and Overview. the WHO Working Group on Guidelines for Integrated Management of the Sick Child." Bulletin of the World Health Organization 75.Suppl 1 (1997): 7-24.

Green, Vanessa. Household Water Treatment and Safe Storage Options for Northern Region Ghana: Consumer Preference and Relative Cost. Master of Engineering in Civil and Environmental Engineering Massachusetts Institute of Technology, 2008 Cambridge, MA.

Greenemeier, Larry. "Aqua Plan: Could Cell Phones Help Aid Workers Ensure Haiti's Supply of Clean Water?" Scientific American February, 18 2011.

Gulyani, Sumila, Debabrata Talukdar, and R. Mukami Kariuki. "Universal (Non)Service? Water Markets, Household Demand and the Poor in Urban Kenya." Urban Studies 42.8 (2005): 1247-74.

Gundry, S. W., and J. A. Wright. " Smiley Diaries: A Simple Way of Recording Diarrhea Episodes." Waterlines 22.3 (2004): 13.

Hendley, J. O., R. P. Wenzel, and J. M. Gwaltney. "Tramission of Rhinovirus by Self-Inoculation." The New England Journal of Medicine 288 (1973): 1361-4.

Hennekens, Charles H., and Julie E. Buring. Epidemiology in Medicine. New York: Lippincott Williams & Williams, 1987.

Hunter, Paul R. "Household Water Treatment in Developing Countries: Comparing Different Intervention Types using Meta-Regression." Environmental Science and Technology 43.23 (2009): 8991-7.

Huttly, S. "Prevention of Diarrhea in Young Children in Developing Countries." The Bulletin of the World Health Organization 75 (1997): 163-74.

Johnson, Sophie M. Health and Water Quality Monitoring of Pure Home Water's Ceramic Filter Dissemination in the Northern Region of Ghana. Master of Engineering in Civil and Environmental Engineering Massachusetts Institute of Technology, 2007.

Mahama, Ibrahim. Dagbani-English Dictionary. Indiana University, 2003.

Majuru, Batsirai, et al. "Health Impact of Small-Community Water Supply Reliability." International Journal of Hygiene and Environmental Health 214 (2011): 162-6.

Miller, Matthew R. "Hemispheric Ceramic Pot Filter Evaluation and Quality Assurance Program in Northern Ghana." Master of Engineering in Civil and Environmental Engineering Massachusetts Institute of Technology, 2012.

Mintz, E., F. Reiff, and R. Tauxe. "Safe Water Treatment and Storage in the Home: A Practical New Strategy to Prevent Waterborne Disease." Journal of the American Medical Association 273 (1995): 948-53.

Morris, S., S. Cousens, and B. Kirkwood. "Is Prevalence of Diarrhea a Better Predictor of Subsequent Mortality and Weight Gain than Diarrhea Incidence?" The American Journal of Epidemiology 144.6 (1996): 582-8.

Murcott, Susan. "Development of Program Implementation, Evaluation, and Selection Tools for POU HWTS Systems in Developing Countries." The Third Annual Meeting of the International Network to Promote Household Water Treatment and Safe Storage and 2005 International Symposium on Household Water Management. Bangkok, Thailand, May 30 - June 2, 2005.

Niquette, Jim. Personal communication. Ed. Connie Lu. Email on 14 Mar. 2012.

Oleckno, William A. Epidemiology: Concepts and Methods. Long Grove, Illinois: Waveland Press, Inc., 2008.

Patrick, J. Molly, Susan Murcott, and Jarvis Punsalan. "Coupling Microbiological Testing and Sanitary Surveys in Drinking Water Quality Programs: Results from Capiz Province, Phillippines." Journal of Water, Sanitation and Hygiene for Development 1.1 (2011): 124-35.

Peletz, Rachel L. Cross-Sectional Epidemiological Study on Water and Sanitation Practices in the Northern Region of Ghana. Master of Engineering in Civil and Environmental Engineering Massachusetts Institute of Technology, 2006 Cambridge, MA.

Pure Home Water. Flood Emergency Relief Project in Northern Ghana, September 2007: Monitoring and Evaluation Report. 2008.

Rabie, Tamer, and Valerie Curtis. "Handwashing and Risk of Respiratory Infections: A Quantitative Systematic Review." Tropical Medicine and International Health 11.3 (2006): 258-67.

Rayner, J. Current Practices in Manufacturing of Ceramic Pot Filters for Water Treatment . Master of Science in Civil and Building Engineering Loughborough University, 2009.

Reed, S. E. "An Investigation of the Possible Transmission of Rhinovirus Colds through Indirect Contact." The Journal of Hygiene 75 (1975): 249-58.

Reither, Klaus, et al. "Acute Childhood Diarrhoea in Northern Ghana: Epidemiological, Clinical and Microbiological Characteristics." BMC Infectious Diseases 7 (2007): 104-14.

Rosner, Bernard. Fundamentals of Biostatistics. 6th ed. Pacific Grove, CA: Duxbury Press, 2005.

Rothman, Kenneth K. Epidemiology: An Introduction. Oxford: Oxford University Press, 2002.

Rothman, Kenneth K., Sander Greenland, and Timothy L. Lash. Modern Epidemiology. 3rd ed. Philadelphia: Wolters Kluwer Health and Lippincott Williams & Williams, 2008.

Schmidt, Wolf-Peter, and Sandy Cairncross. "Household Water Treatment in Poor Populations: Is there enough Evidence for Scaling Up Now?" Environmental Science and Technology 43.4 (2009): 986-92.

Schulz, Kenneth F., and David A. Grimes. "Sample Size Calculations in Randomised Trials: Mandatory and Mystical." The Lancet 365 (2005): 1348-53.

Scott, Beth E., et al. "Health in our Hands, but Not in our Heads: Understanding Hygiene Motivation in Ghana." Health Policy and Planning 22 (2007): 225-33.

Scott, Beth E., David W. Lawson, and Val Curtis. "Hard to Handle: Understanding Mothers' Handwashing Behaviour in Ghana." Health Policy and Planning 22 (2007): 216-24.

UNDP. Handbook on Planning, Monitoring, and Evaluating for Development Results. New York: United Nations Development Programme, 2009.

UNICEF. "UNICEF -- At a Glance: Ghana -- Statistics." <http://www.unicef.org/infobycountry/ghana_statistics.html>.

---. UNICEF Baseline Household Survey: Household-Based Drinking Water Treatment. UNICEF, 2005.

USAID, and Hygiene Improvement Project (HIP). Access and Behavioral Outcome Indicators for Water, Sanitation, and Hygiene. USAID Hygiene Improvement Project, 2010.

Victora, C., et al. "Water Supply, Sanitation and Housing in Relation to the Risk of Infant Mortality from Diarrhoea." Int J Epid 3.651 (1988): 654.

Waddington, Hugh, et al. Water, Sanitation and Hygeine Interventions to Combat Childhood Diarrhoea in Developing Countries. The International Initiative for Impact Evaluation (3ie), 2009.

WHO Department of Health Statistics. World Health Statistics. Geneva, Switzerland: World Health Organization, 2011.

WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. Progress on Drinking Water and Sanitation: 2012 Update. United States: WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, 2012.

WHO/UNICEF Joint Monitoring Program. A Toolkit for Monitoring & Evaluating Household Water Treatment and Safe Storage Programmes: Revised Draft for Comment. To be published, 2012.

Wood, Lesley, et al. "Empirical Evidence of Bias in Treatment Effect Estimates in Controlled Trials with Different Interventions and Outcomes: Meta-Epidemiological Study." British Medical Journal 336.7644 (2008): 601-5.

# 9 Appendices

## Appendix A: Baseline survey tool

**Rotary Foundation Global Grant (FVGG25252)–Ceramic Filter & Tippy Tap Distribution**
Impact Evaluation: Baseline Survey (before or at installation)

Hello, my name is _______ and I am a researcher working with a team from Pure Home Water in Tamale, Ghana and Massachusetts Institute of Technology, in the United States. This study is funded by the Rotary Foundation, an international voluntary organization. We are talking with people in your community to learn what you currently do to manage your household water and wash your hands. This survey is not a test in any way. All information we collect will be kept confidential, which means that we will not share the information you give to us with others. The data will be kept only as a collection of the responses given by all survey participants.

We would like to talk with the mother, grandmother or other primary caretaker of household children for about one hour. We are planning to ask questions about your household profile, health status, water management practices and hand washing practices. You may find some of the questions sensitive. In this case, you may choose to not answer any or all of the questions, and if you wish, you may end the interview at any point.

Participation is completely voluntary. Do you understand? Are you willing to participate?
Yes No

IF NO, thank you for your time and we will end here.
IF YES, do you have any questions about the survey or may we begin?

**Household Information**

1. We would like to return to you in about 6 months to ask similar questions. You may choose to not participate then, but would you please tell us your name and the name of your compound so that we may ask for you?

Household: ________________________________________ Compound: ______________________________________

2. Are you the mother, grandmother, or other caretaker?

   Mother Grandmother Other primary caretaker

3. How many people live in your household? Total: _______ Under age 5: ________

**Water Use Practices**

4. When you are at home, where do you get your drinking water in the dry season? What about the in the wet season?

   Dry season:

   Surface water HDW unprotected Borehole Other

   Piped supply HDW protected Community water treatment

   Wet season:

   Surface water HDW unprotected Borehole Rainwater

   Piped supply HDW protected Community water treatment Other

5. Do you ever treat your water to make it safer to drink? How do you treat it? CIRCLE ALL THAT APPLY

   Boil Alum Chlorine tablets/liquid Ceramic filter Cloth filter None Other: ____________

6. Could you show me how you take water from the containers?

   Pour directly Draw with cup/scoop w/ handle Draw with cup/scoop w/o handle Spigot Other

**Hygiene Practices**

7. Could you please show us what kind of soap you have in your home?
   Present    Not present
8. What do you use the soap for? CIRCLE ALL THAT APPLY, DO NOT PROMPT ANSWERS.

   Handwashing    Dishes    Laundry    Other

**Diarrhea and Respiratory Disease**

We will now ask you some questions about the health status of your family. We will be asking about diarrhea and respiratory illness. If you do not feel comfortable with sharing this information please tell us.

SKIP 11 IF THERE ARE NO CHILDREN UNDER 5 IN HOUSEHOLD.

9. Let's start with your youngest child. USE **FORM A** FOR EACH CHILD UNDER AGE 5.

10. Has anyone (else) in the household had diarrhea or abdominal pain in the last two days?
    Yes    No

11. Has anyone (else) in the household had blood or mucus in the stool in the last two days?
    Yes    No

12. Has anyone (else) in the household had nausea or vomited in the last two days?
    Yes    No

    USE **FORM B** FOR EACH PERSON WHO HAS HAD ANY OF ABOVE SYMPTOMS IN THE LAST WEEK.

13. Has anyone (else) in the household had a cough or difficulty breathing in the last two days?
    Yes    No

    USE **FORM C** FOR EACH PERSON WHO HAS HAD A COUGH OR DIFFICULTY BREATHING IN THE LAST WEEK.

14. Are you interested in purchasing a sale price ceramic water filter for GHC 5?
    Yes    No

THANK SUBJECT FOR HER/HIS TIME.

---

RECORD THIS INFORMATION UPON LEAVING HOUSEHOLD:

**Interview Background:**

Community: ________________________ Survey number: _______

Date: ________________________

GPS number: ___________________    GPS coordinates: __________________________________________

FORM A

| Questions | Youngest under age 5 | Next youngest | Next youngest | Next youngest | Eldest under age 5 |
|---|---|---|---|---|---|
| A1. Has he/she had diarrhea in the last 2 days? | Yes No | Yes No | Yes No | Yes No | Yes No |
| IF HE/SHE HAD DIARRHEA: A2. Was the diarrhea severe or watery? | Yes No | Yes No | Yes No | Yes No | Yes No |
| A3. Has he/she had blood or mucus present in his/her stool? | Yes No | Yes No | Yes No | Yes No | Yes No |
| A4. Has he/she vomited in the last 2 days? | Yes No | Yes No | Yes No | Yes No | Yes No |
| A5. Has he/she had a cough or difficulty breathing in the last 2 days? | Yes No | Yes No | Yes No | Yes No | Yes No |
| IF HE/SHE HAD A COUGH OR DIFFICULTY BREATHING: A6. Was the cough or difficulty breathing severe? | Yes No | Yes No | Yes No | Yes No | Yes No |

FORM B

| Questions | Person 1 | Person 2 | Person 3 | Person 4 | Person 5 |
|---|---|---|---|---|---|
| B1. Which symptoms did the individual have? LIST AS NECESSARY (HCGI = PRESENCE OF ANY: WATER DIARRHEA, VOMITING, SOFT DIARRHEA W/ ABDOM PAIN, OR NAUSEA W/ ABDOM PAIN; DIARRHEA = THREE OR MORE LOOSE OR WATERY STOOLS IN 24 HOURS OR A SINGLE STOOL W/ BLOOD OR MUCUS) | Diarrhea Abdom. Pain<br>Vomiting Nausea<br>Blood/mucus in stool | Diarrhea Abdom. Pain<br>Vomiting Nausea<br>Blood/mucus in stool | Diarrhea Abdom. Pain<br>Vomiting Nausea<br>Blood/mucus in stool | Diarrhea Abdom. Pain<br>Vomiting Nausea<br>Blood/mucus in stool | Diarrhea Abdom. Pain<br>Vomiting Nausea<br>Blood/mucus in stool |
| IF HE/SHE HAD DIARRHEA: B2. Was the diarrhea severe or watery? | Yes No | Yes No | Yes No | Yes No | Yes No |

| Questions | Person 6 | Person 7 | Person 8 | Person 9 | Person 10 |
|---|---|---|---|---|---|
| B1. Which symptoms did the individual have? LIST AS NECESSARY (HCGI = PRESENCE OF ANY: WATER DIARRHEA, VOMITING, SOFT DIARRHEA W/ ABDOM PAIN, OR NAUSEA W/ ABDOM PAIN; DIARRHEA = THREE OR MORE LOOSE OR WATERY STOOLS IN 24 HOURS OR A SINGLE STOOL W/ BLOOD OR MUCUS) | Diarrhea Abdom. Pain<br>Vomiting Nausea<br>Blood/mucus in stool | Diarrhea Abdom. Pain<br>Vomiting Nausea<br>Blood/mucus in stool | Diarrhea Abdom. Pain<br>Vomiting Nausea<br>Blood/mucus in stool | Diarrhea Abdom. Pain<br>Vomiting Nausea<br>Blood/mucus in stool | Diarrhea Abdom. Pain<br>Vomiting Nausea<br>Blood/mucus in stool |
| IF HE/SHE HAD DIARRHEA: B2. Was the diarrhea severe or watery? | Yes No | Yes No | Yes No | Yes No | Yes No |

FORM C

| Questions | Person 1 | Person 2 | Person 3 | Person 4 | Person 5 |
|---|---|---|---|---|---|
| C1. Was the individual's cough or difficulty breathing severe? | Yes No | Yes No | Yes No | Yes No | Yes No |

| Questions | Person 6 | Person 7 | Person 8 | Person 9 | Person 10 |
|---|---|---|---|---|---|
| C1. Was the individual's cough or difficulty breathing severe? | Yes No | Yes No | Yes No | Yes No | Yes No |

## Appendix B: Draft of one-month follow-up survey tool

**DRAFT – 1 Month Followup**
**Rotary Foundation Global Grant (FVGG25252) –Ceramic Filter & Tippy Tap Distribution**
Impact Evaluation: 1-Month Follow-Up

Hello, my name is _______ and I am a researcher working with a team from Pure Home Water in Tamale, Ghana and Massachusetts Institute of Technology, in the United States. This study is funded by the Rotary Foundation, an international voluntary organization. We are talking with people in your community to see if the ceramic filters and hand-washing stations we installed last month are helpful. We want to hear about your current water use and hand washing practices. We would like to talk with one of the primary caretakers in the household for about ten to fifteen minutes. Participation is voluntary; you may decline to answer any or all of the questions, and you end the questionnaire early if you wish. All identifying information will be kept confidential.

Do you understand? Will you be willing to participate?
(1) Yes (2) No (If no, thank and close)

**Interview Background:**

Household: ________________________________________________________Date: __________________________

**Filter Use:**

1. Were you the person who purchased the filter?
   Yes No
2. Were you present the day the filter was installed?
   Yes No
3. Did you receive training on how to use the filter? Yes No (Who was? ___________)
4. Are you using the filter? Yes No
5. How often do children <5 in your household drink untreated water?
   Daily Weekly Monthly Never
6. How often do others in your household drink untreated water?
   Daily Weekly Monthly Never
7. If you are not using the filter, why? (Don't read the options, circle all that they say)

   (1) Filter/Storage container/Spigot broke
   (2) Did not like using it
   (3) Felt it was not necessary
   (4) Felt it was not improving the quality of your water
   (5) Too time consuming
   (6) No longer here in this household
   (7) Found a better or more trusted source of water

8. Filter Problems (multiple answers possible)

☐ breakage   since: ..........   where:   pot lip   pot side   container   other: ..........
reason: ..........

☐ leakage   since: ..........   where:   filter tap   container   other:
reason: ..........

☐ other   since: ..........   where: ..........
reason: ..........

9. Replacement Parts Required (multiple answers possible)

☐ filter pot   ☐ container   ☐ lid   ☐ ring lid   ☐ tap   ☐ washer(s)   ☐ brush   ☐ other: ..........

10. Can you tell me how you would describe to a neighbor how to use this technology?
Correct use   Incorrect use

11. Can you please pour me a cup of your drinking water?
Safely removing water   Incorrect method of removing water

12. Do you clean the filter?   Yes   No

13. How often?
Daily   Weekly   Monthly   Never

14. Will you please demonstrate how you clean the filter?
Correct cleaning   Incorrect cleaning

**Observation:**

15. Is the ceramic filter moist or wet?   Yes   No

16. Is safe storage container securely covered?   Yes   No
…out of reach of small children or animals?   Yes   No
…clean (free of dirt, debris, garbage, fecal matter)?   Yes   No

**OTHER OBSERVATIONS** ..........

**Tippy Tap Use:**

17. Were you present the day the Tippy Tap was installed? Yes No

18. Were you one of the people who received training on how to use the Tippy Tap? Yes No (Who was? ______________)

19. Are you still using the Tippy Tap? Yes No

20. If not, why? (Don't read the options, circle all that they say)

    (1) Problem with Tippy Tap
    (2) Did not like using it
    (3) Felt it was not necessary
    (4) Felt it was not improving hand cleanliness
    (5) Too time consuming
    (6) No longer here in this household
    (7) Found a better way to wash hands

21. Have you noticed any problems with the Tippy Tap?
    (1) Yes (2) No

22. If yes, what was the problem?
    (1) Structure broke
    (2) String tore
    (3) Container broke
    (4) Ran out of soap
    (5) Messy
    (6) Other: ______________

23. Can you please ask one of your children demonstrate how to use the Tippy Tap? (If no children present, indicate this and ask respondent to demonstrate)

    Correct use Incorrect use

Name Surveyor: Date Survey:

## Appendix C: Draft of six-month follow-up survey tool

**DRAFT – 6 Month Followup**
**Rotary Foundation Global Grant (FVGG25252)–Ceramic Filter & Tippy Tap Distribution**
Impact Evaluation: 6-Month Follow-up Survey

Hello, my name is _______ and I am a researcher working with a team from Pure Home Water in Tamale, Ghana and Massachusetts Institute of Technology, in the United States. This study is funded by the Rotary Foundation, an international voluntary organization. We are talking with people in your community to learn what you currently do to manage your household water and wash your hands. We would like to talk with the mother, grandmother or other primary caretaker of household children for about one hour. We are planning to ask questions about your household profile, health status, water management practices and hand washing practices. Participation is voluntary; you may decline to answer any or all of the questions, and you end the questionnaire early if you wish. All identifying information will be kept confidential.

Do you understand? Will you be willing to participate?
(1) Yes (2) No (If no, thank and close)

**Household Information**

1. Would you please tell us your name and the name of your household and compound? This information will be kept confidential.

Household: ________________________________________ Compound: ______________________________________

2. Are you the mother, grandmother, or other caretaker?

Mother Grandmother Other primary caretaker

3. How many people live in your household? Total: _______ Under age 5: ________

**Filter Use:**

1. Were you the person who purchased the filter?
Yes No
2. Were you present the day the filter was installed?
Yes No
3. Did you receive training on how to use the filter? Yes No (Who was? ___________)
4. Are you using the filter? Yes No
5. How often do children <5 in your household drink untreated water?
Daily Weekly Monthly Never
6. How often do others in your household drink untreated water?
Daily Weekly Monthly Never
7. If you are not using the filter, why? (Don't read the options, circle all that they say)

(1) Filter/Storage container/Spigot broke
(2) Did not like using it
(3) Felt it was not necessary
(4) Felt it was not improving the quality of your water
(5) Too time consuming
(6) No longer here in this household
(7) Found a better or more trusted source of water

8. Filter Problems (multiple answers possible)

| | | | | | | |
|---|---|---|---|---|---|---|
| ☐ breakage | since: | where: | pot lip | pot side | container | other: |
| reason: | | | | | | |
| ☐ leakage | since: | where: | filter tap | container | other: | |
| reason: | | | | | | |
| ☐ other | since: | where: | | | | |
| reason: | | | | | | |

9. Replacement Parts Required (multiple answers possible)

☐ filter pot ☐ container ☐ lid ☐ ring lid ☐ tap ☐ washer(s) ☐ brush ☐ other:

10. Can you tell me how you would describe to a neighbor how to use this technology?
Correct use Incorrect use

11. Can you please pour me a cup of your drinking water?
Safely removing water Incorrect method of removing water

12. Do you clean the filter? Yes No

13. How often?
Daily Weekly Monthly Never

14. Will you please demonstrate how you clean the filter?
Correct cleaning Incorrect cleaning

**Observation:**

15. Is the ceramic filter moist or wet? Yes No

16. Is safe storage container securely covered? Yes No
…out of reach of small children or animals? Yes No
…clean (free of dirt, debris, garbage, fecal matter)? Yes No

**OTHER OBSERVATIONS**

| H2S Test | Take sample and test water for H2S |
| --- | --- |
| SUGGESTIONS | |
| OBSERVATIONS | |

**Hygiene Practices**

4. Could you please show us what kind of soap you have in your home?
Present Not present
5. What do you use the soap for? CIRCLE ALL THAT APPLY, DO NOT PROMPT ANSWERS.

Handwashing Dishes Laundry Other

**Tippy Tap Use:**

17. Were you present the day the Tippy Tap was installed? Yes No

18. Were you one of the people who received training on how to use the Tippy Tap?
Yes No (Who was? ______________)

19. Are you still using the Tippy Tap? Yes No

20. If not, why? (Don't read the options, circle all that they say)

    (1) Problem with Tippy Tap
    (2) Did not like using it
    (3) Felt it was not necessary
    (4) Felt it was not improving hand cleanliness
    (5) Too time consuming
    (6) No longer here in this household
    (7) Found a better way to wash hands

21. Have you noticed any problems with the Tippy Tap?
    (1) Yes (2) No

22. If yes, what was the problem?
    (1) Structure broke
    (2) String tore
    (3) Container broke
    (4) Ran out of soap
    (5) Messy
    (6) Other: ______________

23. Can you please ask one of your children demonstrate how to use the Tippy Tap? (If no children present, indicate this and ask respondent to demonstrate)

    Correct use Incorrect use

**Diarrhea and Respiratory Disease**

We will now ask you some questions about the health status of your family. We will be asking about diarrhea and respiratory illness. If you do not feel comfortable with sharing this information please tell us.

SKIP 11 IF THERE ARE NO CHILDREN UNDER 5 IN HOUSEHOLD.

6. Let's start with your youngest child. USE **FORM A** FOR EACH CHILD UNDER AGE 5.

7. Has anyone (else) in the household had diarrhea or abdominal pain in the last two days?
   Yes No

8. Has anyone (else) in the household had blood or mucus in the stool in the last two days?
   Yes No

9. Has anyone (else) in the household had nausea or vomited in the last two days?
   Yes No

   USE **FORM B** FOR EACH PERSON WHO HAS HAD ANY OF ABOVE SYMPTOMS IN THE LAST WEEK.

10. Has anyone (else) in the household had a cough or difficulty breathing in the last two days?
    Yes No
    USE **FORM C** FOR EACH PERSON WHO HAS HAD A COUGH OR DIFFICULTY BREATHING IN THE LAST WEEK.

11. Are you interested in purchasing a sale price ceramic water filter for GHC 5?
    Yes No

THANK SUBJECT FOR HER/HIS TIME.

---

RECORD THIS INFORMATION UPON LEAVING HOUSEHOLD:

**Interview Background:**

Community: _________________________ Survey number: _______

Date: _________________________

GPS number: ___________________ GPS coordinates: ____________________________________________

Name Surveyor: Date Survey:

FORM A

| Questions | Youngest under age 5 | Next youngest | Next youngest | Next youngest | Eldest under age 5 |
|---|---|---|---|---|---|
| A1. Has he/she had diarrhea in the last 2 days? | Yes No | Yes No | Yes No | Yes No | Yes No |
| IF HE/SHE HAD DIARRHEA: A2. Was the diarrhea severe or watery? | Yes No | Yes No | Yes No | Yes No | Yes No |
| A3. Has he/she had blood or mucus present in his/her stool? | Yes No | Yes No | Yes No | Yes No | Yes No |
| A4. Has he/she vomited in the last 2 days? | Yes No | Yes No | Yes No | Yes No | Yes No |
| A5. Has he/she had a cough or difficulty breathing in the last 2 days? | Yes No | Yes No | Yes No | Yes No | Yes No |
| IF HE/SHE HAD A COUGH OR DIFFICULTY BREATHING: A6. Was the cough or difficulty breathing severe? | Yes No | Yes No | Yes No | Yes No | Yes No |

FORM B

| Questions | Person 1 | Person 2 | Person 3 | Person 4 | Person 5 |
|---|---|---|---|---|---|
| B1. Which symptoms did the individual have? LIST AS NECESSARY (HCGI = PRESENCE OF ANY: WATER DIARRHEA, VOMITING, SOFT DIARRHEA W/ ABDOM PAIN, OR NAUSEA W/ ABDOM PAIN; DIARRHEA = THREE OR MORE LOOSE OR WATERY STOOLS IN 24 HOURS OR A SINGLE STOOL W/ BLOOD OR MUCUS) | Diarrhea Abdom. Pain<br>Vomiting Nausea<br>Blood/mucus in stool | Diarrhea Abdom. Pain<br>Vomiting Nausea<br>Blood/mucus in stool | Diarrhea Abdom. Pain<br>Vomiting Nausea<br>Blood/mucus in stool | Diarrhea Abdom. Pain<br>Vomiting Nausea<br>Blood/mucus in stool | Diarrhea Abdom. Pain<br>Vomiting Nausea<br>Blood/mucus in stool |
| IF HE/SHE HAD DIARRHEA: B2. Was the diarrhea severe or watery? | Yes No | Yes No | Yes No | Yes No | Yes No |

| Questions | Person 6 | Person 7 | Person 8 | Person 9 | Person 10 |
|---|---|---|---|---|---|
| B1. Which symptoms did the individual have? LIST AS NECESSARY (HCGI = PRESENCE OF ANY: WATER DIARRHEA, VOMITING, SOFT DIARRHEA W/ ABDOM PAIN, OR NAUSEA W/ ABDOM PAIN; DIARRHEA = THREE OR MORE LOOSE OR WATERY STOOLS IN 24 HOURS OR A SINGLE STOOL W/ BLOOD OR MUCUS) | Diarrhea Abdom. Pain<br>Vomiting Nausea<br>Blood/mucus in stool | Diarrhea Abdom. Pain<br>Vomiting Nausea<br>Blood/mucus in stool | Diarrhea Abdom. Pain<br>Vomiting Nausea<br>Blood/mucus in stool | Diarrhea Abdom. Pain<br>Vomiting Nausea<br>Blood/mucus in stool | Diarrhea Abdom. Pain<br>Vomiting Nausea<br>Blood/mucus in stool |
| IF HE/SHE HAD DIARRHEA: B2. Was the diarrhea severe or watery? | Yes No | Yes No | Yes No | Yes No | Yes No |

FORM C

| Questions | Person 1 | Person 2 | Person 3 | Person 4 | Person 5 |
|---|---|---|---|---|---|
| C1. Was the individual's cough or difficulty breathing severe? | Yes No | Yes No | Yes No | Yes No | Yes No |

| Questions | Person 6 | Person 7 | Person 8 | Person 9 | Person 10 |
|---|---|---|---|---|---|
| C1. Was the individual's cough or difficulty breathing severe? | Yes No | Yes No | Yes No | Yes No | Yes No |

## Appendix D: Draft of Rotary FVGG Contract with Purchasers

Appendix D

## Draft Contract Concept

## for Rotary (and Buy 1, Give 1?) Distributions

"PHW will see you a Kosim calabash filter at the special sale price of GHC 5. With this purchase, you will not only receive a Kosim filter, but also a Tippy Tap handwashing station. These tools are better than medicine, insofar as they will protect your family's health.

We will return to a number of households in 1 month to check to make sure you understand how to use and maintain your Kosim filter and hand-washing station.

Your GHC 5 is held in a special account by your WATSAN Committee, a community fund to pay for damaged or broken parts.

If your filter or Tippy Tap is damaged or broken, you will receive a new one.

After 3 years, the ceramic filter element needs replacement. It costs GHC 5. You must buy the replacement yourself.

If you are not using the filter or Tippy Tap when we come back in 6 months, because you don't wish to continue to use it, we would ask that we reclaim the items so that someone else who wants to use it can benefit from it. "

## Appendix E: How to Build A Tippy Tap (WOT, n.d.)

# How to make a Tippy Tap

## A hygienic hand washing device with running water

Mark Tiele Westra

Werkgroep OntwikkelingsTechnieken (WOT)
University of Twente, the Netherlands

## Introduction

This document describes how to make a Tippy Tap, a simple handwashing device with running water.

The Tippy Tap consists of a 5 liter container hanging on a horizontal stick. The container can be tipped by pulling a rope through the cap. The rope is attached to a stick lying on the ground, which is pushed down by foot.

As only the soap is touched during hand washing, the device is very hygienic.

## Materials needed

1. Two wooden branches of 2 meter length, with Y-shaped end.
2. Two thinner sticks of ~1 meter length.
3. A saw to cut the wood.
4. A nail
5. A pair of pliers
6. A lighter
7. A shovel
8. Two lengths of rope (0.5 m and 1 m)
9. A 5 liter container
10. A piece of soap
11. A screwdriver
12. A bag of gravel

## Cutting the wood

Cut two branches of wood of ~2 meter length, which have a Y-shape at the end.

Cut two thinner branches, each of ~1 meter length.

Attache a piece of string of ~1 meter length to one of the sticks.

**Making the hole**
Mark the location for the hole on the container, around 12 cm below the cap

**Heating the nail**
Hold the nail with a pair of pliers, and heat the nail with a lighter.

**Making the holes**
With the hot nail, make the hole in the container, and a second hole in the cap

**Inserting the rope**

Put the rope, which is attached to the stick, through the hole in the cap.

**Knotting the rope**

Make a knot in the rope which cannot pass through the hole.

**Putting it together**

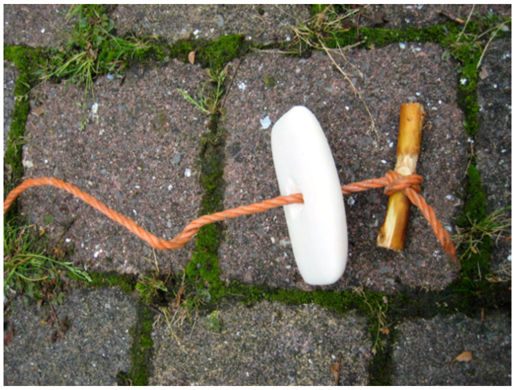
Screw the cap back on the container. The stick is now connected to the container with the rope.

**Making the hole through the soap**

Using a screwdriver, make a hole through the soap by slowly rotating and pushing the screwdriver through the soap

**Inserting the rope**

Put the second piece of rope through the hole in the soap, and tie a piece of wood to it.



**Filling the container**

Fill the container with water, up to the level of the hole.

**Putting the poles in the ground**

Using a shovel, put the poles in the ground to a depth of 50cm. The distance should be about 70 cm.

**Hanging up the container**

Put the stick through the handle of the container, and put the stick between the poles.

Adjust the length of the rope such that the end of the stick is about 15cm above the ground

**Adding the soap**

Tie the rope with the soap to the stick.

**Gravel soakaway**

Between the two poles, below the container, dig a hole of 40 x 40 cm, and 10 cm deep. Fill the hole with gravel.

The water soaks away in the hole, and prevents a mudhole from forming. The gravel also keeps mosquitos from breeding.

**Using the Tippy Tap**

Push the stick down with your foot. This tips the container, which makes water run out of the hole. (in the photo, the gravel soakaway is missing)

Wet your hands and release the stick. Apply soap to your hands. Push the stick down again and clean your hands.

This information can also be found on

www.wot.utwente.nl
www.connectinternational.nl
www.akvo.org

## Appendix F: Calculation of 95 % Confidence Intervals

## Method for confidence interval calculations

Standard error, SE, for each proportion of the population was calculated using Equation 1:

**Equation 1**

$$SE = \sqrt{\frac{P(1-P)}{n}}$$

where $P$ is the proportion estimated by survey and $n$ is the number of households in the sample of the population.

The margin of error, $MOE$, for 95% confidence intervals was than calculated using Equation 2:

**Equation 2**

$$MOE = p * SE$$

where $p$ is the upper-tail probability at a 95% confidence level for the number of households, $n$, using a one-tailed t-test.

The 95% confidence interval (CI) was calculated using Equation 3:

**Equation 3**

$$95\%CI = p \pm MOE$$

## Appendix G: Rapid Assessment of Borehole Status in Tugu and Duuyin (Josh Hester and John Adams)

Boreholes in Tugu and Duuyin:
Rapid Assessment Report by Josh Hester (Pure Home Water) & John Adams (Pure Home Water)
May 19, 2012

Tugu has four boreholes, but only one of them is functional because the other three were determined to produce water that is unfit for human consumption. They said that the water was "salty". Our guess is that it has something to do with the use of pesticides and other chemicals on the nearby farm fields. Surprisingly, the borehole that produces adequate drinking water is only about 100 yards away from one of the ones that does not. They have sealed off at least two of the three bad boreholes. People clearly do use the borehole and prefer it because they seem to be fairly aware of water-borne illnesses (or at least are somewhat uncomfortable with drawing water from sources that animals also use because they are aware that it's not good for their health). Unfortunately, it seems that there is never enough water from the borehole, and especially not in the dry season when it is almost completely dry. When there is not enough water, they draw water from a dam (dugout) or a stream, but these are also farther away than the boreholes, making the boreholes attractive in terms of convenience, too. Everyone said that if there were enough boreholes, then they would certainly choose to use the boreholes over the dam or the stream. There seems to be a shortage of water in general. One of the things contributing to there not being enough water is that people from the surrounding communities also come and draw water from it. In addition, farmers come from other areas in the rainy season to farm, and they also take water from the same sources, putting an additional strain on the combined water supply of the borehole, dam, and streams.

Duiyin has two boreholes, both of which work year round but produce less water in the dry season. When there is not enough water, they draw water from a dugout, but their preference is to use the water from the borehole because it is cleaner (clearer) and because (as in Tugu) they are aware that sharing water sources with animals is unhealthy. Only Duiyin uses their boreholes, but surrounding communities also use the dam. They say that during water shortages, people come from Tamale to use the dam, too. The borehole that is closer to the community draws water of a higher quality, even though it is more turbid, because the borehole farther away - while clearer - is "salty". The closer borehole is "5 pipes" deep (5-10 meters, I'm guessing) and the one that is farther away is "17 pipes" deep (probably 17-34 meters).

**Figure G-1: Working boreholes in Tugu (left) and Duuyin (right).**

**Figure G-1: Left, turbid but better tasting borehole in Duuyin; Right, Tugu borehole was sealed because it produced salty water that was considered unfit for human consumption.**