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Assessing Appropriate Technology Handwashing Stations in Mali, West Africa

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by

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DEDICATION

I would like to dedicate this work to Jean-Claude Konaré, my former Malian, Peace Corp's work partner (pictured later in the document in Figure 1.3 in Chapter 1). Jean-Claude was instrumental in implementation of this study through his assistance with my service and sadly passed away July 27, 2013. "Ala ka lafiya di ale ma" which means "May God grant him peace" in Bambara, the local language in Mali.

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ABSTRACT

Proper hand hygiene is the most effective and efficient method to prevent over 1.3 million deaths annually from diarrheal disease and Acute Respiratory Infections (ARIs). Hand hygiene is also indispensable in achieving the fourth Millennium Development Goal (MDG) to reduce the childhood mortality rate by 2/3rds between 1990 and 2015. Handwashing has been found in a systematic review of studies to reduce diarrhea by 47% and is, thus, capable of preventing a million deaths (Curtis et. al., 2003). Despite this evidence, hand washing rates remain seriously low in the developing world (Scott et al., 2008).

This study developed and implemented a comprehensive monitoring strategy of five usage variables (i.e., soap usage, functionality, presence of cleansing agent, ground wetness under station, amount of water in the jug) for 42-64 appropriate technology handwashing stations. These stations were monitored throughout 2011-2013 in two communities in Mali, West Africa. Statistically significant ($p < 0.05$) results include: 1) a 29% decrease in soap usage from dry (October-June) to rainy seasons (July-September), 2) 35% decrease in stations with presence of cleansing agent between 2011 and 2012, 3) higher station usage for stations in households with higher scores on the Progress out of Poverty Index® , 4) 27% less of the stations far from a water source (35 meters-172 meters away) had a cleansing agent present than stations close to a water source (less than 35 meters) during the rainy season. Station usage also differed based on gender of the handwashing station owner in the two communities where stations built by women were used more in Zeala than those in Nci'bugu. In contrast to Zeala, handwashing stations built by men in Nci'bugu had higher soap usage and usage variable proportions than those built by women. Handwashing training and promotions resulted in 98% of households reporting that they wash their hands with soap in 2012 from 0% in 2011. Altogether, this study designed and implemented a robust monitoring system that succeeded in quantifying handwashing station usage for over two years. In-depth analysis of the data established six sustainability factors for handwashing stations (gender, training, water, seasonality, wealth, and monitoring) that are critical for lasting handwashing behavior change and successful hygiene interventions to save lives.

CHAPTER 1: INTRODUCTION

Proper hand hygiene is the most effective and efficient method to prevent over 1.3 million deaths annually from diarrheal disease and Acute Respiratory tract Infections (ARIs). It is also indispensable to achieve the fourth United Nation's Millennium Development Goal (MDG) to reduce the childhood mortality "…rate by 2/3rds between 1990 and 2015 (United Nations, 2011)." In addition, every year there are an estimated 4 billion cases of diarrhea in the world that result in 2.2 million deaths, accounting for 15% of the mortality for children at their most vulnerable age (under 5 years). Furthermore, most of these deaths (1.7 million) are children under five years of age (UNICEF, 2008). Though interventions in sanitation and water quality and quantity improvements also reduce incidences of diarrheal disease, hygiene is the most effective as demonstrated in Figure 1.1.

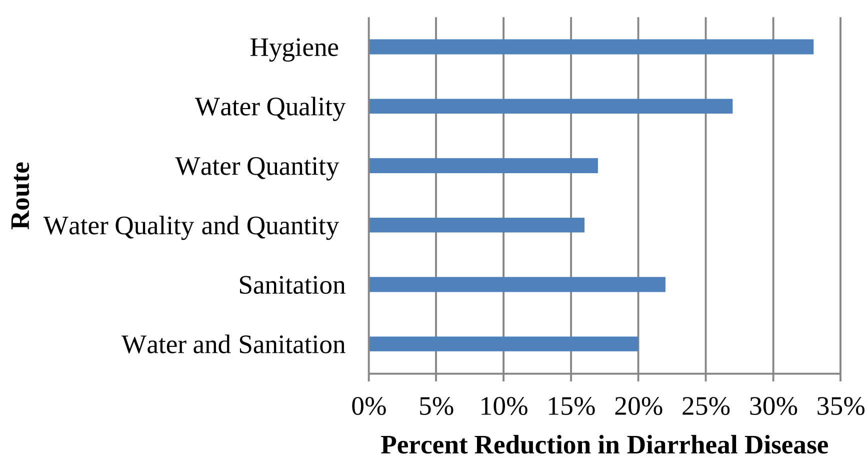

Figure 1.1: Percent reduction in diarrheal disease based on type of intervention (figure reproduced from results available from Esrey et al. 1985, 1991; Esrey 1996 cited by Mihelcic, 2009).

Initial hygiene training also does not require the same immediate investment in infrastructure with installation of water pumps or latrines as in water and sanitation projects. For example, in a systematic review of studies to reduce diarrhea, handwashing alone has been proven to reduce diarrhea by 47% which has the potential of preventing a million deaths (Curtis et al., 2003).

Furthermore, 2 million deaths a year worldwide are attributed to ARIs that are also the leading cause in childhood morbidity and mortality (WHO, 2002). A systematic review by Rabie and Curtis (2006) found that handwashing can reduce respiratory infections by 16%. Despite the proven effectiveness of handwashing, the rates of handwashing remain seriously low in the developing world; for example, results from structured observations of 531 rural and urban households in five regions of Ghana found that only 2% of 251 mothers washed their hands with soap after cleaning up their child after they had defecated and 4% of 397 mothers washed their hands with soap after defecation themselves (Scott et al., 2007). Additionally, a meta-analysis of handwashing studies across sub-Saharan Africa observed handwashing frequencies with soap between 3% and 29% (Curtis et al., 2009; Schmidt et al., 2009).

The tippy tap (see Figure 1.3) is a renowned appropriate technology for successful adoption of handwashing behavior. In fact, tippy taps are made of local materials and have been promoted in communities without access to running water for over 20 years (Watt, 1988). A study in Bangladesh found that households with a dedicated handwashing area were more likely to have soap and concluded that handwashing interventions that incorporated handwashing facilities were more likely to be successful (Luby et al., 2008).

Nevertheless, it is not enough to simply educate about handwashing and promote handwashing facilities and expect immediate behavior change. Handwashing interventions are often found ineffective just two years after implementation (Luby et al., 2009). Monitoring and evaluation is thus needed following these interventions. Consequently, the overall goal of this research was to design and implement a low cost and effective monitoring system for handwashing stations over two years to identify key factors in adoption of proper hand hygiene behaviors in Mali, West Africa that may be applied throughout the world.

1.1 Research Motivation

The author served as a Peace Corps Volunteer from 2009-2012 in a small village, Zeala, approximately 90 km north of the capital, Bamako, of Mali, West Africa (see Figure 1.2) as part of the Master's International Program (http://cee.eng.usf.edu/peacecorps/) (Mihelcic and Phillips, 2006). Mali is one of the poorest and unequal countries for women in the world, ranking 182 of 186 countries on the Human Development Index (HDI) and 128 of 135 countries on the gender gap index (Malik, 2013; Hausmann et al., 2012).

Motivation for this research originated from the author's experiences and activities in Mali as a water and sanitation engineer. The thesis author was very integrated in her community and became fluent in the local language, Bambara, scoring advanced high on her ACTFL close of service language exam in April of 2012. Before being installed in her community, the thesis author also went through nine weeks of intense cultural, language, and technical training provided by the Peace Corps. One of the first activities she organized were handwashing lessons at the primary school for Global Handwashing Day on October 12, 2009. She focused her service particularly on promoting handwashing in the community through the primary school, women's microfinance groups, and the water and sanitation committee she helped create. The author designed a tippy tap from local materials appropriate to her village like the one pictured in Figure 1.3 and piloted it outside her residence in the village.

Stations were not constructed or installed in each household by the thesis author. Instead, villagers, after having seen the station at the volunteer's house, started building them in their family compounds. The first station was installed by a woman on the water and sanitation committee that the thesis author helped create as part of her Peace Corps service. After she installed the station, other committee members followed her lead and within a matter of months, tippy tap handwashing stations spread throughout the entire village resulting in 47 stations that served 42 families. Later, through her work in a neighboring village, Nci'bugu, each of the 19 households there built a handwashing station. The author identified this as an opportunity for research to monitor the stations over time. She had seen and read about similar interventions in development that saw a high enthusiasm and adoption in the beginning with a subsequent decline to the status quo. Thus, she started visiting the stations once or twice a month to see if they were being used. Four usage variables were identified and monitored at least monthly over a two-year period: 1) presence of station, 2) whether the station was wet underneath after meal times, 3) how full the jerry can was (0%, 25%, 50%, 100%), and 4) presence and weight of soap.

Figure 1.2: The two study locations (Zeala and Nci'bugu) where handwashing stations were monitored were located 90 kilometers North West of Mali's capital, Bamako. The two villages are three kilometers apart (CIA, 2013). Figure is from government website and public domain.

Figure 1.3: The thesis author (left) and her work partner (right) promoting the tippy tap at the Peace Corps Training Center in Mali. Photo taken by the author.

1.2 Objective and Hypotheses

As previously stated, the overall goal of this research was to design and implement a low cost and effective monitoring system for handwashing stations over two years to identify key factors in adoption of proper hand hygiene behaviors in Mali, West Africa. This research goal was comprised of three main objectives:

1. Develop a comprehensive monitoring strategy for tippy tap handwashing stations.
2. Implement the tippy tap handwashing station monitoring system.
3. Analyze monitoring data and determine key differences between stations that may promote handwashing behavior change.

Based on a detailed literature review and the author's experience in Mali, the author developed a sustainability framework (see Figure 1.4) for the usage of handwashing stations that included six factors: gender, water, seasonality, wealth, training, and monitoring. (Larson et al., 1991; Pinfold and Horan, 1996; Carabin et al., 1999; Web et al., 2006; Bowen et al., 2007; Luby et al., 2007;

Scott et al., 2008; Schmidt et al., 2009; Luby et al., 2009; Wang and Hunter, 2010; Findley et al., 2010; Pickering et al., 2010). Six hypotheses were made in respect to these six sustainability factors (see Table 1.1) for the handwashing stations that were monitored throughout 2011-2013 in two rural communities in Mali.

Figure 1.4: Framework for the sustainability of handwashing stations usage with key factors of gender, water, seasonality, wealth, training, and monitoring.

Table 1.1: Hypotheses for the research on "Assessing Appropriate Handwashing Technologies in Mali, West Africa."

Theme	**Hypothesis**
1. Gender	1.1 Handwashing stations built or maintained by women will have higher usage rates over time.
2. Training	2.1 Lessons on handwashing behavior change will increase the usage of handwashing stations temporarily.
3. Water	3.1 Handwashing stations closer to water sources will have higher usage. 3.2 Handwashing stations that have more people involved in adding water will continue to be used more than those that only have one person or a select group (i.e. women or children) involved in refilling the station.
4. Seasonality	4.1 There will be a significant decrease in handwashing station usage during the rainy season (July-September).
5. Wealth	5.1 Handwashing stations in households that score higher on the Progress out of Poverty Index (PPI) for Mali will have higher usage.
6. Monitoring	6.1 Usage of handwashing stations will decrease with the age of the station and time of the intervention.

CHAPTER 2: PREVIOUS RESEARCH

2.1 History of Handwashing

Handwashing has an extensive history and life saving implications compared to other hygiene interventions. The importance of handwashing was first documented in 1199 by a Spanish physician in Cairo, Maimonides, who implemented the practice after contact with sick patients and noticed a reduction in morbidity and mortality. A physician in Italy in the 1800s and an American physician, Oliver Wendell Holmes, in 1843 also supported handwashing related to patient care (Larson et al., 1991). Two recent systematic reviews of handwashing research have shown an average 47% reduction of diarrheal risk which is consistent across studies (Curtis et al., 2003; Cairncross et al., 2010). This is an even greater reduction in risk than from sanitation improvements (36%) and water quality improvements (17%) (Cairncross et al., 2010). Furthermore, there is less evidence that providing community water supplies prevents diarrheal disease more than handwashing and such improvements are difficult to maintain (Zwane et al., 2007).

Handwashing can also prevent illnesses such as diarrhea that has many negative health implications. Diarrhea has been linked to poor growth which may be a result from decreased tropical entropathy; defined as under nutrition caused by a disorder in the small intestine which can be prevented by handwashing (Humphrey, 2009). Diarrheal disease is reported to cause 759,000 DALYs in persons 0-14 years of age in Mali (WHO, 2004). Finally, though less researched, handwashing is not only linked to decreasing diarrheal disease risk but decreased respiratory illness as well. For example, four studies showed a median reduction in respiratory illness of 45% after implementation of handwashing interventions (Curtis et al., 2003).

2.2 Handwashing and Behavior Change

In order to have more successful handwashing interventions, behavior change theories must be applied such as PRECEDE (predisposing, reinforcing, and enabling factors in education and health diagnosis evaluation) that may have a different message than germ theory. The PRECEDE behavior change model has been used in a handwashing intervention involving automated sinks in hospitals (Larson et al., 1997). The predisposing factor included focus groups of hospital staff to discuss important aspects and barriers to handwashing, enabling included automated sinks, and reinforcing included feedback from hospital staff in evaluations and observers results. This resulted in an increase in handwashing incidences during the study and immediate observation period but after several months the control and experimental group returned to baseline. The study concluded that although predisposing and enabling factors continued; reinforcing, in the form of feedback, did not (Larson et al., 1997). Though this study was not sustainable, important lessons on how to structure interventions can be gained.

Expanding on the enabling factor of PRECEDE, it is also important to understand "what motivates, facilitates, and hinders adequate handwashing behavior" (Curtis et al., 2003). This may not necessarily be the usual messages associated with interventions asserting that handwashing is good for your health and kills germs that you cannot see. For example, a large media intervention in Ghana used TV, radio and community events to promote handwashing which resulted in a 30% increase in reported handwashing with soap after defecation or cleaning up after a child (Scott et al., 2008). This promotion focused on the fact that "hands are not truly clean unless washed with soap" and did not mention germs at all (Scott et al., 2008).

Furthermore, a study in Botswana used key informant interviews, in-depth interviews, and focus groups to identify traditional beliefs about handwashing and diarrhea (Kaltenthaler and Drašar, 1996). In that study the authors found the three main reasons for people to wash their hands did not include disease prevention but removing dirt, looks, and comfort. Moreover, mothers identified 19 causes of diarrhea, none of which were associated with fecal-oral transmission but causes such as witchcraft, teething, food, and climate (Kaltenthaler and Drašar, 1996). Many cultures in Asia and Africa also separate dirty and clean hands; the left hand usually used for anal cleansing after defecation is the dirty hand which cannot be used to eat, shake hands, or handle money while the right hand is the clean hand (Hoque, B.A., 2003). Thus, when washing their hands, people in other countries may only wash the right hand based on their cultural beliefs and practices. Religious beliefs may also play an important role in hygiene behaviors such as the importance of cleanliness and ablutions before prayer for Muslims (Schmidt et al., 2009). Thus, these traditional concepts and beliefs must be identified and incorporated into any handwashing intervention.

Therefore, though handwashing may seem like a simple act, the sustained behavior change necessary to adopt the practice is much more difficult and complex (Schmidt et al., 2009). An effective message is important to motivate people to wash their hands whether they are hospital personnel that are too busy with patients and paperwork or mothers in developing countries busy with fetching water, cooking, taking care of children, and many other household chores. Before implementing a handwashing intervention or training program, it is also important to know those barriers to handwashing behavior change whether it is lack of time, access to water, or lack of money to buy soap.

2.3 Handwashing and Training

Training is an important component in any hygiene intervention particularly in schools. Handwashing education is not only limited to why handwashing is important but also when and why to wash hands. Those not accustomed to proper handwashing must learn the proper technique for the practice to be effective to prevent illness: use of a cleansing agent (soap, ash, or mud), rubbing of hands together for significant amount of time, rinsing, and proper drying (Hoque, 2003). It has also been demonstrated that families with higher education and literacy were significantly more likely to wash their hands with soap (Schmidt et al., 2009; Luby et al., 2009). Children can be catalysts for behavior change in communities as they may use what they learn to motivate fellow classmates, their parents, other family members, and siblings (Bowen et al., 2007). This is partially because their behaviors are not as embedded as those of adults. A study of 87 primary schools in China found that an expanded intervention which provided teacher training, videos, and a take-home pack for students with a handwashing game and soap resulted in a significant decrease in in-class illness (71% decrease) and absences (54% fewer) from the control (Bowen et al., 2007). This is crucial to children's education as more and healthier days in school will result in better knowledge retention (Snell, 2004). In addition, healthier children will not be able to spread illness to fellow classmates, teachers, or family members (Snell, 2004; Bowen et al., 2007).

2.4 Handwashing Appropriate Technology

Though training is an important component in adoption of handwashing behavior, it cannot be assumed that once people are educated on the practice that this alone will result in immediate behavior change (Pinfold et al., 1996). As stated in the section 2.2 that discussed the behavior change theory (PRECEDE), an enabling factor/product is required such as the automated sinks used in a hospital study (Larson et al., 1991; Biran, 2011). Research in Bangladesh found that households with a dedicated handwashing area were more likely to have soap and concluded that handwashing interventions that incorporated handwashing facilities were more likely to be successful (Luby et al., 2008). Tippy taps could fulfill this roll with little to no cost in developing country communities without access to running water. Tippy taps are an existing, widespread, and simple enabling technology appropriate for people in communities without access to running water to wash hands with soap (Biran, 2011).

Figure 2.1: Tippy tap handwashing station (reproduced from CDC, 2013). Figure is from government website and public domain.

Figure 2.1 shows an example of a tippy tap. The construction and use of tippy taps was explained in scientific journals as far back as 1988 in a letter to the editor in the *Journal of Tropical Pediatrics* by Major J. Watt who referenced their success in Zimbabwe (Watt, 1988). The U.S. Centers for Disease Control also promotes the use of the tippy tap (CDC, 2013).

The Global Scaling Up Hand Washing Project defines a tippy tap as an “enabling technology” which “are some of the external or environmental factors that influence individuals’ opportunity to perform a behavior, regardless of their ability and motivation to take action (Devine, 2010).” Tippy taps accomplish three important tasks: 1) they store and regulate the flow of water in sufficient quantity to facilitate handwashing, 2) manage or store soap within a household or institution, and 3) bring together water and soap in one place (Devine, 2010). This is especially important for busy mothers to have soap and water readily available whether they are washing before preparing meals, feeding their children, or cleaning up their child after they defecate.

There are many different variations of the tippy tap design (see http://www.tippytap.org/) because they are often made from locally available materials. Figure 2.2 provides an example of the tippy tap design used in this study. This design incorporates a bamboo foot peddle that attaches to the water jug handle so that it can pivot on the cross bar. This ensures that users do not need to touch the water jug with their hands and risk recontamination. Villagers surveyed in Uganda listed this as the primary advantage of the tippy tap (Biran, 2011). Soap is pierced using a nail or long metal “needle” used for hair braiding heated up on coals. String or a strip of cloth is then threaded through the hole in the soap and tied to a twig or metal washer and hung from the cross bar. A metal sardine can be pierced in the same way and positioned over the soap to protect it from rain, dust, and animals.

All materials to construct the tippy tap can be found locally. Used rope for tying the cross and the water jug and foot pedal is available as many families have small animals they tie up. The most the family may need to spend to construct a station is 250 cfa (about $0.50 USD) for the four-liter jug (originally contained motor oil or cooking oil) at a local market.

Tippy taps also consume less water which is important in developing countries where women often have to travel long distances to fetch water. Automatic sinks are programmed to run for 10 seconds to first wet hands, are then turned off for 10-15 seconds to lather, and turned back on for 10 seconds to rinse (Larson et al., 1997). If the faucet runs an average of 1.3 gallons/min, 20 seconds of water flow for wetting and rinsing hands would be approximately 0.33 gallons or 1.26 liters. If a woman defecates once a day, cleans up after her baby defecates twice a day, cooks three times, eats three times a day, and feeds her baby an extra two times then that adds up to a total of eleven hand washes corresponding to 13.9 liters per day as follows in Equations 2.1 and 2.2.

$$water\ for\ one\ handwash = 1.3\ \frac{gallons}{minute} \times \frac{1\ min}{60\ s} \times \frac{20\ s}{handwash}$$

$$= \frac{1}{3}\ gallon \times \frac{3.78\ L}{gallon} = 1.26\ L \qquad \text{(Equation 2.1)}$$

$$\frac{water\ required\ for\ one\ day}{woman} = 11\ \frac{handwashes}{day} \times 1.26\ L = 13.9\ L \qquad \text{(Equation 2.2)}$$

This is a significant volume of water since reasonable access to water is defined by the World Health Organization (WHO) as 20 L/capita-day (WHO, 2000). Conversely, tippy taps have a significantly lower flow rate and, accordingly, consume less water. Field measurements by the study's author (discussed later) have shown that a four-liter apparatus is enough for as many as 19 hand washes. The tippy tap thus uses on average of 211 ml per hand wash which would only correspond to 2.3 liters used for eleven hand washes, much smaller than the 13.9 liters needed for an automated sink. This of course is an ideal estimate as the design and use of the station impacts the water usage per hand wash. For example, the person who installs the station may incorporate a larger hole in the water jug that will increase the flow rate. Also, some users will keep their foot on the pedal while lathering with the soap which wastes water. Users often stated to the thesis author that children like to play with the stations and may empty the jug of water. In Mali, the common handwashing practice is to pass around a partially filled bucket of water and each person takes a turn rinsing their hands in the same water. Women and men eat separately and consequently have their own, separate washing buckets. Often the adults will wash their hands first, leaving the children for last and with the dirtiest water. This facilitates fecal-oral transmission rather than preventing it as the wash water becomes infected with the bacteria and pathogens from other peoples' hands and then they use those hands to eat with. Because the buckets are usually only 12.5% full and have a standard size of 17 liters this is at least two liters of wash water for four to ten people who may be eating together. A tippy tap would not require more water than this handwashing method but would take more time for each person to wash their hands separately especially if smaller children need to be helped by their mothers or siblings.

Figure 2.2: Tippy tap design used in this research study in Mali, West Africa. The design includes a bamboo foot peddle. Photos taken by author.

In conclusion, the tippy tap has a number of advantages and disadvantages (summarized in Table 2.1). One of the main disadvantages of the technology listed in the table and expressed by users in Uganda and Mali was that they needed to replace the station components (jerry can, posts, string, etc.) annually particularly because the plastic jerry would degrade in the sun leading to cracking and subsequent leaks (Biran, 2011). Moreover, in Mali, many families also keep goats, sheep, and cows that eat the soap even if it is covered with a sardine can. In Uganda, theft of soap occurred for some users since stations are left outside in an open compound at night or during the day when people are sleeping or in the fields (Biran, 2011). Though there are a number of important disadvantages to this appropriate technology, there are many important advantages to users as described in Table 2.1. Some of these advantages are the previously explained low-flow rate and water usage of the stations, the economy of the station since all materials can be found locally, and that the station serves as an enabling technology and constant reminder to wash hands with soap.

As with any technology there are disadvantages and it is important to understand these to both improve and promote the technology. Throughout and at the end of this research, users were consulted on their perceptions of the handwashing stations (this is why the sardine can was added to the design to prevent soap damage and the wooden foot pedal was replaced with bamboo as a more durable material) to fully evaluate the technology.

Table 2.1: Advantages and disadvantages of the tippy tap, an appropriate technology handwashing station (Biran, 2011).

Advantages	**Disadvantages**
• Low flow rate and water use • Constructed of local materials • Inexpensive • Entertaining for children, encourages use • Enabling technology for handwashing (visual cue) • Easy to construct	• High maintenance (components must be replaced annually) • More time required to wash hands • Aesthetics • Children use apparatus as a toy (empty out water and break components) • Animals can eat soap • Soap theft

2.5 Handwashing and Culture

Culture, and therefore religion and gender roles are extremely important when introducing and promoting a new behavior, particularly handwashing. Allegranzi et al. (2009) conducted an extensive literature review on the influence of religion and culture on handwashing promotion in the health care sector for the World Health Organization's (WHO) Global Patient Safety Challenge. They found in the review of 27, relevant articles that religion and culture are crucial to the development and practice of hand hygiene and must be incorporated in hand hygiene promotions globally. For example, Muslims practice ablutions (the act of washing oneself to cleanse before prayer) five times a day and view cleanliness as extremely important in the respect of Allah (Allegranzi et al., 2009). However, Muslims may be averse to using alcohol-based, hand sanitizers since they prohibit alcohol consumption. According to the 2009 census, 94.8% of the population in Mali is Muslim, 2.4% are Christian and 2% are Animist (CIA, 2013). Thus, hand hygiene promotion in Mali and other Islamic countries could focus on the importance of cleanliness to please Allah and should introduce hand sanitizers cautiously if at all.

In addition to cleanliness, a common belief in African and Muslim cultures is that the left hand is the "dirty" hand and the right is the "clean" hand (Allegranzi et al., 2009). This is the case in Mali where they use water and their left hand for anal cleansing, thus the left hand is considered dirty (Peace Corps-Mali, 2011). Only the right hand should be used to eat and prepare food, shake hands, and exchange money (Peace Corps-Mali, 2011). Though the statistics on Mali have a high percentage of Muslims and only 2% animist, many people in the rural communities have a mix of animist and Islamic beliefs particularly in the communities where this research was conducted (Peace Corps-Mali, 2011). Both communities observe the major Muslim holidays but also have sacred trees, fetishes and wells where sacrifices of chickens and other animals are performed several times a year particularly before the rainy season in hopes of a good harvest. Specifically in regards to hand hygiene, there is a general belief in the Bambara culture that if you wash your hands with soap you will wash your wealth away which makes promoting hand washing, especially among the older generations, more difficult (Peace Corps-Mali, 2011).

A general practice is to pass around a bucket partially filled with water before meal times and each person rinses their right hand before they eat from a communal bowl. Men and women eat separately while younger children of both sexes eat with the women. No soap is used and children are generally last to rinse their hands. Concepts of illness and transmission pathways are also different and Malians do not necessarily know about or believe in germs. They believe that people can fall ill even with Malaria from eating rich, sweet, or spicy foods, the cold, the wind, and witch craft.

Moreover, when considering culture we must also consider gender. As previously stated, Mali rates low on the global gender gap (128 of 135) and in Islam a man can have multiple wives. It is legal in Mali for a man to have up to four wives and arranged marriages are very common where girls can marry as young as 16. Furthermore, the average woman will have at least six children (CIA, 2013). The literacy rate of people over age 15 that can read and write is 43.1% for men and 24.6% for women and the average school life expectancy is eight years for men and seven years from women (CIA, 2013). Thus, women have little power, education, or influence in household decisions which is important in the purchase of soap, training comprehension, and construction of handwashing stations. They also have limited time to commit to handwashing as they have many children and household responsibilities from their defined gender roles to cook all meals, fetch water, take care of the children, wash clothes, and other household chores. In conclusion, it is essential to understand and incorporate this cultural context including religion and gender roles in hand hygiene promotion.

2.6 Handwashing and Gender

As most issues related to water and sanitation, handwashing is a gendered activity different for men and women in most developing countries as are the effects of diarrhea on women and their families. The following are some reasons why handwashing is a gendered activity because women are responsible for:

- fetching and storing the water that is used for handwashing and other hygiene activities;
- cooking meals which should involve washing their hands with soap before preparing;
- feeding children where they need to first wash their hands with soap;
- cleaning handwashing stations;
- cleaning latrines where they should wash their hands afterward; and,
- cleaning up after children since in direct observation of family compounds, most fecal contacts observed involved women (78%) (Luby et al., 2009).

It is understandable, then, that most hygiene interventions are directed toward women, specifically mothers, and evaluations in form of surveys or hand tests are also sampled from the woman head of the household (Webb et al., 2006; Luby et al., 2007). In addition, higher level of education of women has been significantly associated with higher rates of handwashing (Luby et al., 2009; Schmidt et al., 2009), while a father's education level was not found to be significant (Luby et al., 2009). El Azar et al. (2009) also hypothesized that diarrhea is a gendered health problem since female children are more likely to be exposed to pathogens from their greater involvement in household chores. Furthermore, the study associated lower empowerment scores for women with reported diarrhea cases but with slim significance (El Azar et al., 2009). These are important findings and thus point to the need to be researched more to quantify the gendered differences in handwashing. Nevertheless, handwashing interventions should incorporate men as well since they may be the purchasers of soap or builders of handwashing stations and also have contact with pathogens and children (Cairncross and Shordt, 2004).

For example, in a study on tippy tap promotion in Guatemala (Hurtado and Booth, 1995), families were first provided tippy taps and asked for their feedback. Mothers felt it was too complicated to construct and maintain so then fathers were encouraged to install the tippy tap while children would maintain it. This finding emphasized the need to involve both genders and all age groups in handwashing. Through later evaluation of the tippy taps in Guatemala diarrheal incidence was found to be higher in the control than the intervention group, but this was not found to be statistically significant. However, intervention group mothers were better able to show correct handwashing techniques than the control groups (Hurtado and Booth, 1995). Consequently, the training component of the handwashing promotion in this research specifically targeted women without neglecting men. Handwashing lessons were given to women's microfinance groups in the target villages and also to the mixed-gender water and sanitation committees. It is hypothesized that handwashing stations built/maintained by women will be used more given women's greater role in the household and with family hygiene as well as extra educational sessions.

2.7 Handwashing and Wealth

Several handwashing studies have identified a form of socio-economic status to have significant association with handwashing practice. Families with radios and mothers with greater than three years of education in Nicaragua were found more likely to wash their hands before preparing a baby's bottle than households where the mother had less than three years of education and no radio (Gorter et al., 1998). In Bangladesh, a study found that mothers with greater material wealth were more likely to state that they washed their hands after defecation than mothers who owned less material goods (Bhuiya et al., 1990). Another study in Bangladesh related a comprehensive socio-economic indicator with a handwashing usage variable (presence of soap). In this 2006 study, 6,970 households were surveyed and divided into wealth index quintiles based on number of household rooms and belongings, household construction type, mother's education and type of cooking fuel. There were significantly higher ($p < 0.05$) proportions of soap presence at each type of area for hand washing (inside or outside at varying distances from the house) in the higher wealth quintiles (Luby et al., 2008).

2.8 Hygiene and Water

In this study, it is hypothesized that handwashing stations that are further away from water sources will be used less. The reason for this is that stations where the water source is further away will be more of a burden on women who are responsible for water collection for bathing and cooking needs and they will not always have the time to fetch more water for handwashing. A study in Kenya found that having a water source in a family compound as opposed to outside resulted in higher handwashing frequencies (Schmidt et al., 2009) while a study in Bangladesh discovered that the availability of water or soap doubled the chances of washing hands with soap (Luby et al., 2009). Through fecal coliform testing of hands, Hoque et al. (2010) found a significant reduction in fecal coliform counts with increasing the volume of water used to rinse hands. Wang and Hunter (2010) conducted a systematic review and meta-analysis of the association between self-reported diarrheal disease and distance from home to water source. Of the seven studies referenced in the meta-analysis, six had positive odds ratios indicating an increase in diarrheal disease for those people who live further away from their water sources. The combined odds ratio in that study was 1.45 (between 1.04-1.68 with a 95% confidence interval).

Moreover, Wang and Hunter (2010) reported that the study by Gascon et al. (2000) had the only negative odds ratio of the six studies relating diarrheal disease and distance to water source, meaning that there was an increase in diarrheal disease with increased proximity to a water source. It should be noted that this particular study was conducted during the rainy season when water sources can often become contaminated from runoff as they are often uncovered (from trash piles, animal and human feces, latrines, etc.). Water sources in this situation may have become vectors for spreading diarrheal disease. Seasonality (discussed in next section) in relation to the diarrheal disease and distance to a water source was out of the scope for this meta-analysis but may be an important factor to consider. Wang and Hunter (2010) called for further research in the correlation between diarrheal disease and distance to a water source. Though the research in this thesis does not attempt to measure diarrheal disease incidence, it does seek to compare the usage of handwashing stations and their distance to a water source.

Based on these literature findings, it is hypothesized that stations closer to water sources will have a higher usage. GPS coordinates were taken of each water source and handwashing station. Women were asked where they fetch their water depending on the season and distances between the station and water source were calculated and compared to overall station usage.

2.9 Seasonality and Handwashing

Seasonality has a huge impact on human health and activities in many developing countries particularly on subsistence farming populations. For example, a study by Findley et al. (2010) in Niono, Mali gathered disease incidence data from seventeen community health centers from January 1996 through June 2004 and found the highest occurrence of diarrheal disease, and elevated occurrences of upper respiratory infection and malaria occurred during the rainy season (months of July-October). This is also the period of highest human energy expenditure when people are in the fields cultivating their crops. Though there have not been many studies in the literature on the impact of seasonality on handwashing, it has been found that there are higher contamination of bacterial fingertip samples during the wet season (Pinfold et al., 1996).

Other research in Mali (Adams, 1994) investigated the seasonal differences in childhood nutrition. Adams (1994) found a significant decrease in weight-for-height z-scores of children under five during the rainy season: June, July, August and September. This period also corresponds to the end of household food stores and rise in grain prices before the new harvest since many families in rural Mali experience food insecurity during this time period. In addition, this is the time of highest human energy expenditures as the subsistence farming reliant rural population cultivate their crops (Adams, 1994). Moreover, there is a slight increase in weight-for-height z-scores from September to October followed by a decline to a minimum in December. In September/October, generally the first harvest of corn in the fields closest to the village are ready for consumption which help supplement empty grain stores in the short-term. It is thought that November and December may "…reflect a time lag in linear growth due to the effect of the particularly harsh rainy season…" (Adams, 1994).

Thus, the rainy season is the most important time for handwashing with the highest incidences of diarrhea and elevated incidences of ARIs that can be easily transmitted from person-to-person if they are not washing their hands before they eat. Additionally, everyone's immune systems, particularly those of children, are also compromised due to malnutrition and this is only exacerbated by illnesses. The study in Mali by Adams (1994) documented an increase in morbidity of children to 64% in the rainy season compared to 24% and 19% in the harvest and hot seasons. This is why the rainy season may also be referred to as the dying season particularly for the elderly and young children. Despite the necessity of handwashing in the rainy season, this time may be the most difficult to maintain the behavior as people, particularly women, have less time in the busy farming season. In fact, a time-use study in Bangladesh found that women devote the least amount of time to chores such as fetching water or cleaning in the busy, rainy season (Zaman, 1995). Moreover, increased work-loads of nurses in the United States were negatively correlated with handwashing rates (Bittner et al., 2002).

This seasonal phenomenon is not only particular to Mali but the Niger River Delta and all countries near the equator with heavy rainy seasons. Food insecurity is a global problem as well. Thus, it is important to incorporate seasonality into handwashing interventions and make particular emphasis on washing hands during seasons known to have high incidences of diarrhea and ARI. This research monitored the usage of handwashing stations over time with particular attention to seasonality in the statistical analysis. It is hypothesized in this research that there will be a statistically significant decrease in the usage of handwashing stations during the rainy season.

2.10 Handwashing Monitoring

There is a serious lack in monitoring and evaluation in development projects particularly in water and sanitation (Schweitzer, 2013). For example, the International Water and Sanitation Center (IRC) found that 36% of pumps across 21 countries in sub-Saharan Africa are non-functional with an investment loss of $1.2 to $1.5 billion dollars in 20 years since NGOs and government agencies focus more on installing new pumps than maintaining the old ones (IRC, 2009). Though similar functionality and expense data are not available on the amount of money spent on hygiene interventions, the promotion model is the same: emphasis on “new” coverage with short intervention timelines of 1-5 years (Fogelberg, 2010). Koestler (2010) emphasized how a long-term approach would require the same investment but also increase people’s access to water as opposed to a short-term model that expends the same amount of money but results in fewer people having access to clean water . A similar model is also needed for promotion of handwashing behavior change. However, while it is easy to assess the functionality of a pump or water source, it is another matter to assess handwashing adoption and impact on diarrheal disease.

Nevertheless, there has been an effort by the scientific community to evaluate the effectiveness of handwashing interventions on diarrheal incidences and developing indicators of handwashing adoption. A wealth of literature is available concerning handwashing and diarrhea prevalence but there are flaws in many of their methodologies and much more research is still needed. In summary, 38 papers before 2002 were identified that are related to handwashing and diarrhea in both systematic reviews mentioned earlier (Curtis et al., 2003; Cairncross et al., 2010). In one systematic review 17 of the papers were not able to be used (Cairncross et al., 2010). Recent articles include hygiene interventions that consist of training, soap distribution, and media interventions (Luby et al., 2004; Scott et al., 2008). Handwashing interventions have also not been found to be sustainable after the study period. For example, a soap distribution intervention in Pakistan found that diarrheal prevalence in control and experimental groups were not much different after several years (Luby et al., 2009). Thus, more research is needed on effective evaluation methods and interventions for handwashing.

Methods for evaluating handwashing behavior and/or interventions have been tested through surveys, simple observation of washes, structured observation, a hygiene index, teacher or parent recordings of illnesses/absences, and bacterial sampling through hand rinses or finger prints (Larson et al., 1991; Scott et al., 2008; Webb et al., 2006; Pickering et al., 2010). Current and past handwashing research has limitations since it is difficult to assess such a behavior. For example, many are not blinded or randomized (Luby et al., 2004; Curtis et al., 2003).

Table 2.2 summarizes important research methods in the area of handwashing adoption in both the developing and developed world. Each method has its advantages and disadvantages, though combinations will help get a more realistic grasp of the actual practice of handwashing. Over reporting of handwashing behavior is inherent in evaluation surveys since oral reporting does not reflect reality especially if respondents have been educated on handwashing (Manun'Ebo et al., 1997; Curtis et al., 2003; Biran et al., 2008). They often tell the surveyor what he/she wants to hear rather than the truth. Though structured observations have been cited as the most effective they are expensive and time consuming. Furthermore, the presence of an observer is known to increase handwashing incidences, commonly referred to as the "Hawthorne effect" in much of the literature on handwashing (Carabin et al., 1999; Bittner et al., 2001; Pittet et al., 2004). The "Hawthorne Effect" was first coined in research at the Western Electrical Company's Hawthorne Works in the 1920s and 30s (McCarney et al., 2007). Researchers were investigating ways to increase productivity such as with lighting and found that even with a decrease in light that productivity increased. The researchers then realized that their *monitoring* was increasing productivity despite any changes they made to the factory environment and was thus coined the "Hawthorne Effect." Similar to structural observation, though maybe less prone to result in a "Hawthorne Effect", bacterial testing is also expensive. Other, cheaper methods have been evaluated but are not as effective at evaluating true handwashing behavior as structured observations (Webb et al., 2006).

There is need for a rapid indicator to assess handwashing adoption after an intervention particularly as we near 2015, the target year for the Millennium Development Goals, and set new goals and indicators that will hopefully incorporate hygiene practices into sanitation and water coverage. A number of studies referenced in Table 2.2 explored the performance of alternative indicators such as surveys, spot-checks, and handwashing demonstrations compared to structured observations (Manun'Ebo et al., 1997; Bittner et al., 2002; Biran et al., 2008; Luby et al., 2009). The study by Biran et al. (2008) in India did not find any statistically significant association between 27 other hygiene indicators including surveys and presence of soap (most of them were an overestimate of hygiene behavior). Bittner et al. (2002) was successful in monitoring soap and paper towel usage to assess handwashing in health care facilities. Manun'Ebo et al. (1997) did not find a relation between reported handwashing behavior from surveys and observations but used the presence of soap to assess handwashing practice. Furthermore, Luby et al. (2009) found that the presence of soap and water doubled the chances of handwashing with soap. Finally, in a Canadian health care study, monitoring alone decreased fecal coliform counts on hands while the handwashing intervention was found to have no significant impact (Carabin et al., 1999).

Thus, this research aims to develop an effective and economical monitoring and evaluation system for handwashing by checking functionality of the station, the wetness under the station after meal time, amount of water in the jerry can, and the presence and weight of soap. As evident in the literature review, this combination of indicators has not been used. This combination of handwashing indicators should provide a better assessment of handwashing adoption and way to identify important factors (gender, water, training, wealth, and seasonality) in better promoting handwashing behavior change.

Table 2.2: Summary of literature on handwashing monitoring methods, findings, and limitations.

Reference	Location	Methods	Findings	Limitations
Kaltenthaler and Drašar, 1996	Botswana	Observations, key informant interviews, in-depth interviews, focus groups, non-participatory direct observation, anthropometric measurements, monitoring of diarrhea morbidity, socio-economic questionnaire	-Hygiene behavior and community and traditional beliefs related to diarrhea -Various qualitative and quantitative methods needed to study hygiene behavior -3 reasons to adopt handwashing: cosmetic, comfort, remove dirt. Health reasons not primary concern -Mothers identified 19 other causes to diarrhea than fecal-oral transmission routes -Higher diarrhea incidence in children >1 year, least diarrhea incidence children >3 years -Poor hygiene index associated with higher diarrhea incidence	-Diarrheal incidence was self reported
Biran et al., 2008	India	Structured observation, questionnaire survey, pocket voting, hand-wash demonstration and environmental check	-27 hygiene indicators (surveys, handwashing demonstration, presence of soap, etc.) did not show agreement with structured observation of handwashing incidences. All an overestimate.	-Hawthorne effect of structured observation
Carabin et al., 1999	Canada	Teacher recording of absences and diarrheal and respiratory disease incidences, measurement of fecal coliform on teacher and student hands, follow-up telephone questionnaire	-Monitoring reduced fecal coliform counts on hands and disease incidence rates (diarrhea (IRR = 0.733) and respiratory tract infections (IRR = 0.80)) -Handwashing intervention had no impact on disease incidence	-Potential underreporting of disease incidence by teachers
Schmidt et al., 2009	Kenya	Surveys, direct structured observation, structured interview, and water access	-Handwashing incidence with soap:24% -Handwashing with just water: 25% -Handwashing more common after defecation (32%) than in food preparation (15%) -Higher incidences of handwashing associated with whether a water source was in the home, higher education and literacy levels, and exposure to media outlets	-Hawthorne effect of direct observation -Compounding factor; people with higher socio-economic status have greater media access (ex. T.V. ownership)

Table 2.2 (Continued)

Reference	**Location**	**Methods**	**Findings**	**Limitations**
Biran, A., 2011	Uganda	Spot check observation of tippy taps (presence of station, soap, and water)	-Knowledge of tippy tap does not translate into construction of one -Weak dissemination of appropriate technology between villages -Difficult to scale-up promotion of tippy taps -Disadvantage of tippy tap is the needed annual replacement of parts -Handwashing with tippy tap uses 40-50ml of water	-Study was only seven days -No quantitative data collected in study -Tippy taps constructed near latrines and only used after latrine use
Hoque, B.A., 2010	Bangladesh	Direct observations, interviews, fecal coliform testing of hands	-Post defecation: 38% used mud, 19% used soap, 2% used ash and 41% used only water as a cleansing agent (n = 90) -81% of respondents who didn't use soap said they would if they could afford it -56% of women only washed their left hand - Women's age, education level and family size were not associated with handwashing quality - Ash showed similar reduction in fecal coliform counts as soap but mud varied depending the source and dryness -Greater rubbing frequency and water usage showed reduction in counts of fecal coliforms	-Hawthorne effect of direct observation
Luby et al., 2009	Bangladesh	Structured observation, cross-sectional observation, spot check of soap and water availability	-Water present at 72% of households -Soap present at 52% of households -Most fecal contacts by females (79%) -18% of people washed hands after fecal contact -Availability of water or soap doubled the probability of handwashing -Mothers education level associated with higher handwashing incidences while fathers education level was unrelated	-Focused only on handwashing after latrine use and fecal contact -Hawthorne effect -Study limited to rural areas

Table 2.2 (Continued)

Reference	Location	Methods	Findings	Limitations
Bowen et al., 2007	China	Teacher recorded illnesses and absences of students	-Standard intervention schools did not have statistically significant decrease in disease incidence compared to control while expanded intervention had significantly fewer absences (42%) and illnesses (71%)	-Teachers not blinded -Illness incidence collected weekly, not daily -Children in control were less likely to have piped sanitation facilities in their homes -Study did not include poorest communities
Manun'Ebo et al., 1997	Zaire	Direct observations, questionnaires	-No agreement between observed and reported handwashing incidences -Over reporting of handwashing practice (Soap present at 68% of households, 97% of respondents claimed to wash hands with soap) -Soap observed 5% of the time before handling food	-Hawthorne effect particularly for female observers
Pinfold and Horan, 1996	Thailand	Finger impression technique (measurement of fecal streptococci), diarrheal incidence surveillance of children under 5, questionnaire	-Handwashing intervention significantly reduced diarrheal incidence and bacterial counts -Villages with improved performance had a "stronger sense of community" and more people involved in the intervention. - No significant difference between homes who received handwashing containers and those that did not -Higher fingertip contamination in wet season than dry season -Knowledge of appropriate handwashing behavior does not always translate into progress	-Under reporting of diarrheal incidence by mothers. -Only 75% of diarrheal incidence calendars turned in
Pittet et al., 2004	United States	Individual observation, self-report questionnaire	-Handwashing adherence: 57% -Handwashing incidences increased with awareness of observer (61% as opposed to 44% of those unaware of being observed), belief of being a good role-model to colleagues, a positive attitude toward handwashing, and easy access to hand-rub solution -High workload decreased handwashing incidences	

Table 2.2 (Continued)

Reference	Location	Methods	Findings	Limitations
Bittner et al., 2002	United States	Direct observation, recording of paper towel, soap usage and occupied hospital beds	-Handwashing incidences reduced with increased patient-to-nurse ratio -Direct observation increased rates of handwashing -Providing handwashing incidence results did not result in increase of handwashing	-Hawthorne effect -Variation between paper towel and soap usage and handwashing incidences observed -Control and intervention units located close to each other (potential for cross-contamination)
Wilson and Chandler, 1997	Indonesia	Survey including diarrheal incidence reporting by mothers	-Two years following intervention 94% of women said they washed their hand with soap but only 79% had soap -89% reduction in diarrheal incidence compared to baseline before intervention and 57% decrease in control	-All data collected in the dry season -under reporting of diarrheal incidence by mothers

CHAPTER 3: ASSESSING APPROPRIATE TECHNOLOGY HANDWASHING STATIONS IN MALI, WEST AFRICA

3.1 Introduction

Proper hand hygiene is the most effective and efficient method to prevent over 1.3 million deaths annually from diarrheal disease and Acute Respiratory tract Infections (ARIs) and is indispensible in achieving the fourth United Nation's Millennium Development Goal (MDG) to reduce the childhood mortality "…rate by 2/3rds between 1990 and 2015" (United Nations, 2011). In addition, every year there are an estimated 4 billion cases of diarrhea that result in 2.2 million deaths, account for 15% of the mortality for children at their most vulnerable age (under 5 years), since most of these deaths (1.7 million) are children under five years of age (UNICEF, 2008). Though interventions in sanitation and water quality and quantity improvements also reduce incidences of diarrheal disease, hygiene is the most effective. In a systematic review of studies to reduce diarrhea, handwashing alone has been found to reduce diarrhea by 47% and respiratory infections by 16% which has the potential of preventing a millions of deaths (Curtis et al., 2003; Rabie and Curtis, 2006).

Despite the proven effectiveness of handwashing, the rates of handwashing remain seriously low in the developing world; for example, results from structured observations of 531 rural and urban households in five regions of Ghana found that only 2% of 251 mothers washed their hands with soap after cleaning up their child after they had defecated and 4% of 397 mothers washed their hands with soap after defecation themselves (Scott et al., 2007). Additionally, a meta-analysis of handwashing studies across sub-Saharan Africa observed handwashing frequencies with soap between 3% and 29% (Curtis et al., 2009; Schmidt et al., 2009). A study in Bangladesh found that households with a dedicated handwashing area were more likely to have soap and concluded that handwashing interventions that incorporated handwashing facilities were more likely to be successful (Luby et al., 2008). The tippy tap may be just what is needed for successful adoption of handwashing behavior since the stations are also easily constructed, affordable and made of local materials. Tippy taps are a renowned appropriate technology for handwashing (see Figure 2.1 in Chapter 2) that has been promoted in developing communities without access to water for over 20 years (Watt, 1998).

Even so, it is not enough to simply educate about handwashing and promote handwashing facilities and expect immediate behavior change. Handwashing interventions are often found ineffective just two years after implementation (Luby et al., 2009). Monitoring and evaluation is thus needed following these interventions. Accordingly, the goal of this research was to design and implement a low cost and effective monitoring system for handwashing stations over two years to identify key factors in adoption of proper hand hygiene behaviors in Mali, West Africa that may be applied throughout the world. The key factors investigated were: gender, seasonality, water, wealth, monitoring, and training as displayed in Figure 1.4 in Chapter 1.

First, any hygiene intervention usually begins with training of a target population (community and/or school). Children can be catalysts for behavior change in communities as they may use what they learn to motivate fellow classmates, their parents, other family members, and siblings (Bowen et al., 2007). A study of 87 primary schools in China found that an expanded intervention which provided teacher training, videos, and a take-home pack for students with a handwashing game and soap resulted in a significant decrease in in-class illness (71% decrease) and absences (54% fewer) from the control (Bowen et al., 2007). In this study, an interactive handwashing lesson was conducted at the local school and the handwashing monitoring data was analyzed to determine if that intervention had an impact on the usage of handwashing stations in that community.

Next, gender has been considered an important component in hygiene promotion as women have more responsibilities related to hygiene such as household chores (fetching water and cooking) and caring for children. Higher level of education of women has been significantly associated with higher rates of handwashing (Luby et al., 2009; Schmidt et al., 2009), while a father's education level was not found to be significant (Luby et al., 2009). It was hypothesized that stations built by women would have higher usage than those built by men.

Another key factor in handwashing behavior adoption is the distance the household is from a water source. A study in Kenya found that having a water source in a family compound as opposed to outside resulted in higher handwashing frequencies (Schmidt et al., 2009) while a study in Bangladesh discovered that the availability of water or soap doubled the chances of washing hands with soap (Luby et al., 2009). This research also investigates how proximity to a water source as well as who adds water to the handwashing station impacts handwashing station and soap usage.

Furthermore, several handwashing studies have identified a form of socio-economic status to have significant association with handwashing practice. Families with radios and mothers with greater than three years of education in Nicaragua were found more likely to wash their hands before preparing a baby's bottle than households where the mother had less than three years of education and no radio (Gorter et al., 1998). In Bangladesh, a study found that mothers with greater material wealth were more likely to state that they washed their hands after defecation than mothers who owned less material goods (Bhuiya et al., 1990). Another study in

Bangladesh related a comprehensive socio-economic indicator with a handwashing usage variable (presence of soap) and found significantly higher ($p < 0.05$) proportions of soap presence at each type of area for hand washing (inside or outside at varying distances from the house) in the higher wealth quintiles (Luby et al., 2008). This study will explore the statistical association of soap usage and other handwashing usage indicators in Progress out of Poverty Index® (PPI®) for Mali rankings.

Less researched in relation to handwashing but just as crucial as the other factors, seasonality has a huge impact on human health and activities in many developing countries particularly on subsistence farming populations. A study by Findley et al. (2010) in Niono, Mali gathered disease incidence data from seventeen community health centers from January 1996 through June 2004 and found the highest occurrence of diarrheal disease, and elevated occurrences of upper respiratory infection and malaria occurred during the rainy season (months of July-October) (see Figure 2.2 in Chapter 2.7). The rainy season is at the highest period of human energy expenditure when people are in the fields cultivating their crops and also the period of greatest food insecurity since the previous year's stores are depleted before the new harvest. There have not been many studies in the literature on the impact of seasonality on handwashing, though it was found in a study by Pinfold et al. in 1996 that there was higher contamination of bacterial fingertip samples during the wet season. It was hypothesized in this study that there will be a decrease in handwashing station usage during the rainy season since people have less time to maintain a handwashing station and less money to buy soap during this period. Even in the United States, handwashing studies in hospitals found that increased patient-to-nurse ratios decreased handwashing incidences (Bittner et al., 2002; Pittet et al., 2004).

Current and past handwashing research has limitations since it is difficult to assess handwashing behavior. Methods for evaluating handwashing behavior and/or interventions have been tested through surveys, simple observation of washes, structured observation, a hygiene index, teacher or parent recordings of illnesses/absences, and bacterial sampling through hand rinses or finger prints (Larson et al., 1991; Scott et al., 2008; Webb et al., 2006; Pickering et al., 2010). Over reporting of handwashing behavior is inherent in evaluation surveys since oral reporting does not reflect reality especially if respondents have been educated on handwashing (Curtis et al., 2003; Biran et al., 2008; Manun'Ebo et al., 1997). Though structured observations have been cited as the most effective they are expensive, time consuming and the presence of an observer is known to increase handwashing incidences, commonly known as the "Hawthorne effect" (Carabin et al., 1999; Bittner et al., 2001; Pittet et al., 2004). Finally, bacterial testing is also expensive and cheaper methods have been evaluated but are not as effective at evaluating true handwashing behavior as structured observations (Webb et al., 2006).

Nevertheless, there have been successful indicators for monitoring handwashing. Bittner et al. (2002) were able to effectively monitoring soap and paper towel usage to assess handwashing in health care facilities. Manun'Ebo et al. (1997) did not find a relation between reported handwashing behavior from surveys and observations but used the presence of soap to assess handwashing practice. Furthermore, Luby et al. (2009) found that the presence of soap and water doubled the chances of handwashing with soap. Thus, based from this literature, this research developed an effective and economical monthly-bimonthly monitoring system to assess handwashing behavior over a two year period by utilizing previous methods (presence of station and soap) in addition to adding new indicators (wetness under the station after meal times, amount of water in the jug) or a health care facility indicator in the developing country context (weighing of soap). This combination of handwashing indicators should provide a better assessment of handwashing adoption and indicators and identify important factors (gender, water, training, seasonality, wealth, and monitoring) in better promoting handwashing behavior change throughout the world.

3.2 Methods

The study took place in two small, rural villages (Zeala and Nci'bugu) in Mali, West Africa approximately 90 kilometers North West of the capital, Bamako (refer to Figure 1.2 in Chapter 1), where the thesis author served as a water and sanitation engineer for the Peace Corps between 2009 and 2012. Both communities spoke the same language and observed the same religious beliefs and practices (Islamic and animist). Zeala is a slightly larger village off the main road with a population of 669 as of November 2009 while Nci'bugu had a population of 252 in October 2010 and was two kilometers from the main road. Zeala had more women's groups (four microfinance and one Shea Butter cooperative) while Nci'bugu had one women's microfinance group.

The research methods described below were first considered exempt by the Institutional Review Board (IRB) of the University of South Florida under IRB# Pro00004487 since monitoring of the handwashing stations was not considered human subjects research. However, when the thesis author added PPI® questionnaires to her research methods, a revised study (IRB# Pro00013532) was submitted and approved on July 2, 2013. See Appendix A for all IRB documentation in this study.

In this research, both qualitative and quantitative methods were utilized in monitoring and evaluation of appropriate technology handwashing stations. Qualitative methods included surveys and seasonal calendars while quantitative methods consisted of monitoring of handwashing station usage variables once to twice a month and measuring soap and water usage for handwashing stations. From October-November of 2009, all 42 households in Zeala were given a baseline water and sanitation survey composed of 42 questions regarding their water, sanitation and hygiene (WASH) practices (see Appendix B). This same baseline survey was administered to the 19 households in Nci'bugu in October 2010. In September-December of 2012, the same survey was administered again in both communities.

In the baseline survey, a representative of each household was asked basic demographic information on household size and composition, their water source and treatment methods, an open-ended question on how they washed their hands followed by a more direct question if they washed their hands with soap. In January and February of 2010, community mapping and seasonal calendars were created by the village water and sanitation committees that consisted of both men and women using the Participatory Action for Community Assessment (PACA) manual. Throughout the researcher's service, she coordinated handwashing lessons at the primary school and women's microfinance committees in Zeala, and the water and sanitation committees in both villages. A demonstration tippy tap handwashing station was installed at the volunteer's house in November 2009 which was followed by spontaneous adoption in both communities throughout 2010 and 2011. By February 2012, 47 handwashing stations had been constructed in Zeala since May 2010 (see Figure 3.1). Stations in Nci'bugu were built 10 months later than those in Zeala. The first station was built March 18, 2011 and the last was built April 30, 2011, bringing the total to 19 handwashing stations (see Figure 3.2).

Once a tippy tap was installed the researcher would conduct a small handwashing lesson at the household. Families were asked three initial questions: 1) who built the station, 2) who adds water to the station, and 3) who purchases the soap. After a household constructed a handwashing station, bi-monthly to monthly visits were made after lunch time usually between 12:30PM and 3:00PM. During these visits, observations were recorded on four usage variables: 1) the presence of cleansing agent (soap or white ash), 2) if the ground under the station was wet, 3) how much water was in the jug (0%, 25%, 50%, 75% and 100%), and 4) soap usage (see Appendix F).

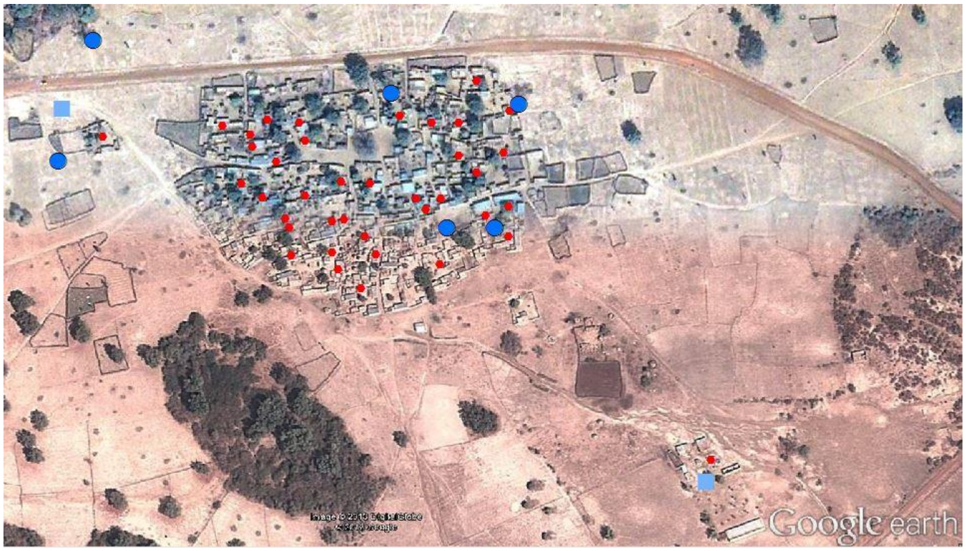

Figure 3.1: Location of 47 tippy taps (red circles), six wells (blue circles) and two pumps (blue squares) in Zeala generated in ArcMap 10.1 using satellite imagery from Google Earth and GPS coordinates collected by the thesis author.

Figure 3.2: Location of the 19 tippy taps (red circles), three wells (blue circles) and pump (blue square) in Nci'bugu generated in ArcMap 10.1 using satellite imagery from Google Earth and GPS coordinates collected by the thesis author.

Concerning soap usage, in the first year, each household was asked how many bars of soap they had purchased between visits and/or the author recorded when there was a new bar of soap. The author weighed 30 standard bars of soap that were sold in the local shops for 100cfa (approximately $0.21 U.S. dollars) to determine their average weight (104.4 g). Soap usage (g/person/household/day) was calculated by dividing the average weight of the soap by the length of time it took the household to use the bar of soap and the household size. During the second year of this study, soap at all stations were weighed each visit using a small scale (0-150 g +_0.01 g) to obtain a more accurate amount of soap usage. A sensitivity analysis for soap weights given moisture content and seasonality was not conducted. However, soap was always weighed at the same time of day (1:00PM-3:00PM) and all stations were visited within 2-4 days of each monitoring period which most likely limited variation of soap weights due to weather changes.

At the end of the two year monitoring period, a more comprehensive survey focusing on handwashing was administered to 39 households in both communities (Zeala and Nci'bugu) in November 2012 (see Appendix C). Users were asked who in the household used the handwashing stations and why or why not, as well as difficulties they encountered with the appropriate technology, the importance of handwashing and follow up questions on diseases that handwashing with soap can prevent and their transmission methods. Lastly, the thesis author administered the ten questions in Progress out of Poverty Index® (PPI®) for Mali (see Appendix D) in July 2013 for all active and previously active handwashing stations in both villages (see Appendix E for the raw PPI® survey data). The Grameen bank coordinates and tests the PPI® in each country, selecting ten questions from larger surveys that are 200 to 1,000 questions on household income or expenditures (PPI®, 2013).

For all statistical analysis, SPSS version 21 software was used to analyze the handwashing station data collected. The Pearson's Chi-squared test for independence, independent-samples t-test, one-way analysis of variance (ANOVA) test, and the one-way repeated measures ANOVA were statistical tests employed in the data analysis of this research. How each of these statistical tests was applied in the data analysis is explained in Table 3.1. First, the Pearson's Chi-squared test for independence was used to determine if there was an association between the categorical variables of gender, season, village, year, and water source proximity to the nominal handwashing station, usage variables of: functionality, presence of cleansing agent, and ground wetness. This test uses variable frequency tables to calculate observed and expected frequencies (the row total multiplied by the column total divided by your sample size) (Blair and Taylor, 2008). Next an obtained chi-square (χ^2) is computed by dividing the sum of the difference between the observed frequencies and expected frequencies squared by the expected frequency for each cell (see Equation 3.1) (Blair and Taylor, 2008).

$$\text{obtained } \chi 2 = \sum \frac{(f_o - f_e)^2}{f_e} \qquad \text{(Equation 3.1)}$$

This obtained chi-square (χ^2) is then compared to a critical χ^2 based on a normal distribution. If the obtained χ^2 value is greater than the critical χ^2 value then the null hypothesis that the variables are independent of each other must be rejected (i.e. gender and presence of a cleansing agent) (Blair and Taylor, 2008). Additionally, the phi correlation coefficient was calculated by dividing the obtained chi-square value by the sample size (Pallant, 2010). The phi correlation coefficient is an indicator of effect size or the magnitude of the difference between the variables being compared (Pallant, 2010). For a two-by-two table or comparison of variables each with two categories (i.e. male and female and presence or absence of soap), a phi correlation, coefficient value of 0.01 is small, 0.03 is medium, and a large effect size has a value of 0.50 or higher (Pallant, 2010).

The independent samples t-test was used to compare soap usage, a continuous variable, amongst the categorical variables (gender, season, and village). In this test, a t-statistic is calculated to determine if there is a statistically significant difference between the means of two groups (i.e. mean soap usage of stations during the rainy season compared to the mean soap usage of stations during the dry season). The obtained t-statistic is calculated using Equation 3.2 by dividing the difference between the square of the means ($\bar{x}_1$ and $\bar{x}_2$) of the two groups by the square root of the variance (S_p) squared multiplied by the sum of the inverse of the two sample sizes (Blair and Taylor, 2008).

$$\text{obtained t} = \frac{(\bar{x}_1 - \bar{x}_2)^2}{\sqrt{S_p{}^2({}^1/_{n_1} + {}^1/_{n_2})}} \qquad \text{(Equation 3.2)}$$

As in the Pearson's chi-squared test for independence with respect to χ^2, the obtained t-statistic is then compared to the critical t-statistic which is derived from a normal distribution given the confidence interval chosen (95% in this study), degrees of freedom, and sample size (Blair and Taylor, 2008). If the obtained t-statistic falls outside of the interval between the negative and positive, critical t-statistic values then the null hypothesis that the two groups are independent of each other must be rejected. The effect size for the independent samples t-test is calculated using Equation 3.3 where t is the t-statistic and n_1 and n_2 are the respective samples for the two groups (Pallant, 2010).

$$\text{Eta} - \text{squared} = \frac{t^2}{t^2 + (n_1 + n_2 + 2)} \qquad \text{(Equation 3.3)}$$

According to the guidelines developed by Cohen in 1988, 0.01 constitutes a small effect size, 0.06 a medium effect size and 0.14 and higher would be a large effect size.

For variables that had more than two groups or levels, such as the distance from a water source, station age, amount of water in the jug, and Progress out of Poverty Index®, the One-way Analysis of Variance (ANOVA) was used to test for the independence of handwashing station usage variables (soap usage, functionality, presence of a cleansing agent, and ground wetness) amongst these different levels. This test is an extension of the independent samples t-test but uses the F-statistic instead of the t-statistic. The F-statistic is calculated, using Equation 3.4, by dividing the mean of the sum of squares between the samples (MS_b) by the mean of the sum of squares within the sample (MS_w) (Blair and Taylor, 2008).

$$\text{Obtained F} = {}^{\mathrm{MS_b}}/_{\mathrm{MS_w}} \qquad \text{(Equation 3.4)}$$

Obtained F is also compared to a critical F derived from a normal distribution based on the degrees of freedom of the samples and the confidence interval chosen. If the obtained F-statistic falls outside of the interval between the negative and positive, critical F-statistic values then the null hypothesis that the variable levels are independent of each other must be rejected (Blair and Taylor, 2008). However, the null hypothesis can be rejected if only two levels of three or more are associated with each other (i.e. the soap usage at stations nearest to a water source is significantly different from those stations that are furthest from a water source but not necessarily different from those stations in the middle distance ranges). Thus, the post-hoc Tukey test was used to test each combination of variable levels to determine which were significantly different. This is accomplished by first calculating the Tukey's Honesty Significant Difference (HSD) using the two means ($\bar{x}_i$ and $\bar{x}_j$), mean of the sum of squares within (MS_w), and harmonic mean (n_h) in Equations 3.5 and 3.6 (Blair and Taylor, 2008).

$$\mathrm{HSD} = \sum \frac{\bar{x}_i - \bar{x}_j}{\sqrt{\mathrm{MS_w}({}^{1}/_{n_h})}} \qquad \text{(Equation 3.5)}$$

$$n_h = \frac{2}{\frac{1}{n_i}+\frac{1}{n_j}} \quad \text{(Equation 3.5)}$$

Tukey's HSD is then compared with critical HSDs developed by Tukey similar to the methods in the independent samples t-test and ANOVA when comparing obtained and critical t and F values for statistical significance. The effect size for the entire test was calculated by dividing the sum of the squares between the groups by the total sum of squares (Pallant, 2010). The small, medium, and large effect size values are the same as in the independent samples t-test.

Finally, an extension of the ANOVA, the one-way repeated measures ANOVA, was used to test for the independence of handwashing station usage variables (soap usage, functionality, presence of a cleansing agent, and ground wetness) before, after, and three months after a handwashing lesson conducted at the school in Zeala. This also uses the F-statistic but it is calculated by dividing the mean of the sum of squares between by the mean error of the sum of squares (Pallant, 2010).

Table 3.1: Explanation of how statistical tests were employed to analyze data collected to assess appropriate technology handwashing stations in Mali.

Test	**Application in data analysis**
Pearson Chi-squared test for independence	Test for the association between categorical variables (gender, season, village, year, water source proximity) and nominal handwashing station, usage variables (functionality, presence of cleansing agent, and ground wetness).
Independent samples t-test	Test for the independence between the continuous, handwashing station, usage variable (soap usage) in categorical variables (gender, season, and village).
One-way Analysis of Variance (ANOVA)	Test for the independence of handwashing station usage variables (soap usage, functionality, presence of a cleansing agent, and ground wetness) in variables with three or more levels (distance from a water source, station age, amount of water in the jug, Progress out of Poverty Index).
One-way repeated measures ANOVA	Test for the independence of handwashing station usage variables (soap usage, functionality, presence of a cleansing agent, and ground wetness) before, after, and three months after a handwashing lesson conducted at the school in Zeala.

3.3 Results

Between 42 and 64 tippy-tap handwashing stations were monitored bi-monthly-monthly between January 2011 and December 2012 and then again for a short period in June and July of 2013 in two villages (Zeala and Nci'bugu). Results of the mean percentage of active stations and mean soap usage per person per household per day over time, both disaggregated by village, are shown in Figures 3.3 and 3.4.

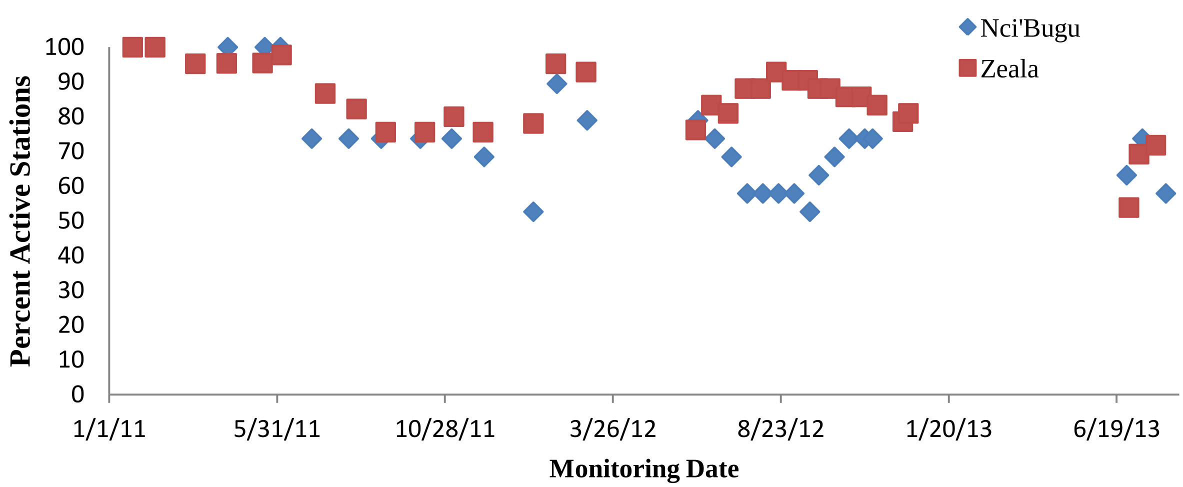

Figure 3.3: Mean percent of active handwashing stations over time (January 1, 2011- August 2, 2013) disaggregated by village (Zeala and Nci'bugu). N = 39-45 for Zeala and n = 18-19 for Nci'bugu.

Three other usage variables were monitored in 2011-2012 and briefly in June and July of 2013: presence of cleansing agent (white ash or soap), whether the ground was wet at time of inspection, and the amount of water in the jug (0%, 25%, 50%, 75%, and 100%). The mean percentage of these usage variables over time in Zeala is displayed in Figure 3.5.

Trends may be observed of the usage of the handwashing stations over time and between the different seasons (the months of July-September are considered to be in the rainy season while October-June are the dry season months). In order to confirm these trends as well as the hypothesis on gender, water, and wealth; the data was also analyzed using statistical tests: 1) the

Pearson's Chi-squared test for independence, 2) independent-samples t-test, 3) one-way analysis of variance (ANOVA) test, and the 4) one-way repeated measures ANOVA to determine the significance associations and differences between usage and categorical variables.

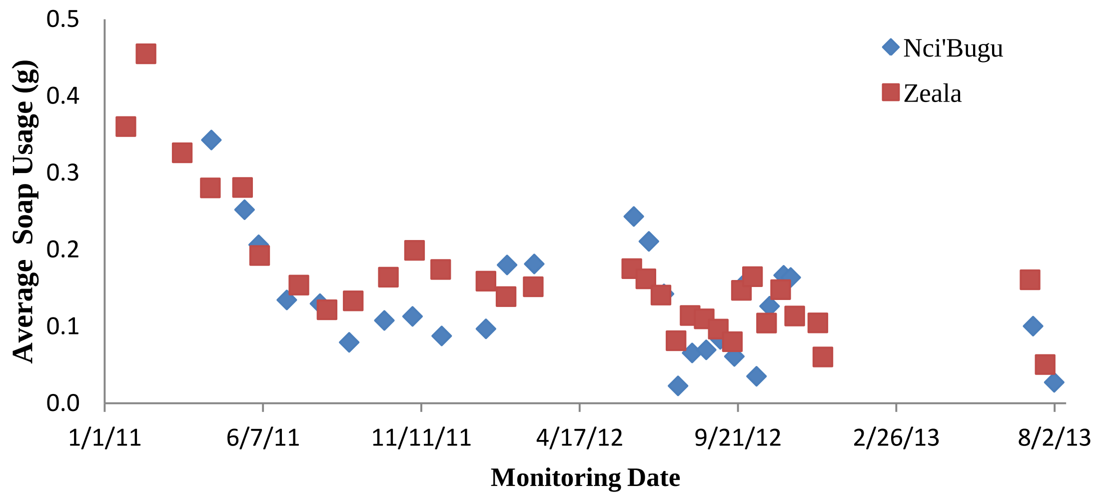

Figure 3.4: Mean soap usage over time (January 1, 2011- August 2, 2013) by village (Zeala and Nci'bugu). n = 22-42 for Zeala and n = 5-19 for Nci'bugu. Range in sample size due to factors where soap usage could not be included in the mean: non-active stations, stations with white ash and stations where the soap was eaten by animals in between visits.

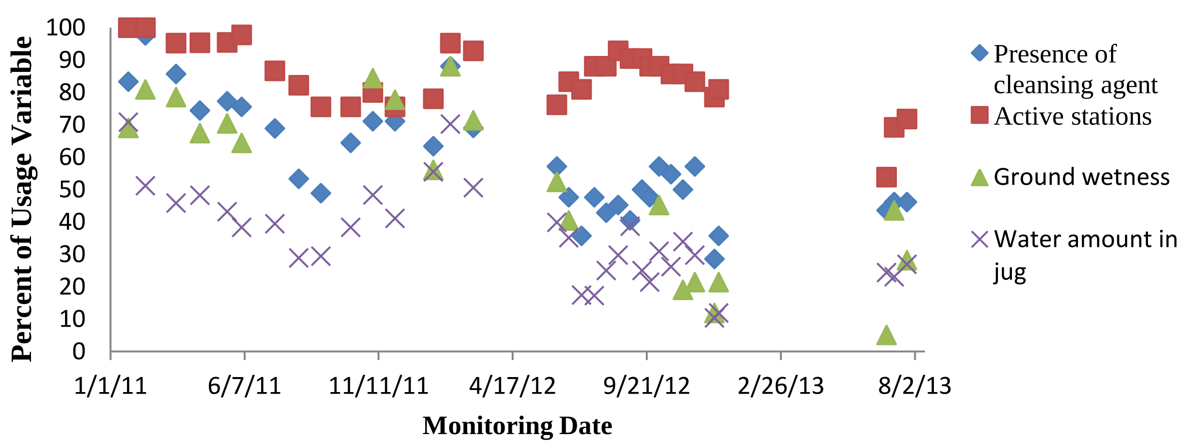

Figure 3.5: Mean percent of usage variables (presence of cleansing agent, active stations, ground wetness, and amount of water in the jugs) over time (January 1, 2011- August 2, 2013) in Zeala (n = 39-45). Ground wetness was not able to be recorded during the rainy season months from July through October.

3.3.1 Independent Samples t-tests

To begin, three independent-samples t-tests were conducted to compare soap usage between the gender of station owners, seasons, and villages. The only significant result of these tests was between soap usage and season (dry versus rainy season). Soap usage was always disaggregated by year since the method of measuring soap usage differed between years. This was calculated by recording when a bar of soap was finished and dividing the average weight of the standard bar of soap by the number of days between visits and members in the household. In 2012, a scale was obtained and soap was weighed each visit. Outliers for soap usage were not eliminated in the analysis as the main outliers were the school director whose usage was verified by the thesis author.

3.3.1.1 Independent Samples t-test between Soap Usage and Gender of Handwashing Station Owner

Regarding the independent-samples t-test to compare the soap usage between stations constructed by males versus those constructed by females; there was no statistically significant difference in mean soap usage per person (M in grams, g), per day for stations built by men (M = 0.24 g, SD = 0.24 g) and stations built by women (M = 0.21 g, SD = 0.19 g; t (550) = 1.56, p = 0.12, two-tailed) in both Zeala and Nci'bugu in 2011 (see Figure 3.6). The magnitude of the differences in the means (mean difference = 0.03 g, 95% CI = -0.01 g to 0.07 g) was very small (eta squared = 0.00). In 2012, there was also no statistically significant difference between the mean soap usage for stations built by men (M = 0.12 g, SD = 0.20 g) and those built by women (M = 0.13 g, SD = 0.18 g; t (751) = -0.07, p = 0.95, two-tailed). The magnitude of the differences in the means (mean difference = -9.2×10^{-4} g, 95% CI = -0.03 g to 0.03 g) was very small (eta squared = 6.2×10^{-6} g). In 2013, there also was no statistically significant difference between the means. Further independent-samples t-tests were conducted that were disaggregated by village and there was also no statistically significant difference for soap usage between stations owned by males and females in either Zeala or Nci'bugu.

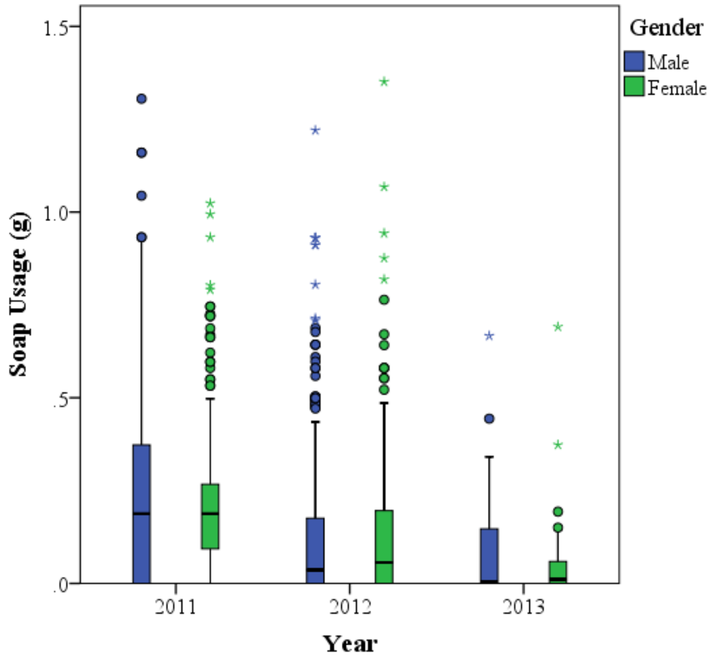

Figure 3.6: Box plot of mean, household soap usage per person per day versus year for both villages disaggregated by gender (male and female owned handwashing stations). In 2011 n = 300 for stations built by males and n = 252 for stations built by females. In 2012 n = 363 for males and n = 390 for females. In 2011 n = 36 for males and n = 41 for females.

3.3.1.2 Independent Samples t-test on Soap Usage and Season

Independent-samples t-tests were conducted to compare the soap usage between the rainy (July-September) and dry seasons (October-June) in Zeala and Nci'bugu in 2011 and 2012 (see Figure 3.7). A seasonal, independent samples t-test was not conducted in 2013 because monitoring data were only collected during the rainy season in that year. In 2011, there was a statistically significant difference in mean, daily, household soap usage per capita for the dry season (M = 0.26 g, SD = 0.23 g) and rainy season (M = 0.13 g, SD = 0.15 g; t (368) = 7.85, p = 0.00, two-tailed). The magnitude of the differences in the means (mean difference = 0.13 g, 95% CI = -0.10 g to 0.17 g) was moderate (eta squared = 0.10). Similarly in 2012, there was a statistically significant difference between the scores in the dry season (M = 0.13 g, SD = 0.17 g) and rainy season (M = 0.11 g, SD = 0.21 g; t (751) = 2.2, p = 0.03, two-tailed). However, the magnitude of the differences in the means (mean difference = 0.03 g, 95% CI = 0.00 g to 0.06 g) was small (eta squared = 0.01). Further independent-samples t-tests were conducted by season disaggregated by village and year. There was significant difference ($p < 0.05$) between the seasons in each village except for Zeala in 2012 with p = 0.13.

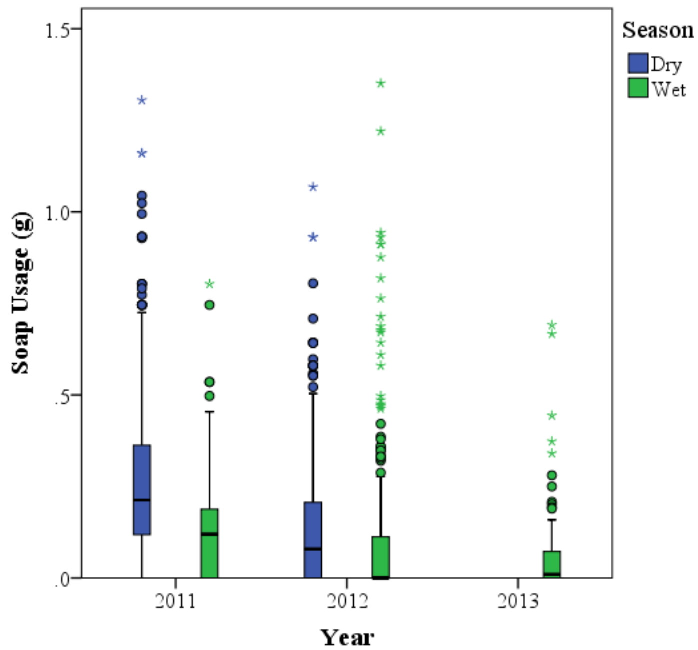

Figure 3.7: Box plot of mean, daily, household soap usage per capita vs. year for both villages disaggregated by season: dry (October-June) and wet (July-September). In 2013, stations were only visited three times during the rainy season (June-August). In 2011 n = 416 in the dry season and n = 136 in the rainy season. In 2012 n = 449 in the dry season and n = 304 in the rainy season. In 2013 n = 77 in the rainy season.

3.3.1.3 Independent Samples t-test on Soap Usage and Village

Independent-samples t-tests were conducted to compare the soap usage between Zeala and Nci'bugu in 2012. A test was not run in 2011 since the stations in Nci'bugu were installed later in April of 2011 compared to the stations in Zeala which were installed starting May of 2010. In 2012, there was not a statistically significant difference in mean, per capita, household, soap usage for Zeala (M = 0.12 g, SD = 0.19 g) and Nci'bugu (M = 0.14 g, SD = 0.17 g; t (751)

= 0.34, p = 0.34, two-tailed). The magnitude of the differences in the means (mean difference = -0.02, 95% CI = -0.05 g to 0.02 g) was very small (eta squared = 0.00).

3.3.2 Pearson's Chi-squared Tests for Independence

Following the independent samples t-test, it was necessary to also perform a non-parametric test, the Pearson's Chi-squared test for independence, to compare the other nominal usage variables (functionality, presence of cleansing agent, and wetness under the station) with categorical variables of gender, village, and season. In total, 99 tests were performed using the different combinations of categories and usage variables disaggregated by year, gender, season, and village where appropriate. The results of these tests are summarized in Table 3.2.

Table 3.2: Results from chi-squared comparisons between categories and usage variables disaggregated by village or year (SPSS, 2011). An "X" indicated statistically significant association at the $p < 0.05$ level between the categorical variable and usage variable.

			Village		**Season**		**Gender**		**Year**[4]	
Categorical Variable	**Usage Variable**	**Overall**[3]	**Zeala**	**Nci'bugu**	**Rainy**	**Dry**	**Male**	**Female**	**2011**	**2012**
Gender	Presence of CA[1]	X	X							
	Functionality[2]		X	X						
Season	Presence of CA	X	X	X			X	X	X	X
	Functionality	X	X	X			X	X	X	
Village	Presence of CA	X						X		X
	Functionality	X			X	X		X		X
Year	Presence of CA	X	X	X	X	X	X	X		
	Functionality	X		X			X			
	Ground wetness	X	X	X	X	X	X	X		
Water source proximity	Presence of CA	X		X	X		X			X
	Functionality	X			X		X			
	Ground wetness	X		X						X
Ground wetness	Presence of CA	X	X	X	X	X	X	X	X	X

[1]CA stands for cleansing agent (white ash or soap).
[2]Functionality indicates whether there was a station at the site and whether it was active (if the water jug and foot peddle were assembled properly).
[3]Overall indicates a comparison over both years of monitoring (2011 and 2012).
[4]Tests not run separately for 2013 data as there were fewer cases over this short monitoring period.

An "X" indicates that there is a statistically significant association ($p < 0.05$) between the categorical variable and usage variable whether overall and/or in different disaggregated categories. Note that there was not a large enough sample size to disaggregate for 2013 but 2013 data were included in the overall analysis.

3.3.2.1 Gendered Pearson's Chi-squared Tests for Independence

A Chi-square test for independence (with Yates Continuity Correction) indicated a significant association between the gender of who constructed the handwashing station and presence of cleansing agent; χ^2 (1, n = 1,939) = 3.8, p = 0.05, phi = 0.05 for both villages including all monitoring data collected in 2011-2013. Overall, 54% of the stations built by men had soap present while 58% of the stations built by women had soap present. When the handwashing monitoring data was disaggregated by year there was no significant association found between the gender of who built the handwashing station and the presence of a cleansing agent. Furthermore, there was no significant association between gender of the station owner and presence of a cleansing agent in Nci'bugu but there was a significant association in Zeala with χ^2 (1, n = 1,410) = 7.4, p = 0.01, phi = 0.07. In Zeala, 55% of the stations built by men and 62% of the stations built by women had a cleansing agent present at the time of inspection.

In contrast, there was no significant association between the gender of who built the handwashing station and whether that station was functioning during the monitoring period overall between 2011-2013 for both villages; χ^2 (1, n = 1,940) = 0.00, p = 0.96, phi = 0.91. However, when the test was performed separately for Zeala and Nci'bugu, there was a significant association between the gender of who built the station and active stations. In Zeala, 88% of the handwashing stations built by women were active while 82% of the stations built by men were functional which resulted in a significant difference of p = 0.00 with a χ^2 (1, n = 1,411) = 10.0, phi = 0.09. Conversely, in Nci'bugu, 69% of stations built by women were functional while 79% of the stations built by men were in use which resulted in χ^2 (1, n = 529) = 5.78, p =

0.01, phi = -0.11. These differences between gender, village, and active stations are displayed graphically in Figure 3.8.

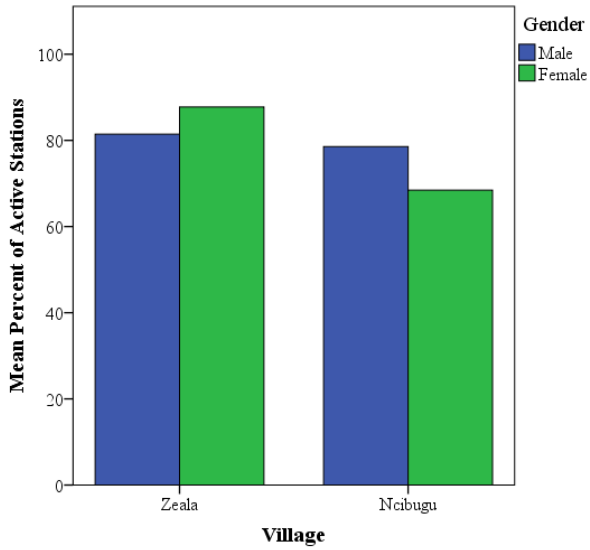

Figure 3.8: Mean percent of active stations disaggregated by the gender of who built the handwashing station and their village between 2011 and 2013. In Zeala, n = 1,411 cases and n = 529 cases in Nci'bugu.

3.3.2.2 Seasonal Pearson's Chi-squared Tests for Independence

As noted in Table 3.2, there were significant associations found between the presence of cleansing agent and the season (dry or rainy) overall, χ^2 (1, n = 1,939) = 63.1, p = 0.00, phi = -0.18, and when disaggregated by gender and village. The mean percentage presence of cleansing agent disaggregated by season in each year is displayed graphically in Figure 3.9.

Continuing with tests concerning seasonality, a Chi-square test for independence indicated a significant association between season and functionality. From 2011-2013 in both villages, 84% of the handwashing stations were active in the dry seasons (October-June) while 76% were active in the rainy seasons (July-September) resulting in χ^2 (1, n = 1,940) = 20.2, p = 0.00, phi = -0.10. When the data was disaggregated by village and year, there was still a significant association between functionality and season except in 2012; χ2 (1, n = 1,058) = 0.57, p = 0.45, phi = -0.03.

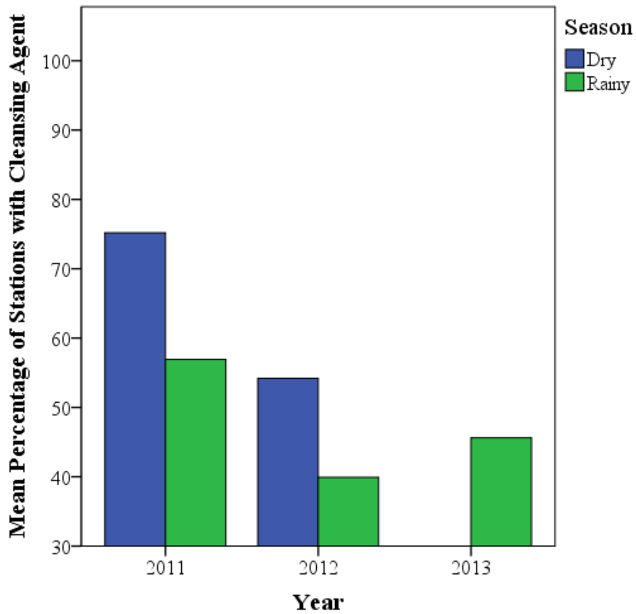

Figure 3.9: Mean percent of stations with cleansing agent present over time disaggregated by dry (November-June) and rainy (July-October) seasons. n = 711 cases in 2011, n = 1,057 cases in 2012 and n = 171 cases in 2013.

3.3.2.3 Pearson's Chi-squared Tests for Independence Comparing Villages

Though there was not a statistically significant difference between village and soap usage using the independent samples t-test, there was a significant association between village and presence of cleansing agent found using the Chi-square test for independence. Overall, 58% of handwashing stations in Zeala had a cleansing agent present at the time of monitoring while 51% of stations in Nci'bugu had a cleansing agent present resulting in χ^2 (1, n = 1,939) = 6.4, p = 0.01, phi = -0.06. This association holds true in 2012 with χ^2 (1, n = 1,057) = 6.5, p = 0.01, phi = -0.08. A Chi-square test for independence was not performed in 2011 as Nci'bugu's stations were built later in the year (April) than those in Zeala (starting May of the previous year). However, when the cases were disaggregated by season, the significant association between village and presence of cleansing agent was only significant during the rainy season with 44% of the stations in Zeala having a cleansing agent and 31% of stations in Nci'bugu having soap or white ash present resulting in χ^2 (1, n = 426) = 6.11, p = 0.01, phi = -0.13. Moreover, when disaggregated by gender, there was not a significant association between village and presence of cleansing agent at the stations built by males in both villages (55% have a cleansing agent present in Zeala, 54% have a cleansing agent present in Nci'bugu) with χ^2 (1, n = 977) = 0.70, p = 0.40, phi = -0.03. However, in Zeala, there is a significant association, χ^2 (1, n = 962) = 9.2, p = 0.00, phi = -0.10, between village and the presence of cleansing agent at stations built by women: 62% of female stations had soap or white ash present upon inspection while 52% of stations in Nci'bugu had a cleansing agent present (see Figure 3.10).

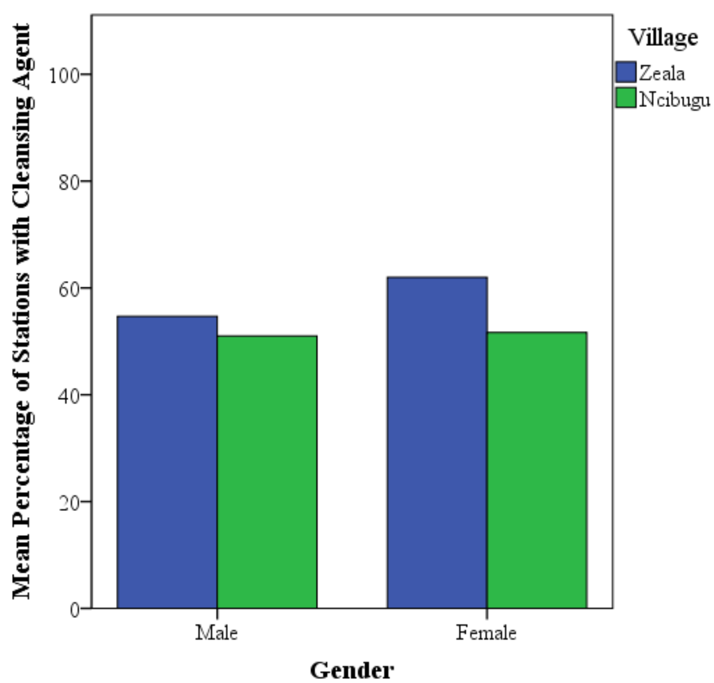

Figure 3.10: Mean percent of stations with cleansing agent present over time disaggregated by village and gender. n = 1,410 cases in Zeala (781 male, 629 female) and n = 529 cases in Nci'bugu (196 male, 333 female).

When further exploring the association between village and handwashing station usage, it was found there is also a significant association between village and percent active stations; i.e., 84% of handwashing stations in Zeala were active while 72% of stations in Nci'bugu were functional resulting in χ^2 (1, n = 1,940) = 35.2, p = 0.00, phi = -0.14. This significant association is maintained in 2012 for both rainy and dry seasons. As was the case in the Chi-square test of independence between presence of cleansing agent and village, there is also a significant association between village and functionality for stations built by women but not a significant association for stations built by men. 88% of the stations built by women in Zeala and 69% of the stations built by women in Nci'bugu were active, resulting in χ^2 (1, n = 962) = 51.6, p = 0.00, phi = -0.23. Though there is a significant association between village and the two usage variables of functionality and presence of cleansing agent, there was no significant association ($p < 0.05$) between ground wetness under the station at time of monitoring depending on the village.

3.3.2.4 Pearson's Chi-squared Tests for Independence Concerning Handwashing Station Proximity to a Water Source

Chi-square tests for independence were also conducted to test for the association between the proximity of a handwashing station to a water source and usage variables (active, presence of cleansing agent, and ground wetness). First, concerning functional stations, the Chi-square test for independence indicated a significant association, χ^2 (1, n = 1,928) = 5.04, p = 0.03, phi = 0.05, between functionality and proximity to a water source (close or far) with 85% of the stations close to the water source were in use and 80% of the stations far from a water source that were functional. This significant association was also true for the presence of a cleansing agent and proximity to a water source where 61% of the stations close to a water source had a cleansing agent present and 55% of those where the water source is far away had white ash or soap present at time of monitoring resulting in a significance of p = 0.03, χ^2 (1, n = 1,927) = 4.62, phi = 0.05. Finally, there is also a significant association between ground wetness and proximity to a water source where 59% of the handwashing stations close to a water source and

52% of the stations far from a water source had their ground wet resulting in χ^2 (1, n = 1,256) = 4.67, p = 0.03 phi = 0.06.

When disaggregated by year, in 2011 there is no significant association between how close a station is to a water source and usage (active, presence of cleansing agent, or ground wetness). However, there is a significant association (at least $p < 0.10$) in 2012 across all usage variables ($p < 0.05$ for presence of cleansing agent and ground wetness). Furthermore when disaggregated by season, there is no significant association between a stations proximity to a water source and whether it is functional or has soap/white ash present during the dry season but there is a significant association during the rainy season as seen in Figure 3.11 with higher percentages of usage variables for stations closer to a water source (0-35 m).

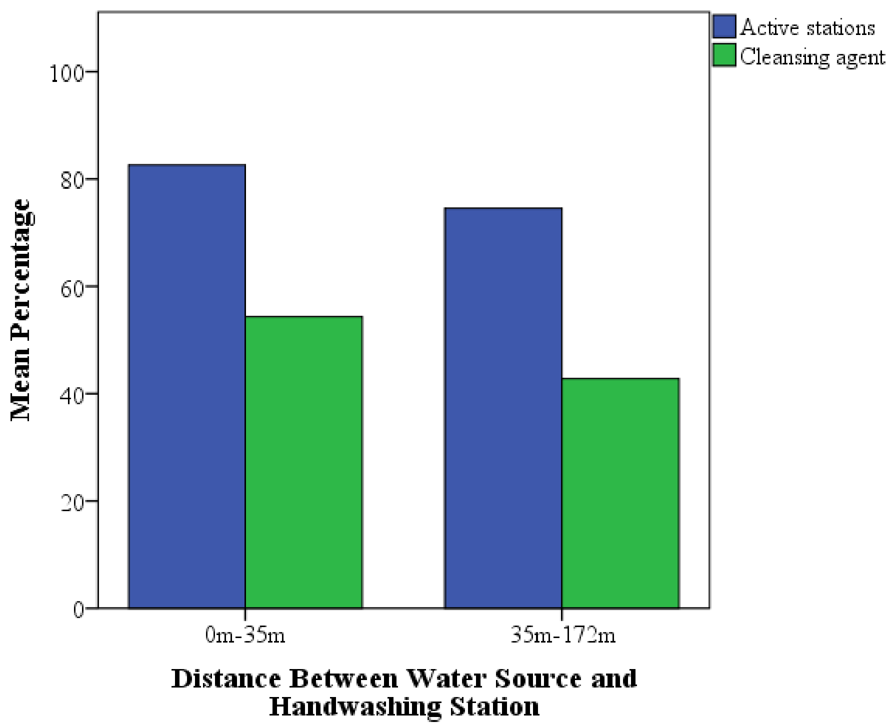

Figure 3.11: Mean percent of active stations and stations with presence of a cleansing agent (n = 793 cases) depending on their proximity to a water source: close (0 m-35 m) (n = 185) or far (36 m-172 m) (n = 605) during the rainy season (July-September).

Nevertheless, when the cases are disaggregated by whether a male or female built the station, there is a significant association between proximity to a water source and whether the station is active or has soap or white ash for stations built by men but not those built by women. Finally, when disaggregated by village there is no significant association between the proximity to a water source and presence of a cleansing agent or ground wetness in Zeala but there is a significant association between them in Nci'bugu. However, when the cases in Zeala are disaggregated by year, there is no significant association between well proximity and usage variables in 2011 but there is in 2012.

3.3.2.5 Pearson's Chi-squared Tests for Independence between 2011 and 2012

Different methods were used for measuring soap usage in 2011 and 2012. As a result, instead of comparing soap usage between years, the Pearson's chi-squared test for independence was used to determine associations between the proportion of active stations, stations with presence of cleansing agent, and stations with ground wetness and year (2011 or 2012). Figure 3.12 shows how there is a significant association between all three usage variables (active, presence of cleansing agent, and ground wetness) and year (2011 and 2012). 2013 data was not included in the Chi-square test for independence as there were only three observation points during the rainy season that were conducted six months after the last monitoring visit and may have skewed the results of the analysis. The results of the Chi-square statistical tests for independence are presented in Table 3.3.

Two of the three usage variables (presence of cleansing agent and ground wetness) have significant association with year when disaggregated by season, village, and gender. Concerning functionality, there is no significant association between mean percent of active stations and year in either rainy or dry seasons, in Nci'bugu, and for stations built by women. For stations built by men, on average 86% were active in 2011 which decreased to 79% in 2012 χ^2 (1, n = 1,897) = 6.35, p = 0.01, phi = -0.09.

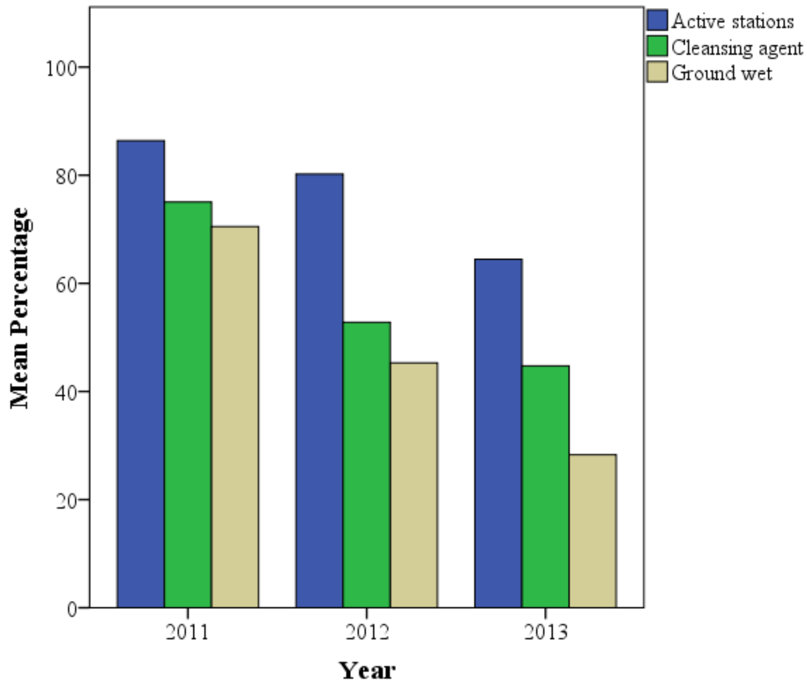

Figure 3.12: Mean percent of stations with cleansing agent present, active stations, and stations where the ground was wet at time of monitoring disaggregated per year. For presence of cleansing agent, n = 1,939 (n = 711 in 2011, n = 1,057 in 2012, n = 171 in 2013). For active stations n = 1,940 (n = 711 in 2011, n = 1058 in 2012, n = 171 in 2013), For ground wetness, which were only data points collected during the rainy season, n = 1,264 (n = 485 in 2011, n = 627in 2012, n = 152 in 2013).

Table 3.3: Statistical results from the Pearson's Chi-square test for independence (with Yates Continuity Correction) between handwashing station usage variables (active station, presence of cleansing agent, and ground wetness) and years that the stations were monitored (2011 and 2012). Degrees of freedom (df), sample size (n), the Pearson's chi-squared statistic (χ^2), statistical significance (p), and phi coefficient are displayed.

Usage variable	**df**	**N**	**χ^2**	**p**	**phi**
Active station	1	1,769	5.55	0.02	-0.06
Presence of cleansing agent	1	1,768	81.2	0.00	-0.22
Ground wetness	1	1,112	69.7	0.00	-0.25

3.3.2.6 Pearson's Chi-squared Tests for Independence between Ground Wetness and Presence of a Cleansing Agent

There was a significant association between wetness and presence of a cleansing agent when disaggregated across all groups (year, gender, and village). Overall, the ground was wet under 76% of stations that had a cleansing agent present at time of inspection and 17% of the stations without a cleansing agent present, resulting in a significance of p = 0.00, χ^2 (1, n = 1,264) = 424, phi = 0.58.

3.3.3 One-way Analysis of Variance (ANOVA)

One-way analysis of variance (ANOVA) tests were conducted to compare soap usage between five different factors: 1) distances between handwashing stations and a water source (0 to 34 meters, 35 to 55 meters, 56 to 83 meters, and 84 to 172 meters), 2) who is designated to add water to the handwashing station (one person, multiple people, everyone), 3) amount of water recorded in the water jugs (0%, 25%, 50%, 75%, 100%) upon inspection of the handwashing station, 4) age of the stations, and 5) household scores on the Progress out of Poverty Index® for Mali. The results of these tests are further summarized below.

3.3.3.1 One-way Analysis of Variance (ANOVA) for Distance from a Water Source

A one-way between-groups analysis of variance was conducted to determine if there is a significant difference in the soap usage at handwashing stations depending on their distance from a water source. Cases were divided into four groups based on equal percentiles of all the cases and their distance from a water source (pump or well): 0 to 34 meters, 35 to 55 meters, 56 to 83 meters, and 84 to 172 meters. There was a significant difference at the $p < 0.05$ level in LOT scores given the Welch robust test of equality of means in 2012 $F(3, 547) = 9.12$, $p = 0.00$. The effect size of the difference in mean scores between the groups was small with an eta squared value of 0.03. There was no significant difference between the well groups in 2011 $F(3, 513)$ =

2.13, p = 0.10 or 2013 F(3, 49.0) = 1.07, p = 0.37. Post-hoc comparisons using the Tukey HSD test for data in 2012 indicated that the mean score for the cases closest to a water source (M = 0.18 g, SD = 0.26 g), 0 to 34 meters, was significantly different from all the other groups (M = 0.09 g, SD = 0.13 g; M = 0.10 g, SD = 0.13 g; M = 0.12 g, SD = 0.17 g respectively from closest to furthest distances between the handwashing station and the well or pump). There was no significant difference between the other groups such as the second closest group to the well (35 to 55 meters) and the furthest away (84 to 172 meters) in 2012 or any groups in 2011 or 2013. Differences in soap usage based on their distance from a water source are displayed in Figure 3.13.

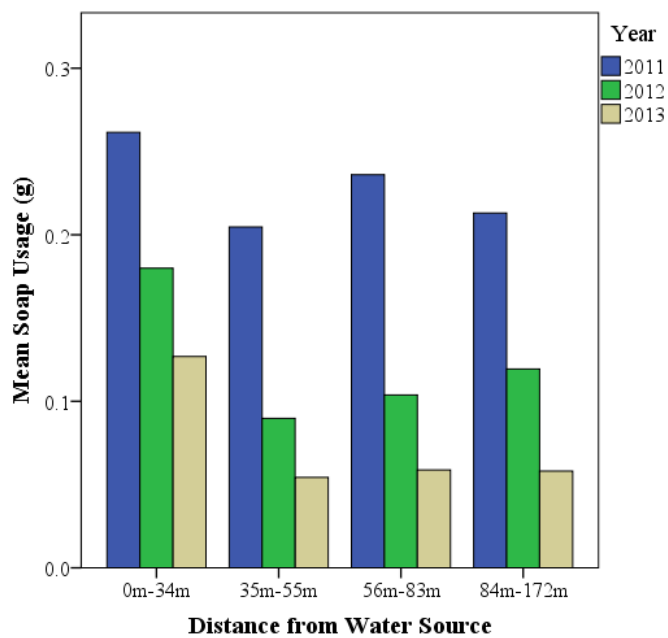

Figure 3.13: Column chart of mean soap usage separated by distance categories (0 m-34 m, 35 m-55 m, 56 m-83 m, and 84 m-172 m) between handwashing stations and their water sources disaggregated by year. In 2011 n = 552 (n = 168, 125, 106, 153 for each of the distance categories). In 2012 n = 754 (n = 194, 181, 154, 225). In 2013 n = 78 (n = 18, 19, 17, 24).

3.3.3.2 One-way Analysis of Variance (ANOVA) for who is Responsible for Adding Water to the Handwashing Station

A one-way between-groups analysis of variance was conducted to explore if there is a statistically significant difference in soap usage per person per day per household and who adds water to the handwashing station. Each handwashing station owner was asked who adds water to the stations most often. Their answers were coded into three groups: One person (young girl, young boy, woman, man), multiple people (children, women, men), and everyone. There was a significant difference at the $p < 0.05$ level in LOT scores given the Welch robust test of equality of means in 2011 $F(2, 216) = 5.93$, $p = 0.00$ and in 2012 $F(2, 290) = 14.6$, $p = 0.00$ (see Figure 3.14). The effect size of the difference in mean soap usage between the groups was small in 2011 with an eta squared value of 0.02 but medium in 2012 with an eta squared value of 0.03. Post-hoc comparisons using the Tukey HSD test indicated that the mean soap usage for the cases where multiple people add water to the station (M = 0.19 g, SD = 0.20 g) in 2011 and (M = 0.07 g, SD = 0.12 g) in 2012 were significantly different from stations where everyone adds water (M = 0.29 g, SD = 27 g) in 2011 and (M = 0.20 g, SD = 0.30 g) in 2012. When disaggregated by village, there was no significant difference between who added water to the station and mean soap usage in Nci'bugu. However, this difference held significant when disaggregated by season.

Three other ANOVAs were conducted to see if the statistical significance with soap usage and people who add water to the station also applied to the other usage variables (station functionality, presence of cleansing agent, and ground wetness). There was a statistically significant difference in the type of people responsible for adding water to the jug and functionality $F(2, 854) = 5.5$, $p = 0.01$, presence of a cleansing agent $F(2, 886) = 9.95$, $p = 0.00$ and ground wetness $F(2, 593) = 3.13$, $p = 0.04$. As seen in Figure 3.15, the same pattern with mean soap usage applies for presence of cleansing agent as soap usage, where the lowest proportion of stations that have a cleansing agent is where multiple people add water to the station. However, in contrast to the ANOVA conducted for soap usage where the highest soap usage was for stations where everyone was involved in adding water, the highest proportion for active stations and stations with a cleansing agent present is where only one person adds water. In fact, the lowest proportion of active stations was for stations where everyone added water to the station. Nevertheless, the usage variable for ground wetness was similar to the trend with mean soap usage, where the highest mean percentage of stations where the ground was wet upon inspection was for stations where everyone is responsible for adding water to the jug. Despite reaching statistical significance, the actual difference in mean scores between the groups was small for all usage variables. The effect size, calculated using eta squared was 0.01 for active stations and presence of cleansing agent and 0.00 for ground wetness.

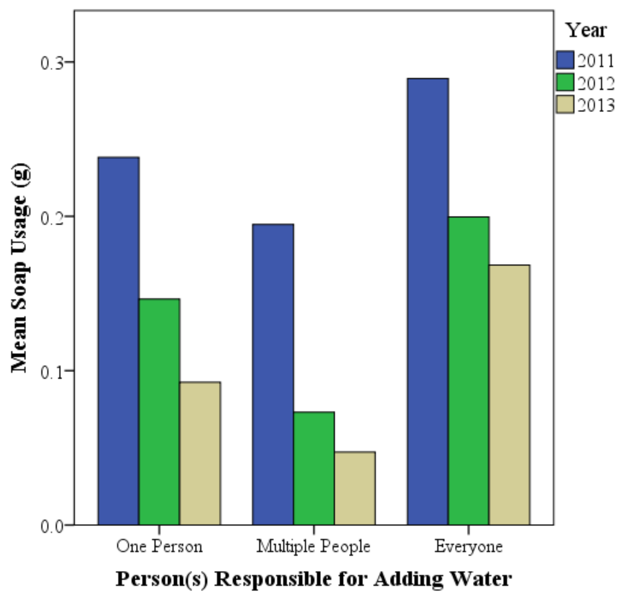

Figure 3.14: Column chart of mean soap usage per person per household based on who adds water to the station (one person, multiple people, or everyone). In 2011, n = 552 cases (267, 200, 85). In 2012, n = 754 cases (382, 250, 122). In 2013, n = 78 cases (42, 22, 14).

In the post-hoc comparisons using the Tukey HSD test for active stations there is statistically significant difference between stations where everyone is responsible for adding water (M = 75%, SD = 44%) and the two other groups: multiple people (M = 82%, SD = 39%) and one person (M = 83%, SD = 38%). Using the same post-hoc comparison test for mean presence of cleansing agent, there was a significant difference between one person (M = 61%, SD = 50%) and multiple people (M = 50%, SD = 1.9%). For ground wetness there was a significant difference between stations where multiple people add water to the station (M = 49%, SD = 50%) and the stations where everyone adds water to the station (M = 59%, SD = 49%).

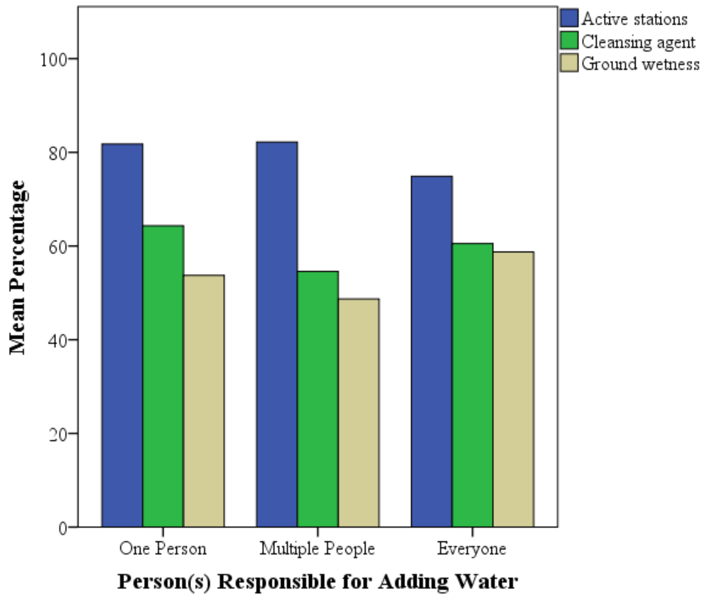

Figure 3.15: Column chart of mean percentage of active stations, presence of cleansing agent and ground wetness based on who adds water to the station (one person, multiple people, or everyone). For active stations and presence of cleansing agent n = 1,940 cases (n = 939, 667, 334 for each of the categories of who adds water from right to left). For ground wetness n = 1264 cases (614, 427, 223 for each of the categories of who adds water from right to left).

When disaggregated by village, statistical significance of $p < 0.05$ held for Zeala in all the usage variables and only for active stations in Nci'bugu which had the highest active stations from those who had multiple people add water (M = 85%, SD = 36%) compared to one person (M = 69%, SD = 47%) and everyone (M = 69%, SD = 46%). When disaggregated by year, statistical significance at the $p < 0.05$ level only held for presence of cleansing agent in 2011 and 2012, and percent active stations in 2012. Seasonally, there still was a statistically significant difference between the person(s) in charge of adding water to the station and cleansing agent. In the rainy season there was a statistically significant difference where stations with everyone involved in adding water to the jug had the lowest active stations (M = 68%, SD = 47%)

compared to multiple people in charge (M = 78%, SD = 42%) and one person in charge (M = 78%, SD = 41%).

Additionally, household responses to who adds water to the stations were also divided into gender groups: male (young boy, man, men), female (young girl, women, woman), and mixed (children, everyone). There was no statistical difference in soap usage (g/capita/day) and the gender of who adds water to the station at the $p < 0.05$ level in LOT scores for the three groups in 2011 or 2012: $F(2, 165) = 1.05$, $p = 0.38$ and $F(2, 751) = 0.44$, $p = 0.65$ respectively. This was also the case whether the cases were disaggregated by village or season. Lastly, there was no statistical difference at the $p < 0.05$ level in LOT scores found between the gender of who added water to the station for proportion of active stations $F(2, 550) = 0.64$, $p = 0.52$, presence of cleansing agent $F(2, 542) = 2.63$, $p = 0.07$ or ground wetness $F(2, 353) = 0.22$, $p = 0.81$.

3.3.3.3 One-way Analysis of Variance (ANOVA) for Amount of Water in the Jug

When stations were inspected the observer would estimate and record if the jug was 0%, 25%, 50%, 75% or 100% full. An ANOVA was conducted to explore the statistical significance of the level of water in the jug of the handwashing station at the time of inspection and handwashing station soap usage. There was a significant difference between soap usage and the amount of water in the jug at the $p < 0.05$ level in LOT scores given the Welch robust test of equality of means in 2011 $F(4, 241) = 3.03$, $p = 0.02$ and 2012 $F(4, 220) = 11.6$, $p = 0.00$. The effect size of the difference in mean scores between the groups was small in 2011 with an eta squared value of 0.02 but medium in 2012 with an eta squared value of 0.07. Post-hoc comparisons using the Tukey HSD test indicated that the mean soap usage (g/person/day) for the cases where jugs were full (M = 0.25 g, SD = 0.18 g) in 2011 were significantly different from those that were empty (M = 0.17 g, SD = 0.23 g). Also in 2012, there was significant difference between jugs that were empty (M = 0.08 g, SD = 0.16 g) and jugs that were full (M = 0.18 g, SD = 0.23 g) as well as between jugs that were 75% full (M = 0.23 g, SD = 0.26 g) and empty, 25% full (M = 0.13 g, SD = 0.18 g), and 50% full (M = 0.14 g, SD = 0.15 g). Average soap usage (g/capita/day) for cases based on the amount of water in the jug is depicted in Figure 3.16.

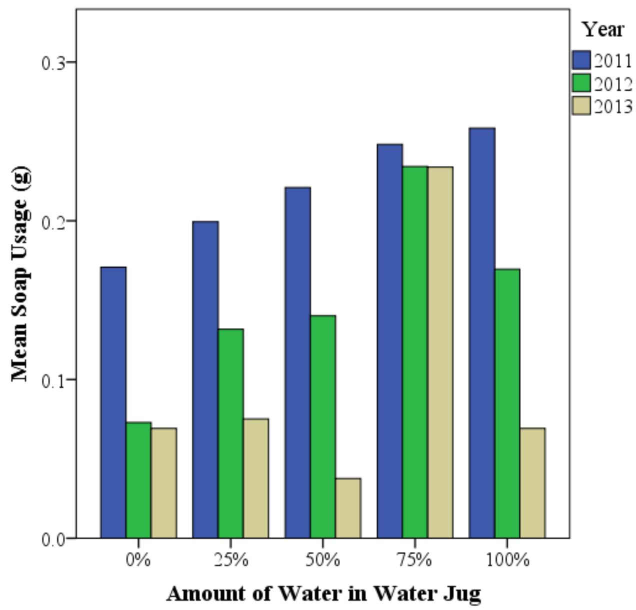

Figure 3.16: Column chart of the mean soap usage separated by the amount of water found in the handwashing stations upon inspection disaggregated by year. In 2011 n = 540 (n = 123, 102, 113, 68, 134 for each of the water jug amounts from 0%-100% in 25% increments respectively). In 2012 n = 754 (n = 328, 128, 75, 76, 147). In 2013 n = 78 (n = 28, 24, 12, 3, 11).

In addition, three other ANOVAs were conducted to further investigate the statistical significance of the level of water in the handwashing station at the time of inspection and other usage variables (station functionality, presence of cleansing agent, and ground wetness). These are depicted graphically in Figure 3.17. There was a statistically significant difference between usage variables and the amount of water in the jug of the handwashing stations at the $p < 0.05$ level in LOT scores given the Welch robust test of equality of means over all years (2011-2013): percent active stations $F(4, 677) = 138$, $p = 0.00$, stations with presence of a cleansing agent $F(4, 663) = 208$, $p = 0.00$ and ground wetness $F(4, 425) = 166$, $p = 0.00$. The effect size of the difference in mean scores between the groups was large for all three usage variables with eta squared values of 0.25, 0.29, and 0.32. Post-hoc comparisons using the Tukey HSD test indicated that the mean percentages across the usage variables for the cases when the jugs were empty for active stations (M = 59%, SD = 49%), stations where a cleansing agent was present (M = 26%, SD = 44%), and ground wetness (M = 18%, SD = 39%) were significantly different from stations that were 25%-100% full. For the presence of cleansing agent usage variable, there was a statistically significant difference between jugs that were 25% and 100% full as well. In the case of ground wetness, stations 25% and 50% full were also significantly different statistically from those that were 100% full. Finally, cases were disaggregated by village, year, and gender and these same trends held as significantly different statistically between usage variables and amount of water in the jug at the $p < 0.05$ level.

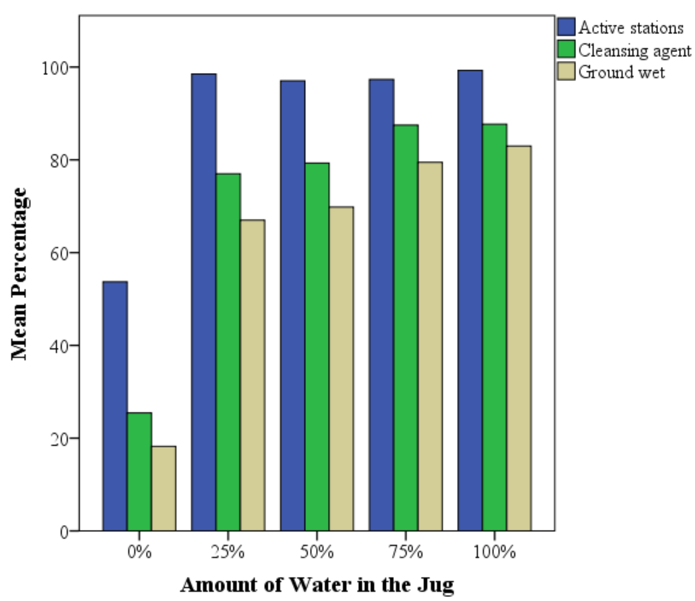

Figure 3.17: Column chart of the mean percentage of active stations, stations with cleansing agent (white ash or soap) present at time of visit, and those stations where the ground was wet upon inspection. For active stations, n = 1,928 (n = 846, 304, 241, 186, 351 for each of the water jug amounts from 0%-100% in 25% increments respectively). For ground wetness, n = 1,256 (499, 200, 169, 112, 276 for each of the water jug amounts from 0%-100% in 25% increments respectively). For presence of a cleansing agent, n = 1927 (n = 846, 304, 241, 185, 351)

3.3.3.4 One-Way Analysis of Variance (ANOVA) for the Age of Handwashing Stations and their Use

In addition to conducting independent samples t-tests between soap usage and year, it was also necessary to conduct an ANOVA between the age of a station upon inspection and soap usage since stations were installed at different dates. Station age was divided into four groups of equal percentiles (1-300 days, 301-522 days, 523-726 days, and 727-1,180 days). There was a significant difference at the $p < 0.05$ level in LOT scores given the Welch robust test of equality of means in 2012 $F(3, 117) = 3.60$, $p = 0.02$ The effect size of the difference in mean scores between the groups was small with an eta squared value of 0.01. Post-hoc comparisons using the Tukey HSD test indicated that the mean soap usage per person per day per household for stations aged 301-522 days ($M = 0.15$ g, $SD = 0.18$ g) was significantly different from those that were 523-726 days old ($M = 0.10$ g, $SD = 0.15$ g). There was no significant difference in station age groups and soap usage in 2011 $F(2, 80.8) = 0.40$, $p = 0.68$ or 2013 $F(1, 1.02) = 0.53$, $p = 0.60$ (see Figure 3.18).

Three more ANOVAs were also conducted to determine if there were statistically significant differences between station age and mean proportion of usage variables (active stations, presence of cleansing agent, and ground wetness under the station at time of monitoring). There was a statistically significant difference at the $p < 0.05$ level in LOT scores given the Welch robust test of equality of means for the four age groups and proportion of active stations $F(3, 1070) = 4.60$, $p = 0.00$, proportion of stations with presence of cleansing agent $F(3, 1070) = 20.5$, $p = 0.00$, and proportion of stations where ground was found wet at time of inspection $F(3, 687) = 45.7$, $p = 0.00$. The effect size of the difference in mean scores between the groups was small for the proportion of active stations and presence of cleansing agent with an eta squared value of 0.01 and 0.03 respectively, but medium for the proportion of stations where the ground was wet with an eta squared value of 0.10 (See Figure 3.19).

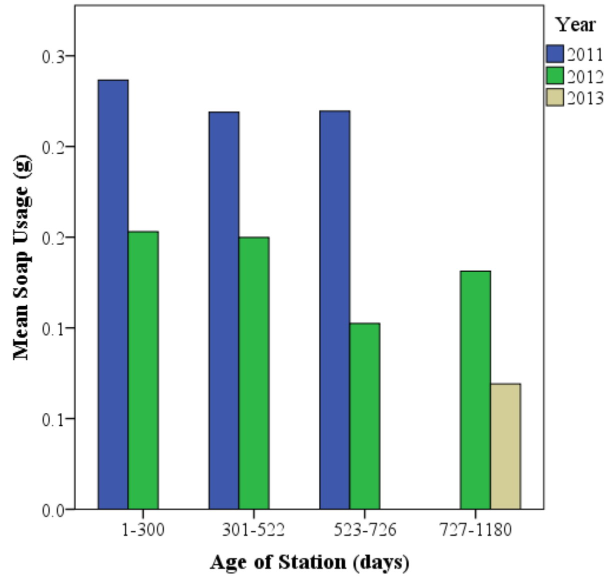

Figure 3.18: Column chart of mean soap usage per person per day per household separated by age categories (1-300 days, 301-522 days, 523-726 days, and 727-1,180 days) and disaggregated by year. In 2011, n = 552 (n = 355, 167, 30 for each of the age categories from youngest to oldest). In 2012, n = 754 (n = 27, 173, 306, 248). In 2013 n = 76 for 727-1,180 days.

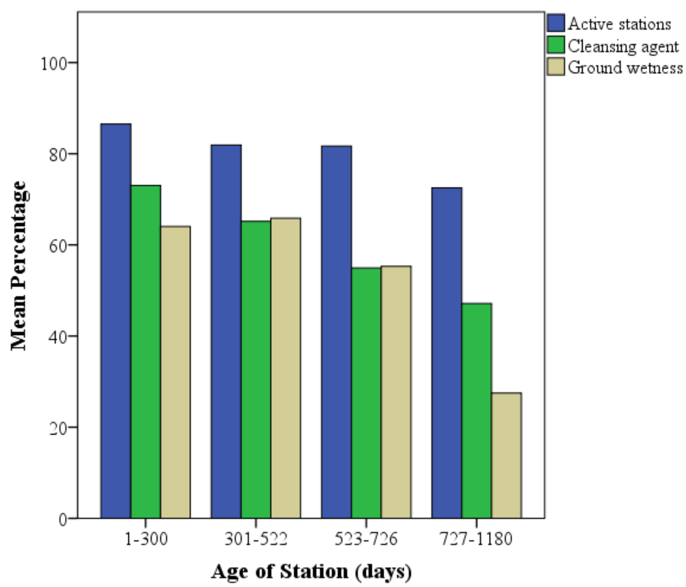

Figure 3.19: Column chart of mean percentage of active stations, presence of cleansing agent, and ground wetness separated by age categories (1-300 days, 301-522 days, 523-726 days, and 727-1,180 days). For active stations, n = 1,940 (n = 477, 499, 476, 488 for each of the age categories from youngest to oldest). For ground wetness n = 1,264 (356, 293, 284, 331). For presence of cleansing agent n = 1,939 (n = 477, 499, 476, 487).

3.3.3.5 One-Way Analysis of Variance (ANOVA) for the Progress out of Poverty Index® of Households and Handwashing Station Use

Finally, a one-way between-groups analysis of variance was conducted to explore the impact of the Progress out of Poverty Index for Mali of households and their handwashing station soap usage. The Progress out of Poverty Index® (PPI®) for Mali was divided into three groups of equal percentiles (0-26 points, 27-38 points, and 39-71 points). There was a significant difference between the soap usage in different PPI® groups at the $p < 0.05$ level in LOT scores given the Welch robust test of equality of means in 2011 $F(2, 213) = 7.78$, $p = 0.00$ and 2012 $F(2, 307) = 9.00$, $p = 0.00$. The effect size of the difference in mean scores between the groups was small in 2011 with an eta squared value of 0.04 and medium in 2012 with an eta squared value of 0.06. Post-hoc comparisons using the Tukey HSD test in 2011 indicated that the mean score for stations with the highest range on the PPI® with 38-71 points (M = 0.31g, SD = 0.29 g) were significantly different from those in the lower ranges on the PPI®: 0-26 points (M = 0.19 g, SD = 0.18 g) and 27-38 points (M = 0.23 g, SD = 0.21 g). In 2012 the same trend was true with statistical significance ($p < 0.05$) between the highest PPI® range, 38-71 points, (M = 0.25 g, SD = 0.41 g) and the two lower ranges: 0-26 points (M = 0.10 g, SD = 0.16 g) and 27-38 points (M = 0.11 g, SD = 0.15 g). Figure 3.20 displays the mean soap usage per person per household per day in the different PPI categories disaggregated by year.

Three ANOVAs were also conducted to determine if there were statistically significant differences between the Progress out of Poverty Index (PPI®) of households and the other handwashing station usage variables (proportion of active stations, presence of cleansing agent, and ground wetness). There was only a statistically significant difference at the $p < 0.05$ level in LOT scores given the Welch robust test of equality of means for the proportion of stations with their ground wet amongst the three PPI® levels $F(2, 621) = 3.43$, $p = 0.03$. There was not a statistically significant difference at the $p < 0.05$ level in LOT scores given the Welch robust test of equality of means for the proportion of active station $F(2, 918) = 1.80$, $p = 0.17$ or proportion of stations that had a cleansing agent present $F(2, 922) = 0.85$, $p = 0.43$ when compared across household PPI® levels. The effect size of the difference in mean percents between the PPI® groups and ground wetness was small with an eta squared value of 0.01.

However, when disaggregated by village, there was a statistically significant difference at the $p < 0.05$ level between all usage variables (active stations $F(2, 452) = 12.05$, $p = 0.00$, ground wetness $F(2, 207) = 3.98$, $p = 0.02$, and presence of cleansing agent $F(2, 338) = 6.02$, $p = 0.00$) sorted into PPI® groups in Zeala (see Figure 3.21). The actual differences in mean scores between the groups and usage variables were small (eta squared = 0.02, 0.01, 0.01 for active stations, ground wetness, and presence of cleansing agent).

Post-hoc comparisons using the Tukey HSD test indicated that the mean percentage of active stations significantly differed between all PPI® groups: 0-26 points (M = 84%, SD = 33%), 27-38 points (M = 81%, SD = 39%), and 39-71 points (M = 97%, SD = 18%). For the ground wetness usage variable there was significant difference at the $p < 0.10$ level between the lowest PPI® group (M = 48%, SD = 50%) and the other two, higher groups: 37-38 points (M = 55%, SD = 50%) and 39-71 points (M = 62%, SD = 49%). Regarding, the presence of cleansing agent usage variable and PPI® groups there is a statistically significant difference between the lowest group (M = 58%, SD = 50%) and the highest group (M = 74%, SD = 44%) as well as between the middle group (M = 57%, SD = 50%) and the highest group. There was no statistical significance found between PPI® groups and usage variables (active, ground wetness, and presence of cleansing agent) when disaggregated by season though there was statistically significant differences found between the soap usage of PPI® groups in both seasons.

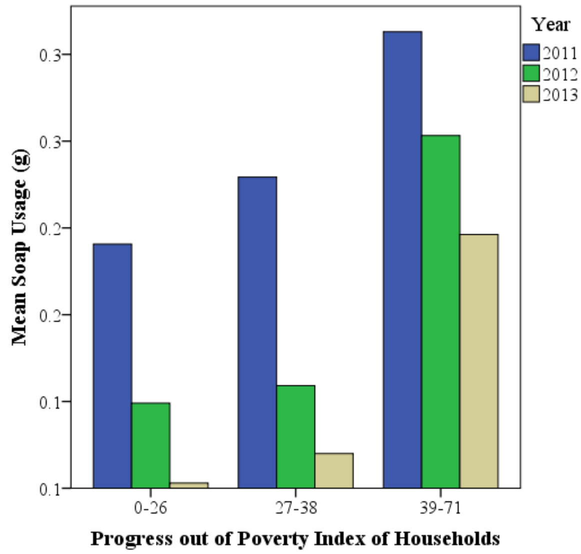

Figure 3.20: Column chart of mean soap usage per person per household per day each year separated in three groups of the Progress out of Poverty Index (PPI®) for Households in Mali (0-26 points, 27-38 points, and 39-71 points). In 2011, n = 547 (n = 246, 213, 88 for each of the PPI categories from lowest to highest). In 2012, n = 754 (n = 343, 274, 137). In 2013, n = 78 (n = 34, 25, 19).

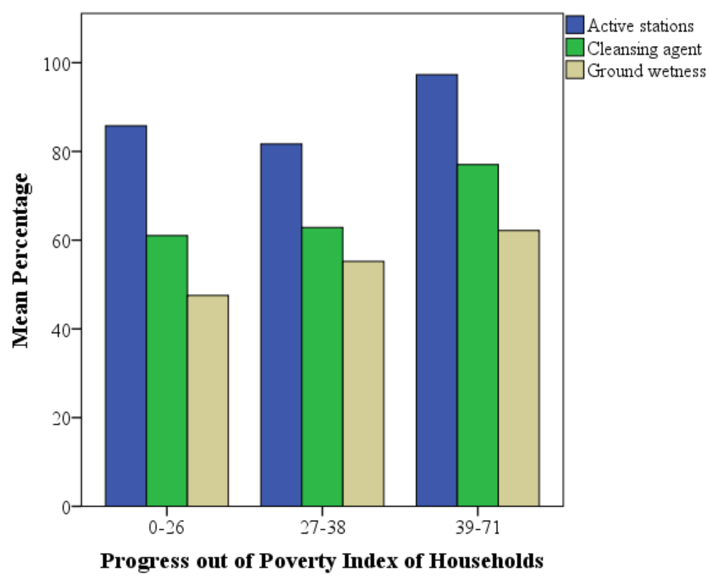

Figure 3.21: Column chart of mean percentage of active stations, presence of cleansing agent, and ground wetness separated in three groups of the Progress out of Poverty Index® household values (0-26 points, 27-38 points, and 39-71 points) for Zeala. For active stations n = 1,387 (n = 644, 625, 118). For ground wetness n = 875 (n = 408, 393, 74). For presence of cleansing agent n = 1,386 (n = 644, 625, 117).

3.3.4 One-Way Repeated Measures ANOVA

On June 25, 2012, a handwashing lesson was given to the students at the primary school in Zeala. The thesis author had trained the school director and other teachers on how to give the interactive lesson on Global Handwashing Day on October 15, 2009 and 2010 in hopes that it would be conducted annually. The importance of handwashing as well as the proper technique and key times you should your hands (before meal times, after defecation, after handling animal, etc.) were all part of the lesson. Germ theory was demonstrated using peppers. The teacher would rub his hands with a hot pepper and shake hands with other students who would then shake hands with other students as well. All infected students were asked if they would like to rub their eyes. They were then asked to wash their hands with water and asked the same question. Finally, the students were told to wash their hands with soap and asked to rub their eyes, demonstrating that only soap can kill germs. At the end of the lesson, students were divided into two groups and had to compete to wash their hands at two tippy tap handwashing stations set up outside the school (see Figure 3.22).

Figure 3.22: Photo from the hand washing lesson given at the Zeala primary school June 25, 2012. Photo was taken by author.

As a control, the lesson was not conducted in the neighboring village, Nci'bugu. A one-way repeated measures ANOVA was conducted to compare soap usage as Time 1 (prior to the handwashing intervention), Time 2 (following the intervention) and Time 3 (three months after the intervention). The descriptive statistics of these tests in both villages (means and standard deviations of soap usage pre, post, and 3 months after the hand washing intervention) are presented in Table 3.4. There was a decrease in soap usage in both villages from the pre-intervention to the post-intervention and three months after the handwashing lesson, indicating that that there was not the hypothesized increase in soap usage anticipated because of the intervention in Zeala. This was confirmed in the statistical tests. There was not a significant effect for time in Zeala (Wilks' Lambda = 1.0, F (2, 15) = 0.09, p = 0.91) or Nci'bugu (Wilks' Lambda = 0.80, F (2, 4) = 0.52, p = 0.21).

Table 3.4: Mean and standard deviations of soap usage (g/person/day/household) before (pre-intervention), after (post-intervention) and three months after a handwashing intervention in Zeala on June 25, 2012.

Village	**Time period**	**N**	**Mean soap usage (g)**	**Standard deviation (g)**
Zeala	Time 1 (pre-intervention)	17	0.18	0.24
	Time 2 (post-intervention)	17	0.15	0.14
	Time 3 (3-month follow-up)	17	0.17	0.21
Nci'bugu	Time 1 (pre-intervention)	6	0.15	0.22
	Time 2 (post-intervention)	6	0.08	0.10
	Time 3 (3-month follow-up)	6	0.06	0.09

To analyze the potential impact of this intervention further, two one-way repeated measures ANOVAs were also conducted to compare the percentage of active stations and stations with presence of cleansing agent immediately before and after the intervention and again three months after a handwashing lesson at the school in Zeala. Descriptive statistics of these two one-way repeated measure ANOVAs are show in Table 3.5. There was no significant effect on the percent of active stations over time in Zeala (Wilks' Lambda = 0.92, F (2, 40) = 1.65, p = 0.21) or in Nci'bugu (Wilks' Lambda = 0.97, F (2, 18) = 0.49, p = 0.49). Similarly, there was no significant effect on the percent of stations with presence of cleansing agent in Zeala (Wilks' Lambda = 0.92, F (2, 40) = 1.75, p = 0.19) or Nci'bugu (Wilks' Lambda = 0.90, F (2, 17) = 0.94, p = 0.10).

Table 3.5: Mean percentage and standard deviations of active stations or stations with presence of a cleansing agent before (pre-intervention), after (post-intervention) and three months after a handwashing lesson was conducted in Zeala on June 25, 2012.

			Active Stations		**Cleansing Agent**	
Village	**Time period**	**N**	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**
Zeala	Time 1 (pre-intervention)	42	83%	38%	48%	51%
	Time 2 (post-intervention)	42	93%	26%	36%	49%
	Time 3 (3-month follow-up)	42	88%	33%	48%	51%
Nci'bugu	Time 1 (pre-intervention)	19	74%	45%	47%	51%
	Time 2 (post-intervention)	19	63%	50%	26%	45%
	Time 3 (3-month follow-up)	19	63%	50%	26%	45%

3.3.5 Qualitative Analysis

In addition to collecting monitoring data of each handwashing stations, other qualitative methods were employed in the research design: baseline and follow up surveys, a participatory exercise in seasonal calendars, and a final detailed survey on handwashing. Among the questions on the baseline survey, each head of the household or representative was asked an open ended question of how they washed their hands. If they did not answer that they washed their hands with soap, they were asked directly if they used soap when they washed their hands. In the baseline survey, none of the 42 households in Zeala or the 19 households in Nci'bugu responded that they washed their hands with soap and water. In September-December of 2012, a follow-up survey with the same questions as the baseline survey was administered again and 98% (60/61) of households responded that they washed their hands with soap.

In January of 2010, a Water and Sanitation committee was created in Zeala and the thesis author helped facilitate Participatory Analysis for Community Action (PACA) tools that included community mapping and seasonal calendars with her counterpart who was also trained by the Peace Corps in these participatory tools. In the seasonal calendar exercise, both the men and women who had been separated to draw their own calendars and then compare them, identified the rainy season (months of July-October) as also the time for sickness and mortality.

A more comprehensive survey focusing on handwashing was administered to 39 households in November 2012. Households were first asked for basic demographic information (number of men, women, children, etc.) in the household. They were then asked which of the members in their household washed their hands with soap. Of 34 households who had active stations, 72% of the household on average washed their hands with soap. Eleven of the households (32%) reported that everyone washed their hands with soap. The minimum reported handwashing rate was 19%. Five household heads specifically stated that the school children in their families washed their hands. One female station owner said that the "school children really like it [handwashing]."

For the households that reported that certain members did not wash their hands with soap, they were asked why they did not practice this behavior. The coded answers to this question are displayed in Figure 3.23. Handwashing station owners were also asked what problems they had with the handwashing station. Their responses are summarzied in Figure 3.24. Most of the households, 44%, stated that their difficulty with the tippy tap was buying soap. For example, a respondent answered that their difficulty with the appropriate technology is: "When the soap is finished and you don't have money." Another woman station owner stated that "When the soap is finished you worry about it a lot." Furthermore, 9% of the respondents said their main problem with the tippy tap was with animals. The handwashing stations are vulnerable to animals (goats, sheep, and cows) that roam the village and eat the soap that are attached to the stations by a string or knock down the stations. One station owner in Zeala had purcahsed a large bar of soap and one of his goats ate it and died. He then dissassembled his tippy tap and never reconstructed it. Another 9% of the respondents stated that children playing with the station (emptying the jug of water, sitting on the cross bar, and playing with the soap) was a major difficulty with the station maintenance since the station owners would constantly have to repair and refill the station.

Next, the station owners were asked when they washed their hand with soap. Of the 37 responses, 81% said they wash their hands before eating and 19% said they washed their hands before eating as well as after the latrine and other times (when hands are dirty, before cooking, after sweeping, etc.). When asked a direct follow up question if they washed their hands after the latrine if they had not answered originally, 72% of respondents confirmed that household members washed their hands with soap after using the latrine. 60% of respondents also confirmed that the women in their household washed their hands with soap before cooking.

Moreover, station owners were asked what the importance of washing hands with soap was to them. Their responses are shown in Figure 3.25. Of those that answered that the importance of handwashing is to prevent illness, they were asked a follow-up question on how handwashing with soap prevents illness and their responses are displayed in Figure 3.26. A popular phrase used by many respondents during the survey and in impromptu conversations with the thesis author regarding the importance of handwashing was that "I kono te se ka ko" or

"You cannot wash your insides/stomach." Other testimonials from respondents concerning the importance of handwashing are included in Table 3.6.

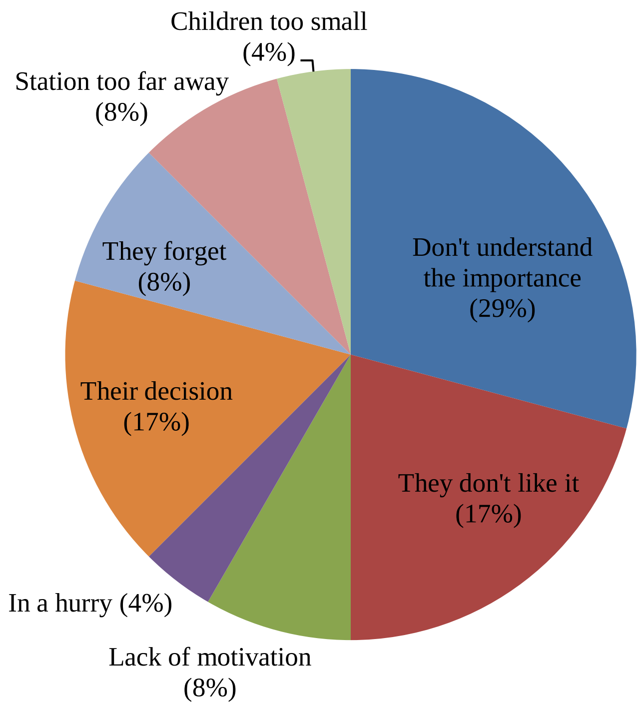

Figure 3.23: Survey responses to why not all the family members wash their hands with soap (n = 23).

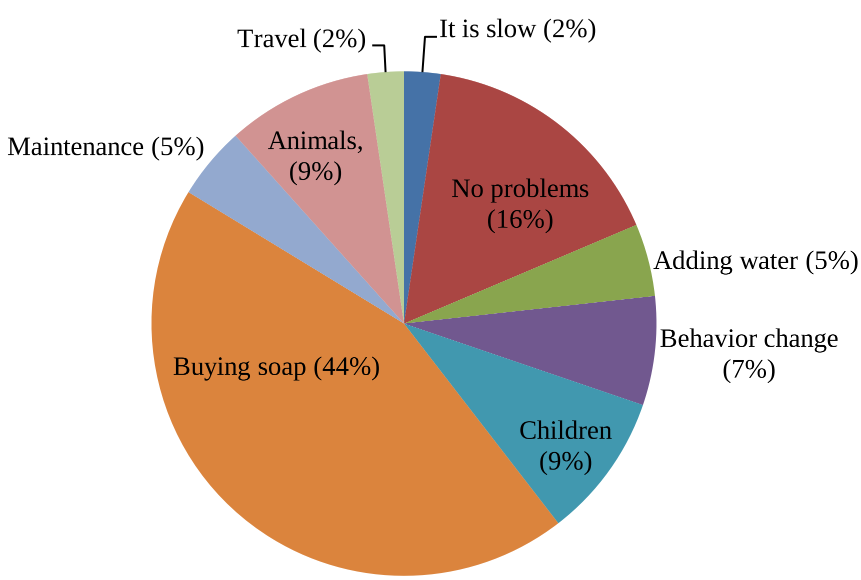

Figure 3.24: Survey responses to users' main problems with the tippy tap, appropriate technology handwashing station (n = 43).

All thirty-nine station owners surveyed were finally asked more specific questions about disease prevention and transmission related to handwashing. 60% of households confirmed that handwashing with soap could prevent ARIs while 86% believed that handwashing with soap could prevent malaria. Lastly, regarding the results from the questions related to germs and disease transmission, 68% of station owners were able to correctly explain what germs were and 100% confirmed that they believed they existed though they could not see them. 62% of households agreed that diseases such as colds, diarrhea, etc. can be transmitted from one person to another.

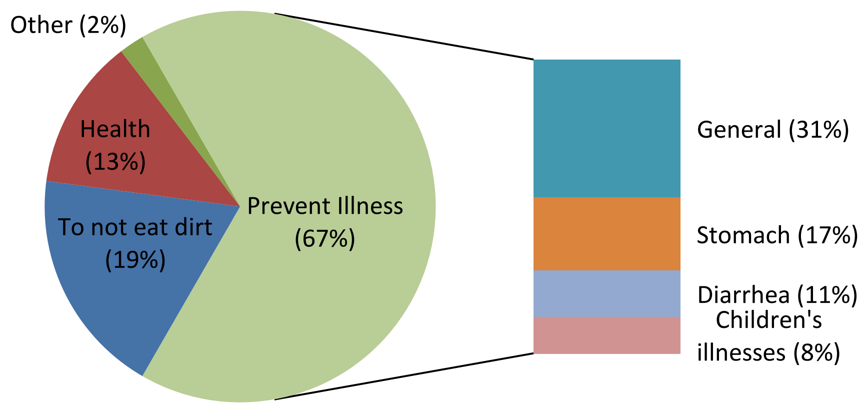

Figure 3.25: Survey responses to what is the importance of washing hands with soap (n = 48).

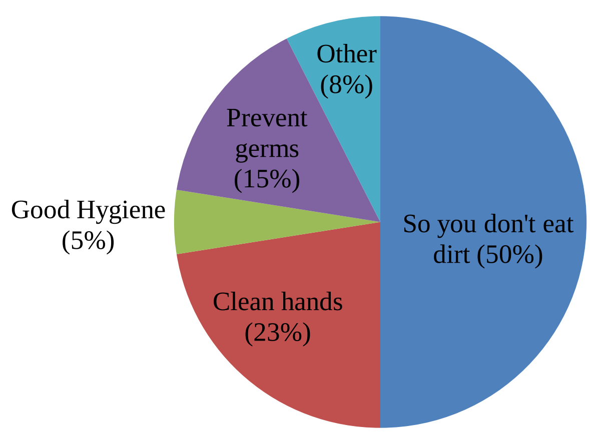

Figure 3.26: Survey responses to how handwashing with soap prevents illness (n = 40).

Table 3.6: Testimonials from household heads in response to the handwashing survey question on the importance of handwashing with soap.

Testimonials
• "Every once and a while I used to get diarrhea but this year it has not happened."
• "Children do not get diarrhea. It [handwashing] is very important."
• "Even if it [diarrhea] occurred this year, it wasn't as bad."
• "It is important to wash your hands with soap. It protects children from many things."
• "You are able to relax [when you wash your hands with soap] since you know that you are not eating dirt."
• "Handwashing with soap is important for the health of your household."
• "Handwashing with soap will reduce expenses [medical] and you will be able to make more money."

3.3.6 Quantitative Measurements of Handwashing Station Soap and Water Usage

Repeated measurements of soap and water usage of the handwashing stations were made. Regarding the amount of soap used per hand wash, the author recorded the number of times she washed her hands in the proper method (lather thoroughly while saying the French alphabet, thus, ensuring a duration of at least 10 seconds) and weighed the soap before and after. She found after five washes she used an average of 0.32 grams of soap per wash. After 32 washes she used an average of 0.26 grams of soap per wash and after 17 washes she used an average of 0.25 grams of soap per wash. In the handwashing intervention conducted at the primary school, 120 children had been instructed on the proper handwashing method and observed during a competition after the lesson. The author weighed the two bars of soap before and after the competition and calculated an average 0.25 grams per wash for the sixty students on one team and 0.28 grams per wash for the sixty students on the other team. These were students in range of ages from 7-15 in third through sixth grades. The weighted average of the author’s personal soap usage measurements and the ones at the school (total of 174 washes) was 0.26 grams of soap per hand wash.

It was also important to get an estimate for how many times you could wash your hands before emptying the 4-L jug of the tippy tap. Over the average of ten full jugs, the study author was able to wash her hands an average of 19 times including wetting her hands briefly before using soap and rinsing after lathering. Thus, in that case the tippy tap uses an average of 211 ml per hand wash which would only correspond to 2.3 liters used for eleven hand washes, much smaller than the 13.9 liters needed for an automated sink. However, this may be an ideal estimate as the design and use of the station impacts the water usage per hand wash. For example, the person who installs the station may incorporate a larger hole in the water jug that will increase the flow rate. Also, some users will keep their foot on the pedal while lathering with the soap which wastes water. Users often stated to this thesis's author that children also like to play with the stations and may continually empty the jug of water.

In Mali, the common handwashing practice is to pass around a partially filled bucket of water and each person takes their turn rinsing their hands in the same water. Women and men eat separately and consequently have their own separate washing buckets. Often the adults will wash their hands first, leaving the children to wash their hands last with the dirtiest water. This facilitates fecal-oral transmission rather than preventing it as the wash water becomes infected with the bacteria and pathogens from other peoples' hands and then they use those hands to eat with since they do not utilize utensils. Because the buckets are usually only 12.5% full and have a standard size of 17 liters this is at least two liters of wash water for four to ten people who may be eating together. Thus, a tippy tap would not require more water than this handwashing method but would take more time for each person to wash their hands separately especially if smaller children need to be helped by their mothers or siblings.

3.4 Discussion

The framework of this research, the sustainability of handwashing stations, revolved around six main themes: gender, training, water, seasonality, wealth, and monitoring. The results of the analysis will be discussed below under each of these main themes and their hypothesis.

3.4.1 Gender

Beginning with gender, it was hypothesized that stations built or maintained by women would have higher usage because of women's more prominent role in household hygiene and because the hygiene intervention was more focused on the women in the communities. This hypothesis was not entirely confirmed in the data analysis of soap usage but it was evident through the Pearson Chi-Square tests for independence conducted that gender played a role in other usage variables (presence of cleansing agent and functionality). In the independent samples t-test, the difference between soap usage of stations built by men or women was not statistically significant at the $p < 0.05$ level in 2011 ($p = 0.12$) or 2012 ($p = 0.97$). However, in the Pearson's chi-squared analysis the association between gender and presence of a cleansing agent was significant at the $p < 0.10$ level overall ($p = 0.05$) and in Zeala ($p = 0.01$) but not in Nci'bugu alone or when disaggregated by year. Overall, stations built by women (M = 58%) were more likely to have soap than those built by men (M = 54%). This difference was even more apparent in Zeala where 62% of the stations built by women on average had a cleansing agent present in contrast to 55% of the stations built by men.

Although there was not a significant association between gender and proportion of active stations overall as was the case with the presence of a cleansing agent, a significance was evident upon a closer look at the results from each village using the Pearson's Chi-square tests for independence ($p = 0.00$ in Zeala and $p = 0.01$ in Nci'bugu). In Zeala, on average, 88% of the stations built by women were functioning while only 82% of men's stations were active. It was the opposite case in Nci'bugu where 69% of stations built by women were functioning while 79% of stations built by men were in working order. This reverse is the reason there was no significant association between gender and functionality overall or in 2011 and 2012 since these proportions cancel each other out when averaged together. Furthermore, this trend is confirmed in the Pearson's Chi-squared test between village and presence of cleansing agent and village and functionality where these associations are significant between the stations built by females but not by those built by males. The stations built by women in Zeala have higher usage (M = 62% for presence of cleansing agent, M = 88% active stations) than those built by women in Nci'bugu (M = 52% for presence of cleansing agent, M = 69% active stations). This difference in functionality between the genders of who built the stations in the two villages was apparent in Figure 3.8.

Moreover, it appears that stations built by women were more resilient against factors of time and proximity to a water source. For stations close to a water source (less than 35 m), 86% of stations built by men were active and 64% had presence of a cleansing agent while 80% of stations were active and 51% had presence of a cleansing agent that were greater than 35 meters from a water source. These associations between water source and active stations and presence of a cleansing agent were significant at the $p < 0.05$ level ($p = 0.04$, $p = 0.00$ respectively) for men but not for women ($p = 0.33$, $p = 0.56$). Between 2011 and 2012, active stations built by men fell from 86% to 79% resulting in a significant association of $p = 0.01$ while this association was not significant for women ($p = 0.46$). Despite these associations between gender and the usage variables of active stations and presence of cleansing agent, there was no significant association found between ground wetness and gender as well as no statistically significant difference in the ANOVA between the gender of who adds water to the station (male, female or mixed) and all usage variables. This is surprising since in Mali, as in many places in Africa, it is the role of women to fetch water and one may assume that they would fill the stations more often.

In conclusion, though it was not proven that stations built by women necessarily have higher usage; gender does play a role in handwashing station usage and should not be ignored in handwashing interventions. On the one hand, in Zeala, it is evident in the statistical analysis that stations owned by women are better maintained and are more likely to have a cleansing agent available based on the Pearson's chi-squared analysis but do not necessarily have a higher soap usage. Conversely, in Nci'bugu, the gender hypothesis that stations built by women are used more can be rejected because the study results revealed that the stations built by men were used more in terms of functionality and having soap or white ash available. Indeed, one could also hypothesize that stations built by men may have higher usage as they have more income than women to buy soap and the materials to construct the stations.

Thus, there appears to be different gender dynamics between Zeala and Nci'bugu even though they are only three kilometers apart from each other. Reasons for these differences may be that the thesis author had more interaction with the women in Zeala than Nci'bugu in her work as a Peace Corps Volunteer (PCV) as her primary village was Zeala and this may have led the women in Zeala to maintain their handwashing stations more. Also, she was told by various people from other villages and even Peace Corps staff that the women in Zeala were very "strong" compared to other villages. There were five active women's organizations in Zeala and only one in Nci'bugu. A study by El Azar et al. in 2009 associated lower empowerment scores for women with reported diarrhea cases. In future studies, an analysis between handwashing station usage variables and empowerment scores should also be performed.

3.4.2 Water

Two hypotheses were made regarding water and handwashing. First, that stations closer to a water source would have higher usage and second that stations with more people involved in adding water would be used more. According to the ANOVA results between soap usage and proximity to a water source, there was a significant difference between the stations closest to a water source (less than 35 meters) from those further away (35 meters and higher) in 2012 but not 2011 (Figure 3.13 depicts the highest soap usage of 0.20 grams compared to the other distances). The reason for this may be that there was an initial high usage during the first year with the novelty of the appropriate technology but in the following year, those closer to a water source had higher soap usage as it takes less time to fetch water to fill the station. From the ANOVA we can also conclude that well proximity is only significant for those stations very close (0-34 m) to a water source. This is noticeable in Figure 3.13, and through post-hoc comparisons because there is little significant difference between the soap usage of the groups 2^{nd}, 3^{rd}, and 4^{th} furthest away from the well.

For this reason, Pearson Chi-squared tests for independence were run between the other usage variables (presence of cleansing agent, active stations, and ground wetness) and only whether the water source was close (0-34 m) or far (over 34 m). Consistent with the results of the ANOVA between well proximity and soap usage, all usage variables were higher for stations close to a well or pump and there was a significant association between the proximity to a water source and all the other usage variables. However, just as in the ANOVA, when disaggregated by year the association between usage variables and well proximity were not significant in 2011 but were significant in 2012 further confirming that well proximity becomes more important with the passage of time.

The second hypothesis related to water stated that stations where more people were involved in adding water would be used more. First, an ANOVA was conducted between soap usage and three groups who add water to the station (one person, multiple people, or everyone). There was a statistically significant difference at the $p < 0.05$ level between which type of people were responsible for adding water to the station and soap usage. However, as evident in Figure 3.14 and the post-hoc analysis, the main difference was between stations where multiple people and everyone added water to the station, where stations with multiple people adding water to the station had the lowest soap usage (even below the group where one person was in charge of adding water to the station) and stations where everyone added water to the station had the highest soap usage. Thus, although stations where everyone adds water had the highest usage, stations where multiple people add water to the station still had the lowest we must therefore reject the hypothesis that stations where more people are involved in adding water will have higher usage.

This was further confirmed in the three ANOVAs between proportion of other usage variables and who adds water to the station where each, though statistically significant at the $p < 0.05$ level, had different trends. The ground wetness usage variable proportions were the only ones to follow the same pattern as soap usage where the highest proportion of stations where the ground was found wet underneath upon inspection after meal times was where everyone added water to the station and the lowest was among stations where multiple people add water to the station. However, contrary to the results for the ANOVA with soap usage and ground wetness where the highest values were found in stations where everyone added water to the station, the highest proportion of active stations and stations with a cleansing agent where when one person was designated to fill the water apparatus. Though the lowest proportion of stations with a cleansing agent present were when multiple people added water to the station as was the case for soap usage and ground wetness, the lowest proportion of active stations was for those stations where everyone added water to the station which was the highest for soap usage and ground wetness. Furthermore, all these ANOVAs had small effect sizes (low eta squared values indicating small differences in the means) and when disaggregated by village or season, there were also different trends. Thus, one can conclude that the people or person that a household designates to add water to the station will not significantly affect the station usage.

Moreover, concerning water as an indicator of station use, other ANOVAs were conducted between soap usage, presence of cleansing agent, ground wetness and proportion of active stations to the amount of water observed in the jug (0%, 25%, 50%, 75%, and 100%). There was a significant difference found between jugs that were empty and those that were full in both years, with those being 75% or 100% full having the highest soap usage. Specifically in 2012, there was a significant difference between jugs that were 75% full and those that were 0%, 25%, and 50% full. Those that were 75% full had the highest soap usage. This may be because the thesis author observed that station users would realize when she was inspecting stations and fill their jugs with water, thus, decreasing the mean usage variable values (soap usage, ground wetness, and presence of cleansing agent) for stations that were 100% full.

3.4.3 Seasonality

The hypothesis that there would be a significant decrease in handwashing station usage during the rainy season can be accepted given the data analysis. Foremost in Figures 3.3 - 3.5, seasonal fluctuations are evident with drops in the percent of functioning stations and stations with a cleansing agent corresponding to those months. These differences were proven significant in the independent samples t-test between soap usage and season both in 2011 ($p = 0.00$) and 2012 ($p = 0.03$). In 2011 the average soap usage (g/person/day/household) in both villages during the dry season was 0.26 grams while the average soap usage in the rainy season was 0.13 grams. In 2012, the mean soap usage was 0.15 g/person/day/household during the dry season and 0.11 g/person/day/household used during the rainy season. This decrease in soap usage during the rainy season is attributed to the fact that most people spend the day in the fields and eat lunch there, so stations are not used during the day as much. Also, there is increased work load during this period and station users may be too busy to maintain and refill the station. Rainy season also corresponds to the depletion of grain stores and food insecurity for many households. Many families have decreased funds and may not be able to purchase soap and they often have a dinner of porridge that they drink using spoons and do not wash their hands.

Also, there were statistically significant associations found between season and station functionality and presence of cleansing agent using the Pearson's chi-squared analyses for independence between 2011-2013 in both villages. Overall, an average of 64% of the stations had a cleansing agent and 84% of stations were functional in the dry season while only 45% of stations had a cleansing agent present and 76% were active in the rainy season. When the cases were disaggregated by village, year, and gender, there was statistical association between the proportion of stations with a cleansing agent and active stations and season in all cases except in 2012 where there was not a statistically significant association between the proportion of active stations and season. It is also important to note that water source proximity and presence of cleansing agent and proportion of active stations do not have a significant association in the dry season but there is a significant association in the rainy season. This could be because as women have less time during the rainy season, the proximity to a water source becomes more important for station use during this season.

3.4.4 Training

The hypothesis made under the theme of training stated that there would be an increase in handwashing station usage after a handwashing training. According to the results of this study, this hypothesis must be rejected as the one-way repeated measures ANOVA was not statistically significant at the $p < 0.05$ level in either village. There was actually a decrease in daily, per capita soap usage and proportion of usage variables (active stations and presence of active stations) though not significant. However, a major reason that the lesson at the school may not have resulted in an increase in handwashing station usage was because it was conducted at the end of June which also corresponds to the last month of dry season. The intervention was not able to be carried out in April when originally planned due to political instability in the country. It was apparent that the lesson was not able to compete with seasonal influences on handwashing station use.

Nevertheless, it is evident through the survey analysis that the handwashing trainings (at the schools, through the water and sanitation committees, and women's groups) had an impact in educating households on the importance of handwashing with soap. Foremost, in the baseline survey administered in 2009, 0% of the household heads reported that they washed their hands with soap while two years later, 98% of household heads said they washed their hands with soap. However, it is evident through the more in depth handwashing survey that there is a knowledge and practice gap. When households were asked who actually washes their hands with soap, they reported, on average, that 72% of their members washed their hands with soap. Only 19% of households said that they washed their hands after defecation or before cooking.

When asked which diseases that handwashing with soap could prevent, cultural beliefs still dominate some of the responses inherent in their definition of illnesses and their transmission routes as evident in the results. 60% of the households stated that handwashing with soap could prevent the spread of ARIs while the remaining 40% probably believe that ARIs are completely transmitted by the wind or in the air as several respondents stated that diseases such as colds are “wind diseases.” A large percentage of household, 86%, believed that handwashing with soap could prevent malaria. This is because the Bambara word for Malaria, “Sumaya”, has a much broader definition. It also is the same word used for rainy season, wetness, and coldness as well as malaria. If a person is sick with a fever or diarrhea they may automatically say that “Sumaya b’a la” or “They have malaria.” Though they may have symptoms of malaria, they may also have the flu or a gastrointestinal illness. Moreover, many rural Malians do not believe that malaria is transmitted by mosquitoes but that you can contract malaria by eating too many bananas or mangos (Peace Corps-Mali, 2011). Regarding disease transmission, only 68% of households could correctly explain what germs were while only 62% agreed that diseases could be transmitted from one person to the other. All these areas of when to wash your hands and specifics on disease prevention and transmission were covered during handwashing lessons, though it is clear through this survey that some areas need to be re-emphasized in the community. Nevertheless, it is important to keep in mind that simply knowledge in handwashing and its’ importance does not necessarily translate into comprehension and action (Pinfold et al., 1996).

3.4.5 Wealth

The hypothesis that handwashing stations that scored higher on the Progress out of Poverty Index® (PPI®) would have higher usage can be accepted. In an ANOVA between the three PPI® groups and soap usage, there was a statistically significant difference at the $p < 0.05$ level in both 2011 ($p = 0.00$) and 2012 ($p = 0.00$) where the highest soap usage was in the highest PPI® index category (39-71 points) as was apparent in Figure 3.20. Though there was not a statistically significant difference at the $p < 0.05$ level in the proportion of active stations and stations with presence of a cleansing agent between the PPI® groups overall, there was a statistically significant difference between them in Zeala for all usage variables. Furthermore, there was a statistically significant difference found in the proportion of stations with their ground wet in their PPI® categories overall.

3.4.6 Monitoring

Although it was outside the scope of this research design to test for the effect monitoring had on handwashing station usage, stations were monitored over time and there were statistically significant differences and associations found between station usage over time of the intervention and as the stations' age. There was a decrease in station usage over time as first evident in Figures 3.3-3.5 and later through the statistical analysis. Across all nominal usage variables, there was a significant association with year where there were lower proportions in active stations, presence of soap, and ground wetness in 2012 than 2011 as indicated in Table 3.2. Overall, in both villages, 70% of stations had cleansing agents in 2011 which decreased to 47% in 2012. Similarly, active stations dropped from an average of 85% in 2011 to 76% in 2012 and ground wetness under the station decreased from 71% in 2011 to 47% in 2012.

When examining actual station age and not just that of the intervention, cases were divided into four different age groups (1-300 days, 301-522 days, 523-726 days, and 727-1,180 days). In an ANOVA between the soap usage of these four different age groups in 2012 there was a statistically significant difference found in their mean soap usage. There was not a statistically significant difference in the soap usage amongst different station age groups in 2011 as there were only cases in the three youngest age groups with a small sample size of 30 in the third age group (523-726 days). Interestingly, the lowest soap usage in 2012 was in the third oldest group (523-726 days) with a soap usage of 0.10 g/capita/day/household compared to an average of 0.15 g/capita/day/household in the other three age categories (1-300 days, 301-522 days, and 727-1,180 days) as seen in Figure 3.18. This may be due to a tipping point in handwashing behavior adoption where the stations over two years old have adopted the behavior and, thus, have a higher soap usage while some of the stations in the third group are struggling to adopt the behavior and reduce the average soap usage of their group.

Three other ANOVAs were conducted to determine if there was also a significant difference in the proportion of active stations, stations with presence of a cleansing agent and ground wetness under stations among the four different age groups. These were all found statistically significant at the $p < 0.05$ level (see Figure 3.19) where the proportion of usage variables in the oldest group (727-1,180 days) was significantly different from the usage variable proportions in the first age group (1-300 days) with the highest proportions. Moreover, often across all statistical tests (independent samples t-tests, Pearson Chi-Squared test for independence, and ANOVAs) there is an increase in statistical significance and actual difference in mean squares (eta-squared) from 2011 to 2012, indicating that factors such as proximity to a water source, seasonality, wealth, and gender are potentially becoming more significant over the intervention once the novelty of the stations has dissipated.

This attenuation in usage is not surprising as it has been noted in other literature not just for handwashing (Chandler, 1997; Luby et al., 2009) but other water and sanitation interventions (IRC, 2009; Koestler, 2010; Schweitzer, 2013). However, this research quantifies this decline specifically for handwashing and, thus, further emphasizes the importance of monitoring and evaluation in development projects particularly in the WASH sector. The final handwashing survey administered in November 2012 to 39 of the handwashing station owners provides insight into the reasons for the decrease in station usage over time. Of the households who admitted that certain members in the household did not wash their hands with soap answered primarily that they did not know the importance (29%) and that they didn't like it (21%) for either cultural reasons or even the taste since they eat with their hands. Other reasons like forgetting to wash their hands and the station being too far away only comprised 16% of the responses (see Figure 3.23). When asked what difficulties they encountered with the appropriate technology handwashing stations, 44% stated that it was replacing the soap when it was finished for monetary reasons. Children playing with the station, animals eating the soap, and difficulty adopting behavior change were each less than 10% of the responses. It is important to note that answers to this particular question may have been different if administered by a member of the community. Respondents may have responded that having money for soap was their greatest difficulty with maintaining the handwashing station in hopes that they would be given free soap.

Thus, it is important to administer these types of surveys to get feedback on an intervention and the technology. From the survey responses, it is apparent that more handwashing promotions need to be implemented to educate both users and non-users in the community particularly on washing hands with soap not just before eating but before cooking and after defecation as well as how handwashing with soap prevents disease. Furthermore, handwashing promotions should be conducted to encourage non-users to realize the importance of handwashing and overcome their dislike for the practice. Finally, since replacing soap was identified as a main constraint in washing hands with soap, station owners should be encouraged to use traditional soap, white ash, or soap powder in place of soap since these cleansing agents may be more cost efficient for families.

Nevertheless, it is important to note as stated by research of handwashing interventions in Thailand and China that training does not necessarily translate into practice or decrease in diarrheal disease as was also seen in the hygiene intervention in this study (Pinfold et al., 1996; Bowen et al., 2007). While their studies documented results of interventions through teacher records of illness (as was the case in the Chinese study) or finger tip impression techniques and diarrheal incidence surveillance in Thailand, this study helped confirm their analysis through the measurement of soap and other usage variables. Lessons and promotions should be culturally appropriate, designed with the audience in mind, implanted in conjunction with key educators (teachers, mothers, etc.) and integrated into formal education materials. It may be helpful to carry out ethnographic interviews on the perception of illness and causes for that culture before implementing an intervention. It is true that 86% of the survey respondents agreed that handwashing with soap could prevent malaria though many Bamanan people in rural communities do not believe that malaria is transmitted through mosquitoes but can also be caused by eating certain fruits (bananas and mangoes). Further, the Bambara word for malaria "sumaya" encompasses the symptoms such as fever, stomach ache, diarrhea, vomiting, etc. and may encompass other illnesses than malaria. Also, many rural Bamanan believe diarrhea for babies is caused by teething.

Moreover, although surveys can be a useful tool, respondents may not always provide honest answers to questions as is evident in the literature on handwashing with soap that there was over reporting of the behavior when survey responses were compared with structured observation or other methods (Curtis et al., 2003; Biran et al., 2008; Ebo et al., 1997). On average, station owners reported that 72% of their household washed their hands with soap, and a large proportion of households reported that everyone washed their hands with soap (32%) even though these were households with low performance in handwashing station usage variables (active stations, presence of cleansing agent, soap usage, and ground wetness). Overall soap usage was very low (0.13 g/person/day/household in 2012) which is half the amount of soap needed for one wash according to measurements in the field (mean of 0.26 g/wash). In contrast, the school director had the highest average soap usage of 0.68 g/person/day/household. Consequently, it can be deduced that there are people in the households that are not washing their hands, and/or they are not practicing proper handwashing technique (i.e. not lathering properly and/or only washing the one hand that they eat with, etc.), and/or not consistently washing their hands.

CHAPTER 4: CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

4.1 Conclusions

In this research, a comprehensive monitoring strategy was developed and implemented for handwashing stations in two villages in Mali and the data collected were analyzed to determine key differences between stations that gave insight into how to better promote handwashing behavior change. Six factors were analyzed in this study: gender, training, water, seasonality, wealth, and monitoring. Seasonality was found to have a powerful, statistically significant role ($p < 0.05$) in soap presence, usage, and station functionality with a 29% decrease in soap usage in 2012, 30% decrease in stations with presence of a cleansing agent, and 9% decrease in active stations in 2011 and 2012 between the dry and rainy seasons. This significant association between usage and season comes at a critical time when handwashing with soap is of the upmost importance since, during the rainy season, there are higher incidences of diarrheal disease and people have weaker immune systems due to malnutrition caused by food insecurity (Adams, 1994; Findley et al., 2010).

Just as 36% of pumps across 21 sub-Saharan African countries were found non-functional (IRC, 2009), there was a 22% decrease in active handwashing stations between 2011 and 2013 of the handwashing intervention along with a 35% decrease in stations with presence of a cleansing agent and 60% decrease in stations where the ground was found wet upon inspection where all these differences were statistically significant at the $p < 0.05$ level using the Pearson's Chi-squared test for independence. Moreover, the lowest usage variable proportions for active stations, presence of cleansing agent and ground wetness were found in the oldest stations (727-1,180 days old) which differed significantly ($p < 0.05$) when compared to stations 1-300 days, 301-522 days, and 523-726 days old. Also, there was a significant difference ($p < 0.05$) between the mean soap usage of stations that were 523-726 days old (0.10 g/capita/day/household) compared to an average of 0.15 g/capita/day/household for stations that were 301-522 days old. This emphasizes the importance of monitoring and evaluation of handwashing interventions. It isn't enough just to educate and introduce a new technology and expect continual usage but interventions should be monitored over time and users should be consulted with their suggestions for and difficulties with the technology. In fact, in this study, handwashing station owners were surveyed two years into the intervention and stated that most of their difficulties (44%) were with buying soap for the stations and that the people who did not wash their hands with soap (28% of people within households) were not aware of the importance of handwashing (29%). Nevertheless, survey responses were compared with the quantitative data and it was found that overall soap usage was very low (0.13 g/person/day/household in 2012) which is half the amount of soap needed for one wash according to measurements in the field (mean of 0.26 g/wash), indicating that not everyone in each household are washing their hands properly at all times.

Wealth, as measured by the Progress out of Poverty Index® (PPI®) for Malian households was also proven to be a statistically significant ($p < 0.05$) factor in handwashing station sustainability where the mean soap usage in 2012 (0.25 g/person/day/household) for households scoring between 38 and 71 points was double the other PPI® groups (0.11 g/person/day/household for stations in households that scored between 27-38 points and 0.10 g/person/day/household for stations in households that scored between 0-26 points). Thus, households should not be considered homogeneous when conducting a handwashing intervention since they may have economic barriers to adopting the behavior such as purchasing soap.

In 2012, the second year of the handwashing intervention, proximity to a water source was found to be significant in soap usage where handwashing stations closest to a well or pump (0-34 m) had a mean soap usage of 0.28 g/person/day/household which was twice as much as the three other distance ranges. It was evident through the data analysis that proximity to water source was only significant for handwashing station usage when the well or the pump was within 34 meters of the station since, in post-hoc tests, there was no statistically significant difference found between the mean soap usage of stations and water sources that were 35-55 m, 56-83 m, and 84-172 m from each other. Concerning the other usage variables in both villages in 2011 and 2012, there was a 5% decrease in active stations between stations that were close to the water source (less than 35 meters) and those that were far (35 meters and over) as well as a 9% decrease in stations with presence of a cleansing agent and 12% decrease in stations that were wet underneath upon inspection. These differences were more pronounced in the rainy season with a 27% decrease in presence of a cleansing agent and 11% decrease in functioning stations, further emphasizing the importance of seasonality in handwashing station usage.

Also related to the factor of water, the amount of water in the jug was a good indicator of soap usage as jugs that were 75% full had a soap usage of 0.23 g/person/day/household that was statistically different ($p < 0.05$) from the soap usage of jugs that were empty (0.08 g/person/day/household). Empty jugs also had the lowest proportion of all other usage variables (active stations, presence of cleansing agent, and ground wetness). However, who added water to the jug did not make a difference in station usage since there was not a consistent trend in average handwashing station usage variables whether one person, multiple people, everyone, males, or females added water to the station.

Nevertheless, the gender of who built the station, not added water, was found to be significant ($p < 0.05$) in Zeala and Nci'bugu in opposite ways. In Zeala, 88% of the stations built by women and 82% of the stations built by men were functional while 69% of the stations built by women and 79% of the stations built by men were functional in Nci'bugu. In a Pearson's chi-squared analysis between villages and gender, the stations built by women in Zeala had a higher presence of cleansing agent (M = 62%) than those built by women in Nci'bugu (M = 52%). Though there was no significant difference in soap usage between stations built by men and women overall or in either village, the significant findings in the other usage variables of functionality and presence of cleansing agent demonstrate that the influence of gender cannot be generalized for all women but is specific to each community. Thus, future studies should incorporate women's empowerment scores (El Azar et al., 2009) and it is still extremely important to consider gender in hygiene interventions.

Though a lesson on handwashing at the local primary school was not found to significantly impact handwashing station usage in this study, it was found through surveys that the intervention overall had educated the community. In the first year, 0% of households stated that they washed their hands with soap while 98% reported that they washed their hands with soap two years later and 68% could explain what germs were. Furthermore, from the timing of the intervention (the week before the onset of rainy season), it can be hypothesized that seasonality is more influential of a factor than training in handwashing station usage. Even so, training still remains the foundation of any hygiene intervention.

Altogether, through this study, gender, training, water, seasonality, wealth, and monitoring have all been shown to play a significant role in the sustainability of handwashing station usage and, thus, handwashing behavior change in a small, rural community setting in the developing world. Governments and non-government organizations (NGOs) should ensure that these six factors, particularly seasonality, are addressed in their hygiene projects. This study used a mixed methods approach to test the significance of these six factors with a unique combination of indictors (soap usage, ground wetness, amount of water in the jug, presence of cleansing agent, and presence of active stations). These same methods, particularly measurement of soap usage, should be employed in monitoring of handwashing interventions though ground wetness could be eliminated as it is very weather dependent. Finally, users should be asked for feedback on the intervention and their perceptions of any technology that is promoted as was done in this study through the handwashing survey.

4.2 Recommendations for Future Research

Handwashing remains one of the most effective methods to reduce diarrheal disease and childhood mortality, however much research is still needed in how to effectively implement handwashing interventions so that the target population maintains the behavior well after the intervention. The handwashing monitoring strategy developed by the author should be implemented on a larger scale where villages are selected randomly that are further away from each other to better satisfy statistical assumptions. Though the cases from both villages were often combined together in data analysis, there were statistically significant differences found between these two communities despite their close proximity of only three kilometers (refer back to Table 3.2).

In future research, the same handwashing station usage variables can be monitored, excluding ground wetness as it was found to be very weather dependent and cannot always be recorded particularly in the rainy season. The most robust indicator in this study that should be utilized in future research was soap usage which was weighed with a scale between visits in the second year. Though an observer may record the presence or absence of a cleansing agent or handwashing station as in previous studies (Bittner et al., 2002; Luby et al., 2009; Biran et al., 2011), this says little about how much of the soap is used. Using multiple, simple indicators helps to provide further verification of hypotheses in data analysis. Another potential usage variable that could be monitored is water usage by placing flow meters on the handwashing stations and comparing the results between genders, seasons, PPI® and over time. Simply recording the amount of water in the jug like recording the presence or absence of soap says nothing about the amount of water used. The use of flow meters would eliminate the potential of users to mislead the observer by adding water to the station once they see that he/she is monitoring stations that day.

Future research should be designed to assess the impact of monitoring on handwashing station usage where control villages are monitored less than intervention villages to see if there is higher usage in villages that are monitored more frequently. This was not able to be assessed during this study with just two villages and testing for multiple hypotheses (gender, wealth, water, etc.) already though it is an important factor as stated in the literature known as the "Hawthorne effect" (Carabin et al., 1999; Bittner et al., 2001; Pittet et al., 2004). The "Hawthorne effect" in respect to handwashing is where there is an increase in handwashing incidences due the presence of an observer.

Furthermore, though it was beyond the scope and ability of the thesis author to monitor health indicators such as diarrheal and ARI incidences, it would be an important contribution to the literature on this topic to measure soap and overall station usage and compare to diarrheal and ARI incidences to see if, in fact, higher soap usage corresponds to lower disease incidences. Moreover, future studies should also test for the impact of different handwashing trainings (at schools, through women's groups, through the radio etc.) on soap usage and other usage variables at different times during the year to see which have the most, if any, impact on handwashing station usage. The training tested in this study was a handwashing lesson that was conducted at the local primary school right before rainy season and there was no significant difference found in handwashing station usage in Zeala or the control village, Nci'bugu. However, this does not mean that other types of interventions or even the same type of intervention at a different time in the year will not increase handwashing station usage in other communities.

Additionally, ethnographic research on illness would be key to better understand perceptions of handwashing with soap in the Bamanaw cultural context. For example, in response to the handwashing survey questions concerning health, 86% of respondents believed that handwashing with soap could prevent Malaria and 40% were unable to describe germs. It is evident that there are cultural beliefs in regards to illness that are influencing handwashing behavior and a better understanding of how they understand and treat different illnesses would be integral in developing trainings to promote handwashing behavior change. Therefore, there are many research opportunities and needs to apply the monitoring system developed in this study on a larger scale, incorporating health and monitoring indicators as well as ethnographic studies in order to better determine how to sustainably disseminate the behavior of handwashing with soap to prevent millions of deaths worldwide.

4.3 Recommendations for Implementers

Though much research is still needed to better understand how to effectively promote handwashing behavior, much was learned from this study to inform governments and non-government organizations (NGOs) to better execute handwashing interventions. In regards to the monitoring sustainability factor, as with future research, the monitoring system developed in this study could be utilized by governments and organizations to continually evaluate their interventions as opposed to just moving on to the next site after giving trainings and promoting a technology. However, a community member should be trained in monitoring the stations as this would be more sustainable and genuine than an outside observer as in this study. This same observer and others could also be designated as handwashing station repairmen or repairwomen who would replace jugs and wood supports when they break for a small fee. A designated repair team may ensure that there is less attenuation in station usage over time. The thesis author observed throughout her monitoring of stations that they would fall into disrepair and some would not be repaired for weeks or months at a time especially during the rainy season.

Concerning the gender sustainability factor, future handwashing interventions should try to promote the construction of two handwashing stations (one for women and one for men and/or one near the latrine and one near the eating area) since women eat separately from men and only 19% of station owners responded that members of their household washed their hands before eating as well as other times (i.e. after defection and before cooking). Concerning the wealth sustainability factor, since the purchase of soap was identified as a major difficulty of the tippy tap, alternatives to soap (white ash, local soaps, or powdered soap) should be better promoted so that users are always utilizing a cleansing agent. These cheaper alternatives are especially important to the lower income households as there was a significant difference in the soap usage between those households that scored the highest on the Progress out of Poverty Index (PPI®) and those in the two lower levels. Future interventions must acknowledge and address these economic disparities. Governments and NGOs should also try to improve a household economic status through microfinance organizations, and income generating activities such as animal husbandry, soap making, gardening, etc. With a higher income, households have more money at their disposal to buy soap.

Moreover, seasonality was identified as a significant sustainability factor for handwashing stations with much lower station usage during the rainy season when washing hands with soap becomes critical with increased diarrheal disease incidences and malnutrition. In interventions, the trainings should emphasize the importance of washing hands at all times of the year especially during the rainy season and more trainings and advertising of handwashing (posters, radio, social marketing, announcements during community meetings, etc.) should be implemented during this period. A message that may be effective in handwashing trainings and messages in Mali is "I kono te se ka ko" or "You cannot wash your stomach" as the thesis author noticed this phrase utilized in survey responses and throughout conversations concerning handwashing with soap. Though prevention of illness and health were identified by 80% of the observers as why it is important to them to wash their hands with soap, in the literature it is emphasized that non-health messages may be more effective in promoting handwashing behavior change. (Curtis et al., 2003) Moreover, it is important during interventions that organizations implement surveys or interviews to get users feedback on the technology and intervention which may also serve to identify effective promotional messages for handwashing.

Pertaining to the training sustainability factor, the handwashing lesson was not found to have significant impact on station usage either due to the timing and/or type of the intervention. As suggested in the recommendations for future research section, interventions should also incorporate a variety of trainings to different groups at different times during the year. They should develop a comprehensive intervention strategy that targets all age groups, men and women, as well as households of all economic classes.

Finally, with respect to the water sustainability factor, it was found that households with stations closest to a water source had the highest and most sustained handwashing station usage. Often governments and organizations are not just focusing on handwashing promotion but also overall water, sanitation and hygiene (WASH) interventions. Combining water source access and hygiene promotion is important to the sustainability of hygiene practices. In conclusion, governments, NGOs, and other organizations should incorporate the six sustainability factors of gender, water, monitoring, seasonality, training, and wealth in the design and implementation of their handwashing interventions to increase their sustainability and effectiveness.

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APPENDICES

Appendix A: Institutional Review Board Clearances

Colleen Naughton <ccnaughton@gmail.com>

NAUGHTON updated account

RSCH ARC <RSCH-arc@usf.edu> Mon, Jun 10, 2013 at 12:19 PM
To: Colleen Naughton <ccnaughton@gmail.com>

Hello Colleen,

I've updated your human subjects protection education certificate in ARC.

The Tippy Tap Handwashing Monitoring Study (Pro 4487) you submitted was determined to not meet the definition of human subject research, therefore did not require IRB review and approval as noted in the history tab of your study:

> "This project has been withdrawn from review as it does not meet the definition of human subjects research requiring review and approval by the USF IRB. This project involves observation of hand washing and does not collect information about living individuals."

I have attached a .pdf file to this email that will give you some guidance on whether your new survey would be classified as human subjects research. If you need additional guidance please send us a email with a summary of your purposed work and we will ask an IRB manager to provide a determination on if you need to submit a new study.

Regards,

Kelley

Kelley Schuler

ARC Help Desk

University of South Florida

Division of Research Integrity and Compliance

RSCH-arc@usf.edu

813-974-2880

ARC Login: https://arc.research.usf.edu/Prod

Appendix A (Continued)

UNIVERSITY OF SOUTH FLORIDA

RESEARCH INTEGRITY AND COMPLIANCE
Institutional Review Boards, FWA No. 00001669
12901 Bruce B. Downs Blvd., MDC035 • Tampa, FL 33612-4799
(813) 974-5638 • FAX(813) 974-7091

7/2/2013

Colleen Naughton
Civil and Environmental Engineering
4202 Fowler Ave.
ENC 3303
Tampa, FL 33620

RE: **Expedited Approval for Initial Review**
IRB#: Pro00013532
Title: Assessing Appropriate Technology Handwashing Stations in Mali, West Africa

Study Approval Period: 7/1/2013 to 7/1/2014

Dear Ms. Naughton:

On 7/1/2013, the Institutional Review Board (IRB) reviewed and **APPROVED** the above application and all documents outlined below.

Approved Item(s):
Protocol Document(s):
Handwashing Study Protocol

Consent/Assent Document(s):
Handwashing Verbal Consent Version 3 HW_verbal_intro_v3_6_30_13.doc 6.30.13

It was the determination of the IRB that your study qualified for expedited review which includes activities that (1) present no more than minimal risk to human subjects, and (2) involve only procedures listed in one or more of the categories outlined below. The IRB may review research through the expedited review procedure authorized by 45CFR46.110 and 21 CFR 56.110. The research proposed in this study is categorized under the following expedited review category:

(5) Research involving materials (data, documents, records, or specimens) that have been collected, or will be collected solely for nonresearch purposes (such as medical treatment or diagnosis).

Appendix A (Continued)

(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

Your study qualifies for a waiver of the requirements for the documentation of informed consent as outlined in the federal regulations at 45CFR46.117(c) which states that an IRB may waive the requirement for the investigator to obtain a signed consent form for some or all subjects.

As the principal investigator of this study, it is your responsibility to conduct this study in accordance with IRB policies and procedures and as approved by the IRB. Any changes to the approved research must be submitted to the IRB for review and approval by an amendment.

We appreciate your dedication to the ethical conduct of human subject research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,

[redacted]

John Schinka, Ph.D., Chairperson
USF Institutional Review Board

Appendix B: Water and Sanitation Baseline Survey

1. Who is the dutigi (head of the household)?
2. Where is your concession?
3. How many men over 16 are there in your concession?
    a. How many married women?
    b. How many children?
4. Where does your drinking water come from?
5. Is your well in your concession?
6. Where does your household fetch water? Who gets it?
7. Does that well have a cover?
8. Is that well treated? If yes, how and when is it treated?
9. Does that well go dry? If yes, which months of the year?
10. Do you treat your drinking water? If yes, how?
11. How many meters are their between the pump and your concession?
12. Where do you wash clothes?
13. Where do the women cook?
14. Where does your dirty water go?
15. How do you store your water? Is it covered?
16. Do all of you drink water from the same cup?
17. How many latrines are in your concession? Are they covered? How far are they away from the well?
18. How many wash areas are in your concession?
19. Is your latrine pit covered? Does your latrine have a dirt or cement floor?
20. Where does your latrine water go?
21. Do you have a soak pit? Is it covered?
22. Are their animals in your concession? Are they far from the well?
23. How many times is your concession swept each day?
24. Where do you put your trash?
25. When do you wash your hands?
26. Before eating, do you wash your hands?
27. Can you explain to me how you wash your hands?
28. Why do you not wash your hands with soap?
29. Where do you eat?
30. Is your food covered?
31. How many mosquito nets do you have?
32. Where did you get your mosquito nets?
33. Do all the people in your concession sleep under a mosquito net?
34. Are your mosquito nets treated? If yes, how?
35. What illnesses do the people in your concession contract? When?
36. Did members of your household have diarrhea last year? Who did? Only children? Older people? Everyone?
37. Where do you get your medicine? Do you get traditional, western, or both?
38. Where do the pregnant women in your concession get their medicine?
39. What is Malaria? How do you get it?
40. Does your family experience food insecurity? If yes, which months?
41. Are you in a village organization? If yes, which one? What do they do? When/how often do they meet? What is your role in the organization?
42. If there were to be a water and sanitation committee here, would that be good to you?

Appendix C: Handwashing Survey

Station #:________
Date: _________

1. Who built the handwashing station?
2. Gender: M/F
3. Who puts water in the water jug?
4. How many people are in the household?
    a. How many married women?
    b. How many men?
    c. How many children?
    d. How many students?
5. Where do the women fetch water?
6. How many people in the household actually wash their hands with soap?
7. If not everyone washes their hand with soap, why do some not wash their hands with soap?
8. What are the difficulties with the hand washing station?
9. When do you wash your hands with soap?
10. When must we wash our hands with soap?
11. Why must we wash our hands with soap?
12. What does washing hands with soap do?
    a. Does hand washing prevent illness? How?
    b. Which illnesses can handwashing prevent?
13. What are germs?
14. Do you believe in germs?
15. Can people spread illnesses to other people? If yes, which sicknesses can be spread? How?

Appendix D: Progress out of Poverty Index® for Mali (PPI®, 2010)

Progress out of Poverty Index™ for Mali

Entity	Name	ID	Date (DD/MM/YY)	
Member:			Joined:	
Loan officer:			Today:	
Branch:			Household size:	

Indicator	Value	Points	Score
1. How many household members are 11 years old or younger?	A. Five or more	0	
	B. Four	10	
	C. Three	13	
	D. Two	15	
	E. One	17	
	F. None	25	
2. How many members of the household usually work as their main occupation in agriculture, animal husbandry, fishing, or forestry?	A. Three or more	0	
	B. Two	7	
	C. One or none	14	
3. What is the main construction material of the roof of the residence?	A. Tile or thatch	0	
	B. Mud, corrugated metal sheets, concrete, or other	12	
4. What is the main construction material of the walls of the residence?	A. Partly cement or others	0	
	B. Cement	7	
5. What is the household's main source of drinking water?	A. Surface water, non-modern well, drilled well, or others	0	
	B. Modern well	3	
	C. Public pump	6	
	D. Faucet tap	11	
6. What toilet arrangements does the household have?	A. Others	0	
	B. Latrine (private or shared with other households) or flush toilet (private inside, private outside, or shared with other households)	7	
7. Does the household own any television sets?	A. No	0	
	B. Yes	6	
8. Does the household own any radios?	A. No	0	
	B. Yes	7	
9. Does the household own any irons?	A. No	0	
	B. Yes	5	
10. Does the household own any motorbikes?	A. No	0	
	B. Yes	6	

Microfinance Risk Management, L.L.C., http://www.microfinance.com Total score

This PPI was updated in January, 2010. For up-to-date PPIs and other information on the Progress out of Poverty Index™ for Mali and other countries go to www.progressoutofpoverty.org

Appendix E: Raw Survey Data of the Progress out of Poverty Index® (PPI®, 2010)

The raw data from Zeala is shown in the table below:

Station Number	Questions[1]										PPI
	1	2	3	4	5	6	7	8	9	10	
1	0	0	12	0	0	7	0	7	0	6	32
2	0	0	12	0	6	7	6	7	0	0	38
3	0	0	0	0	0	7	0	7	0	0	14
4	0	0	12	0	6	7	0	7	0	0	32
5	0	0	12	0	0	7	0	7	0	6	32
6	0	0	12	0	0	7	0	7	0	0	26
7	10	0	0	0	0	0	0	7	0	0	17
8	0	0	0	0	6	7	0	7	0	0	20
9	0	0	0	0	0	7	0	7	0	0	14
10	0	0	0	0	0	7	0	7	0	0	14
11	13	14	12	0	6	7	6	7	0	6	71
12	0	0	12	0	0	7	0	7	0	6	32
13	13	0	12	0	0	0	0	7	0	0	32
14	0	0	12	0	0	7	0	7	0	0	26
15	10	0	12	0	0	7	0	7	0	0	36
16	0	0	12	0	0	7	0	7	0	6	32
18	13	0	0	0	0	0	0	7	0	6	26
20	0	7	0	0	0	0	0	7	0	0	14
21	0	0	12	0	6	7	0	7	0	6	38
22	0	0	12	0	0	7	0	7	0	0	26
23	0	0	12	0	0	0	0	7	0	0	19
24	0	7	12	0	6	0	0	7	0	6	38
25	0	0	12	0	0	7	0	7	0	0	26
26	0	0	12	0	0	7	0	7	0	0	26
27	0	0	12	0	0	7	6	7	0	6	38
28	0	0	12	0	0	7	6	7	0	6	38
29	0	0	12	0	0	7	0	7	0	0	26
30	0	0	12	0	0	7	0	7	0	0	26
31	4	7	0	0	0	0	0	7	0	0	18
32	0	0	12	0	6	7	0	7	0	6	38
33	0	7	12	0	6	0	0	7	0	6	38
34	13	0	12	0	0	0	0	7	0	0	32
35	0	0	12	0	6	7	0	7	0	6	38
36	10	0	12	0	0	7	0	7	0	0	36
37	0	0	12	0	0	0	0	7	0	6	25

Appendix E (Continued)

Station Number	Questions[1]										PPI
	1	2	3	4	5	6	7	8	9	10	
38	10	7	12	0	0	0	0	7	0	0	36
39	0	0	12	0	0	0	0	7	0	0	19
40	15	7	12	0	0	0	0	7	0	0	41
41	25	7	12	0	0	7	0	7	0	0	58
42	17	7	0	0	0	7	0	7	0	0	38
43	0	0	12	0	0	0	0	7	0	0	19
44	0	0	0	0	6	0	0	7	0	0	13
45	0	0	0	0	6	7	0	7	0	0	20
46	13	0	0	0	0	7	0	7	0	0	27
47	13	7	12	0	0	7	0	7	0	0	46

[1] Questions 1-10 refer to the ten PPI® questions in Appendix D

The raw data from Nci'bugu is shown in the table below:

Station Number	Questions[1]										PPI
	1	2	3	4	5	6	7	8	9	10	
1	0	0	12	0	6	7	0	7	0	0	32
2	0	7	12	0	6	7	0	7	0	0	39
3	15	0	0	0	6	7	0	7	0	6	41
4	0	7	0	0	6	0	0	7	0	0	20
5	0	0	0	0	6	0	0	7	0	6	19
6	10	0	0	0	6	0	0	7	0	0	23
7	17	0	0	0	6	0	0	7	0	0	30
8	0	0	12	0	6	7	0	7	0	6	38
9	0	0	0	0	6	7	0	7	0	6	26
10	0	0	12	0	6	7	6	7	0	6	44
11	10	7	0	0	6	7	6	7	0	6	49
12	10	7	12	0	6	7	0	7	0	6	55
13	0	0	0	0	6	7	0	7	0	0	20
14	0	0	0	0	6	7	0	7	0	6	26
15	25	0	0	0	6	0	0	0	0	0	31
16	10	7	12	0	6	7	0	7	0	6	55
17	10	0	12	0	6	7	0	7	0	0	42
18	0	0	0	0	6	0	0	7	0	0	13
19	17	7	12	0	6	7	0	7	0	0	56

[1] Questions 1-10 refer to the ten PPI® questions in Appendix D

Appendix F: Handwashing Station Data Collection Sheet

Date:	

Station #	**Soap Present? (Y/N)**	**White ash present? (Y/N)**	**Ground Damp? (Y/N)**	**Soap bar number (2011)/ Soap weight (g) (2012)**	**Amount of water in Jug? (0%, 25%, 50%, 75%, 100%)**	**Notes**