Evaluation of Household Water Treatment and Safe Storage (HWTS) Alternatives in Ghana

by

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ABSTRACT

Ghana's water quality and sanitation condition are very poor. Pure Home Water (PHW), a local non-profit organization has been successfully improving the supply of safe drinking water in the northern region by producing and disseminating ceramic pot filters to low income family. In order to further their impact, PHW decided to explore the possibility of a new for-profit water filter targeted at the middle and high income families. For this purpose, the author evaluated the water quality of 42 households using bacteria indicator to determine whether there is a need or market for Household Water Treatment and Safe Storage (HWTS). Findings clearly show there is a market, given that Accra and Tamale two of the biggest cities in Ghana suffer severe intermittent water supply and water quality degradation. In addition, the author conducted 82 household surveys to understand their water practices and their knowledge, preferences, attitudes and motivation for HWTS purchase. Findings show that there is awareness of the water quality issue but not much knowledge about household water treatment. The survey also shows Gravity Driven Membrane (GDM) and Ceramic Pot Filter have the potential to do best in the market. PHW may either partner with EAWAG and sells GDM as its high-end product, or further develop its own product by taking recommended product features into design. Payment via monthly installments with small initial investment may encourage purchase.

Thesis Supervisor: Susan Murcott
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Abbreviations and acronyms

CDC	Center for Disease Control
CFU	Colony Forming Units
CV	Contingent Valuation
E. coli	*Escherichia coli*
EAWAG	Swiss Federal Institute of Aquatic Science and Technology
GDP	Gross Domestic Product
GHS	New Ghana Cedi (1 USD = 2.35 GHS, 1/06/14)
GWCL	Ghana Water Company Limited
HWTS	Household Water Treatment and Safe Storage
MEng	Master of Engineering
MDG	Millennium Development Goal
MIT	Massachusetts Institute of Technology
MPN	Most Probable Number
PATH	Program for Appropriate Technology in Health
POU	Point-of-Use
PHW	Pure Home Water
SDWA	Safe Drinking Water Act
SODIS	Solar Water Disinfection
UNICEF	United Nations Children's Fund
U.S. EPA	United States Environmental Protection Agency
USAID	United States Agency for International Development
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization
WTP	Willingness to pay

1. Introduction

1.1 Global Water Supply

Poor drinking water quality remain one of the major threats to human health. According to the World Health Organization (WHO), 1.7 billion people are diagnosed with diarrheal diseases annually, 88 % of which are attributed to unsafe water supply, inadequate sanitation and hygiene. Every one hour about 87 children under five are dying because of diarrhea (WHO; UNICEF, 2013). As a strategy to overcome the immense challenge of water supply, the United Nation aims to halve the proportion of people without sustainable access to safe drinking water by 2015 under the Millennium Development Goal (MDG) program. Latest report from WHO showed that over two billion people gained access to improved drinking water sources between 1990 and 2010 (WHO; UNICEF, 2012). The same statistic had shown that the world has met the target well in advance of the 2015 deadline (WHO; UNICEF, 2012).

While statistic shows tremendous advancement in global drinking water supply, there are still more than 768 million people who have no access to improved drinking water (WHO; UNICEF, 2012). Over two quarter of these people live in rural areas where poverty is often most severe. One of the main concerns for current global water supply is the inequality of water supply and services between regions, countries and even within country. In most countries that fall into the category of Least Developed Countries, 97 per cent of the population does not have piped water and 14 per cent of the population drinks surface water—for example, from rivers, ponds, or lakes (WHO; UNICEF, 2012). The truth is that while statistic shown tremendous achievement in improving the global drinking water supply, many countries are still struggling to reach the MGD goal and beyond that to supply safe drinking water to their entire population.

In addition, despite the increase of urban drinking-water coverage rates, issues of water quality remain. WHO defines "improved drinking water sources" as "any sources that are by nature of its construction or through active intervention, protected from outside contamination, in particular from contamination with fecal matter". This category includes household connections, public standpipes, boreholes, and protected dug wells, protected springs, and rain harvested water. On the contrary, "unimproved drinking water sources" refers to "any type of open surface water, uncovered, or unprotected well" (World Health Organization; UNICEF, 2013). It should be noted that this definition is different from "safe drinking water" which means "water that is free of waterborne pathogens or other disease-causing contaminants". Several studies have shown evidence of bacteriological contamination in the drinking water of different households, even when that water is supplied from an "improved drinking water source" (Vacs Renwick, 2013; Wright, et al., 2005). Intermittent piped water supply and unsafe water storage practices were considered the two main reasons of contamination. In most developing countries, continuous piped water supplies are rarely provided. In addition to microbial infiltration in the system due to back-pressure condition, an intermittent system also causes householders to store water in ways that is subjected to recontamination (Vacs Renwick, 2013; Wright, et al., 2005; WHO, 2013).

1.2 Household Water Treatment and Safe Storage (HWTS)

In an effect to improve the quality of drinking water in the developing world, a new set of technology known as household water treatment and safe storage (HWTS) or point-of-use

(POU) water treatment has been developed and disseminated during the past two decades. HWTS and POU water treatment are commonly referred to as treating water and safely storing it at the household or community level (WHO, 2013). HWTS often uses the same basic approaches of conventional water treatment such as filtration, coagulation, and disinfection (boiling, chlorination, solar) on a smaller decentralized scale.

Several studies had shown HWTS can successfully, kill or deactivate most microbial pathogens (Quick, et al., 1996; Luby, et al., 2001; Rangel , et al., 2003; Souter, et al., 2003) While there are significant evidences to suggest that these systems have been successful in improving the drinking water quality and preventing diarrheal disease (Fewtrell, et al., 2005), there also has been double-blinded studies that showed conflicting evidence regarding HWTS efficacy (Schmidt & Cairncross, 2009). Nevertheless, many studies had recognized the fact that by focusing at the point-of-consumption rather than the point-of-delivery, HWTS creates an additional barrier of protection even for those using improved water supplies, and therefore minimize the risk of recontamination (Mintz, et al., 2001; Wright, et al., 2005; Murcott, 2006)

In fact, the WHO promotes the scaling up of HWTS as a means of accelerating the health benefits of safe water and in 2003 it brought together about 20 different organizations to form the International Network to Promote Household Water Treatment and Safe Storage. The Network today has more than 150 institutional organizations that include representatives of UN agencies, bilateral development agencies, international non-governmental organizations, research institutions, international professional associations, and private sector and industry associations. In 2006, the Bill & Melinda Gates Foundation awarded a US$ 17 million grant to Program for Appropriate Technology in Health (PATH) to identify, evaluate and develop appropriate products and investment strategies to enable sustainable commercial enterprises to produce, distribute and sell HWTS products to low and middle-income populations (Clasen, 2009). Despite the international efforts, the promise of HWTS have yet to be fully realized (Clasen, 2009; WHO, 2013).

Today, there are 100s of HWTS products or practices that are available throughout the world. However, none of them except boiling has been successfully scaled up (Clasen, 2009). There are many challenges to scale-up, including constraints on distribution, user acceptance, and effective use of products, price-economics, training-methods, sustainability, inadequate maintenance, monitoring and evaluation (Arnold, et al., 2009; Mäusezahl, et al., 2009; Brown & Clasen, 2012). One of the main constraints in scale-up of HWTS is the behavior barrier. In some areas where the practice of treating water before drinking itself was never a norm, HWTS is not just a product or technology but a novel idea (Jain, 2010). HWTS thus calls for a behavioral change on the part of the user, which is hard to promote and achieve. It requires collaborative efforts of multiple parties to introduce and educate throughout the community. This has certainly raised the bar to implement HWTS. Furthermore, the demand for HWTS due to low purchasing power of the targeted community is also a dominant factor that holds back the scale-up (Murcott, 2006; PATH, 2009; Jain, 2010). According to report *Implementation, Critical Factors and Challenges to Scale-Up of Household Drinking Water Treatment and Safe Storage Systems*, among a variety of financing approaches of 34 organizations, only 12 percent use commercialization or "for proft model" to implement HWTS product (Murcott, 2006). Despite the fact that there is still a lot of work to get HWTS t breakthrough these barriers, the health benefits it promises to those who lack access to safe drinking water sources is inspiring.

1.3 The Republic of Ghana

Ghana is a developing country of 25 million people, located in West Africa along the Gulf of Guinea. The country is divided into ten administrative regions (Figure 1-1), with the majority of the population centered in the southern part of the country. The population is densest in the Greater Accra Region where the capital, Accra is located. The Northern Region is least densely populated but is currently experiencing rapid development. In fact, according to the 2010 population and housing census, Tamale, the capital city of the Northern region has a projected population of 537,986 people and is referred as the fastest growing city in West Africa (Ghana Statistical Service, 2011)

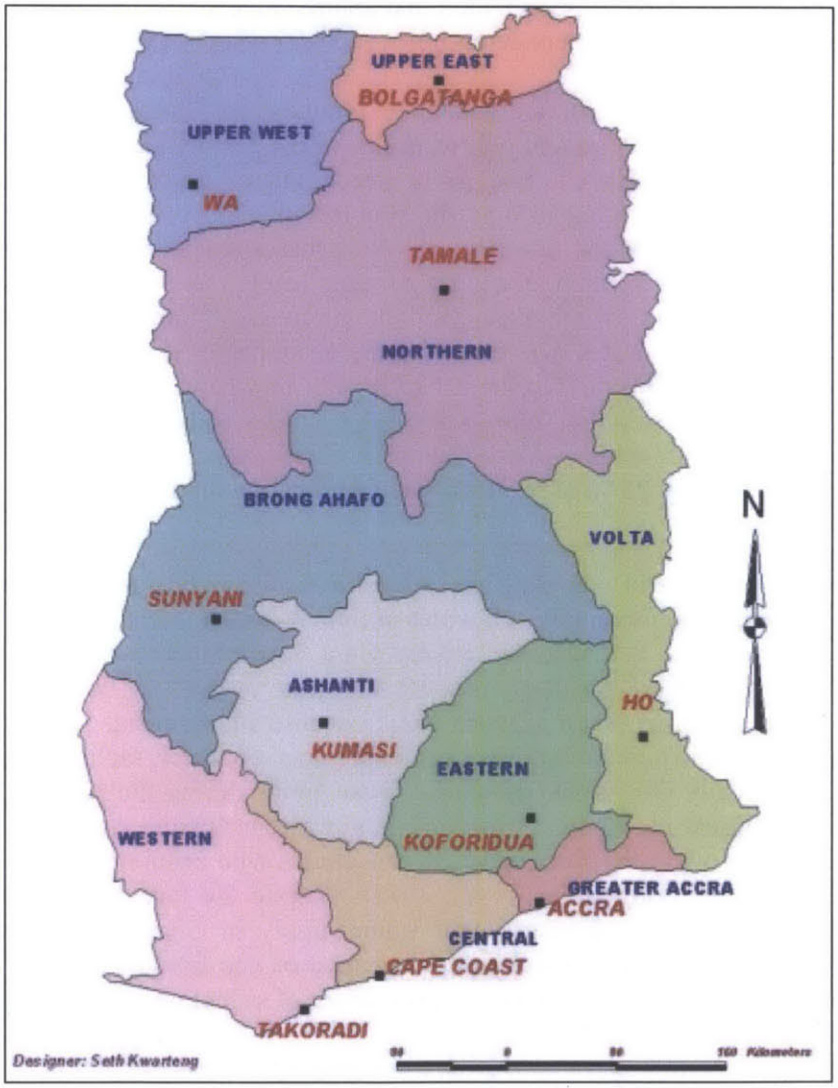

Figure 1-1: Administrative Regions of Ghana

(Source: IAEA, 2012)

The economy of Ghana is driven by the services sector and the strong export performance of cocoa, gold and recently oil revenues. Its gross domestic product (GDP) growth decreased from 14.4 % in 2011 to 8 % in 2013 (African Development Bank; Economic Commision for Africa, 2013). Although Ghana's economic growth had shown deceleration, it remains as one of the top-ten fastest growing economies in the world, and the fastest growing economy in Africa. However, the country remains in the bottom 25 % of low middle-income countries on the United Nations Human Development Index with 28.6 % of the population lives below the poverty line, making less than $1 per day (Malik, 2013). Poverty remains endemic in the country as economic growth has been primarily focused in extractive and capital intensive sectors, which do not have a direct poverty reducing effect (Malik, 2013).

According to the recent WHO/UNICEF Progress Report on Drinking Water and Sanitation, 83.8 % of the total population in Ghana has access to improved drinking water. Ghana has performed above the average in Sub-Saharan Africa, and is expected to meet the water Millennium Development Goal by 2015 (WHO; UNICEF, 2012). While these results indicate significant improvement in the Ghana's water supply, disparities in water supply exist between regions within Ghana. It is estimated that approximately 50 % of people living in the Northern Region still do not have access to improved water sources (Murcott, 2013).

In urban area of Ghana, water service is mainly provided by Ghana Water Company Ltd (GWCL). Despite being a government owned utility whose history can be traced back to the foundation of the country, GWCL had never succeeded to provide water to the whole population of urban Ghana. Reasons for this problem include overwhelming demand for water in over-populated cities and non-revenue water losses due to poor water management (Vacs Renwick, 2013; Van-Rooijen, et al., 2008). As a result, more than half of residents do not have a pipe connection within their yard or compound (Van-Rooijen, et al., 2008). Furthermore, the quality of water delivered is also questionable. Previous study had shown 87 % of residents in Tamale, the Northern capital city of Ghana, suffer intermittent water supply and 73 % of water samples from their drinking water sources showed positive result for total coliforms contamination (Vacs Renwick, 2013). Accra, the capital city suffers similar problem where only 25 % of residents have continuous supply (WaterAid, 2005).

The lack of infrastructure and rationing has created a blooming business for entrepreneurial water vendors. These vendors mainly sell water in three ways: (1) delivery via a tanker truck to household poly tank; (2) a dispenser delivery via a 5 gallon carboy and (3) packaged as sachet water. Sachet water, popularly known as "pure water" is typically a 500 mL polyethylene plastic bags of water (Figure 1-2). Because of its cheap price, conveniently availability and the public perception that it is cleaner than tap water, sachet water has gained popularity in specifically Ghana and generally West Africa during the past decade. In fact, the percentage of households who use piped drinking water in Greater Accra Region dropped from 84.4 to 58.2 %, while the percentage of households who primarily drink sachet water increased to 34.5 % in 2008 (Stoler, et al., 2012). Despite the fact that sachets water has somehow relieved the stress of insufficient water supply in Ghana, it is notorious as a massive plastic waste generator. From the perspective of eco-friendly as well as of price, HWTS is a better solution. Nevertheless, the prevalence of sachet water pose major barrier to entry of HWTS.

Figure 1-2 Sachet Water

1.4 Pure Home Water

Pure Home Water (PHW) is a registered non-profit organization based in Tamale, Ghana. Founded in 2005, the organization aims to:1) Provide safe drinking water, sanitation, and hygiene (WASH) in Ghana, with a particular focus on Northern Ghana; and 2) Become locally and financially self-sustaining. To meet these goals, PHW has developed a ceramic pot water filter called the AfriClay Classic Filter. This filter has been effective at pathogen removal and treating household drinking water. Through the production and distribution of the AfriClay Filter, PHW has reached to date over 100,000 people in the northern region of Ghana. However, this number is insignificant to the 9 million Ghanaians throughout the country that have no access to safe drinking water (WaterAid, 2005). Although PHW has made some strides towards becoming locally self-sufficient and financially self-sustaining, its ceramic filter Africlay product that is generally meant for humanitarian distribution and low-income community, has limited expansion and the ability to do further good. In order to expand business and improve the conditions of more households in Ghana, a new product which is meant for profit and targeted at middle and upper income families is necessary.

1.5 Research Objectives

This project has been a collaborative effort between the Massachusetts Institute of Technology Civil and Environmental Engineering Department and Pure Home Water (PHW), to help assess the drinking water conditions in Ghana and develop a strategy to meet the needs of its middle and high income family as well as the financial viability of PHW.

The goal of this research is to explore the feasibility of several higher-end HWTS products to the Ghanaian market, particularly the middle and high income consumers. The author will use this analysis to make recommendations to PHW on developing a profitable product that would help subsidizing the cost of its humanitarian expenditure. As the purpose of the product is to generate revenue, different from PHW's usual practices in its traditional market in the northern region of Ghana, the primary market is thought to be the southern region of Ghana, where most of the middle and high income families reside. Hence, this study is conducted primarily in two different locations; Accra and Tamale.

Through a consumer survey and water quality testing, the author assessed the feasibility of the selected products for Ghanaian market. The objectives of the study were the following:

- To determine whether there is a need or market for HWTS through households surveys and water quality evaluation;
- To establish baseline household profiles and consumer segments based on knowledge, preferences, attitudes and motivation for HWTS purchase and use;
- To characterize challenges to HWTS product adoption through field study.

The consumer survey included two sections. First, through a baseline household profile we gathered information on demographics, current water treatment practices and beliefs. Then, we accessed the relative value of a HWTS product and each feature through a multiple choice based survey. A detailed description of the baseline survey, attribute levels and selection criteria will be provided in the Chapter 4 of this thesis. The technical component of this research included water quality testing from all households surveyed in Accra. We hoped that this element would allow us to understand the quality and safety of drinking water they use and the degree of necessary efficacy for a HWTS.

1.6 Thesis Outline

The following three chapters provide background and context for this work. Chapter 2 gives an overview of previous work that had been done in Ghana regarding household water treatment and safe storage products developed to date and methods used in market research specifically for HWTS. Chapter 3 describes the range of new membrane HWTS products available. The subsequent four chapters focus specifically on the content of this research. Chapter 4 focuses on the study design and methodology. Chapter 5 offers results of the research conducted to date. Chapter 6 highlights key findings from the research. Chapter 7 draws relevant conclusions for HWTS and Chapter 8 gives specific recommendations for PHW.

2. Literatures Review

2.1 HWTS Product Development in Ghana

2.1.1 First product of PHW: Kosim Filter

PHW had been putting efforts into developing a HWTS suitable for Ghana, ever since it's founding. The initial strategy of PHW was based on marketing a range of locally manufactured and affordable HWTS products. This included different technologies such as solar disinfection (SODIS) systems[1], biosand filters[2], ceramic candle filters and the ceramic pot filter[3]. Due to limited capacity and resources, PHW decided to focus on promoting only the ceramic pot filter. The ceramic pot filter was selected as the main product due to the following factors:

- Proven user acceptability;
- Possibility of local production;
- Low cost treatment over the life of the filter;
- High treatment efficiency and performance;
- "One-step" treatment and safe storage;
- Cultural Compatibility with traditional ceramic clay storage vessels;
- Ability to treat water of very high turbidity, as is common in Northern Ghana.

Adapted from (Okioga, 2007).

PHW started to sell its first product, branded the Kosim Ceramic Filter, which parts are purchased from manufacturer Quali Plastic and Cermica Tamakloe Ltd in Accra and assembled in Tamale, Ghana (Figure 2-1). PHW later set up its ceramic pot filter factory in Tamale, Ghana and started to produce its own hemispherical-shaped clay pot filter, AfriClay Filter (Figure 2-2). The current price of AfriClay is set at 50 GHS (21 USD). In the past years, the primary customer of PHW has been large NGOs and agencies such as UNICEF and Rotary International mainly for disaster relief and humanitarian expenditure. According to surveys conducted by Peletz (2006), the willingness-to-pay for filter technologies was between 8 and 8.90 USD. Hence, it is difficult for the poor to buy the ceramic pot filter at the current price without subsidies. In order to help PHW to develop strategy for HWTS implementation, several studies regarding its product development have been done.

Figure 2-1: Kosim Ceramic Filter

Figure 2-2: Africlay Ceramic Filter

[1] Solar disinfection features a clear plastic bottle filled with low-turbidity water, shaken vigorously for oxygenation and then left out under the sun for some time to kills diarrhea-causing pathogens.

[2] Biosand filter is water treatment system adapted from traditional slow sand filters.

[3] Ceramic filters are water filter that rely on the small pore size of ceramic material to filter dirt, debris, and bacteria out of water. It consists of ceramic filter unit (candle shape or pot shape) and a plastic safe storage container.

2.1.2 HWTS consumer preference study in Tamale

Like most interventions, the efficacy of HWTS highly depends on geographic regions, source water characteristics and community type. Hence, for the purpose of promoting HWTS uptake, consumer understanding as well as assessments of product appropriateness for local conditions and relative cost are necessary. For this purpose, a consumer preference study comprised of survey and water quality testing in 237 households in four rural and three urban communities around Tamale was conducted (Green, 2008). The author conducted a Choice-Based-Conjoint analysis (CBC) to understand customer preference of HWTS product features. The product features included water look/water taste, product type, treatment time, health impact and relative price. Green concluded that generally there is a strong demand for health improvements and traditional durable products with little sensitivity to water taste and price. The study also indicated that there are differences in relative importance of the product features in different consumer segments. The author suggested that by tailoring the product type, design, educational material and marketing strategy to the preferences of targeted consumer segments, implementing organizations can substantially enhance product uptake and sustained use. Green also pointed out the opportunity to stimulate further revenue by exploring high-margin sachet water business or modern durable filter sales, focused on the urban upper and middle class.

A similar study based on product preferences instead of feature preferences was conducted by Qiu (2012). Market surveys were conducted at a distribution point where consumers chose their preferences based on six real HWTS products: Aquatab[4], CrytalPur/Tulip Siphon Water Filter[5], LifeStraw® Family[6], PUR[7], and two PHW's product which for the purpose of the study were branded Kosim Classic and Kosim Deluxe[8]. Among all six products, Kosim Deluxe received the highest preference score, mostly due to its outstanding appearance. One of the interesting elements in this study is that consumers are allowed to re-rank their preferences after the price is announced. Surprisingly the total preference score of Kosim Deluxe increased more than other products given the reason that the price is highest among all. Most consumer thought that higher the price, better the quality, despite the question of whether they could afford it or would actually purchase it. While the two studies conducted by Green and Qiu gave several insights on how consumer in the Northern Region Ghana view on HWTS products, the result however do not reflect those in other location particularly Southern Ghana where the social and economic conditions varies.

2.1.3 AfriClay Deluxe Product Development

Another study devoted to develop a for-profit product, a deluxe model of Africlay Filter (previously known as Kosim Filter) was conducted (Yang, 2013). The author studied and analyzed four HWTS products: AfriClay Filter, Super Tunsai[9], C1 Common Interface [10]and Ecofiltro[11]. Yang ran design assessment and financial assessment for all four products, and concluded that Super Tunsai represents a better model for PHW to adopt for further development. Based on Bass Diffusion Model conducted in this study, the author also

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[4] Aquatabs are effervescent tablets which, when added to unsafe drinking water, make the water safe to drink.
[5] CrytalPur is a small ceramic siphon filtering device that is put in water bucket or water tank
[6] LifeStraw® Family is a HWTS that utilize ultrafiltration technology.
[7] PUR is package of chemical that settles particles and microorganisms
[8] Kosim Deluxe is a hypothetical deluxe model of Kosim Classic
[9] Super Tunsai is a Cambodian Filter edesigned by PATH with the emphasis of aesthetic value.
[10] C1 Common Interface is a design by PATH with specification for interchangeable filter element usage at a common connection point between unfiltered and filtered water receptacles.
[11] Ecofiltro is a Guatemala ceramic pot filter unit similar that has slightly better aesthetic value

forecasted the demand for the AfriClay Deluxe Filter to be 1539 units per year at the price of $30 per unit. Yang also conducted customer preferences on HWTS product feature survey, similar to (Green, 2008) at Accra, Kumasi and Tamale, the three largest cities in Ghana. The study showed health impact, time to treat water, and size as the most important features of a HWTS intervention. However, in contrast to the studies done by Green and Qiu, Yang finds that in addition to the efficacy, the aesthetic value of the product as important factor for consumer preference. While Yang had demonstrated the consumer acceptance of relatively expensive high-end product in Ghana, the study however failed to evaluate other modern water technologies such as membrane filtration or activated carbon absorption. The evaluation of the possibility of such technologies is important to determine which products have the greatest potential for long-term sustainable impact in the given region.

2.2 Methods in Market Research for HWTS

Consumer understanding is a key barrier to sustained use of improved water sources and products. To have successful HWTS interventions, local consumer preference research is essential. There have been several methods in understanding consumer preference for HWTS. In emerging market research conducted by PATH in Vietnam, focus group discussions, observations and interviews were used. Furthermore, as some find HWTS to be non-market resources, Contingent valuation (CV) / Willingness to Pay Assessment (WTP) have been used (PATH, 2009; Job, 2012).

2.2.1 Focus group discussion, observation and interviews

In the context of market research, Focus Group discussion, observation and interviews are three commonly used methods to gather raw data from customers, specifically in identifying customer needs. It is believed that Focus Group can yield more ideas than one-to-one interviews, since group members are encouraged to share their opinions. However, statistic showed that the number of needs revealed by one 2-hour focus group is about the same as the number revealed by two 1-hour interviews (Ulrich & Eppinger, 2012). As interviews usually require less cost and effort than focus group, the author decided to use interviews as primary data collection

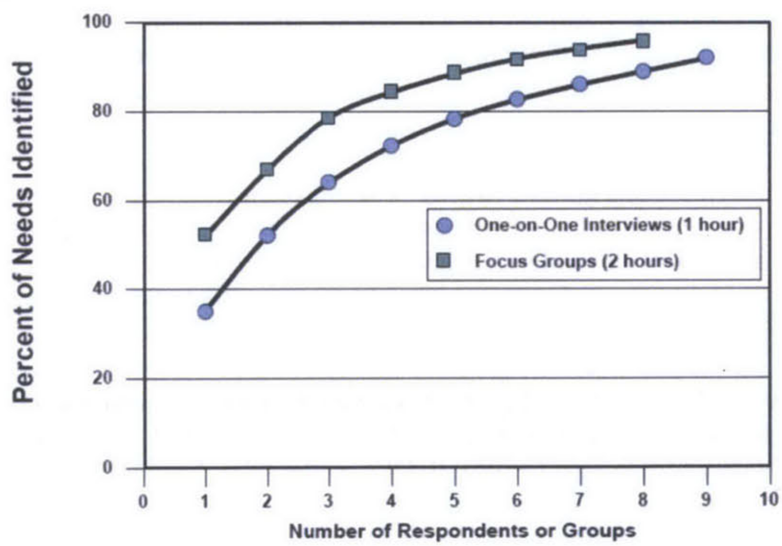

Figure 2-3: Focus Group vs One-on-one Interviews in Customer Needs Identification (Source: Griffin and Hauser, 1993)

2.2.2 Contingent Valuation/ Willingess to Pay

Contingent valuation (CV) is generally a survey method that asks how much money people would be willing-to-pay (WTP) for something. It is an economic valuation, specifically for non-market goods and services that do not have a price although they offer utility. For example, people receive benefit from a beautiful view of a mountain, but it would be tough to value using price-based models. CV is one technique which is used to measure these aspects. Because a CV survey always asks WTP questions, it also commonly known as a "WTP study.

CV had been used in assessing the relative value and cost of various water infrastructure projects since 1980s (Whittington & MacRae 1988). Gunatilake, et al (2007) estimated the net economic benefits of improved water by calculating the difference between the WTP and the actual cost of the services provided. In another study, Hastler, et al (2005) used CV to estimate the non-marketed benefits of protecting ground water resources as compared to purifying ground water for drinking purposes. A WTP study regarding an innovative HWTS product, Gravity-Driven-Membrane, was conducted in Kenya (Job, 2012). Job found that WTP for a GDM is a factor of different demographic characteristics including household income, the amount of water consumed in the household, diarrhoea prevalence, education and awareness levels, sanitation and gender of the respondent. In conclusion, several studies indicate that CV helps in appropriate design of prices and subsidies based on the value the target population.

2.3 Methods in Water Quality Evaluation

2.3.1 Chlorine Residual

Chlorine is an effective disinfectant due to its ability to oxidize enzymes of microbial cells (Reynolds and Richards 1996). Chlorine disinfectant that is commonly added to water systems is generally referred to hypochlorous acid (HOCl) and the hypochlorite (OCl^-) ion or bleach and usually known as free chlorine. When free chlorine reacts with ammonia or organic nitrogen present in the water, chloramines known as monochloramine, dichloramine, and trichloramine are quickly formed (Hach, 2014). These chloramines are also known as combined chlorine. The sum of free chlorine and combined chlorine is usually called total chlorine. The level of total chlorine will always be higher than or equal to the level of free chlorine.

The amount of chlorine used up by reacting with substances in the water is known as the chlorine demand. The amount of chlorine dosage is usually slightly above chlorine demand to ensure a certain amount of chlorine remains in the water after the reaction. The remaining portion of the dosed chlorine is known as the chlorine residual. This remaining chlorine is often tested to evaluate the resistance of the water to bacterial contamination.

According to the WHO, effective chlorine disinfection requires a residual concentration of free chlorine to be greater than or equal to 0.5 mg/l after at least 30 minutes contact time (WHO, 2004). Centers for Disease Control (CDC) on the other hand recommends a minimum of 0.2 mg/L of free chlorine residual at 24 hours after the addition of sodium hypochlorite to containers that are used by families to store water. For this study, free chlorine residual is selected as a key parameter because it shows the quality of piped water and can be done in the field using a minimum of equipment.

2.3.2 Coliform Bacteria and Escherichia coli (E.coli)

Bacteria are often used as indicators of possible sewage contamination. The most commonly tested fecal bacteria indicators are total coliforms, fecal coliforms, *Escherichia coli* (*E.coli*), fecal streptococci, and enterococci. Among all these indicators, total coliforms and *E.coli* was chosen for this study because they are well studied indicator with standard guidelines from U.S. EPA and WHO, and it can be easily done at situ.

Total coliforms are a group of bacteria that are widespread in nature and mostly (with few exceptions) not harmful to humans. However, because total coliforms are common inhabitants of ambient water, it is a good indicator of other harmful pathogens. U.S. EPA requires public water system not to detect total coliforms in more than 5 % of the samples they take each month (U.S. EPA, 2001)

E.coli is a species of coliform bacteria that only come from human and warm blooded animal fecal waste. Most *E. coli* strains are harmless, but some strains are pathogenic and can cause diarrhoea to their hosts. The WHO requires all water directly intended for drinking, treated water entering the distribution and treated water in the distribution system not to have detectable level of *E. coli* in any 100-ml sample (WHO, 2004).

3. HWTS Product Descriptions

This section provides a brief overview of available HWTS options.

According to the following classification system, there are five core categories of HWTS products in the emerging market (Murcott, 2006).

1) Safe Storage Products;
2) Disinfection (Including boiling, chlorination and UV disinfection);
3) Particulate Removal Products;
4) Chemical Removal Systems;
5) Combined Systems (Product that incorporate multiple functions mentioned above).

Previous studies regarding HWTS product preference done by Green (2008), Qiu (2012) and Yang (2013) showed that consumers prefer particulate removal products over the others. Therefore, for the purpose of this thesis, the scope of HWTS options has been narrowed down to particulate removal technology. It is believed that particulate removal technologies have higher adoption rate and could be sold as a for-profit product. In addition to the current product of PHW, AfriClay Filter, three product were identified as possible HWTS alternatives. They are LifeStraw® Family 1.0, Gravity Driven Membrane (GDM) and Life Saver JerryCan.

3.1 LifeStraw® Family 1.0

LifeStraw® Family 1.0 is a HWTS product designed and manufactured by the Swiss-based Vestergaard Frandsen Inc. targeted for use in low income countries and for distribution in a humanitarian crisis (Figure 3-1). It is built upon the success of LifeStraw®, a personal water filtration that won several awards including the 2008 Saatchi & Saatchi Award for World Changing Ideas and the 'INDEX: 2005' International Design Award (Vestergaard Frandsen Inc., 2008). Other products of the LifeStraw® series include LifeStraw® Family 2.0, LifeStraw® Community, LifeStraw® Go and LifeStraw® Guinea Worm.

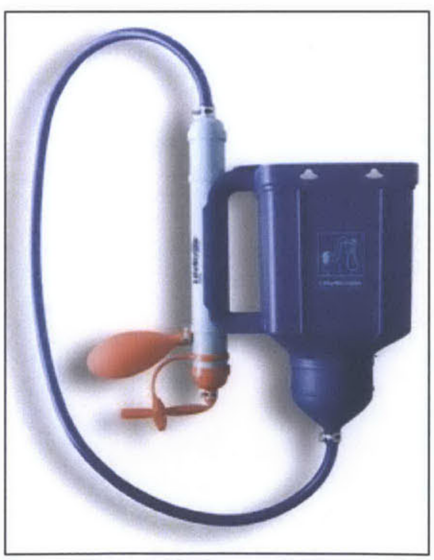

Figure 3-1: LifeStraw® Family 1.0

(Source: Vestergaard Frandsen Inc, 2008)

The LifeStraw® series basically uses advanced hollow fiber membrane technology that removes particles larger than 20 nm. For LifeStraw® Family 1.0, the process of filtration begins when dirty water is poured into the pre-filter bucket where coarser turbidity is removed by a 27 micron pre-filter. The water then flows through a tube into a purification cartridge which contains millions of capillary membranes. Under 0.1 mbar pressure driven by gravity, water is forced through the capillaries while bacteria, viruses, parasites and other particles are retained. At the bottom of the bucket, there is a halogen chamber that releases minimal chlorine to prevent the formation of biofilm on the membrane. LifeStraw® Family 1.0 also feature a backwash function that flushes contaminants trapped inside the hollow fibers. According to the manufacturer, the flow rate of the device averages 9 liters per hour. It has also been tested and certified to remove 99.9999 % of bacteria, 99.99 % of virus and 99.9 % of parasites. It does not; however remove giardia (Vestergaard Frandesen Inc., 2008).

Several field studies were conducted on investigating the efficacy of the device. Most of them showcased the ability of the device in improving water quality as well as its effectiveness against diarrhea (Clasen, 2009; Boisson, et al., 2010; Peletz, 2012). Prior to the launching of the device, it is claimed that Lifestraw® Family cost US$ 20 a piece for up to 500 units (Vestergaard Frandsen Inc., 2008)., however the current retail price in North America is about US$ 75 (Vestergaard Frandsen Inc., 2013). Paul Hetherington, of the charity WaterAid, has criticized the Lifestraw® for being too expensive for the target market. As a matter of fact, currently the majority of Lifestraw® Family 1.0 is distributed as part of public health campaigns or in response to complex emergencies by NGOs and organizations that give them away for free in the developing world.

3.2 Gravity Driven Membrane (GDM)

Gravity Driven Membrane (GDM) is an ultra-low pressure membrane filtration technology that requires gravity as the only input to remove bacteria and viruses. It is developed by EAWAG and had been a continuous study for household application. Figure 3-2 shows a the household application prototype of Gravity-Driven-Membrane-Disinfection (GDMD).

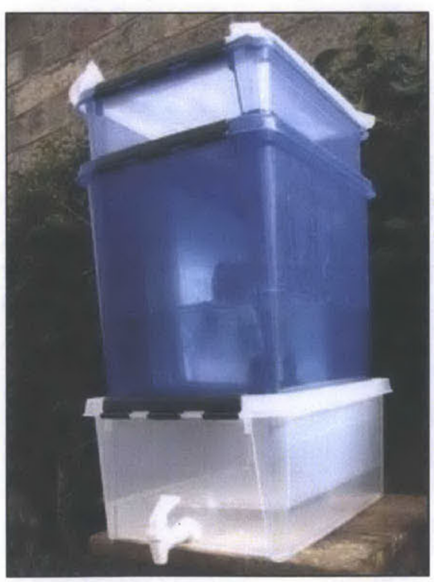

Figure 3-2: Gravity Driven Membrane

(Source: Peter-Varbanets, et al., 2010)

GDM that based on ultra-low pressure membrane filtration technology requires no back flushing or cleaning. During ultra-low pressure filtration, formation of a biofilm occurs and counteracts the resistance caused by deposition and fouling (Peter-Varbanets, et al., 2010; Boulestreau, et al., 2010). This causes the flux to stabilize at around 4-10 L/hr/m^2. This value is low for conventional membrane systems but with 0.5 m^2 of membrane, it can provide 48 L of safe drinking water per day, which is sufficient to cover drinking water needs of a family.

GDMD features a feed water tank and permeate tank with a membrane (0.5 m^2, Polyethersulfone (PES) flat sheets, 150 kDA cut off) immersed in the feed water tank. In order to avoid complete drying of the membranes which can lead to the damage of membrane integrity, the membrane is always submerged by locating the permeate collection pipe in the middle of the membrane module. Currently the configuration of GDMD system is a two-container type system similar to ceramic candle unit.

The total cost of a household system is expected to be about US$ 30, mainly attributed to cost of the membrane as container can be locally produced. Assuming stable flux of 4-10 $L.m^{-2}h^{-1}$, the membrane area needed for a house hold is less than 0.5 m^2. The market price of a high quality membrane is currently US$ 40 /m^2. Thus, the membrane cost is expected to US$ 20 per household system (Peter-Varbanets, 2011). However, the production cost of the current prototype is about US$ 100 per unit (Peter-Varbanets, personal comunication).

Several field studies have been conducted to test GDM filtration under real conditions. Selina et al. (2012) distributed 24 prototypes to households in Nairobi, Kenya where raw water consisted of pond, river, dug well, borehole and tap water. Despite the challenging raw water quality, 72 % of the water samples showed no *E.coli* contamination. It is believed that the low levels of *E.coli* observed in some of the filters are most likely due to recontamination from untreated water or particles entering the clean water tank in an unexpected way. After one year of operation, 92 % of the filters are still functioning and none have failed due to technical reasons (Derksen-Müller, et al., 2012). A WTP study was also conducted in Nakuru, Kenya (Job, 2012). The result showed strong social demand for GDM while WTP ranged from US$ 6.25 to US$ 63 with significant dependency on income. Purchase price, effectiveness of GDM and the flow rate significantly affects the choice of end users while storage capacity is the least considered factor.

3.3 LifeSaver JerryCan

LifeSaver JerryCan is a combined system of ultra-low pressure filtration and activated carbon absorption that requires the addition pressure by hand pumping (Figure 3-3). It is invented and developed as a full-profit product by Michael Pritchard, a British water-treatment expert. Initially the product is developed for emergency use during the happening of natural disaster. Other products of the LifeSaver series include LifeSaver Bottle, LifeSaver Cube and LifeSaver C2.

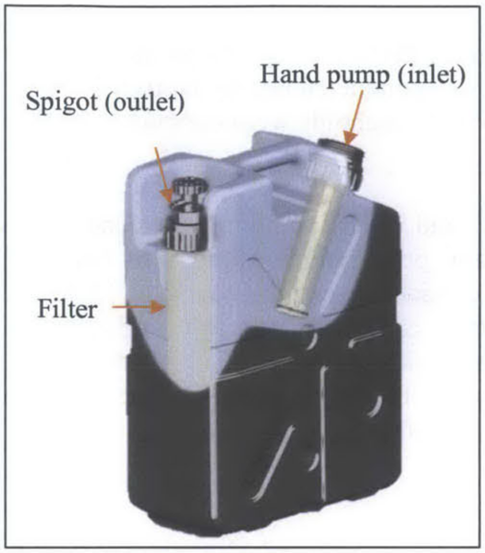

Figure 3-3 Life Saver Jerry Can
(Source: LifeSavey System Inc., 2011)

LifeSaver JerryCan features a rod shape 15nm ultra filtration membrane at one side of the container and hand pump at the other side. Untreated water is put into the product. With the lid on, under the confined space, pressure is added manually by pumping. The pressure force pushes the water through the membrane which retains micro-organisms and particles. An optional activated carbon filters is also attached to remove chemical residues. The current retail price of a LifeSaver JerryCan in North America is about US$ 285.

The LifeSaver JerryCan was tested and certified by London school of Hygiene Tropical Medicine to have a 6 log reduction (99.9999 % removal) for bacteria and a 4 log reduction (99.99 %) for viruses. Collaboration work for humanitarian distribution has been implemented in South Sudan, Ethiopia, Kenya and Zambia (LifeSaver Inc., 2013).

4. Methodology

In order to aid the design of PHW's for-profit product, a water quality evaluation and an in-depth household survey was conducted during January 2014. A total of 42 water samples and 84 qualitative surveys with households were conducted in Accra and Tamale, the two largest cities of Ghana.

At each location, surveys and water sampling were conducted simply by walking through the neighborhood without any prior planning and visit householder whoever available at the moment. Surveys were conducted over the course of 15 days between January 5 and January 20, 2014. The researcher conducted surveys initially in English. However, whenever translation in needed, the author was assisted by the local students. The translation was usually done from English to Ga, Twi or Dagbani, the three most common Ghanaian languages spoken in Accra and Tamale.

4.1 Locations

4.1.1 Locations in Accra

In order to better understand the condition of drinking water supply and HWTS preference in Accra, a total of 42 surveys and household water samples were conducted across six neighborhoods in Accra, as shown in Figure 4-1:

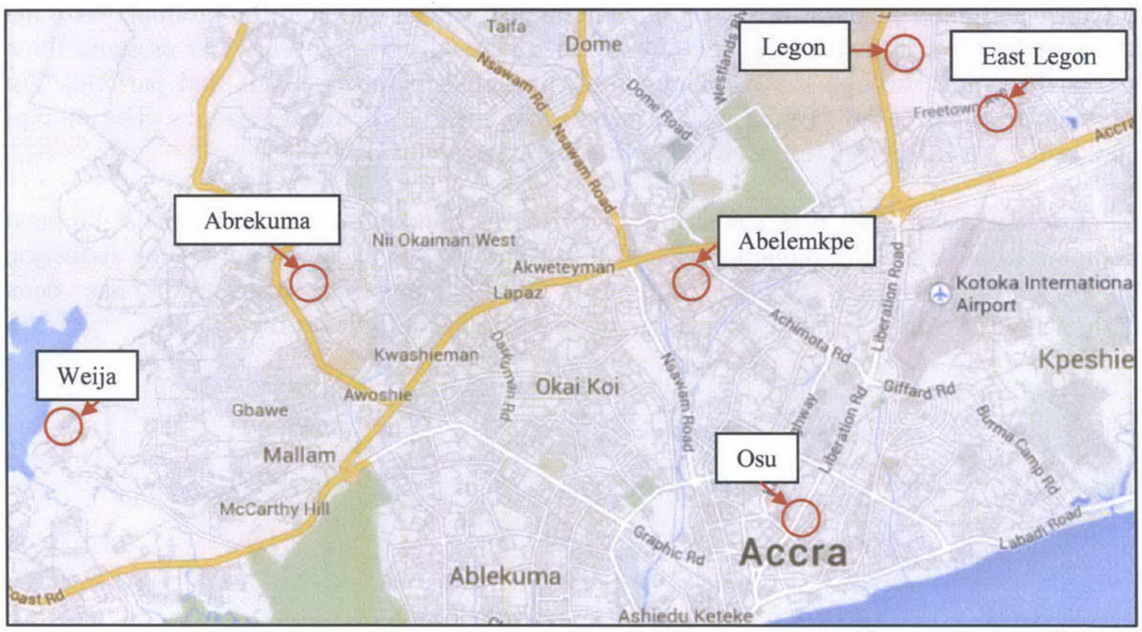

Figure 4-1: Map of Accra showing survey areas
(From Google Maps)

East Legon (7 households)

This neighborhood is located 11 km northeast of the city center. East Legon is noted for its sophisticated modern low-rise apartment blocks and detached houses with gated yards. The area is sparsely populated and is occupied mainly by high-income groups and foreigners. The neighborhood was chosen to represent the middle and high income communities.

Figure 4-2: East Legon Neighborhood

Legon (7 households)

Legon is situated about 12 km north-east of the city center. It is known as the home of the main campus of the University of Ghana. The neighborhood consists of low-rise apartment blocks and detached houses (without gated yards). This neighborhood is occupied mainly by student, faculty and medical staff of a nearby hospital. The neighborhood was chosen to represent the student and academic segments of the community in Accra.

Figure 4-3: Legon Neighborhood

Osu (7 households)

This neighborhood is one of the oldest neighborhoods of Ghana, situated at the center of the city. Osu consists of a mix of houses including low-rise apartment blocks, detached houses and modern office towers. The neighborhood was chosen because of its location and historical background.

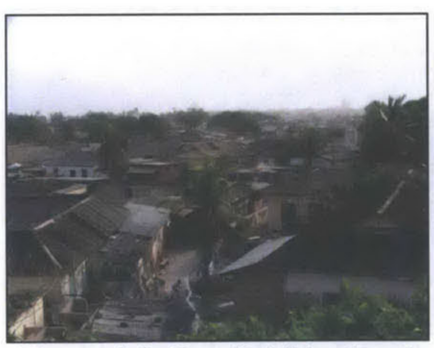

Figure 4-4: Osu Neighborhood

Weija (7 households)

Weija is located 15 km west of the city center. The housing consists of detached houses with gated yards and without gated yards. This neighborhood offers free water supply to everyone who lives in the neighborhood as it hosts one of the city's water treatment plants. This area was chosen to examine whether the quality of water service is better at neighborhood nearby the source.

Figure 4-5: Weija Neighborhood

Abrekuma (7 households)

Abrekuma is located about 10 km north-west of the city center. The housing varies from single-family detached homes to multifamily walled compounds. The neighborhood was chosen to represent the low and middle income families.

Figure 4-6: Abrekuma Neighborhood

Abelemkpe (7 households)

Ablelemkpe is located 6 km north of the city centre. The neighborhood is divided into two parts: Old Abelemkpe and New Abelemkpe. The new area is mostly occupied by the wealthy, academics and foreigners, while the old area is occupied by medium- and low-income groups. The neighborhood was chosen because it offers a good mix of poor and rich families.

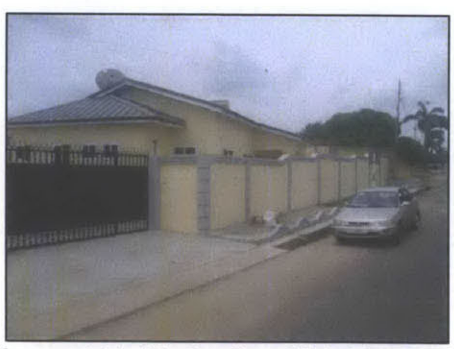

Figure 4-7: Abelemkpe Neighborhood

4.1.2 Locations in Tamale

A total of 42 surveys focus only on HWTS preference were conducted across the six neighborhoods in Tamale, as shown on the map below:

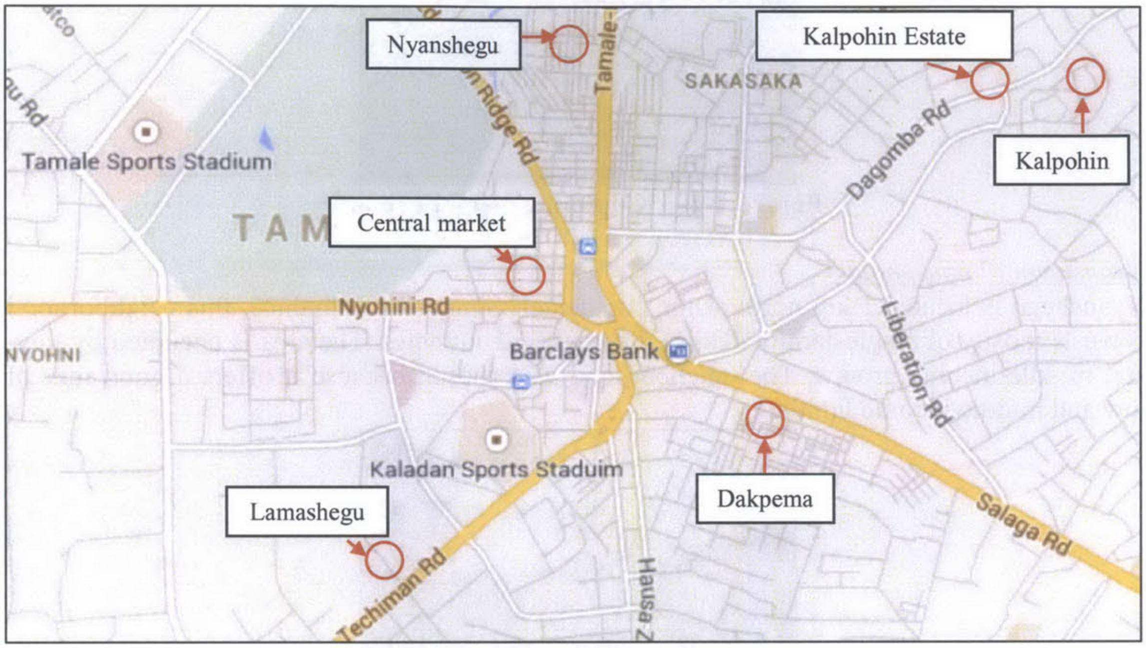

Figure 4-8: Map of Tamale showing survey areas
(From Google Maps)

<u>*Kalpohine Estate (7 households)*</u>

Kalpohine Estate is located north-east of the downtown Tamale area. This neighborhood consists mostly of single-family detached homes with gated yards. The area is sparsely populated and occupied mainly by high-income groups and foreigners. This neighborhood was chosen to represent the middle and high income families.

Figure 4-9: Kalpohine Estate Neighborhood (from Google maps)

<u>*Kalpohine (7 households)*</u>

Kalpohine is located east of Kalpohine Estate. This neighborhood consists mostly of single-family detached homes without gates. This neighborhood was chosen for its convenience as the researcher was living in this neighborhood during the field study period.

Figure 4-10: Kalpohine Neighborhood

Nyanshegu (7 households)

Nyanshegu is located 1 km north of the city center. Similar to Kalpohine, this neighborhood consists mostly of single-family detached homes without gates. The area is occupied by low- and middle-income groups. The neighborhood was chosen because it offers a good mix of low and middle income families.

Figure 4-11: Nyanshegu Neighborhood

Central Market (7 households)

Central Market is located in the downtown center of Tamale. The housing varies from single-family detached homes to multifamily walled compounds. This neighborhood was chosen because of its location at the center of Tamale.

Figure 4-12: Central Market Neighborhood

Lamashegu (7 households)

Lamashegu is located 1 km south of the city center. The housing varies from detached houses to mutlti-family walled compounds, similar to Central Market. The neighborhood was chosen to represent low and middle-income groups.

Figure 4-13: Lamashegu Neighborhood

Dakpema (7 households)
Dakpema is located 1 km east of the city center. The neighborhood is occupied by middle- and high-income groups, mostly academic and government officer. The housing mainly consists of single-family detached homes with gated yards. The neighborhood was chosen because it represents rich family.

Figure 4-14: Dakpema Neighborhood

4.2 Water quality evaluation

The purpose of this evaluation is to determine whether there is a need or market for HWTS products in the middle and high income communities. Accra was chosen as the primary site of study because it is where the population concentrated. Tamale was excluded from this study because a similar one was done in 2013. The outcome of this evaluation is expected to complement the result of that previous study. In addition to the evaluation of water samples taken from the households, an in-depth interview regarding the consistency of water supply together with the HWTS preference was conducted.

4.2.1 Water sampling

All samples were collected from household storage using 100mL sterile Nasco Whirl-Pak® sampling bags for chlorine residual and bacteriological tests (Figure 4-15). However, the method of collection varied according to the configuration of the household's water supply. In houses where no storage device was used, samples were collected from the taps directly. The taps were not sterilized before sample collection in order to reflect actual household water quality conditions. The sample was collected during the initial flow of water from the tap rather than after a flushing period in order to avoid waste of water belonging to the respondents. In households where water was stored in a drum or jar, the householders were asked to fill a drinking cup with water from such containers that was then poured into the sample container. Having the householder to collect the sample was meant to ensure that samples are representative of water actually used by the respondent, including any possible contamination from the users.

Figure 4-15: Water Samples Bag

4.2.2 Chlorine Residual

At every household surveyed, samples were collected and tested immediately for residual chlorine using a colorimeter (Figure 4-16). The instrument uses DPD powder pillows and was used in accordance with the standard method recommended by the manufacturer, which is equivalent to the U.S. EPA method and the Standard Method 4500-CL G (American Public Health Association; American Water Works Association; Water Environment Federation 2012). See Appendix A for the complete method as outlined by Hach.

Figure 4-16: Hach Pocket Colorimeter II
(source: www.camlab.co.uk)

4.2.3 Coliform Bacteria and E.coli

Bacteriological sampling and testing was conducted at 42 households in Accra. Samples were collected during the interviews (in the daytime) and stored temporarily in an insulated portable cooler until all interviews were completed for the day. The samples were then tested for total coliforms and Escherichia coli (E. coli) bacteria using the EC-Kit, a combination of the Colilert and Petrifilm. It is developed by Professor Robert Metcalf of California State University and Susan Murcott of MIT. The EC Kit has been tested and verified against standard methods (Chuang T. M., 2011). Directions for execution of the EC Kit test can be found in Appendix B.

Colilert, produced and sold by IDEXX, makes use of the enzyme substrate method, which is approved by the U.S. EPA and is listed in the Standard Methods for Examination of Water and Wastewater. The Colilert detection limit is set at 10 MPN/100ml for the 10ml predispensed sample size (IDEXX, 2011). In this study, Colilert was used in a presence/absence format testing 10ml samples of drinking water.

Petrifilm™ *E.coli*/Coliform Count Plates are used to quantitatively assess the presence of total coliforms and *E.coli* present in 1 ml of the collected drinking water samples. Petrifilm™ is comprised of a nutrient-rich media that provides a food source for bacteria to grow. Also in the media are specific indicator sugars that when metabolized produce either red dots for total coliforms, or a blue dots for E. coli. A covering film also traps gas (CO2) produced by the bacterium metabolic processes (3M, 2011).

4.3 Household Surveys

The purpose of the surveys is to understand the current drinking water practice of households and their attitudes and preferences towards HWTS purchase and use in Accra and Tamale. For that purpose, the survey is designed in three parts: 1) Demographic section; 2) Water quality section; 3) HWTS preference section. The water quality section was based on Vacs Renwick's survey in order to compare the author's result in Accra to her result in Tamale. The demographic section and HWTS preference section drew largely from Green, Qiu and Yang's household survey methodologies of past years in Ghana, and was further developed according to the objectives of this study. Figure 4-17 shows the core questions of each section. The survey itself is shown on Appendix C.

Demographic data	Water Quality	HWTS Preference
1. Gender of respondent 2. Age of respondent 3. Role of respondent in the household 4. Occupation of the head of the household 5. Number of members in the household 6. Education of the household	1. Water Source 2. Drinking Water Source 3. Amount of Drinking Water Consumption 4. Condition of Water Supply 5. Water Storage Practices 6. Water Treatment Practices 7. Drinking Water Quality Perception 8. Condition of diarrhea within the household	1. Experience with HWTS 2. First impression of HWTS 3. HWTS product preferences 4. Willingness to pay 5. Ideal Attributes 6. Most important feature 7. Ideal Location for vendor and purchase 8. Factor Influences on purchase 9. Comment or problem statement

Figure 4-17: Core questions for survey designs

4.3.1 Demographic Data

The demographic section provides information for future customer profiling. Gender, age and role in household questions help us understand the decision making culture in Ghana. The number of members in the households, occupation and education questions help us categorize potential customer segments for HWTS.

4.3.2 Water Quality

Based on prior field investigation, we identified the possible water sources in this region including piped water, dug out, sachet and etc. In addition, we believe that there is a difference between the main water source and drinking water source. The condition of water supply and water storage practices give context to the quality of water source and ultimately help us sort out the suitability of a HWTS product.

4.3.3 HWTS preference

The major part of this study is to analyze consumer's HWTS product preferences. As it was difficult to make all four products available at the same time, the interview was conducted based on description from the interviewer with a color-plated catalogue. The catalogue is included in Appendix D. In addition to the product preferences, a list of question that includes willingness to pay, ideal attributes of time-to-treat and size was included to understand the feature's preference. Respondent was asked to rank the most important features as well in order to weigh the attribute for further design. Ideal Location for vendor and purchase question was asked to understand consumer's buying habit and identify potential product distribution points. A final comment or problem statement question was asked as an open question to identify latent customer need.

4.4Field Study

In order to identify potential challenges of a high-end HWTS product in actual environment and understand the user's acceptance of the product, a field study that involves the implementation of three units of LifeSaver JerryCan was conducted. The initial plan of this of this portion of the overall study was to include two unit of Gravity Driven Membrane (GDM) as well; however the devices failed due to contamination during laboratory testing. Nevertheless, the evaluation of LifeSaver JerryCan was successfully carried out.

4.4.1 Location

Two LifeSaver JerryCan units were given to two households located in East Legon and Legon. They were selected because they were willing to use it frequently and accept frequent visits from the authors. Figure 4-18 and 4-19 shows the recipient and the location where the field studies were conducted.

Figure 4-18: The author and recipient Mr.Twaney at East Legon

Figure 4-19: The author and recipient Mr.Abaloo at Legon

4.4.2 Unit Performance Test :Coliform Bacteria and E.coli

In order to test the performance of the product, two water samples (inlet and outlet) were collected for each unit every two days over the period of the first week after it was introduced to the households. The number of samples was limited due to the schedule of the author involving traveling to two different cities. However, for the two units in East Legon and Legon, two more samples were collected at day 20 and day 21, after the author travelled back to Accra.

Water samples were collected using the same 100mL sterile Nasco Whirl-Pak®. The samples were then tested for total coliforms and *E. coli* bacteria using the EC-Kit method described above.

4.4.3 User's Feedback

A follow-up interview of the recipient regarding the usage of the product was conducted on day 21. Figure 4-20 shows the core questions of the interview while the survey itself is shown in Appendix E.

User's feedback

1. What was your first impression on the product?
2. What is your impression on the product now?
3. Do you feel that there is a change of the water quality after using the product?
4. What do you like about this product? What do you not like about this product?
5. What was your willingness to pay for the product before? And what about now?
6. Would you purchase or not purchase this product?
7. What final comments or questions do you have for our filter?

Figure 4-20: Core question for follow-up interview

The purpose of this follow-up interview is to identify the latent needs of the user and investigate whether there is a change of behavior or attitute after the actual usage of the product.

5. Results

5.1 Water Practice Surveys & Water Quality Evaluation

This section summarizes findings of household surveys regarding their water usage in Accra and the result of the water quality evaluation. For a complete listing of all household survey responses, see Appendix F. For a complete listing of the water evaluation result see Appendix G.

5.1.1 Types of Water Sources

Figure 5-1 shows the water sources of all respondents. Most users surveyed have access to piped water supply with 21 of the 42 households have connection to pipe supply inside their residence and 18 of them have access to a tap within their yard or a nearby public tap. Only 3 of them do not have connection to water distribution network and have to rely on bore hole or water vendor. The connection to piped water supply, however, varies among public tap, piped water inside compound and piped water inside compound.

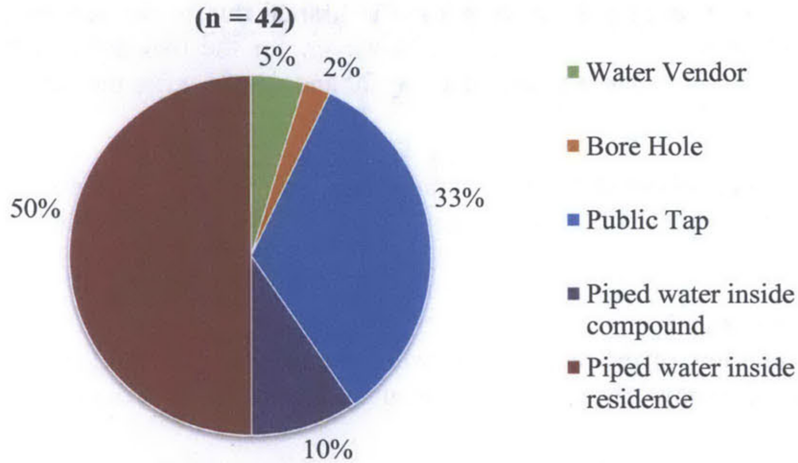

Figure 5-1: Response to Question: "What is your main water source?"

Figure 5-2 shows the percentage of householders who would drink from the pipe directly and Figure 5-3 shows the main drinking water sources they rely on regularly basis. Forty eight percent of the respondents do not drink from the tap and only use it for non-drinking purposes, such as cleaning and cooking. Of all 42 respondents, only 26 % rely on piped water as their main water supply. Sachet water is the most popular drinking water source with 57 % of the respondents uses it as a primary source. For household that rely on sachet water as main drinking water source, it is usually bought in a bag of 30 sachets (500 mL x 30 = 15L) at the price of 2 GHS (0.85 USD). The quantity of purchase varies depending on the household size. Some households reported buying one bag per week, while some claimed that they even buy two bags per day. All respondents who rely on bottled water (1.5 L and 5 gallon carboy) reside in Abelemkpe and East Legon, two of the richest area in this study.

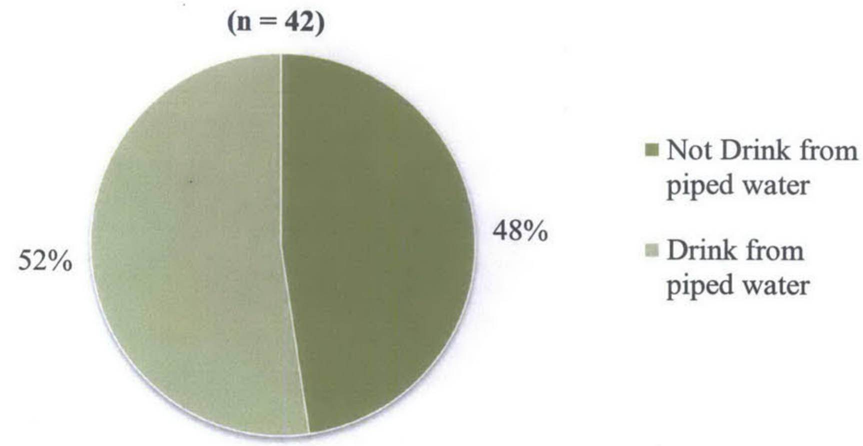

Figure 5-2: Response to Question: "Do you drink from the piped water?"

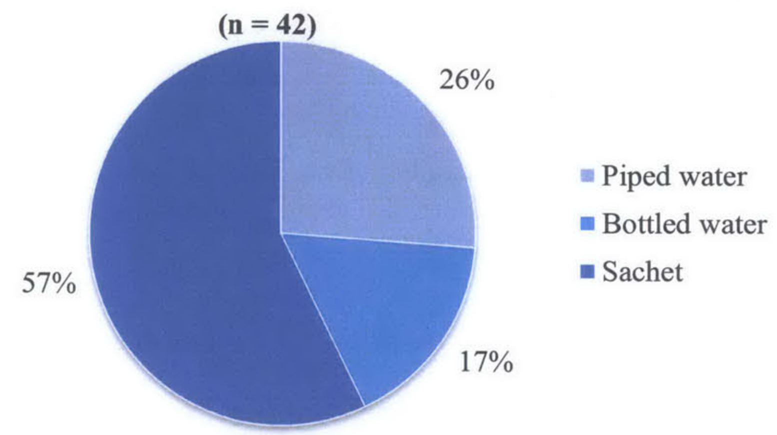

Figure 5-3: Response to Question: "What is your main source of drinking water?"

5.1.2 Water Supply Condition

Figure 5-4 and Figure 5-5 show the consistency of piped water supply in all 42 households. Three households with no access to piped water supply were excluded in this section. Out of 39 interviewees, 30 suffer some degree of intermittent water supply with supply of once a week as the most predominant pattern. Although the degree of intermittent water supply varies from house to house, most of them show similar pattern within the area. For example, in the Weijer district, where one of the water treatment plants and reservoirs is located, six out of seven household have continuous water supply. The other three households that have continuous water supply are all located in Osu, the center of the city. According to one respondent, he is lucky to have continuous water supply because his house is located on top of the main pipe that supply water to the Osu Castle, which is the seat of government. This shows that the location of infrastructure affect the quality of water service.

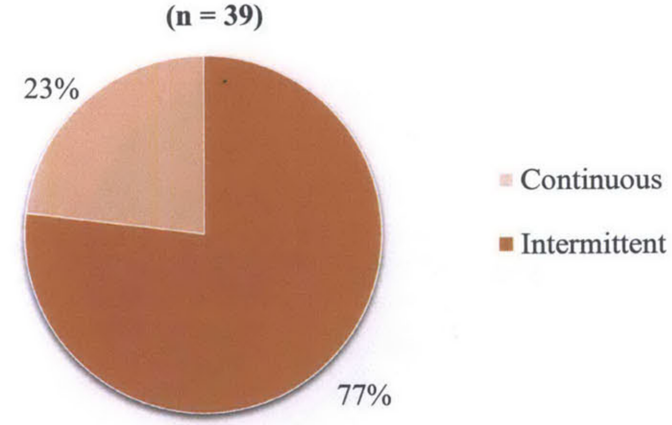

Figure 5-4: Response to Question: "Had you experience any intermittent supply?"

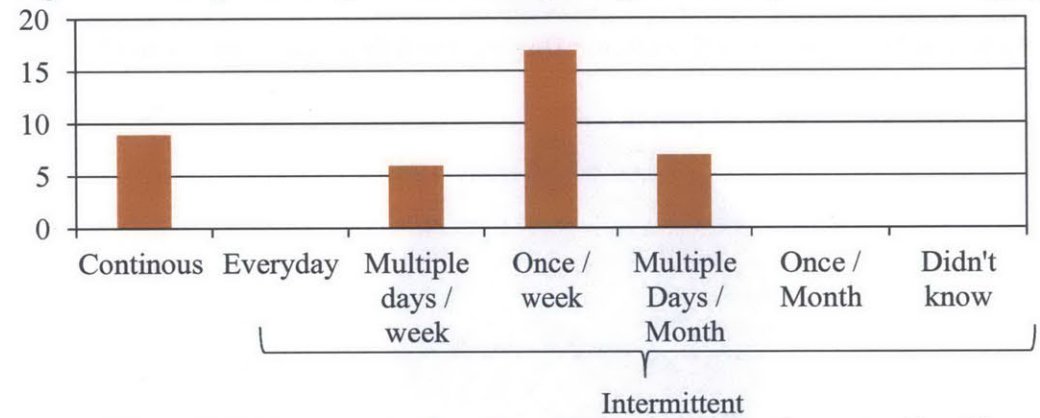

Figure 5-5: Response to Question: "How often does the water flow?"

5.1.3 Household Storage and Water Treatment Practices

Excluding three respondents who do not practice water storage because they have access to continuous piped water supply, 39 respondents reported storing water in their households.

Storage vessels vary between households and between neighborhoods. Table 5-1 shows the types of storage vessels the author encountered throughout the period of this study. Figure 5-6 shows the distribution of different types of water storage observed during the surveys. For households with multiple types of storage, each type was counted once, without counting the overall number of total units the family possesses. Jerry cans, poly tanks and plastic drums were the three most common types of vessels used in Accra. Not many traditional clay pots or cement tanks was observed. Most storage vessels were kept out door. One of the cement tank owners was observed to be selling water to nearby neighbors during the interview.

Table 5-1: Types of Storage Vessels

Vessel Type	Approximate Capacity	Photograph
Poly Tank	Varies 200-25,000 L (44-5,556 gal)	
Cement Tank	Varies 1000-2000 L observed (300-500 gal)	
Plastic Drum	Varies 75-200 L observed (20 – 50 gal)	
Clay Pot	Varies 75-200 L observed (20 – 50 gal)	
Jerry Can	5-10 L (1-3 gal)	

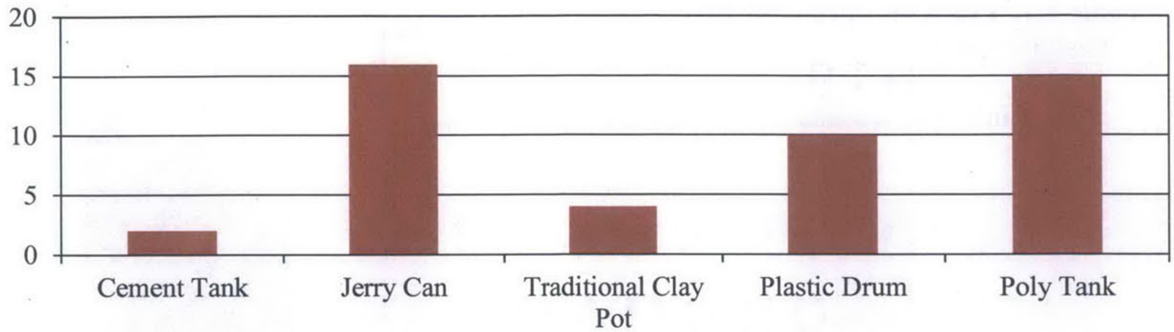

Figure 5–6: Types of Storage Vessels Observed

Figure 5-7 shows the frequency of cleaning of storage vessels. When the interviewee was asked how often they clean the vessel, the initial response was often "whenever it is empty". When more specific follow-up questions such as "When did you clean it recently?" or "How often it is emptied?" were introduced, it was discovered that the frequency of cleaning is highly dependent on the size of the storage vessels. For example, jerry cans and plastic drums are mostly cleaned daily or once a week while poly tanks are cleaned after months of usage. Five households who store water in poly tanks did not clean their vessel at all. They explained that the reason behind their behavior was due to the fact that they do not drink water from these sources.

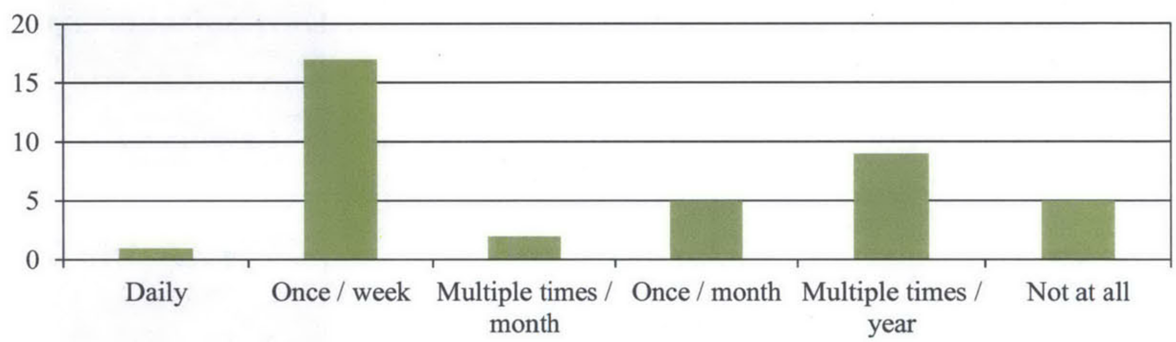

Figure 5-7: Response to Question: "How often do you clean your water storage vessel?"

Figure 5-8 shows data on whether people in Accra treat water before consumption. A majority of households do not treat their water as they believe it is safe to drink. Most of these households, however, rely on either bottled water or sachet water as their main source of drinking water. Fourteen respondents reported that they drink directly without any treatment from the tap. Out of the six households who treat their water, five practice boiling while one uses alum coagulation. About half of the respondents do not think it is safe to drink from the pipe. Reasons given are the taste of water is bad; it is muddy; and contaminated with germs. Only four households reported the children had experienced diarrhea in the past two months.

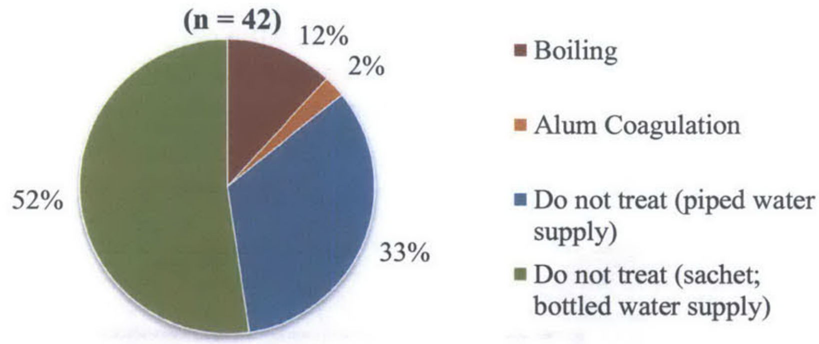

Figure 5-8: Response to Question: "Do you treat your water before consumption?"

Figure 5-8 shows distribution of total chlorine residual and free chlorine residual of water samples taken from 42 households in Accra. Most of the samples are taken from the water kept in their storage vessels but three samples were taken directly from the tap. The total chlorine residual and free chlorine residual averages at 0.06 mg/L and 0.04 mg/L respectively. Three households showed 0 mg/L concentration for both total and free chlorine residual. None of the households had more than 0.2 mg/L free chlorine, which is the minimum requirement of the WHO guideline for chlorine disinfection.

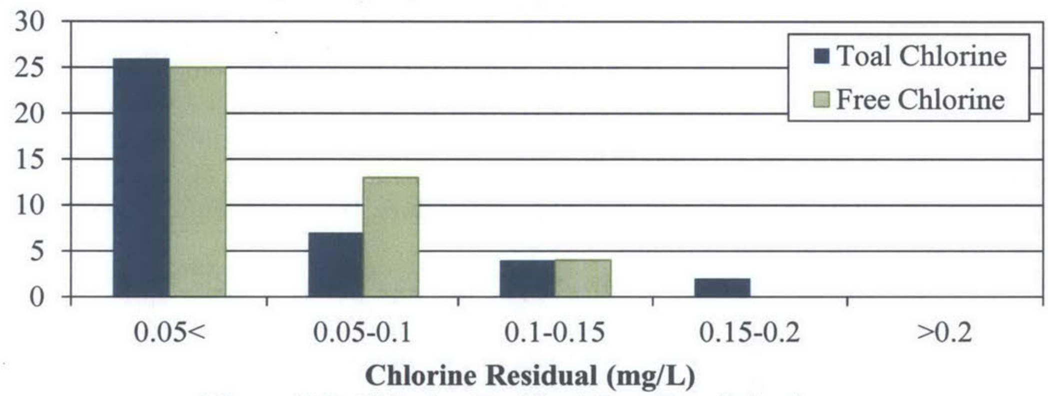

Figure 5-9: Chlorine Residual Test Result in Accra

5.1.3 Household Bacteriological Results

Figure 5-10 shows the overview results of the bacteriological test in Accra. The 42 samples are grouped according to the following categories by the WHO guidelines.

- <1 CFU/100 mL E. coli: "No Risk" *Not detectable with EC kit
- 1-10 CFU/100 mL E. coli: "Low Risk" *Not detectable with EC kit
- 10-100 CFU/100 mL E. coli: "Intermediate Risk"
- 101-1000 CFU/100 mL E. coli: "High Risk"
- >1000 CFU/100 mL E. coli: "Very High Risk"

(World Health Organization, 1997)

Only 26 % of the samples show undetectable level of total coliform. Over 70 % of the samples were contaminated with total coliform. This number does not meet the U.S. EPA standard that requires 95 % of monthly water distribution system samples test negative for total coliforms (U.S. Environmental Protection Agency 1989). Of the 74 % samples that shows presence of total coliform, 7 % falls into category "Intermediate risk", 38 % falls into category "High Risk" and 29 % falls into category "Very High Risk". It is clear that a majority of the water in these households are subjected to bacteria contamination.

As for *E.coli* test result, 40 % of the samples were found to have at least 10 CFU/100 mL, with 2 % fall into category "Intermediate Risk", 33 % fall into category "High Risk" and 5 % fall into category "very high risk", for which according to the WHO, urgent action is required. This indicates that householder who drinks from these sources faces high risk of getting diarrhea diseases.

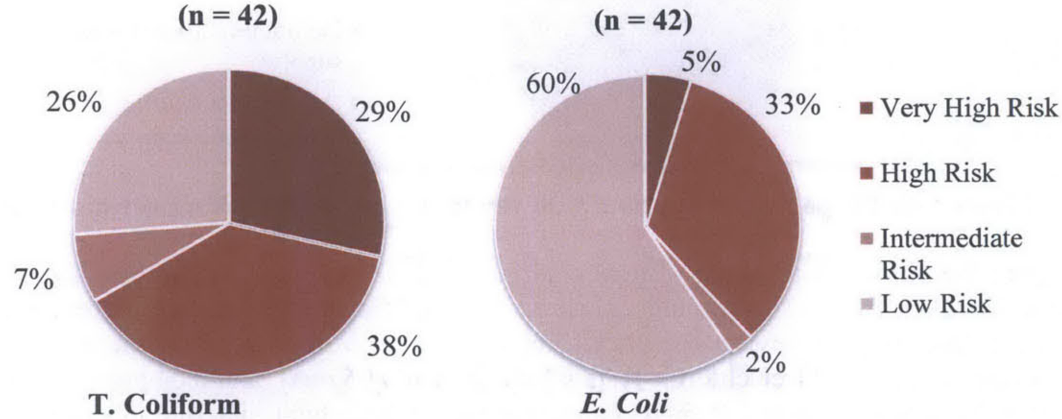

Figure 5-10: Bacterialogical Test Result in Accra

Figure 5-11 shows the bacteriological test results categorized by different sources of water samples. The number of each source varies as it depends on the water storage practice of each household. For example, only one cement tank was found and thus one sample was collected. Among all household water storage devices, poly tank has the least number of positive results for both indicators. Excluding cement tank and clay pot which has insufficient number of samples, jerry can has the highest percentage of contamination with over 80 % of the samples showed positive results for total coliform. One of the three tap water samples was found to have 500 CFU/100 mL of total coliform.

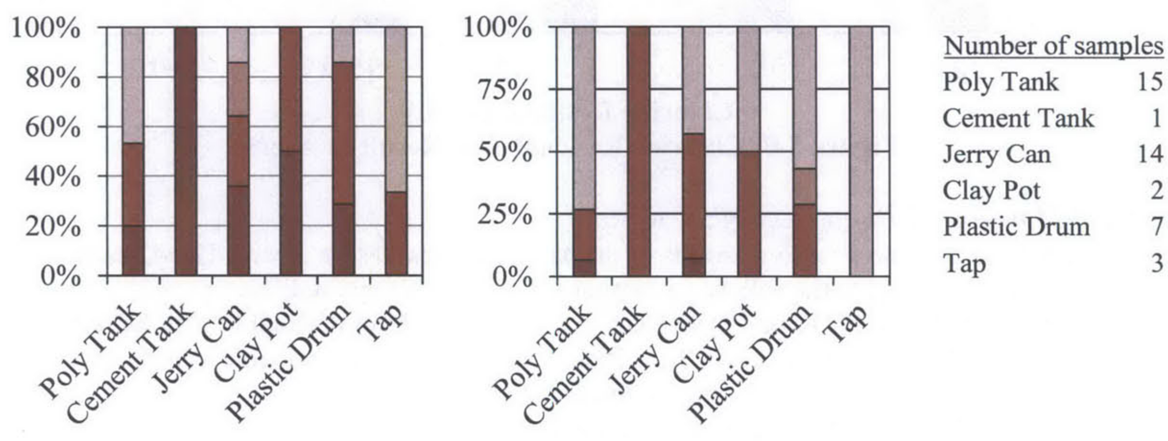

Figure 5-11: Bacterialogical Test Result from Different Sources

5.2 HWTS preference surveys

This section focuses on findings from the household surveys regarding HWTS products and features preferences in Accra and Tamale. The complete listing of all household survey responses is the same as the

5.2.1 Sample Population Demographics

Table 5-2 shows the demographics of sample population in Accra and Tamale. The gender of the sample population split equally in Accra but was 62 % male in Tamale. Half of the surveys were conducted in English and the other half in local languages. The majority of the respondents in Accra were not the head of the household, while half of the respondents in Tamale were head of the household. The education received in Accra is better than Tamale with only 5 % of the interviewees never having received any education at all. The number of respondents who received tertiary education in both cities was the same. The household size in Tamale is about two times larger than Accra, with an average household size of thirteen in Tamale and seven in Accra respectively. This phenomenon may be due to the majority of Tamale were Muslim and they are allowed to have more than one spouse.

Table 5-2: Demographics of Sample Population

Location	Gender (Male)	Language (English)	Head of house (Yes)	Education				Average Household size
				None	Primary	Secondary	Tertiary	
Accra	52 %	62 %	29 %	5 %	7 %	60 %	29 %	7
Tamale	62 %	57 %	50 %	38 %	7 %	26 %	29 %	13

5.2.2 HWTS Product Awareness

Only two respondents in Accra and one in Tamale had used a Ceramic Pot Filter before and they are satisfied with it performance. These householder who had experience with Ceramic Pot Filter said that they had used in the village where connection to water distribution were not available, and now that they had come to the city, they do not think they need it. Majority of the respondents had not seen or used any HWTS products. Some however mentioned that they had tried to put on filter on their piped connection but got tired of the clogging issue. As they were asked for the first impression of the HWTS products, they were impressed with the concepts and look of the products. However, these could have been courtesy responses.

5.2.3 Product Preference

Figure 5-12 shows the consumer preference for the four HWTS products. The distribution of product preferences in both cities shows similar trend. A total of 50 out of 82 interviewees picked GDM as their most favorite product. The reasons given were GDM requires the least maintenance; it is easy to use and appropriate size for family. Ceramic Pot Filter came in second with 26 votes. Most respondents chose Ceramic Pot because they like frequent cleaning it requires, contradicting reasons given for GDM. LifeSaver JerryCan and LifeStraw® family were least popular with only six and three votes respectively. Two respondents did not pick any product because they did not know which one to pick and they are satisfied with their current practice of using products from water vendor.

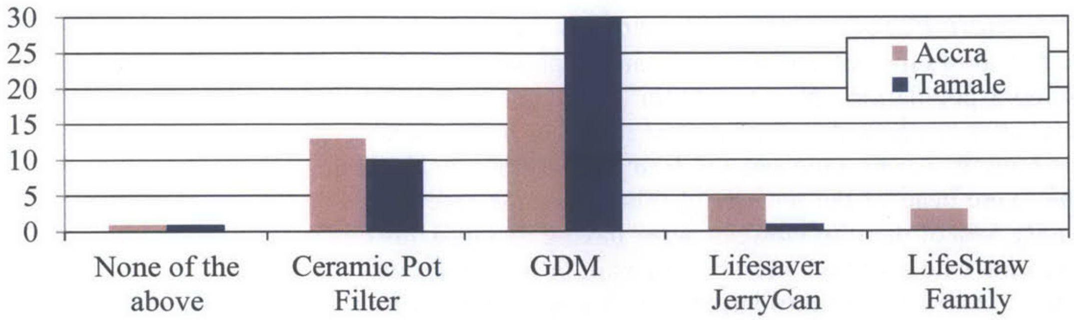

Figure 5-12: Response to question "Which product do you prefer?"

5.2.4 Feature Preference

Figure 5-13 and Figure 5-14 shows the ideal features preference for a HWTS product. The distribution of each feature preference as well as the average ideal treat time and size in two cities are about the same, which is 18 min and 8 L respectively. A product that features the size of 10L and flow rate of 6 L/hr earns the most popularity. This is followed by the size of 5L and flow rate of 2 L/hr. Some respondent believes longer treat time means better the health impact, thus chosing 30 min for the treat time for 1 L of water. As for size, the response varies according to their household size. Interviewees that have household size smaller than 5 indicate that 5 L would be enough for their family while household size larger than 5 usually go for 10 L. Eight families with household size larger than 10 wanted something as big as a steel tank, thus falls into category "more than 10 L". A small portion of the interviewees reported that they can only make decision after physically seeing and using the product.

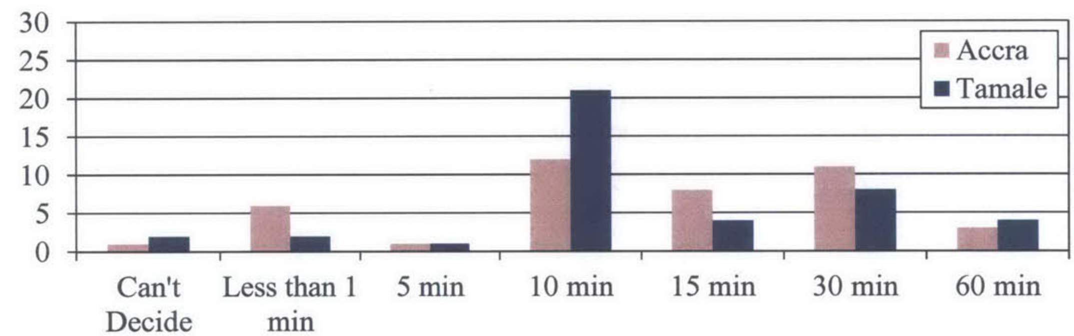

Figure 5-13: Response to question "How long would you wait to treat 1 L of water?"

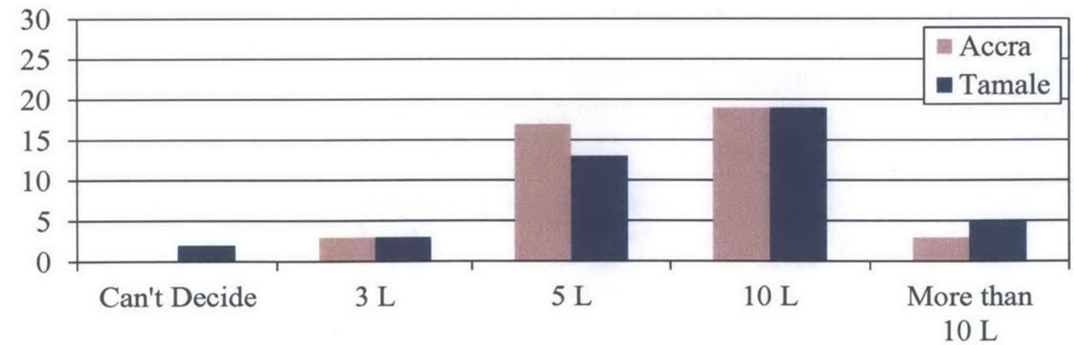

Figure 5-14: Response to question "What is the size that you prefer for your house?"

Figure 5-15 shows the Willingness-to-Pay (WTP) of users for a HWTS product. The distribution of WTP in two cities is similar. Thirty GHS is the most popular choice. However, there were more people willing to pay for a higher price in Accra than in Tamale. The average WTP in Accra is 62 GHS while the average of WTP in Tamale is 36 GHS. Some respondents mentioned that they need to see and have physical contact of the product to make better judgment. Before the question of WTP, interviewees were asked whether they would accept a free product and whether they are willing to pay for a product even though it is not free. All but one respondent would accept a free product and willing to pay even if it is not free. That particular interviewee said that she is satisfied with her drinking water source which relies on bottled water. Based on the observation of the author, she may be the richest person among all respondents.

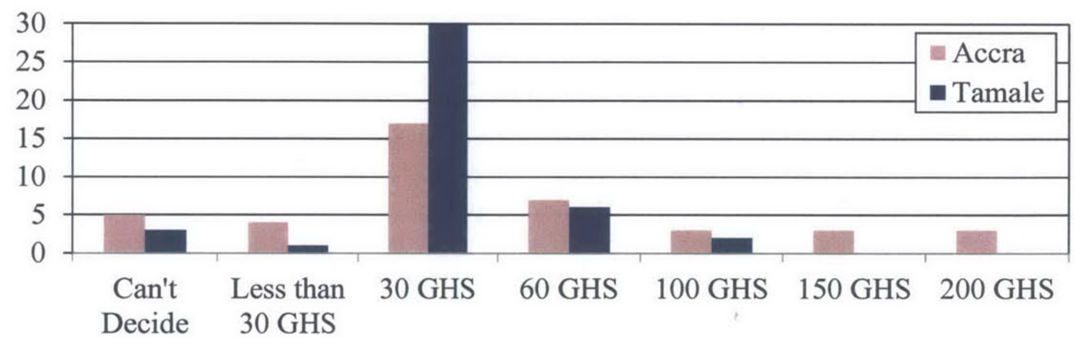

Figure 5-15: Response to question "How much would you pay for a water filter?"

5.2.5 Final Comment

Only 31 householders responded to the final open question. Several respondents were skeptical about the product's performance while many expressed their interest and hope of having HWTS on the market soon. Several key concerns about the product identified include the affordability of the product, the service and supports from the provider and counterfeit. Nevertheless, many respondents indicate that HWTS is not publicly known and thus requires some effort of advertisement. Several respondents also expressed interest in having a product that incorporates refrigeration. These respondents said that this may be a key factor to compete with sachet water and bottled water that is often sold in cold temperature.

5.3 Field Study: Products Assessment

This section summarizes the findings from implementation of two units of LifeSaver Jerry Can in Accra.

5.3.1 Bacteriological Results

Table 5-3 shows the bacteriological test result of the LifeSaver JerryCan units given to two household in Accra. Only the first and fifth results were presented to users due to the schedule of the author. No contamination of total coliform or *E.coli* in the effluent was observed. However, there was a sudden increase of total coliform concentration from about 1000 CFU/100 mL to 5000 CFU/100 mL observed in the influent of Unit 1 between day 7 and day 20. On the other hand, the total coliform concentration in the influent of Unit 2 stabilized around 1000 CFU/100 mL throughout the course. It was reported that the User 1 had never cleaned the product while the User 2 flushed the product every time before he filled it with water although he is told that cleaning is not required. This suggests that when there is on flushing, bacteria may accumulate in the influent. Nevertheless, despite the high concentration of total coliform and *E.coli* in the influent, both units perform effectively.

Table 5-3: Performance of LifeSaver Jerry Can

Day	Unit 1 (East Legon)				Unit 2 (Legon)			
	Total Coliform (CFU / 100 mL)		*E.Coli* (CFU / 100 mL)		Total Coliform (CFU / 100 mL)		*E.Coli* (CFU / 100 mL)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
01	1700	0	200	0	500	0	200	0
03	1400	0	100	0	300	0	100	0
05	2000	0	0	0	700	0	200	0
07	1300	0	200	0	1000	0	0	0
20	5000	0	0	0	1200	0	0	0
21	4000	0	800	0	800	0	0	0

5.3.2 User Feedback

Table 5-4 summarizes the key information from the interviews of the two users at the end of the study. Both users did not experience any change in the quality of the water. However, one of them claimed that by having it under the shade, the water is cooler and better. Nevertheless, they were pleased with the product, believing it provides clean water that is free of bacteria and dirt. Both users were satisfied with the mechanism and time to treat. However, for the size, one of the users claimed that he would prefer a bigger unit. When they were asked for another estimation of price, the WTP of both users increased two to three times of the first estimation. Their final WTP was 100 GHS. When follow questions asking why the WTP increased, the users stated that the visual appearance and the material used in the body of the product give a sense of the quality of the product, in addition to the claims regarding the bacterial test result and description of the product made by the author.

Table 5-4: Summary of User Feedback

Key Questions	User 01	User 02
1. How often do you use the filter?	everyday	everyday
2. How much water do you filter a day?	20 cups	half gallon
3. What kind of water do you use as a source?	Piped water inside residence	Public tap
4. Do you clean your filter?	No	Just flush once before use
5. Do you feel there is a change of water quality?	No but it is colder	No
6. Is the filter easy to use?	Yes	Yes
7. Do you use the filter for purpose other than drinking?	No, just drinking	No just drinking
8. Do you think the size is enough for your family?	Yes	No
9. Is the time-to-treat good enough for your family?	Yes	Yes
10. How much money would you pay for this product? (Before)	30 GHS	50 GHS
11. How much money would you pay for this product? (After)	100 GHS	100 GHS
12. Is there anything you would like to change about the filter?	No	Size

6. Discussion

6.1 Household Water Supply & Water Quality Evaluation

The purpose of this study is to determine whether there is need or a market for a HWTS product among middle and high income families who have access to a piped water supply. The findings clearly suggest that there is.

6.1.1 Degradation of water quality in Accra

The majority of the population is subjected to degradation of water quality, given that 40 % of the samples were found to have detectable level of *E.coli* and 73% showed the presence of total coliform. Several reasons for this degradation were identified, including the usage of unsafe storage vessels, prevalence of animal husbandry and contamination at the source.

More than 70 % of the households surveyed in Accra reported having intermittent water supply. This supports the findings of Ghana Statistical Service and Ghana Health Service (2009), which showed similar results of only 25% of residents in Accra, receives a continuous water supply. As an effect of the intermittent water supply, over 90% of the population relies on storing water in containers for their daily supply. This indicates that there is a massive need or demand for safe water storage device in urban Accra.

According to recommendation in the Safe Water Storage Fact Sheet published by the Centers for Disease Control and Prevention (CDC), a safe storage container should incorporate a small opening with a lid for inlet, a spigot or other small opening for outlet and instructions for the treatment and cleaning method (CDC, USAID 2009). According to this recommendation, only poly tank and cement tank witnessed in this study can be categorized as safe storage. Based on the fact that most contaminated samples were collected from jerry can and plastic drum which do no incorporate any of the safe elements, it is clear that the types of water storage vessels impact on the quality of the water. One of the reasons for this is that these types of storage allow unsanitary practices of the users such as dipping their hands into the water, storing water in open containers and insufficient efforts of cleaning and maintenance.

In addition to the types of storage containers, the location of the storage matters as well. Most water storage devices observed were located outdoors. Sometime herds of livestock such as poultry, goats and sheep can be seen strolling around the container (Figure 6-1). Animal husbandry is a common practice for additional source of income or food in Ghana. In a friendly neighborhood, even if the family may not practice animal husbandry, they may allow livestock of their neighbor to graze in their residence. This practice of allowing animals to exist within the perimeter of water storage device is unsanitary and may likely be one of the main sources of bacterial contamination. In order to implement HWTS in Ghana, it is important to include the factors of environment where agriculture prevails but safe storage practices do not.

Figure 6-1: Livestock in Accra

While poly tanks are considered safer and more sanitary than other containers due to its design of closed system with small openings, the fact that 8 out of 15 water samples taken from poly tank showed different degree of bacterial contamination is shocking. Since the poly tanks and cement tank only have two opening (inlet and outlet) and most of them are directly connect to the source which is piped water supply or ventured water from a tanker truck, the routes of contamination are limited to contamination of the source and/or the outlet. As one of the tap water samples showed positive result for total coliform, it may be the case that the degradation of water quality begins in the distribution system itself. This implies the possibility of infiltration of polluted water due to back-pressure condition in an intermittent network. As the number of samples was limited, it is not clear to what degree the water quality is degraded within the distribution network. However, it is clear that there are a number of people who are exposed to this threat of contaminated water supply. In these circumstances, HWTS is certainly a good option to provide additional barrier to contamination.

6.1.2 Dependence on Water Vendor for Drinking Water Source

Given that only 52% of the sample population would drink from the tap and 26% of them use piped water as their primary drinking source, it is clear that the majority of the population is aware of the degradation of their water quality. Many respondents claimed that they can sometimes see and taste dirt in water coming out from the tap. As a result, half of the respondents turn to sachet water and bottled water as their main source of water for drinking purpose. Most of the purchase made for these products is done on a regular basis with direct delivery from the retailer. This demonstrates that the distribution system surrounding these water products is well developed, which may pose a strong barrier to entry for HWTS. However, the fact is that in terms of cost-benefits, HWTS may be a better solution than these disposable water products. For example, a LifeSaver JerryCan can provide a family of 20 who drinks 3 L of sachet water a day the same amount of water at the equal price. Nevertheless, the fact that the people are aware of the issue of water quality implies the significance of a HWTS can be easily understood and possibly adopted by the consumer.

6.1.3 Comparison between Accra and Tamale

A comparable study regarding the water supply and household water quality was conducted by Vacs Renwick (2013) in Tamale. Table 6-1 summarizes the results from the two cities.

Table 6-1: Water Supply and Quality in Accra and Tamale

	Accra (This Study, 2014)	Tamale (Vacs Renwick, 2013)
Rely on piped water supply as main source for drinking water	26 %	70 %
Intermittent Water Supply	77 %	87 %
Practice Water Storage	93 %	100 %
Practice Water Treatment	14 %	25 %
Free Chlorine Residual below 0.2 mg/L	100 %	93 %
Presence of Total Coliform	74 %	83 %
Presence of *E.coli*	40 %	33 %

As shown in the Table 6-1, both cities suffer a high degree of intermittent water supply and water quality degradation. Overall, Accra does slightly better than Tamale. However, the percentage of the population who rely on piped water supply as their main drinking water source is significantly lower in Accra. This may due to the economic difference of the two cities where Accra, the capital has more people who can afford to have sachet water and bottled water as their main drinking water supply. Another possible explanation is the water vendor industry is better developed in Accra. The percentage of households who practice water treatment is lesser in Accra. This is probably due to the fact that there are more people in Accra who rely on safe water products that do not require additional treatment. Nevertheless, it appears that the intermittent water supply and degradation of water quality issue is universally true in Ghana. This suggests the possibility to introduce HWTS across the country.

6.2 Consumer Preference for HWTS

The purpose of this study is to understand the consumer's knowledge, preferences, attitudes and motivation for HWTS purchase and use in Accra and Tamale. The findings show that the people in the two cities are not familiar with the concept of household treatment; however with the appropriate product and strategy, they may be willing to accept it and purchase it.

6.2.1 Awareness regarding HWTS

Given that the majority of the respondents had not seen or used any HWTS products, the lack of awareness of HWTS may pose a major barrier to HWTS adoption. It will require tremendous effort to introduce and promote HWTS in these cities.

6.2.2 Product Preference

Over 60 % of the respondent picked GDM and 30 % picked Ceramic Pot Filter as their favorite. It is clear that these two products have the potential to do best in the market. Reasons given by the respondents to support their choices include separate storage for clean container, one-step treatment that is easy to use, appropriate size, filter time and maintenance. Life Straw Family 1.0 and LifeSaver Jerry Can did not earn as many votes as the other two products. However, respondents who picked these products were fascinated by the filter time. Given that GDM and Ceramic Pot Filter earned the highest popularity, it is believed that consumer is willing to trade off time-to-treat for the element of ease of use.

There are more people who like GDM over Ceramic Pot Filter because it requires less effort to clean. However, many respondents picked Ceramic Pot Filter because of the weekly cleaning it requires. Some household surveyed believe that cleaning would guarantee the efficiency of the filter and ultimately provide better health impact. This difference of opinions showcases the possibility of two different customer segments that could to be targeted.

Another reason given for the choice of GDM worth mention is the transparent storage container that was featured in the picture during the survey. Surprisingly, some consumers prefer to have a see-through device which enable them to monitor the quality of the water themselves. This may be one of the features that would affect the decision of the consumer.

6.2.3 Feature Preference

Like the product preference survey question, the distribution of each feature preference in two cities is almost the same. This indicates that the perception value to the consumer in the two cities does not vary despite the cultural and economic difference.

While the choice of 10 L for ideal size and 10 min for ideal time-to-treat 1 L has the highest votes, the distribution of each choice is not significantly different. This implies that consumers have high tolerance regarding the increment of each feature. In other words, consumers may be willing to accept the size and the time-to-treat 1 L of water as long as it is in range of the choices they made. Based on the distribution and average number, it is suggested to have the ideal product to be set in 5 to 10 L capacity and 10 to 30 min time-to-treat 1 L of water.

Based on the average number of the ideal flow rate which is 3.33 hr/L, it seems like LifeStraw® Family and LifeSaver JerryCan maybe the best option for the consumer, which contradicts the product preference result. This implies that time-to-treat/flow rate is not the first feature consumers would consider. Taking account of the product preference, the importance of HWTS features maybe the easy-to-use element, the size, followed by the time-to-treat. Based on these assumptions, it is important to design a user-friendly product with the appropriate size with less emphasis on time-to-treat.

The final open questions also revealed several insights on additional customer needs. One of the latent needs identified is a product with refrigeration function, a full technical service and support from the provider, and a product that only requires parts replacement instead of full product replacement after its life time. While many of these features were not included in a basic HWTS unit, it is important to explore the possibility of incorporating them during the design.

6.2.4 Willingness to Pay

In order to not influence the decision of the consumer on WTP, the cost of each HWTS products was not included. As many respondents were not familiar with any of the HWTS products introduced or the concept of HWTS, the WTP of the respondent is shockingly low. The average WTP in Accra and Tamale is 62 GHS and 36 GHS respectively. About half of the respondents chose the lowest price point which is 30 GHS. This contradicts the findings of Yang (2013) who found the WTP of a deluxe model of AfriClay Filter to be 40 GHS. The retail price of PHW's current product, AfriClay, is set at 50 GHS. This means that if the price is set in the range of 36 to 62 GHS, it will be difficult to fulfill the purpose of the new product to generate income.

Nevertheless, most people in Accra and Tamale are willing to accept or even pay for a HWTS product, believing it will bring health benefits to the family. The major hesitancy on the price is the insufficient knowledge and experience with the product. With enough effort of introducing the HWTS to the public through advertisement or product demonstrations, the WTP may be increased. This notion will be further discussed in the next two sections.

6.3 Products Assessment

The purpose of this study has been to characterize possible challenges to two HWTS product's adoption through field testing. However, due to time constraint and contamination of GDM during transportation, only LifeSaver JerryCan was studied in situ. Nevertheless, the findings show that LifeSaver LifeCan performs perfectly in the setting of Ghana and the attitude of the users towards HWTS changes after experiencing the benefits of the product.

6.3.1 Bacteriological Results

Given that no detectable level of bacteria was observed in the effluent of the LifeSaver JerryCan, it is clear that this HWTS product is effective in filtering water of Accra. As the purpose of this study is not to challenge the limit of the product itself, it is not clear that to what extent the product will perform. However, based on the description of the company, it is said to have a 6 log reduction for bacteria.

One interesting phenomenon that occurred during this field test was the sudden increase of total coliform concentration in one of the units whose user did not clean the filter at all. This suggests that when there is no cleaning, bacteria may accumulate in the container. However, it is not likely to have an impact on the effluent unless the concentration of the bacteria exceeds the 10^6 CFU/100 mL. Nevertheless, it may be a good idea to have regular cleaning in order to avoid any risk of contamination.

6.3.2 User Feedback

One of the key findings here is the significant increase of user's WTP after the usage of the product. The WTP of each user was originally 30 GHS and 50 GHS, but after the usage of the product for about three weeks, it increases to 100 GHS. This shows that they can afford for the product at the price of 100 GHS but they were skeptical about the value of the filter prior to actual adoption.

It is not clear if it is the physical appearance of the product or the experience using the product that changed the customer-perceived-value. Although the users reported that they were satisfied with the performance of the product, they cannot really tell the change of the water quality without performing test. The only actual proof of the health benefits was the bacterial test run by the author. This indicates that a demonstration that showcases the effectiveness of the product may replace the whole experience of using the product.

Another feedback given in this section is that the size of the product is a key feature that the user is aware of. This contradicts the findings of Job (2012) in Kenya that showed size of the product is the least important factor in WTP for GDM. This suggests the difference between customer perceived value in Kenya versus Ghana. Nevertheless, for the purpose of PHW which focus on the market in Ghana, it is important to give a variety of sizes that are appropriate for different family sizes.

7. Conclusion

7.1 The Need, the Preference & the Performance

The goal of this study has been to PHW design a for-profit product targeted at middle and high income families in Ghana. One of the key questions that needed to be answered was if there is a market for HWTS products in the middle and high income customers who largely reside in Accra, the capital city. The findings clearly suggest that there is a market, given that there is a severe issue of water quality degradation within the water distribution system and at the point of consumption.

The next question was what HWTS product would be of interest and what kind of HWTS product would prevails in this market. Surveys concluded that products such as GDM and Ceramic Pot Filter that incorporate the following characteristics: separate storage for clean container; easy to use; appropriate size, filter time and maintenance will meet most customer need. Findings also imply that the ideal price point of the product is highly influenced by the knowledge and experience of the user with the product.

The last question is what challenges HWTS products will meet during usage. The findings show that LifeSaver JerryCan performs perfectly in the setting of urban water of Ghana and the customer-perceived-value changes after the experience. The performance of GDM however is unknown.

7.2 Challenges for HWTS adoption

Several barrier-to-entries for HWTS were identified. They are the lack of product awareness, competition from bottled water and sachet water supply and unsanitary storage practice.

Most people in the two cities had not seen or used a HWTS product before. However, unlike the rural community whose lack of health consciousness is the most predominant barrier to HWTS adoption, the urban middle and high income families are aware of the deficiencies in water quality and seek alternative they perceive to be safer, such as bottled water and sachet water.

The preference for bottled water and sachet water drives down demand for HWTS that most people think of as more expensive solutions. However, this is not necessarily true, as the money they spend on these water products each year can easily surpass the price of a HWTS. In terms of cost-benefit, a HWTS product may be a better solution and it is important to showcase this aspect of the product to the urban rich consumer.

The prevalence of animal husbandry along with unsanitary storage had given a challenging condition of water quality at the source. It is important to incorporate features that address these issues such as instruction on the ideal location of the product and cleaning, additional barrier to potential contamination via airborne, contact of user or animal and in-house inspection service.

8. Recommendation

8.1 Implementation Strategy for PHW

There are two major approaches to sell a HWTS product targeted at middle and high income families. One is to partner with EAWAG and sells GDM as PHW's high-end product; two is to further develop its own product by taking recommended product features including safe storage, one-step treatment, transparent container, filter size between 10 to 15L and flow rate of about 3L/hr. Although GDM did slightly better than Ceramic Pot Filter in the surveys, it is hard to say that Ceramic Pot Filter will do worse than GDM in the market. In a country that has a diverse set of consumer needs, developing different products targeted at different customer segments may not be a bad idea.

The recommended price for the future product is 100 GHS per unit as indicated by the change of the user's WTP during the field study. However, as the initial WTP of most consumers is far lower than 100 GHS, it may be a good idea to incorporate payment via monthly installment with small initial investment of 30 GHS in which the users can experience the benefits of the product gradually and ultimately increase their perceived value of the product.

One of the drawbacks of most HWTS interventions is lack of product awareness. In order to reach out to potential buyers, investment in advertisement is essential. The long existing sachet water and bottled water business are still extensively advertising their products via printed media and television broadcast. In order for HWTS to compete with the strong public perception that cheap and good quality sachet and bottled water have, the same amount of efforts in advertising is necessary. As PHW has limited resources, instead of facing the big players in the market head on, it is possible to propose partnership with one of the water ventures to promote and sells HWTS together over the long run. HWTS serves as better solution in terms of sustainability and cost benefits.

8.2 Future Work Needed

The purpose of this research was to help PHW design a for-profit product targeted at middle and high-income families that would generate revenue for its current humanitarian product. This is a fairly large topic and this study only explored a few questions regarding the need, the preference and performance of some products. In order to further develop PHW's product and plan of expansion, the following research projects are proposed.

8.2.1 Water Quality Evaluation in the Water Distribution System in Accra

The household survey and water quality evaluation showed the possibility of bacterial contamination within the water distribution system. As this study was not designed to address the water quality within the water distribution system, an independent study is needed to justify the issue. This project would involve partnering with the local Ghana Water Company and collecting data at different distribution points. By understanding the degree of contamination within network and locating the source of contamination, the design of HWTS with appropriate specifications can potentially be done.

8.2.2 Household surveys in Explicit High-Income Family Area

The household surveys and water quality evaluation increased our understanding of the user's water practices and attitude towards HWTS in Accra and Tamale. However, there are data limitations on the composition of samples. Areas with tight security where the explicit high-income families reside were not included in this study due to absence of authorization to access those areas. This project requires the investigator to get the authorization to visit these sites from either the government department or real estate owner prior to entrance. By understanding the need of explicit high-income families, a product with better margin could be designed.

8.2.3 Field Study of all four HWTS products

The initial plan of the study included identifying the possible challenges each HWTS interventions may face upon adoption through field studies. Due to time constraint, not all interventions were investigated. Hence, a future studies that accommodate all four products is needed.

While all two units of LifeSaver JerryCan showed excellent performance, the duration of 3 weeks may not be sufficient to certify the efficacy of the product. A follow-up visit to the same householders or an independent study that monitors the performance of HWTS products for a longer duration is recommended.

As the advancement of HWTS is rather rapid, it is important to keep updated with development of each product families. For example, LifeStraw® had just launched their latest product, LifeStraw® Family 2.0 right after the study was commenced in January 2014. This does not only change the performance of the product we have described but also may change customer preferences for the new model. Hence, it is important to test the latest version of all models instead of the old ones.

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Appendices

Appendix A: Hach Pocket Colorimeter II Total Chlorine Method

Adapted from: Hach POCKET COLORIMETER II ANALYSIS SYSTEMS NSTRUCTION MANUAL, 2009

1. Fill a 10-mL cell with sample (the blank). Cap.
2. Press the POWER key to turn the meter on. The arrow should indicate the low range channel (LR).
3. Remove the meter cap. Wipe excess liquid and finger prints off sample cell. Place the blank in the cell holder with the diamond mark facing the keypad. Fit the meter cap over the cell compartment to cover the cell.
4. Press ZERO/SCROLL. The display will show "----" then "0.00" . Remove the blank from the cell holder.
5. Fill a second 10-mL cell to the 10 mL line with sample.
6. Add the contents of one DPD free Chlorine Powder Pillow to the sample cell (the prepared sample).
7. Cap and shake gently for 20 seconds. Allow the bubbles to dissipate.
8. Wipe excess liquid and fingerprints from the sample cell. Put the prepared sample cell in the cell holder, with the diamond mark facing the keyboard, and then cover the cell with the instrument cap.
9. After one minute, press the READ/ENTER button. The instrument will show "----" followed by the results in mg/L chlorine.

Appendix B: EC-Kit Instructions

Setup and Quality Control Procedures

▪Materials obtained locally: isopropyl (rubbing alcohol- available in pharmacies), paper towels or tissues, permanent black marker, garbage bag/masking tape or ceramic/plastic tile, soap, liquid bleach, field notebook.

▪Wash hands with soap and water.

▪Locate a clean, level surface. Cover surface with a large plastic garbage bag, taped down with masking tape. Or, use a square ceramic or plastic tile as a work surface. Wipe down work surface with isopropyl

▪Run blanks and duplicates – minimum of 5% of total samples tested - using boiled, cooled water, or bottled water.

▪Record all your test results in a lab notebook. Be sure to include date, each test result and observations.

Procedure for Colilert Test

▪Using the black-marked 10 milliliter (mL) guide test tube provided (the one tube with colored tape in the package), mark **all** the other test tubes in your kit with a permanent black marker at the same 10 mL level.

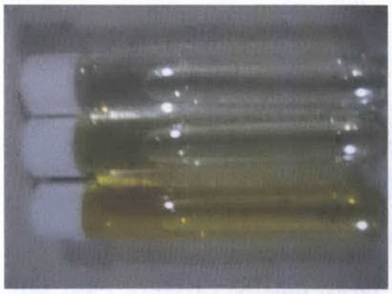
▪Label each tube with the sample name, time, and date of sample collection, initials of person sampling.

▪Remove cap, without touching the inside of the cap with fingers or hand. Then fill the Colilert test tube with 10mL of sample water to the black mark 10 mL level in one of two ways.

> ⅄ *Using Tap other water supply delivered via a spout or on/off spigot (e.g. hand pump, public standpipe, treatment unit spout)*: Fill Colilert tube to the 10 mL mark by adding water directly. Do not exceed the 10 mL black-marked level on the tube. Replace cap & invert tube several times to mix.
>
> ⅄ *Using Sterile Plastic Bag*: Collect water sample in a sterile plastic bag that has been provided in the kit, then pour directly from bag into the Colilert tube. Or, use the sterile pipette provided in kit (graduated at 1 mL) to transfer sample water from the plastic bag to the test tube 10 times. Take care not to touch the sides of the tube or the water in the tube with the pipette. Then, replace the cap and mix the water in the test tube by inverting it several times to dissolve the nutrients.

▪Put Colilert tube in top pocket of incubator belt. Tie the incubator belt around your waist and wear it non-stop for 24 hours +/- 2 hrs. This will incubate the water sample using your body heat.

Interpreting Results: After 24 hours, if samples are clear, no coliform bacteria are present (See top tube in *Figure 1*). If samples are slightly yellow or yellow, coliform bacteria are present (See middle and bottom tubes in *Figure 1*). Record as clear (absent) or yellow (present) on data sheets. If the samples fluoresce to form a milky-blue color under UV/black light, then *E. coli* are present (See bottom tube in *Figure 2*). Otherwise, if the sample does not fluoresce, then *E.coli* are not present (See top 2 tubes in *Figure 2*. NOTE!!! 2 tubes in *Figure 2* show UV/black light reflecting off the Colilert tube glass. THIS IS NOT FLUORESCE!!!) If *E.coli* are present, a Petrifilm test should also be performed in order to quantify (If sample risk is unknown, perform both tests).



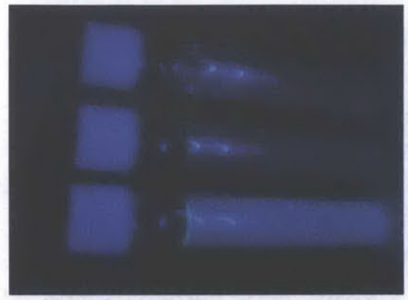


FIGURE 1 - COLILERT (NEGATIVE AND POSITIVE TOTAL COLIFORM)
FIGURE 2 (COLILERT (NEGATIVE AND POSITIVE *E.COLI*)

Procedure for Petrifilm Test

- Place the Petrifilm on a flat surface that has been wiped down with isopropyl alcohol.
- Fill sterile pipette with 1mL of sample water (1 mL= top graduated line just below pipette bulb)
- Lift the top film. With pipette perpendicular to Petrifilm plate, carefully dispense the 1 mL of sample from the pipette on to the center of the pink circle.
- Gently roll the top film onto the Petrifilm plate. Take care not to trap air bubbles under the top film.
- Allow the water to naturally spread out to fill the entire pink circle and allow gel to set for 1-2 minutes.
- Place the Petrifilm between two pieces of cardboard. Secure the Petrifilm between the cardboard using rubber bands.
- Place Petrifilm samples in bottom pocket of incubator belt. Up to five Petrifilms can be stacked between one set of cardboard squares. Incubate at body temperature non-stop for 24 hours +/- 2 hours at body temperature.

Interpreting Petrifilm Results:

E.coli are blue colonies with gas bubbles. Total coliform are the sum of red plus blue colonies with gas bubbles. If the total number of blue colonies with gas bubbles is less then 1, then the water may still have an intermediate risk level that is below the detection limit of the Petrifilm test (See Table 1, page 3). If the total number of blue colonies with gas bubbles counted is between 1 and 10, this represents a high risk level. If the total number of blue colonies with gas bubbles counted is above 10, this is a very high risk level.

Interpretation of EC-Kit Results *for E.coli* using a Risk Table

The two right-hand columns of Table 1 show the World Health Organization's risk rankings for *E.coli* (WHO, 1997). At less than 1 (<1) *E.coli* colony forming units (CFU) per 100 milliliter of sample, WHO quantifies risk as "conformity" meaning that it meets the WHO Guideline value of non-detection of any E.coli in 100 milliliter of sample (see above). At 1-10 *E.coli* colony forming units (CFU) per 100 mL sample, WHO quantifies risk as "low," 10-100 as "intermediate," 100-1000 as "high," and greater than 1000 as "very high." Looking at the "Colilert" (3rd) column, an "absent" result (clear, no fluorescence) is equivalent to either a WHO risk category of "conformity" or "low" risk. A test result for Colilert that comes out "present" i.e. yellow, showing total coliform and showing blue fluorescence means that the Colilert tube contains at least 1 *E.coli* per 10mL of sample added. This can be equivalent to one of three risk levels, depending on the corresponding Petrifilm result. If Petrifilm counts of blue colonies with gas bubbles are zero, the present/yellow/fluorescent Colilert + the Petrifilm, shows intermediate risk (equivalent to WHO risk categories of between 10 – 100 colony counts /100 mL). High and very high risk waters are identified by present/yellow/blue fluorescent Colilert results and *E.coli* counts of blue colonies with gas bubbles on the Petrifilm test at either the 1-10 count (equivalent to WHO "high" risk level) or 10 – 100 count (equivalent to WHO "very high" risk level).

TABLE 1: RISK LEVELS FROM *E.COLI*

WHO Risk Level Categories – *E.coli*		**EC-Kit Results – *E.coli***	
Risk Level (WHO, 1997)	*E.coli* in sample (Coliform Forming Unit per 100 mL) (WHO, 1997)	Colilert *E. coli* Result (Metcalf, 2006)	*E.coli* in sample (Coliform Forming Unit per 1 mL)
Conformity	<1	(-) Absent (clear, no fluorescence)	0
Low	1 – 10	(-) Absent (clear, no fluorescence)	0
Intermediate	11 – 100	(+) Present (yellow color, blue fluorescence)	0
High	101 – 1,000	(+) Present (yellow color, blue fluorescence)	1-10 (blue with gas bubbles count)
Very High	➢ 1,000	(+) Present (yellow color, blue fluorescence)	> 10 (blue with gas bubbles count)

Interpretation of EC-Kit Results for Total Coliform

Total coliform are the sum of red plus blue colonies with gas bubbles in the Petrifilm test. Interpret the total coliform counts using Table 2.

TABLE 2: INTERPRETING TOTAL COLIFORM COUNTS WITH THE EC-KIT

EC-Kit Results –Total Coliform		**Total Coliform Interpretation**	
A	B	C	D
Colilert Total Coliform Result	Petrifilm Total Coliform Result	Combined Colilert and Petrifilm result as a total coliform count (WHO, 1997)	Standardized Unit Equivalent (for comparison, assuming a 100 milliliter sample size - which is the widely used standard sample size)
Absent (clear, no	0	0	<10 total coliform / 100 ml

fluorescence)			
Absent (clear, no fluorescence)	0	0	<10 total coliform/100 ml
Present (yellow)	0	at least 1 total coliform per 10 ml of sample in Colilert test	At least 10 total coliform /100 ml
Present (yellow)	1-10 count (red + blue colonies with gas bubbles)	1 – 10 total coliforms per 1 mL in the Petrifilm test	100-1000 total coliform/100 mL (standardized by multiplying C5 result by 100)
Present (yellow)	> 10 count (red + blue colonies with gas bubbles)	10 – 100 total coliforms per 1 mL in the Petrifilm test	1000 – 10,000 total coliform/100 mL (standardized by multiplying C6 result by 100)

Disposal of Tests

Colilert and Petrifilm tests can be safely stored for a period of days, weeks or even months, in order to be used as training tools, or to refer back to them. However, interpretation of results should only be done after 24 hours of body heat incubation.

Once you are ready to dispose of the tests, a simple, safe method is to add a few drops of undiluted household bleach (which is typically about 6 % chlorine concentration). Add bleach to both to the Colilert tubes and to the Petrifilm, by lifting the film and dispensing the drops. Allow to sit for 30 minutes, then the Colilert can be disposed down a drain, a latrine, or a dug hole. The Petrifilm can be disposed of as waste.

Appendix C: Questionnaires for Household Surveys

Name of Interviewer..Questionnaire Number.............................
Address ....Date.....................................
.....

INTERVIEWER INSTRUCTIONS
INTERVIEW ONLY HOUSEHOLD MEMBERS WHO LIVE IN THE HOUSE
INTERVIEW ONLY ADULT HOUSEHOLD MEMBERS (18 YEARS AND OLDER)
INTERVIEW AN EQUAL NUMBER OF MEN AND WOMEN IF POSSIBLE
INTERVIEW AN EQUAL NUMBER OF YOUNG AND OLD PEOPLE IF POSSIBLE
INTRODUCE YOURSELF
THIS IS AN INDEPENDENT RESEARCH PROJECT
THE INTERVIEW WILL LAST ABOUT 30 MINUTES
PLEASE ANSWER AS TRUTHFULLY AS POSSIBLE
YOUR ANSWERS WILL BE TREATED COMPLETELY CONFIDENTIAL
YOU WILL NOT BE CONTACTED AFTERWARDS BY ANYONE ELSE ABOUT THE ANSWERS

Hello, my name is TengKe Wong. This is ....

We are a research team from MIT in the United States. We are conducting a survey about drinking water quality in Tamale and water filter product we are currently developing. Can we speak with you and ask a few questions about the quality of your drinking water and the prototypes that we have? Your comments and feedback will be very valuable for us to improve our product. This is not a sales team, meaning we are not selling or promoting our product. Instead, we are a research team and the survey is purely for research purposes. Your responses will be kept confidential. Are you willing to participate?
--If NO, thank you for your time and we will end here.
--If YES, do you have any questions or might we begin?

Section one: Demographic data

1. Language used in during interview.........,,,

2. Gender of the respondent (0) Male (1) Female

3. Can you state your age ....years

4. What is your role in this household, are you the head of the household? (0) No (1) Yes

5. If No, what is your relationship to the head of the household? I am:
(0) Husband/wife of the head of the household (1) Son/daughter of the head of the household
(2) Brother/sister of the head of the household (3) father/mother of the head of the household
(4) Other, namely ....

6. What is the occupation of the head of the household? ....

7. How many people live in your household, including yourself? ....

8. Did you go to school? (0) No (1) Yes

9. If yes, what is the highest level of education you reached?

(0) Primary school (1) Secondary school (2) Diploma colleges (3) University degree
(4) other, name grade ....

10. Can you tell me the highest level of education of any other adult household member?

(0) Primary school (1) Secondary school (2) Diploma (3) University degree
(4) Others (specify)..................................

Section two: Water quality Question

1. What is the main source of water in your household? Do you drink for it? (0)Yes (1)No
2. What is the main source of drinking water in your household?

(0) Piped water inside residence
(1) Piped water inside compound
(2) Public taps
(3) Protected Dug wells
(4) Bottle Water
(5) Sachet
(6) Bore Hole
(7) Rain water
(6) Protected Dug well
(4) Unprotected dug well
(8) Unprotected spring
(9) River Water/Stream
(10) Other, namely..............

3. What is the amount of water your household uses for drinking on average in a day? .... liters? ....sachets of water per week?

4. If you are using piped water, had you experience any intermittent supply? (0) Yes (1) No
How often do you get your water supply?

(0) Continuous (no intermittent)
(1) Daily (Some intermittent within a day)
(2) Multiple days per week
(3) Once per week
(4) Multiple days per month
(5) Once per month
(6) other, namely..............

5. Do you store water? (0) Yes (1) No
What kind of storage vessel do you use?

(0) Poly Tank
(1) Metal Drum
(2) Clay Pots
(3) Plastic Drum
(4) Steel Tank
(5) Jerry Can
(6) other, namely..............

6. Do you ever clean your storage vessels? (0) Yes (1) No
How often do you clean your storage tank?

(0) Multiple times per week
(1) Once per week
(2) Multiple times per month
(3) Once per month
(4) other, namely..............

7. Do you treat your water? How (Boiling / Filtration)? (0) Yes (1) No (2) I don't know

8. Do you think the pipe water is safe for drinking purpose? (0) Yes (1) No (2) I don't know
If no why not?

(0) Contaminated by germs
(1) It is muddy
(2) It smells
(3) its taste is bad
(4) Other, namely..............................

9. Has any of your children suffered from diarrhea in the last two months? (0) Yes (1) No

Section three: Product Question

1. Have you had similar product before? If so, how was your experience with it?

....

2. What is your first impression on these filters?

....

3. Which do you think is the best (Rank 1 to 2)?

A. GDM B. Ceramic Pot Filter

C. Life Saver Family D. Lifesaver JerryCan

Reason: ....

4. If this is given to you for free, will you use it? (0) Yes (1) No

5. If the product is not free but very cheap, how much money are you willing to pay for?

(0) 30 GHS (1) 50 GHS

(2) 75 GHS (3) 100 GHS

(4) 150 GHS (5) 200 GHS

6. How long should a filter treat 1 liter of water?

(0) less than 1 minute (1) 10 min

(2) 15 min (3) 30 min

(4) 1 hour (5) others, namely ....

7. What is the size you would like to filter be?

(0) 3L (1) 5 L

(2) 10 L (3) 15 L

(4) Others, namely ....

8. What do you think is the most important feature of a water filter?

(0) Health impact (1) Durability (Life Span)

(2) Product price (3) Product size

(4) Time to treat (5) Water taste

(6) Look

9. Where would you most like to purchase such filters for your family?

(0) Door to door (1) Shop / Mall

(1) Roadside stand (2) Specialty store

(3) Street vendors (4) Market day

10. What influences your decision about purchasing a product like this?

(0) Family members (1) Health professional

(2) Friends and peer group (3) Health issues

(4) Other, namely.............................

11. What final comments or questions do you have for our filter?

....

Appendix D: Product Description Catalogue used in Surveys

	(A) Ceramic pot filter	(B) Gravity Driven Membrane	(C) LifeStraw Family	(D) LifeSaver Jerry Can
				
Operation	Water is poured into the upper vessel and let it slowly passed through the ceramic. Weekly cleaning of the ceramic is recommended.	Water is poured into the upper vessel and let it slowly passed through the membrane . Minimum cleaning is needed	Water is poured into the upper vessel and let it slowly passed through the membrane. Daily cleaning through flushing and pumping is recommended.	Water is poured into can. Applying pressure through hand pump. Turn on the tap and use clean water from outlet. Minumum cleaning is needed.
Time to treat 1 liter	30 min ~ 1 hour	30 min	10 min	Less than 1 min
Storage capacity	5 ~10 liters	5 ~10 liters	None. Separate storage required.	None. Separate storage for clean water is required.
Life Span	1 ~ 4 years	3 ~ 4 years	2 ~ 3 years	3 ~ 4 years

Appendix E: Questionnaires for User's Feedback

1. How often do you use the filter?

(0) ....per day (1) once per day

(2) ....per week (2) once per week

2. How much of water you filter a day?_______ buckets of water

3. What kind of water do you use as source?..........................

4. Do you feel that there is a change of the water quality after using the product? (Yes /No)
What do you think it changed?

(0) The Taste (1) The Smell

(2) The Quality (3) others, namely......

5. Is this filter easy to use? What is the difficulty of the filter?

....

6. Do you use the filter for purpose other than drinking?

....

7. Do you think the size of the filter is enough for you family? Yes / No
If not, what size?..............................

8. What was your initial willing to pay ?

(0) 30 GHS (1) 50 GHS

(2) 75 GHS (3) 100 GHS

(4) 150 GHS (5) 200 GHS

9. Now how much money are you willing to pay for?

(0) 30 GHS (1) 50 GHS

(2) 75 GHS (3) 100 GHS

(4) 150 GHS (5) 200 GHS

10. Is there anything you would like to change about this filter?

(0) Mechanism (1) Size

(2) Time to treat (3) Look

(4) Others, namely..............

11. What final comments or questions do you have for our filter?

....

Appendix F: Surveys Responses

Questionnaire No	01	02	03	04
Language	English	Local	Local	English
Location	East Legon	East Legon	East Legon	East Legon
Gender	Male	Female	Male	Male
Age	79	37	23	30
Head of Household	Yes	Yes	No	No
Occupation	Retired Diplomat	Seamstress	Real estate developer	Musician
Members in the household	3	7	2	4
Highest level of education	University Degree	Junior High School	Junior High School	University Degree
Main Water Source	Piped Inside Residence	Public Tap	Public Tap	Bottle Water
Do you drink from it?	No	Yes	No	No
Main Drinking Water Source	Bottle Water	Public Tap	Sachet	Bottle Water
Amount of Water			3 L	100 Box / week
Intermittent Water Supply	Yes	Yes	Yes	Not supply at all
How often do you get your water?	Multiple Days per Month	Once per week	Once per week	
Do you store water? What vessel??	Poly Tank	Jerry Can	Poly Tank	Poly Tank
Cleaning the storage	Multiple times per week	Once per week	No	Once per week
Water Treatment	No	No	No	No
Do you think pipe water is safe to drink? Why not?	Yes	Yes	Yes	Yes
First Impression		never used them before, but they seem reliable	Good	GDM/CPF seems safe
Best Product	GDM	GDM	Life Straw Family	GDM
Reason	No Cleaning	Time to treat	Time to treat	Safe Storage
Have you seen similar product before?	No	No	No	No
Have you used similar product before?	No	No	No	No
Your Experience				
Will you want a free product?	Yes	Yes	Yes	Yes
Willingness to Pay (GHS)	200	30	30	200
Time to treat 1L of water	15	10	10	10
Ideal Size	5	3	5	5
Important Feature	Health Impact	Time to treat	Water taste	Health Impact
Place to buy	Specialty Store	Specialty Store	Mall	Mall
Influence factor	Family Members	Family members	Family Members	Health Professional
Final comment	It is doubtful to see the necessity of such item		It seems like a good product. But need to be careful with fake products.	Consistency is the key

Questionnaire No	05	06	07	08
Language	Local	Local	English	English
Location	East Legon	East Legon	East Legon	Legon
Gender	Male	Male	Female	Male
Age	45	45	56	50
Head of Household	Yes	Yes	No	Yes
Occupation	Construction worker	Business Man	Structure Engineer	Plumber
Members in the household	3	3	5	5
Highest level of education	Junior High School	Diploma	Diploma	Diploma
Main Water Source	Public Tap	Public Tap	Piped Inside Residence	Public Tap
Do you drink from it?	Yes	Yes	No	No
Main Drinking Water Source	Public Tap	Public Tap	Bottle Water	Sachet
Amount of Water	6 gallons	6 bucket		
Intermittent Water Supply	Yes	Yes	Yes	Yes
How often do you get your water?	Once per week	Once per week	Once per week	Once per week
Do you store water? What vessel??	Jerry Can	Plastic Drum	Poly Tank	Jerry Can
Cleaning the storage	Once per week	Once per week	Once per month	Once per week
Water Treatment	No	No	Boiling	No
Do you think pipe water is safe to drink? Why not?	Yes	Yes	Yes	Yes
First Impression	Good idea. It seems useful in Ghana	Good	Cheaper than bottle water	
Best Product	GDM	Life Saver Jerry Can	GDM	GDM
Reason	clear storage for clean water	It seem durable	Easy to use	Easy to use
Have you seen similar product before?	No	No	No	No
Have you used similar product before?	No	No	No	No
Your Experience				
Will you want a free product?	Yes	Yes	Yes	Yes
Willingness to Pay (GHS)	20	20	50	50
Time to treat 1L of water	30	10	15	15
Ideal Size	5	3	10	10
Important Feature	Product Size	Durability	Durability	Health Impact
Place to buy	Shop	Health Centre	Door to door	Shop
Influence factor	Family Members	Family Members	Family Members	Family Members
Final comment	It need to be available at affordable price.	Larger size for more water.	Cooling System; Choking of the effluent tap; Filter Accessory	

Questionnaire No	09	10	11	12
Language	English	English	English	English
Location	Legon	Legon	Legon	Legon
Gender	Male	Male	Male	Male
Age	18	18	63	19
Head of Household	No	No	No	No
Occupation	Business Man	Security Officer	Security Officer	
Members in the household	8	5	8	5
Highest level of education	Secondary School	Secondary School	Secondary School	Secondary School
Main Water Source	Piped Inside Residence	Piped Inside Residence	Piped Inside Residence	Piped Inside Residence
Do you drink from it?	No	Yes	No	No
Main Drinking Water Source	Sachet	Piped Inside Residence	Sachet	Sachet
Amount of Water			15 Liters / day	7 Liters / day
Intermittent Water Supply	Yes	Yes	Yes	Yes
How often do you get your water?	Once per week	Once per week	Multiple days per month	Once per week
Do you store water? What vessel??	Poly Tank	Poly Tank	Poly Tank	Plastic Drum
Cleaning the storage	Once per week	Once per week	Multiple times per year	Once per week
Water Treatment	No	No	Boiling	Boiling
Do you think pipe water is safe to drink? Why not?	Yes	The taste is bad	Yes	Yes
First Impression		Good	I wish I could get one	It is good and creative
Best Product	Ceramic Pot Filter	Life Saver Jerry Can	Ceramic Pot Filter	Ceramic Pot Filter
Reason	You can clean them	No cleaning	It is easy to use	You can clean it to prevent germs
Have you seen similar product before?	No	No	No	No
Have you used similar product before?	No	No	No	No
Your Experience			It is durable	
Will you want a free product?	Yes	Yes	Yes	Yes
Willingness to Pay (GHS)	30	50	30	50
Time to treat 1L of water	10	15	30	30
Ideal Size	5	10	5	5
Important Feature	Health Impact	Health Impact	Health Impact	Health Impact
Place to buy	Shop	Shop	Shop	Shop
Influence factor	Family Members	Health Professional	Health Issues	Health Issues
Final comment	Is there any community scale product?			It is very good and helping. Come out with such filter.

Questionnaire No	13	14	15	16
Language	English	English	English	English
Location	Legon	Legon	Osu	Osu
Gender	Female	Female	Male	Male
Age	34	40	21	35
Head of Household	No	Yes	No	Yes
Occupation	Policeman	Trader	Retired Telecom Officer	Bussiness Man
Members in the household	3	15	7	6
Highest level of education	Diploma	Primary School	University Degree	Primary School
Main Water Source	Piped Inside Residence	Piped Inside Compound	Piped water inside residence	Piped water inside compound
Do you drink from it?	Yes	Yes	Yes	Yes
Main Drinking Water Source	Sachet	Piped Inside Compound	Sachet	Piped water inside compound
Amount of Water	10 sachets / day		1 Bag / 3 days	
Intermittent Water Supply	Yes	Yes	No	No
How often do you get your water?	Multiple days per month	Once per week		
Do you store water? What vessel??	Poly Tank	Plastic Drum	No	Jerry Can
Cleaning the storage	Once per week	Once per week		Once per week
Water Treatment	No	No	Boiling	No
Do you think pipe water is safe to drink? Why not?	No	Yes	Yes	Yes
First Impression	Sachet water use this	Good. Can make our water safe	If it works, why not?	
Best Product	Ceramic Pot Filter	Ceramic Pot Filter	GDM	GDM
Reason	Cleaning	Cleaning	Time to treat ,Look	Clean Water Tank
Have you seen similar product before?	No	No	No	No
Have you used similar product before?	No	No	No	No
Your Experience			It was okay.	
Will you want a free product?	Yes	Yes	Yes	Yes
Willingness to Pay (GHS)	30	20	50	30
Time to treat 1L of water	15	30	15	30
Ideal Size	10	15	5	10
Important Feature	Durability	Product Size	Health Impact	Health Impact
Place to buy	Shop	Street Vendors	Shop	Door to Door
Influence factor	Health Professional	Health Professional	Family Members	Family Members
Final comment	No	No	It should be available.	Transparent is good.

Questionnaire No	17	18	19	20
Language	Local	English	Local	English
Location	Osu	Osu	Osu	Osu
Gender	Male	Female	Male	Female
Age	57	31	43	70
Head of Household	No	No	Yes	No
Occupation	Hospital Staff	Business Man	Brick Mason	Retired Store Keeper
Members in the household	4	6	3	5
Highest level of education	Secondary School	Junior High School	Secondary School	Secondary School
Main Water Source	Piped water inside residence	Piped water inside residence	Piped water inside compound	Piped water inside residence
Do you drink from it?	No	Yes	Yes	Yes
Main Drinking Water Source	Sachet	Sachet	Sachet	Sachet
Amount of Water	4 Bags / day	1 Bag / day	4 Bags / week	2 Bags / week
Intermittent Water Supply	No	Yes	Yes	Yes
How often do you get your water?		Once per week	Multiple days per week	Multiple days per week
Do you store water? What vessel??	No	Plastic Drum	Jerry Can	Poly Tank
Cleaning the storage		Once per week	2 times per month	once two week
Water Treatment	No	No	No	No
Do you think pipe water is safe to drink? Why not?	Yes	Yes	Yes	Yes
First Impression				Good / No electricity
Best Product	GDM	GDM	GDM	Ceramic Pot Filter
Reason	Easy to use	Time		It is easy to use
Have you seen similar product before?	No	No	No	No
Have you used similar product before?	No	No	No	No
Your Experience				
Will you want a free product?	Yes	Yes		Yes
Willingness to Pay (GHS)	30	30		30
Time to treat 1L of water	15	30		10
Ideal Size	5	10	3	10
Important Feature	Product Size	Health Impact		Health Impact
Place to buy	Door to Door	Shop		Door to Dorr
Influence factor	Family Members	Health Issues		Health Issues
Final comment	It is safe to door to door.	Life Span is a concern.		Good price for everyone

Questionnaire No	21	22	23	24
Language	English	Local	English	English
Location	Osu	Weijer	Weijer	Weijer
Gender	Male	Female	Female	Male
Age	19	35	19	18
Head of Household	No	Yes	No	No
Occupation	Business Man	Trader	Tailor	Carpenter
Members in the household	15	4	8	7
Highest level of education	Secondary School		Secondary School	Secondary School
Main Water Source	Piped water inside residence	Piped water inside residence	Piped water inside residence	Public Tap
Do you drink from it?	Yes	Yes	No	No
Main Drinking Water Source	Piped water inside residence	Piped water inside residence	Sachet	Sachet
Amount of Water	-		2 Bags / week	5 / days
Intermittent Water Supply	Yes	No	No	No
How often do you get your water?	Multiple days per week			
Do you store water? What vessel??	Clay Pot	Jerry Can	Jerry Can	Jerry Can
Cleaning the storage	Once per month	Multiple times per week	Multiple times per week	Multiple times per week
Water Treatment	No	No	No	No
Do you think pipe water is safe to drink? Why not?	Yes	Yes	Sometime muddy	Yes
First Impression			Ceramic pot Filter is not enough	
Best Product	GDM	-	LifeStraw Family	LifeSaver
Reason	Time		Fast/ No pumping	Simple to use
Have you seen similar product before?	No	No	Yes, had seen Ceramic Pot Filter	No
Have you used similar product before?	No	No	Yes, had used	No
Your Experience			Charcoal	
Will you want a free product?		Yes	Yes	Yes
Willingness to Pay (GHS)	30		30	30
Time to treat 1L of water	1	30	10	60
Ideal Size	5	10	5	10
Important Feature	Durability	Health Impact	Health Impact	Water taste
Place to buy	Specialty Store	Door to door	Door to door	Shop
Influence factor	Health Issues		Health issues	Health Professional
Final comment	Problem with scam and copies.	You need advertisement	Need to be tested	

Questionnaire No	25	26	27	28
Language	English	Local	Local	English
Location	Weijer	Weijer	Weijer	Weijer
Gender	Male	Female	Female	Male
Age	19	37	20	21
Head of Household	No	Yes	No	No
Occupation	Driver	Trader	Trader	Pharmacist
Members in the household	16	4	15	10
Highest level of education	Secondary School	Secondary School	Junior High School	University Degree
Main Water Source	Public Tap	Public Tap	Public Tap	Piped water inside residence
Do you drink from it?	No	No	No	No
Main Drinking Water Source	Sachet	Sachet	Sachet	Sachet
Amount of Water	2 Bags / week	1 Bag / day	5 Bag / day	2 Bag / day
Intermittent Water Supply	No	No	Yes	No
How often do you get your water?			Multiple days per week	
Do you store water? What vessel??	Jerry Can	Jerry Can	Jerry Can	No
Cleaning the storage	Once per week	Once per week	Multiple times per week	
Water Treatment	No	No	No	No
Do you think pipe water is safe to drink? Why not?	Contaminated by germs	Yes	Yes	Yes
First Impression	Good, it is necessary			
Best Product	Ceramic Pot Filter	Ceramic Pot Filter	Ceramic Pot Filter	Ceramic Pot Filter
Reason	Transparent	Simple to use	Can be cleaned	Can be cleaned
Have you seen similar product before?	No	No	No	No
Have you used similar product before?	No	No	No	No
Your Experience				
Will you want a free product?	Yes		Yes	Yes
Willingness to Pay (GHS)	150		150	100
Time to treat 1L of water	60	60	10	30
Ideal Size	10	10	15	5
Important Feature	Product Price	Product Price	Health Impact	Health impact
Place to buy	Shop	Shop	Shop	Door to door
Influence factor	Family Members	Family Members	Family Members	Health Professional
Final comment				Size / Refrigeration

Questionnaire No	29	30	31	32
Language	English	Local	English	Local
Location	Abrekuma	Abrekuma	Abrekuma	Abrekuma
Gender	Female	Male	Male	Female
Age	24	24	18	28
Head of Household	No	No	No	No
Occupation	Insurance Officer	Designer	Trader	Trader
Members in the household	25	4	5	5
Highest level of education	University Degree	vocational training	Secondary School	Secondary School
Main Water Source	Piped water inside residence	Public Tap	Public Tap	Piped water inside compound
Do you drink from it?	Yes	Yes	Yes	No
Main Drinking Water Source	Piped water inside residence	Public Tap	Public Tap	Sachet
Amount of Water	2 Bag / day	2 Bag / day	2 Bag / day	2 Bag / day
Intermittent Water Supply	Yes	Yes	Yes	Yes
How often do you get your water?	Multiple days per month	Once per month	Once per week	Multiple days per month
Do you store water? What vessel??	Clay Pot	Jerry Can	Jerry Can	Cement Tank
Cleaning the storage	Multiple times per week	Once per month	Once per week	Multiple times per week
Water Treatment	Add Alum	No	No	No
Do you think pipe water is safe to drink? Why not?	Bad Taste	Yes	Yes	Yes
First Impression		Good	Good	Good
Best Product	GDM	Ceramic Pot Filter	GDM	GDM
Reason	Separated Storage tank	Can be cleaned	No Cleaning	Simple to use and Transparent
Have you seen similar product before?	No	No	No	No
Have you used similar product before?	No	No	No	No
Your Experience				
Will you want a free product?	Yes	Yes	Yes	Yes
Willingness to Pay (GHS)	30	10	30	
Time to treat 1L of water	1	20	1	30
Ideal Size	15	5	10	10
Important Feature	Product Size	Health impact	Health impact	Durability
Place to buy	Shop	Door to door	Door to door	Market day
Influence factor	Health Issues	Health Professional	Health Professional	Health Issues
Final comment	Some people collect simlar data before but never come back			I think It will be good if it comes to our market

Questionnaire No	33	34	35	36
Language	Local	Local	Local	Local
Location	Abrekuma	Abrekuma	Abrekuma	Abelemkpe
Gender	Female	Female	Female	Female
Age	18	24	52	19
Head of Household	No	No	No	No
Occupation	Trader	Pastor	Farmer	Navy
Members in the household	7	9	3	9
Highest level of education	Junior High School	Secondary School		Secondary School
Main Water Source	Bore Hole	Water vendor (Tank)	Public Tap	Piped water inside residence
Do you drink from it?	No	No	No	No
Main Drinking Water Source	Sachet	Sachet	Sachet	Bottle Water
Amount of Water	2 Bag / day	6 Bag / day	1 Bag /day	5 Bags / day
Intermittent Water Supply	No supply at all	No supply at all	Yes	Yes
How often do you get your water?			Once per month	Multiple days per week
Do you store water? What vessel??	Jerry Can	Poly Tank	Poly Tank	Plastic Drum
Cleaning the storage	Multiple times per week	No	Once per week	Once per month
Water Treatment	No	No	No	No
Do you think pipe water is safe to drink? Why not?	Yes	I don't know	Yes	Contaminated by germs
First Impression	Good	Difficult to use	Good	Instant / Save Time
Best Product	Life Saver Jerry Can	LifeStraw Family	GDM	GDM
Reason	High flow rate	Can be cleaned	Clean Container	Storage
Have you seen similar product before?	No	No	No	Yes, had seen GDM / Life Saver
Have you used similar product before?	No	No	No	No
Your Experience				
Will you want a free product?	Yes	Yes	Yes	Yes
Willingness to Pay (GHS)	200	100		30
Time to treat 1L of water	10	1	30	10
Ideal Size	5	10	10	10
Important Feature	Durability	Durability	Health Impact	Healt Impact
Place to buy	Shop	Specialty Store	Specialty Store	Door to door
Influence factor	Family Members	Health Issues	Health Issues	Health Professional
Final comment		nice designs for homes		

Questionnaire No	37	38	39	40
Language	English	English	English	Local
Location	Abelemkpe	Abelemkpe	Abelemkpe	Abelemkpe
Gender	Female	Male	Female	Female
Age	30	22	38	42
Head of Household	No	No	No	No
Occupation	Head dresser	Medical Officer	Self-Employ	Carpenter
Members in the household	2	4	5	3
Highest level of education	Junior High School	University Degree	Secondary School	Junior High School
Main Water Source	Public Tap	Piped water inside residence	Piped water inside residence	Public Tap
Do you drink from it?	Yes	No	Yes	Yes
Main Drinking Water Source	Sachet	Sachet	Bottle water	Sachet
Amount of Water	2 Bags / week	2 Bags / week	2 Bags / week	2 Bags / week
Intermittent Water Supply	Yes	Yes	Yes	Yes
How often do you get your water?	Once per month	Once per week	Multiple days per week	Once per week
Do you store water? What vessel??	Plastic Drum	Poly Tank	Poly Tank	Plastic Drum
Cleaning the storage	Daily		Once per month	Once per week
Water Treatment	No	No	No	No
Do you think pipe water is safe to drink? Why not?	Contaminated by germs	Yes	Yes	Yes
First Impression	Good	It seems helpful		Can help our community
Best Product	Life Saver Jerry Can	GDM	Ceramic Pot Filter	Ceramic Pot Filter
Reason	Simple to use	Save Storage, Time, Performance	Slowly, silt well	Cleaning
Have you seen similar product before?	No	No	No	No
Have you used similar product before?	No	No	No	No
Your Experience				
Will you want a free product?	Yes	Yes	Yes	Yes
Willingness to Pay (GHS)	30	30	50	150
Time to treat 1L of water	10	10	1	15
Ideal Size	10	10	5	5
Important Feature	Product Size	Health Impact	Specialty Store	Health Impact
Place to buy	Specialty Store	Street Vendors	Specialty Store	Door to door
Influence factor	Family Members	Friends and peer group	Health Issues	Health Professional
Final comment		Price is the main issue; Skeptical with the performance; Size and function		

Questionnaire No	41	42	43	44
Language	English	English	Local	Local
Location	Abelemkpe	Abelemkpe	Kalpohine	Kalpohine
Gender	Male	Female	Male	Male
Age	44	55	65	40
Head of Household	Yes	Yes	Yes	Yes
Occupation	Developer	Bussiness woman	Farmer	Farmer
Members in the household	9	3	10	26
Highest level of education	University Degree	University Degree		
Main Water Source	Piped water inside residence	Piped water inside residence	Public Taps	Piped water inside compound
Do you drink from it?	No	No	Yes	Yes
Main Drinking Water Source	Bottle Water	Bottle Water	Piped water	Piped water
Amount of Water	5 Bags / week	4 day / dispensor	10 gallons	
Intermittent Water Supply	Yes	Yes	Yes	Yes
How often do you get your water?	Multiple days per month	Every two weeks		Once per week
Do you store water? What vessel??	Poly Tank	Poly Tank	Metal Drum	Plastic Drum
Cleaning the storage	No	No	Multiple times per week	Multiple times per week
Water Treatment	No	No	No	No
Do you think pipe water is safe to drink? Why not?	Yes	It is muddy	Yes	Yes
First Impression	Applicable		I like it. It will be good if there is no piped water.	They seem good
Best Product	GDM	GDM	LifeSaver	GDM
Reason	Size	Easy to use	No cleaning, fast	Size
Have you seen similar product before?	Had seen Ceramic Pot Filter	Yes, had seen Ceramic Pot Filter	No	No
Have you used similar product before?	No	No	No	No
Your Experience				
Will you want a free product?	Yes	No	Yes	Yes
Willingness to Pay (GHS)	50	100	30	30
Time to treat 1L of water	1	5	10	1
Ideal Size	10	5	10	10
Important Feature	Health Impact	Water taste	Health Impact	Life Span
Place to buy	Specialty Store	Shop/Mall	Street Vendors	Street Vendors
Influence factor	Family Members	Health Professional	Health Issues	Health Issues
Final comment	Parts is a concern		How long can we store the water	You need advertisement

Questionnaire No	45	46	47	48
Language	Local	Local	English	English
Location	Kalpohine	Kalpohine	Kalpohine	Central market
Gender	Male	Female	Female	Female
Age	60	70	70	18
Head of Household	Yes	Yes	Yes	No
Occupation	Farmer	Trader	Security	Trader
Members in the household	20	19	10	10
Highest level of education				Secondary School
Main Water Source	Piped water inside residence	Public Tap	Public Tap	Piped water inside residence
Do you drink from it?	Yes	Yes	Yes	Yes
Main Drinking Water Source	Piped water	Piped water	Sachet	Sachet
Amount of Water	16 gallons	10 gallons	7 bags / week	7 bags / week
Intermittent Water Supply	Yes	Yes	Yes	Yes
How often do you get your water?				
Do you store water? What vessel??	Clay Pots	Clay Pot	Clay Pot	Jerry Can
Cleaning the storage	Multiple times per week	Multiple times per week	Multiple times per week	Multiple times per week
Water Treatment	No	No	No	Filtration
Do you think pipe water is safe to drink? Why not?	Yes	Yes	Yes	Yes
First Impression	It will be good for our health	It is good	It is good	Nice
Best Product	GDM	Ceramic Pot Filter	GDM	GDM
Reason	Size	Looks	Storage	Storage
Have you seen similar product before?	No	No	No	No
Have you used similar product before?	Yes	No	No	No
Your Experience				
Will you want a free product?	Yes	Yes	Yes	Yes
Willingness to Pay (GHS)	30	30	30	30
Time to treat 1L of water	10	30	30	30
Ideal Size	5	5	5	5
Important Feature	Health Impact	Health Impact	Life Span	Health Impact
Place to buy	Door to door	Door to door	Street Vendors	Shop/Mall
Influence factor	Health Issues	Family Members	Family Members	Health Professional
Final comment			Free Gift	Free Gift

Questionnaire No	49	50	51	52
Language	Local	Local	English	English
Location	Central market	Central market	Central market	Central market
Gender	Female	Female	Male	Male
Age	18	18	25	54
Head of Household	No	No	No	Yes
Occupation	Trader	Driver	Student	Trader
Members in the household	12	13	5	20
Highest level of education	Secondary School	Diploma	Diploma	Secondary School
Main Water Source	Piped water inside residence	Piped water inside residence	Piped water inside compound	Piped water inside residence
Do you drink from it?	Yes	Yes	Yes	Yes
Main Drinking Water Source	Sachet	Bottle Water	Piped water	Piped water
Amount of Water	4 Bags / week	4 Bottles / day	1 Bag / week	
Intermittent Water Supply	Yes	Yes	Yes	Yes
How often do you get your water?	Once per week	Multiple days per week	Multiple days per week	Multiple days per week
Do you store water? What vessel??	Jerry Can	Poly Tank	Metal Drum	Poly Tank
Cleaning the storage	Once per week	Once per month	Once per month	Once per month
Water Treatment	Alum	No	No	No
Do you think pipe water is safe to drink? Why not?	Yes	Yes	Yes	I don't know
First Impression	I like them	Nice	Good but need the price	They look goof
Best Product	GDM	GDM	GDM	GDM
Reason	Storage	Easy to use / No cleaning	No Cleaning	Life Span and the size
Have you seen similar product before?	No	No	No	No
Have you used similar product before?	No	No	No	No
Your Experience				
Will you want a free product?	Yes	Yes	yes	Yes
Willingness to Pay (GHS)	100	30	50	10
Time to treat 1L of water	15	10	10	10
Ideal Size	5	5	10	10
Important Feature	Durability	Health Impact	Health Impact	Durability
Place to buy	Shop / Mall	Door to door	Door to door	Shop / Mall
Influence factor	Health Professional	Health Professional	Family Members	Health Issues
Final comment				

Questionnaire No	53	54	55	56
Language	English	English	English	English
Location	Central market	Central market	Nyanshegu	Nyanshegu
Gender	Female	Male	Female	Female
Age	40	28	28	20
Head of Household	No	No	No	Yes
Occupation	Farmer	Teacher	Farmer	Trader
Members in the household	8	2	20	5
Highest level of education		University Degree	Secondary School	Junior High School;
Main Water Source	Piped water inside residence	Piped water inside residence	Piped water inside residence	Piped water inside residence
Do you drink from it?	No	No	Yes	Yes
Main Drinking Water Source	Sachet	Sachet	Sachet	Piped water
Amount of Water	7 bags / week	1 Bag / week	10 Bags / week	
Intermittent Water Supply	Yes	Yes	Yes	Yes
How often do you get your water?	Multiple days per week	Multiple days per week		
Do you store water? What vessel??	Clay Pot	Poly Tank	Clay Pot	Poly Tank
Cleaning the storage	Once per week	Once per month	Once per week	Once per week
Water Treatment	No	No	No	No
Do you think pipe water is safe to drink? Why not?	Yes	It is muddy	I don't know	
First Impression	Good	It is good		Good
Best Product	Ceramic Pot Filter	GDM	GDM	Ceramic Pot Filter
Reason		Storage Cleaning	Size	Looks
Have you seen similar product before?	No	No	No	No
Have you used similar product before?	No	No	No	No
Your Experience				
Will you want a free product?		Yes	Yes	Yes
Willingness to Pay (GHS)		100	30	50
Time to treat 1L of water		10	10	60
Ideal Size		5	5	10
Important Feature		Health Impact	Health Impact	Health Impact
Place to buy		Specialty Store	Door to door	Door to door
Influence factor		Health Issue	Family Member	Family Member
Final comment		useful		

Questionnaire No	57	58	59	60
Language	English	English	Local	Local
Location	Nyanshegu	Nyanshegu	Nyanshegu	Nyanshegu
Gender	Male	Male	Male	Female
Age	45	22	21	28
Head of Household	Yes	No	No	No
Occupation	Construction	Farmer	Student	Trader
Members in the household	10	32	10	3
Highest level of education	Diploma	Diploma	Secondary School	Junior High Schoo;
Main Water Source	Piped water inside residence	Piped water inside residence	Piped water inside residence	Piped water inside compound
Do you drink from it?	Yes	Yes	Yes	Yes
Main Drinking Water Source	Piped water	Piped water	Piped water	Sachet
Amount of Water	Not plenty			2 Bags / week
Intermittent Water Supply	Yes	Yes	Yes	Yes
How often do you get your water?	Multiple days per week	Daily	Multiple days per week	Daily
Do you store water? What vessel??	Metal Drum	Clay Pot	Metal Drum	Jerry Can
Cleaning the storage	Once per week	Once per week	Once per week	Once per week
Water Treatment	No	No	No	No
Do you think pipe water is safe to drink? Why not?	Yes	Yes	Yes	No
First Impression	Good			Good
Best Product	Ceramic Pot Filter	GDM	GDM	GDM
Reason	Storage, Drink Instantly	No Cleaning	No Cleaning	No Cleaning
Have you seen similar product before?	No	Seen Ceramic Pot Filter	Seen similar thing	No
Have you used similar product before?	No	No	No	No
Your Experience				
Will you want a free product?	Yes	Yes	Yes	Yes
Willingness to Pay (GHS)	30	30	30	30
Time to treat 1L of water	10	10	10	1
Ideal Size	3	3	10	10
Important Feature	Health Impact	Health Impact	Health Impact	Health Impact
Place to buy	Door to door	Door to door	Door to door	Door to door
Influence factor	Family Member	Health Professional	Health Impact	Family Member
Final comment				

Questionnaire No	61	62	63	64
Language	English	Local	Local	Local
Location	Nyanshegu	Lamashegu	Lamashegu	Lamashegu
Gender	Male	Female	Male	Female
Age	38	37	80	30
Head of Household	Yes	Yes	Yes	No
Occupation	Teacher	Trader	Retired	Trader
Members in the household	22	18	19	16
Highest level of education	University Degree			
Main Water Source	Piped water inside compound	Piped water inside compound	Piped water inside compound	Piped water inside compound
Do you drink from it?	No	Yes	No	Yes
Main Drinking Water Source	Sachet	Sachet	Sachet	Sachet
Amount of Water	100 sachets	5 bags / day	1 Bag / day	
Intermittent Water Supply	Yes	Yes	Yes	Yes
How often do you get your water?	Daily	Multiple days per month	Twice a week	Once per week
Do you store water? What vessel??	Steel Tank	Plastic Drum	Plastic Drum	Metal Drum
Cleaning the storage	Once per week	Once per week	Once per week	Once per week
Water Treatment	No	No	No	No
Do you think pipe water is safe to drink? Why not?	Yes	Yes	Yes	Contaminated with germs
First Impression		Good	Good	good
Best Product	GDM	GDM	GDM	GDM
Reason		Size	Structure	Time, size
Have you seen similar product before?	No	No	No	No
Have you used similar product before?	No	No	No	No
Your Experience				
Will you want a free product?	Yes	Yes	Yes	Yes
Willingness to Pay (GHS)	30	30	30	30
Time to treat 1L of water	10	10	10	15
Ideal Size	10	10	10	5
Important Feature	Time to treat	Health Impact	Health Impact	Health Impact
Place to buy	Market Day	Door to door	Roadside	Door to door
Influence factor	Health Professional	Health Issue	Health Issue	Family Member
Final comment			The performance is highly doubted	Product for children

Questionnaire No	65	66	67	68
Language	Local	Local	Local	Local
Location	Lamashegu	Lamashegu	Lamashegu	Lamashegu
Gender	Female	Male	Female	Female
Age	40	23	39	25
Head of Household	No	No	No	No
Occupation	Trader	Chief	Trader	Security
Members in the household	14	15	22	9
Highest level of education	Primary School	University Degree	Primary School	
Main Water Source	Public Taps	Piped water inside residence	Public Taps	Public Taps
Do you drink from it?	Yes	Yes	Yes	Yes
Main Drinking Water Source	Piped water	Sachet	Piped water	Piped water
Amount of Water				
Intermittent Water Supply	Yes	Yes	Yes	Yes
How often do you get your water?	Once two week	Once three weeks	Multiple days per moth	Once three weeks
Do you store water? What vessel??	Metal Drum	Metal Drim	Metal Drum	Clay Pots
Cleaning the storage	Once two week	Once per month	Once per month	Once three weeks
Water Treatment	No	No	No	No
Do you think pipe water is safe to drink? Why not?	Insects	Yes	Yes	Yes
First Impression				
Best Product	GDM	GDM	Ceramic Pot Filter	GDM
Reason	The mechanism	Simple to use		Life Span and the size
Have you seen similar product before?	No	No	No	No
Have you used similar product before?	No	No	No	No
Your Experience				
Will you want a free product?	Yes	Yes	Yes	Yes
Willingness to Pay (GHS)	30	30	30	50
Time to treat 1L of water	5	30	15	60
Ideal Size	15	5	10	15
Important Feature	Life Span	Health Impact	Health Impact	Life Span
Place to buy	Market Day	Market Day	Door to door	Market Day
Influence factor	Family Members	Health Issues	Health Issues	Family members
Final comment				

Questionnaire No	69	70	71	72
Language	English	English	English	English
Location	Kalpohine Estate	Kalpohine Estate	Kalpohine Estate	Kalpohine Estate
Gender	Male	Male	Male	Male
Age	21	55	42	60
Head of Household	No	Yes	Yes	Yes
Occupation	Security	Businessman	Farmer	Trader
Members in the household	8	12	9	12
Highest level of education	Junior High School;			
Main Water Source	Piped water inside residence	Public Taps	Public Taps	Public Taps
Do you drink from it?	Yes	Yes	Yes	Yes
Main Drinking Water Source	Piped water	Sachet	Piped water	Piped water
Amount of Water				
Intermittent Water Supply	Yes	Yes	Yes	Yes
How often do you get your water?	Twice a week			
Do you store water? What vessel??	Clay Pots	Metal Drum	Clay Pots	Clay Pots
Cleaning the storage	Twice a week	Once per week	Everyday	Once per week
Water Treatment	No	No	No	No
Do you think pipe water is safe to drink? Why not?	Yes	I don't know	Yes	Yes
First Impression				
Best Product	GDM	Ceramic Pot Filter	GDM	GDM
Reason		Seen it before	No Cleaning	Size
Have you seen similar product before?	No	No	No	No
Have you used similar product before?	No	No	No	No
Your Experience				
Will you want a free product?	Yes	Yes	Yes	Yes
Willingness to Pay (GHS)	30	30		30
Time to treat 1L of water	10	60	20	60
Ideal Size	10	10	10	10
Important Feature	Life Span	Health Impact	Health Impact	Health Impact
Place to buy	Market Day	Door to door	Roadside	Door to door
Influence factor	Family members	Health Issues	Health Issues	Health Issues
Final comment				

Questionnaire No	73	74	75	76
Language	English	English	English	English
Location	Kalpohine Estate	Kalpohine Estate	Kalpohine Estate	Kalpohine
Gender	Male	Male	Male	Male
Age	72	56	32	20
Head of Household	Yes	Yes	Yes	No
Occupation	Retired	Farmer	Teacher	Welder
Members in the household	8	17	15	20
Highest level of education		Secondary School	University Degree	Secondary School
Main Water Source	Piped water inside compound	Piped water inside compound	Piped water inside compound	Public Taps
Do you drink from it?	Yes	Yes	No	Yes
Main Drinking Water Source	Piped water	Piped water	Bottle Water	Piped water
Amount of Water				
Intermittent Water Supply	Yes	Yes	Yes	Yes
How often do you get your water?	Daily	Once per month	Multiple days per week	Multiple days per week
Do you store water? What vessel??	Metal Drum	Clay Pot	Clay Pots	Clay Pots
Cleaning the storage	Once per week	Twice a week	Multiple days per week	Multiple days per week
Water Treatment	No	No	No	No
Do you think pipe water is safe to drink? Why not?	Yes	Yes	Yes	Yes
First Impression	Foreign	Good	Good	
Best Product	GDM	GDM	Ceramic Pot Filter	GDM
Reason	Size, no cleaning	Life Span	Cleaning	Size
Have you seen similar product before?	No	No	No	No
Have you used similar product before?	No	No	No	No
Your Experience				
Will you want a free product?	Yes	Yes	Yes	Yes
Willingness to Pay (GHS)	30		30	30
Time to treat 1L of water	10		10	30
Ideal Size	5		10	10
Important Feature	Health Impact	Health Impact	Health Impact	Health Impact
Place to buy	Door to door	Door to door	Door to door	Door to door
Influence factor	Health Issues	Health Issues	Health Issues	Health Issues
Final comment	Good for places that has no piped water.			

Questionnaire No	77	78	79	80
Language	Local	English	English	English
Location	Kalpohine	Dakpema	Dakpema	Dakpema
Gender	Male	Male	Male	Male
Age	55	32	35	26
Head of Household	Yes	No	Yes	No
Occupation	Farmer	Farmer	Contractor	Deputy Principle
Members in the household	10	6	5	8
Highest level of education	Primary School	Diploma	Junior High School	University Degree
Main Water Source	Public Taps	Piped water inside residence	Piped water inside residence	Piped water inside residence
Do you drink from it?	Yes	No	No	Yes
Main Drinking Water Source	Piped water	Sachet	Sachet	Sachet
Amount of Water			1 Bag / week	3 Bags / week
Intermittent Water Supply	Yes	Yes	Yes	Yes
How often do you get your water?	Multiple days per week		Once per week	Multiple days per week
Do you store water? What vessel??	Clay Pots	Poly Tank	Steel Tank	Poly Tank
Cleaning the storage	Multiple days per week	Once per week	Once every 3 weeks	Once every 2 weeks
Water Treatment	No	No	No	No
Do you think pipe water is safe to drink? Why not?	Yes	Yes	Yes	Yes
First Impression	Good			Good
Best Product	-	GDM	Ceramic Pot Filter	Ceramic Pot Filter
Reason		No Cleaning	Weekly Cleaning	
Have you seen similar product before?	No	No	No	I had seen CPF
Have you used similar product before?	No	No	No	No
Your Experience				
Will you want a free product?	Yes	Yes	Yes	Yes
Willingness to Pay (GHS)	30	30	50	50
Time to treat 1L of water	10	30	30	10
Ideal Size	5	10	5	3
Important Feature	Health Impact	Health Impact	Health Impact	Health Impact
Place to buy	Market Day	Shop / Mall	Shop / Mall	Shop / Mall
Influence factor	Health Issues	Health Issues	Health Issues	Family Members
Final comment				

Questionnaire No	81	82	83	84
Language	Local	Local	English	English
Location	Dakpema	Dakpema	Dakpema	Dakpema
Gender	Male	Female	Male	Female
Age	50	34	25	42
Head of Household	Yes	No	Yes	No
Occupation	Farmer	Driver	Accountant	Government Officer
Members in the household	11	7	8	4
Highest level of education			University Degree	University Degree
Main Water Source	Public Taps	Public Taps	Piped water inside residence	Piped water inside residence
Do you drink from it?	Yes	Yes	Yes	Yes
Main Drinking Water Source	Piped water	Piped water	Sachet	Piped water
Amount of Water				
Intermittent Water Supply	Yes	Yes	Yes	Yes
How often do you get your water?	2 times per month	Once per week	Multiple days per week	Multiple days per week
Do you store water? What vessel??	Clay Pots	Poly Tank	Poly Tank	Poly Tank
Cleaning the storage	two times per month		Every three months	Twice in a year
Water Treatment	No	No	No	Yes
Do you think pipe water is safe to drink? Why not?	Yes	I don't know	Yes	Yes
First Impression	Good			
Best Product	GDM	GDM	GDM	Ceramic Pot Filter
Reason	Life Span	Size, no cleaning	No Cleaning	Easy to use
Have you seen similar product before?	No	No	I had seen LifeStraw before	Yes, used CPF
Have you used similar product before?	No	No	No	No
Your Experience				
Will you want a free product?	Yes	Yes	Yes	Yes
Willingness to Pay (GHS)	30	30	30	50
Time to treat 1L of water	10	10	10	15
Ideal Size	10	10	10	10
Important Feature	Health Impact	Health Impact	Health Impact	Health Impact
Place to buy	Door to door	Shop / Mall	Shop / Mall	Door to door
Influence factor	Health Issues	Family Members	Health Professional	Family Members
Final comment	It need technical support			

Appendix G: Water Quality Evaluation Test Results

Household Number	Total Chlorine Residual (mg/L)	Free Chlorine Residual (mg/L)	Coliert Total coliform (Presence/ Absence)	Coliert *E.Coli* (Presence/ Absence)	Petrifilm Total coliform (CFU per 1 mL)	Petrifilm *E.coli* (CFU per 1 mL)
01	0.2	0.1	-	-	0	0
02	0.02	0	+	+	14	10
03	0.16	0.02	+	-	13	0
04	0.14	0.02	-	-	0	0
05	0	0	+	-	0	0
06	0.03	0	+	+	14	1
07	0.15	0.08	-	-	0	0
08	0.01	0	-	-	0	0
09	0.04	0.03	+	-	4	0
10	0.14	0.08	+	+	5	4
11	0.08	0.03	+	+	51	10
12	0.04	0.02	-	-	0	0
13	0.04	0	+	-	6	0
14	0.04	0	+	-	5	0
15	0.03	0.03	+	-	0	0
16	0.01	0	+	+	1	2
17	0	0	+	-	5	0
18	0	0	+	+	8	4
19	0.01	0	+	-	3	0
20	0.01	0	-	-	0	0
21	0.03	0	+	-	6	0
22	0.09	0.07	-	-	0	0
23	0.05	0.12	+	+	1	1
24	0.1	0.07	+	-	0	0
25	0.03	0.07	+	+	10	5
26	0.04	0.05	+	+	10	6
27	0.06	0.13	+	+	1	1
28	0.05	0.13	-	-	0	0
29	0.05	0.07	+	+	53	2
30	0.04	0.07	+	+	9	2
31	0.1	0.11	+	+	30	2
32	0.01	0.09	+	+	21	2
33	0.02	0.06	+	+	12	1
34	0.02	0.02	-	-	0	0
35	0.05	0.01	+	+	24	2
36	0.1	0.03	+	-	30	0
37	0.12	0.09	+	-	3	0

Household Number	Total Chlorine Residual (mg/L)	Free Chlorine Residual (mg/L)	Coliert Total coliform (Presence/ Absence)	Coliert *E.Coli* (Presence/ Absence)	Petrifilm Total coliform (CFU per 1 mL)	Petrifilm *E.coli* (CFU per 1 mL)
38	0.04	0.03	+	-	2	0
39	0.05	0.04	+	+	6	6
40	0.02	0.07	+	+	7	0
41	0.05	0.05	-	-	0	0
42	0.06	0.07	-	-	0	0