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Evaluation of the Impact and Sustainability of Hospital Water Purification Systems in Honduras

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B.A.
Skidmore College
2011

Thesis Committee Chair: Christine Moe, PhD

An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
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Background: Water quality and quantity play important roles in the transmission of diarrheal disease, a leading cause of death in children under five worldwide. In Honduras, 87% of the population has access to water from improved sources, such as piped networks. However, the water supplied by improved sources may not be safe for human consumption, as an improved source does not imply clean water. Decentralized water purification systems have shown potential to provide high quality water at the institutional-level in low-income settings. Various organizations, including the General Electric Foundation (GEF), have implemented decentralized membrane ultrafiltration systems in low-income institutional settings, such as in hospitals and schools. Despite the potential of these systems to increase access to safe water, research regarding the sustainability and overall impact of this technology in low-income settings is lacking.

Objective: The objective of this study was to assess the environments that enable or limit the sustained provision and use of safe water in hospitals in Honduras.

Methods: A metric was developed to systematically assess the sustainability of safe water provision at four hospital sites using four domains of sustainability: accountability, on-site capacity, technical feasibility, and institutional engagement and support. To assess each domain, knowledge, attitudes, and practices surveys, water quality testing, and facility inspections were conducted. Data was also collected at two control hospitals without water purification systems in order to measure the impact of the GEF-donated systems.

Results: The results of the sustainability assessment showed that all intervention hospitals were vulnerable to becoming unable to sustain safe water provision. Each hospital had different strengths and challenges within the four sustainability domains. Intervention hospitals were found to have significantly cleaner water than control hospitals; however, additional benefits of the water purification systems were minimal.

Discussion: Targeted efforts must be made to increase sustainability within specific domains. Best practices from each hospital can be adopted to increase the sustainability and impact of the water purification systems in other hospitals, as well as improve future donations of water purification systems.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

AI: Assist International
BID: *Banco Interamericano de Desarrollo* (Inter-American Development Bank)
CDC: The Centers for Disease Control and Prevention
CFU: Colony-forming unit
CGSW: Center for Global Safe Water, Emory University
GE: General Electric
GEF: General Electric Foundation
IRB: Institutional Review Board
JMP: Joint Monitoring Program for Water Supply and Sanitation, the WHO/UNICEF mechanism tasked with monitoring MDG 7, Target 7c
KAP: knowledge, attitudes, and practices
MDG: Millennium Development Goal
MOH: Ministry of Health
MPN: most probable number
NTU: Nephelometric turbidity unit
POE: point-of-entry
POU: point-of-use
RO: reverse osmosis
SANAA: *Servicio Autonomo Nacional de Acueductos y Alcantarillados* (National Autonomous Service of Aqueducts and Sewers), the national public water service provider in Honduras
SD: standard deviation
SSS: small-scale system
UF: ultrafiltration
UNICEF: United Nations Children’s Fund
USAID: US Agency for International Development
UV: ultra-violet
WASH: water, sanitation, and hygiene
WHO: World Health Organization

1 INTRODUCTION

The General Electric Foundation (GEF), through its Developing Health Globally™ initiative, has worked to improve hospital and health center care within many low-income regions through the donations of various types of biomedical equipment. What GEF discovered, through working with these hospitals, was a lack of more basic resources, such as continuous electricity and clean water. Since this discovery, GEF has donated water purification systems to hospitals and health centers in many low-income settings, such as in Ghana, Kenya, and Honduras. Although these water purification systems were originally designed for private water treatment in high-income settings, many organizations, like GEF, have begun donating these systems to schools and hospitals in low-income settings despite a lack of research regarding the impact and sustainability of these systems in low-income settings.

This research project set out to evaluate the impact and sustainability of GEF-donated hospital water purification systems in Honduras. As this type of technology becomes increasingly available and affordable, its potential for use in low-income settings will increase. Research regarding its impact and sustainability is therefore essential. This research will also allow GEF to maximize the impact of their current and future donations of water treatment technology.

1.1 Problem Statement

Water quality plays an important role in the transmission of diarrheal disease, one of the leading causes of death in children under five years old worldwide. In Honduras, one of the poorest countries in the western hemisphere, it was estimated in 2007 that among children under five there were three million cases of diarrheal disease and 1,050 premature deaths attributed to lack of access to safe water.(Pan American Health Organization, 2009) Honduras is one of the only countries in Latin America or the Caribbean that is predicted not to meet any of its Millennium Development Goals (MDGs), with only 87% of the population having access to improved water sources in 2012, down from 96.8% coverage between 1990 and 1994, potentially as a result of Hurricane Mitch in 1998.(Bussolo & Medvedev, 2006; Pan American Health Organization, 2009; WHO/UNICEF, 2012)

Moreover, while 87% of the population may have access to improved water sources, the water being supplied may not be adequately safe for human consumption, as improved water is generally defined as piped water provided by a centralized distribution system, where the actual quality of the water is not guaranteed.(Lee & Schwab, 2005) In low-income settings, power outages, pipe breakage, and inconsistent water pressure make it difficult to ensure the quality of the water being supplied, and failures in the water treatment process in centralized water systems have become the norm.(Center for Global Safe Water, 2010; Lee & Schwab, 2005) Many point-of-use (POU) and decentralized water systems are now being used in low-income settings to improve quality of water at the household-level, however, the daily volume of water produced by these systems is often not sufficient for drinking and personal hygiene purposes.(Center for Global Safe Water, 2010; Huang, Jacangelo, & Schwab, 2011)

Membrane ultrafiltration (UF) systems were originally designed to provide microbiologically safe drinking water without the need for chemical treatment at a household-level for private water sources in high-income settings.(Huang et al., 2011) However, as this technology improved and became increasingly available, it has shown potential for providing affordable, safe, and reliable access to clean drinking water in resource poor settings at the community or institutional level, by providing both the quality and quantity of water required.(Butler, 2010; Center for Global Safe Water, 2010) Various organizations, such as

GEF, have implemented these systems in disaster relief settings, as well as in low-income institutional settings.(Center for Global Safe Water, 2010)

Despite the potential that membrane UF systems have for improving water quality while providing the quantity of water required for daily living, research regarding the sustainability of this technology in low-income settings is still lacking. In addition to sustainability assessments, there is a lack of evaluation regarding the overall impact of these systems in low-income settings after they have been installed by donor organizations. Therefore, while organizations continue to donate and install membrane UF systems in low-income institutional settings, the appropriateness and overall success of this technology in these settings is unknown.

1.2 Purpose

The overall purpose of this study was to evaluate the sustainability and impact of water purification systems installed in hospitals within Honduras by GEF. The specific objectives were to:

1. Develop a metric and data collection process to systematically assess the sustainability of membrane UF systems within a low-income hospital setting.
2. Apply the data collection instruments and sustainability metric to evaluate the sustainability of water purification systems in Honduran hospitals donated by GEF.
3. Assess the impact of GEF donated systems by comparing knowledge, attitudes, and practices (KAPs) of hospital staff, patients, and visitors and overall water quality among hospitals with water purification systems donated by GEF and hospitals without water purification systems donated by GEF.
4. Develop recommendations on how GEF can better maximize the impact and improve the sustainability of their donations.

1.3 Significance

Due to the design of the MDGs relating to water and sanitation, research within the water, sanitation, and hygiene (WASH) field has often focused on access to improved water at the household-level. With this focus on a household-level, there has been a lack of research and innovation surrounding institutional-level water supply, where treatment systems that can provide a greater quantity of water are still required. As research on institutional-level water treatment becomes increasingly relevant in the post-2015 MDG targets, where indicators are billed to include institutional-level targets, these technologies and their effectiveness will become increasingly relevant. Moreover, sustainability of water provision is becoming increasingly important. In order for the MDG target for water to be maintained and exceeded, long term sustainability of current water service projects is vital.

This research will inform the literature on factors influencing the sustainability and impact of membrane UF systems in low-income settings, particularly in Honduras at a district hospital level. The development of a sustainability metric will aid current and future researchers to systematically evaluate water service sustainability. Most importantly, this research will help GEF improve their current and future donations and projects so that they can continue to maximize their donations within the communities where they work.

1.4 Definitions

- Enabling Environments: Environments that promote factors associated with the sustainability of a project.
- *Botellón*: A large plastic water jug (19 L) that is used with free standing water coolers and is a common type of drinking water in Latin America.

- Hospital filled *botellón*: A *botellón* filled with purified water from the GE water purification system on site at the hospital.
- General Electric (GE) Ambassador: A US-based GE employee who acts as a voluntary liaison between project sites and GEF and is a native speaker of the language spoken at the project site.

2 REVIEW OF THE LITERATURE

A literature review was conducted to understand the central issues and previous research surrounding: 1) access to safe water and 2) assessment of the impact and sustainability of water treatment systems in institutional settings. First, worldwide access to safe water will be discussed, including the burden of disease associated with lack of access to clean water, as well as, the differences between safe and improved water sources. This will be followed by focusing on issues surrounding safe water access in Honduras. Next, the potential benefits and limitations of decentralized water treatment methods to provide safe water in low-income settings will be discussed. This will be followed by a discussion of the benefits and limitation of membrane UF systems, with a specific focus on the GE HomeSpring® System. Then, the importance of sustainability and methods for assessing sustainability will be discussed. Finally, GEF and their Developing Health Globally™ initiative will be described.

2.1 Worldwide Access to Safe Water

Target 7.C of the MDGs is to halve the proportion of the world's population without sustainable access to safe drinking water between 1990 and 2015. This target was met in 2010.(WHO/UNICEF, 2012) Over 2 billion people worldwide gained access to improved water sources between 1990 and 2010.(WHO/UNICEF, 2012) However, the definition of "improved water sources" does not implicitly include the safety of the water source.(WHO/UNICEF, 2012) Therefore, more work remains, as an estimated 9.1% of total disease burden worldwide could still be prevented through universal use of safe water and proper sanitation facilities.(Prüss-Üstün, Bos, Gore, & Bartram, 2008)

2.1.1 Burden of Disease Associated with Unsafe Water

Pathogens transmitted through water are mostly of fecal origin and can be bacterial, viral, or protozoan.(Ashbolt, 2004) These pathogens account for 88% of worldwide diarrheal cases, which results in roughly 1.5 million deaths each year, mostly in children under five years of age.(Prüss-Üstün et al., 2008) Overall, the World Bank estimated in 2002 that 3 million people die prematurely every year from water-related diseases.(The World Bank, 2002) Wide spread educational and promotional campaigns focusing on oral rehydration therapy have reduced the case-fatality rate of diarrheal disease in recent decades; however, the associated morbidity, or prevalence of diarrheal diseases, has not been affected.(T. F. Clasen et al., 2010) Repeated cases of diarrhea throughout childhood are a major cause of malnutrition, and an estimated 50% of underweight and malnutrition is associated with repeated diarrheal cases as a result of unsafe water, lack of proper sanitation, or poor hygiene.(T. F. Clasen et al., 2010; Prüss-Üstün et al., 2008) Water quality interventions have been found to be effective even in the absence of improved sanitation, where the World Health Organization (WHO) estimates that water quality interventions could reduce diarrheal frequency by 31%.(T. Clasen, Schmidt, Rabie, Roberts, & Cairncross, 2007; Prüss-Üstün et al., 2008; Sobsey, 2002)

2.1.2 Safe Water Sources Compared to Improved Water Sources

The MDG target uses the term “safe water” without defining it. The WHO/UNICEF Joint Monitoring Program (JMP) for Water Supply and Sanitation measures worldwide access to safe water through a proxy by measuring access to improved water sources.(Toubkiss, 2006; WHO/UNICEF, 2012) The JMP defines an “improved water source” as “one that, by nature of its construction, adequately protects the source from outside contamination, particularly fecal matter.”(WHO/UNICEF, 2012) This definition includes: piped water into a dwelling or yard, public taps or standpipes, tubewells or boreholes, protected springs, protected dug wells, and rainwater collection systems.(WHO/UNICEF, 2012) The definition, however, focuses on the water source rather than on POU and lacks any reference to the quality of water being provided.(Ali, 2010; Bain et al., 2012) Due to a lack of water quality data, particularly dating back to 1990, the safety of the water being provided was not included in the MDG target for 2015.(Bain et al., 2012)

The proportion of the population with access to safe water as measured by the JMP may therefore be an inflated value, especially in developing countries, as some improved water sources may not provide safe water.(Bain et al., 2012; Onda, LoBuglio, & Bartram, 2012; Sobsey, 2002) In many low-income settings, piped distribution systems are often not properly maintained and repaired.(Lee & Schwab, 2005; Moe & Rheingans, 2006) Therefore, even if the water piped through the system is from an improved water source, common problems such as power outages, pipe breakage, and inconsistent water pressure can compromise the quality of the water being supplied.(Center for Global Safe Water, 2010; Moe & Rheingans, 2006) In addition, failures in the water treatment process in centralized water systems have become the norm in low-income settings, which compromises the quality of the water supplied through certain improved water sources.(Ali, 2010; Lee & Schwab, 2005; Sobsey, 2002)

Looking beyond 2015, however, new goals are being developed for 2040 that use indicators for measuring water quality rather than water source.(Joint Monitoring Program, 2012) Additionally, proposed metrics include indicators for institutional-level water quality and household-level water quality.(Joint Monitoring Program, 2012) Therefore, with these potential new metrics, the percentage of people with access to safe water, according to JMP, may go down in areas where people have access to piped water sources that may not actually be providing safe water.

2.2 Access to Safe Water in Honduras

Like most of Latin America, the majority of Hondurans have access to piped water within their housing compound.(WHO/UNICEF, 2012) According to the 2012 JMP update, 85% of the population of Honduras has access to piped water within their housing compound and 87% have access to improved water sources overall.(WHO/UNICEF, 2012) However, Honduras is one of the only countries in Latin America and the Caribbean that is not predicted to meet any of its MDGs. This is a result of the country's high poverty rate and failure to recover after Hurricane Mitch in 1998.(2010; Bussolo & Medvedev, 2006; Pan American Health Organization, 2009) Despite high coverage rates of improved water sources throughout Honduras, less than half of the population is estimated to drink properly disinfected water and more than 90% of the water distribution systems are estimated to have intermittent water supplies.(Pan American Health Organization, 2007) According to a study by the Swiss Agency for Development and Cooperation conducted in 2004, over 70% of piped water systems sampled in rural Honduras had over 5 CFU / 100 mL of fecal contamination.(2004) WHO estimates there are three million cases of diarrheal disease and 1,050 premature deaths each year attributed to lack of access to safe water in children under five years of age in Honduras.(Pan American Health Organization, 2009)

Bottled water, generally in the form of 19 L *botellones*, is a common type of drinking water in Honduras; however, there is very little literature on bottle water consumption rates in Honduras. Within cities, *botellón* home delivery services are available and are a common mean for obtaining bottled water in Honduras. Bottled water consumption in Latin America is estimated to range between 7% of the population in Costa Rica and 51% of the population in the Dominican Republic.(Molina, 2007; Sandoval, 2010)

2.3 Decentralized Water Treatment Systems in Low-Income Settings

Water treatment can occur at many different stages between the water source and when the water is consumed. Centralized water treatment occurs at the city or community level near the source, and the treated water is then piped through a distribution system to the user.(Peter-Varbanets, Zurbrugg, Swartz, & Pronk, 2009) Decentralized water treatment systems have been defined in a number of different ways, generally encompassing all water treatment that does not occur in a centralized system.(Peter-Varbanets et al., 2009) In this paper the term will be limited to point-of-entry (POE) treatment systems and other small-scale systems (SSS), where water treatment occurs directly prior to the water entering the distribution system of a household, institution, or small community.(Peter-Varbanets et al., 2009; Silverstein, 2006) POU treatment is the other main level of water treatment, which occurs within the household directly prior to use by the consumer and is generally only used to treat drinking water.(Peter-Varbanets et al., 2009) This review will focus on three main types of decentralized water treatment technologies used in low-income settings: ultra-violet (UV) irradiation, membrane reverse osmosis (RO) filtration, and membrane UF.

2.3.1 Potential of Decentralized Water Treatment Systems

Centralized water treatment systems are often viewed as the gold standard in the industrialized world and therefore are often implemented in low-income settings as well.(Ali, 2010) However, as discussed previously, the quality of water being piped through a centralized system is often compromised in low-income settings.(Lee & Schwab, 2005) These systems are often resource intensive and plagued with operational challenges, such as lack of capacity for repairs and frequent power outages.(Ali, 2010; Bieker, Cornel, & Wagner, 2010) Therefore, even in areas with centralized water treatment systems, treatment at or near the POU is necessary to assure safe drinking water quality.(Ali, 2010)

Often, POU treatment systems are used for this purpose; however, the daily volume of water produced by these systems may not be sufficient for drinking and personal hygiene purposes.(Center for Global Safe Water, 2010; Huang et al., 2011) Examples of POU treatment include: boiling, filtration, and chlorination of water after collection from the tap.(Sobsey, 2002) Most POU treatment systems were developed for use at a household-level and cannot feasibly be scaled up to provide the quantity of water required for institutions, such as district level hospitals.(Arnal, Fernandez, Verdu, & Gracia, 2001; Huang et al., 2011; Peter-Varbanets et al., 2009) While POU treatment systems can be quite inexpensive (with treatment methods like solar disinfection being almost free), many cannot remove all pathogens completely, which could be even more hazardous in a hospital setting compared to household settings for which they were originally designed.(Arnal et al., 2001; Huang et al., 2011; Sobsey, 2002)

Decentralized treatment systems have the potential to eliminate the problems associated with both centralized water treatment systems and POU treatment systems. Decentralized treatment systems, when paired with a central distribution system, surface water source, or groundwater source, can provide very high quality of water while also delivering sufficient water quantity.(Center for Global Safe Water, 2010) Of the three decentralized treatment systems mentioned previously, all three can provide at least 4-log removal of bacterial and protozoan pathogens and removal of some viral pathogens as well, without the addition of chlorine or other disinfectants.(Butler, 2010; Hagen, 1998; Huang et al., 2011; Silverstein, 2006; United States

Environmental Protection Agency, 2005) These systems can also be paired with a post-treatment disinfectant that can protect the clean water from recontamination over time.(Arnal et al., 2001) Decentralized treatment systems also have a much greater capacity compared to POU treatment systems with regard to water quantity, some being able to treat over 10,000 L per day.(Peter-Varbanets et al., 2009)

2.3.2 Limitations of Decentralized Water Treatment Systems

Despite the potential that decentralized water treatment systems have for improving water quality while providing the quantity of water required for daily living, there are still limitations for their use in low-income settings, including their expense, complexity, and unknown sustainability.(Center for Global Safe Water, 2010) All three types of decentralized water treatment systems mentioned above also require pre-filtration, particularly if a surface water source is used, which is often the case in low-income settings.(Arnal et al., 2001; Peter-Varbanets et al., 2009)

As decentralized water treatment systems have generally been developed for high-income settings and are mostly produced in high-income settings, many parts are not available locally in low-income settings.(Center for Global Safe Water, 2010; Loo, Fane, Krantz, & Lim, 2012) Most of these systems require a constant supply of electricity which is often not available in low-income settings.(Peter-Varbanets et al., 2009) Even if proper supply chains are put into place, highly trained personnel are required to maintain and repair the system should it break.(Hokanson et al., 2007; Peter-Varbanets et al., 2009)

Moreover, as decentralized water treatment systems are generally highly technical and often produced in high-income settings, these systems tend to have a high investment cost, particularly compared to inexpensive POUs.(Peter-Varbanets et al., 2009; Sobsey, 2002) While costs are declining as these technologies improve, there are currently no products available that meet the cost criteria for developing countries. Institutions and communities in low-income settings who wish to use these technologies generally must generally receive them at a subsidized rate or as a donation.(Peter-Varbanets et al., 2009)

2.4 Membrane Ultrafiltration Systems in Low-Income Settings

Membrane filtration is a pressure or vacuum driven separation process where particulate matter is blocked from passing through pores in fiber membrane strands based off of its size.(GE Water and Process Technologies, 2012; United States Environmental Protection Agency, 2005) Membrane UF systems have membranes with a pore size range of 0.01-0.05 μm.(United States Environmental Protection Agency, 2005) Many membrane UF systems were originally designed for private water sources in high-income settings to provide microbiologically safe drinking water at the household-level without the need for chemical treatment.(Huang et al., 2011) However, as UF technology improved and became increasingly available, it has shown potential to address the need for affordable, safe, and reliable access to clean drinking water in resource poor settings at a community or institutional-level.(Butler, 2010; Center for Global Safe Water, 2010) Various organizations and government bodies, such as GEF have implemented these systems in disaster relief settings, as well as in low-income community settings, such as in hospitals, clinics, and schools.(Arnal et al., 2001; Center for Global Safe Water, 2010)

2.4.1 Potential of Membrane Ultrafiltration Systems

When compared to the other two types of decentralized water treatment systems mentioned above (RO and UV irradiation), membrane UF systems are the easiest to maintain and are best capable of treating surface water sources.(Hokanson et al., 2007; Peter-Varbanets et al.,

2009) RO systems, because of their small pore size, require defined source water quality, and some use membrane UFs as a pre-filter to decrease fouling of the RO membrane.(Peter-Varbanets et al., 2009; Silverstein, 2006) Turbidity and certain dissolved constituents can severely decrease the effectiveness of microbial inactivation using UV irradiation, requiring pre-treatment as well.(Peter-Varbanets et al., 2009) On the other hand, UF systems do have the potential to clean highly turbid waters; however, water with high mineral content can still lead to membrane fouling and may decrease the lifespan of the filters.(Peter-Varbanets et al., 2009)

Additionally, UF systems have the greatest potential to be used without electricity.(Center for Global Safe Water, 2010) As UF systems have larger membrane pores, compared to RO systems, lower incoming pressure is required, which decreases the need for an electricity driven pressure gradient.(Peter-Varbanets et al., 2009) Since UV irradiation requires a high powered light source, it too requires a stable and regular source of power.(Peter-Varbanets et al., 2009) Moreover, as membrane UF systems are compact and modular in nature, they can be more easily transported, and the capacity of the system can be expanded as needed.(Arnal et al., 2001; Butler, 2010)

2.4.2 Limitations of Membrane Ultrafiltration Systems

While some of the greatest potentials of membrane UF systems, compared to the other two decentralized water treatment systems discussed, stem from their larger pore size, some of their greatest limitations are due to the same characteristic. Since RO systems have much smaller pore sizes, they have a much greater efficacy for the removal of viral pathogens.(Silverstein, 2006) RO systems can also be used for desalination and the removal of some organic compounds, while membrane UF systems cannot.(Peter-Varbanets et al., 2009)

Depending on the turbidity level of the water, UV irradiation systems may be able to more effectively inactivate viral pathogens than membrane UF systems.(Silverstein, 2006)

Furthermore, while UF systems can filter more highly turbid water, the filters must be backwashed regularly to decrease potential fouling. Backwashing can be done automatically on some systems as long as there is a constant supply of electricity.(Center for Global Safe Water, 2010; Huang et al., 2011) A system for the disposal of waste water from the backwash must be put in place, as this waste water has much higher concentrations of pathogens than the original source water.(Huang et al., 2011)

2.4.3 General Electric HomeSpring® System

The Homespring® membrane filter was originally designed by Zenon and is currently distributed by GE and primarily marketed as a POE water purifier for households in high-income settings.(Center for Global Safe Water, 2010; Huang et al., 2011) The filter system is comprised of an activated carbon filter in series with an UF membrane filter.(GE Water and Process Technologies, 2012) The membrane filter can remove >99.999% of all bacteria and viruses and operates at 95% efficiency.(GE Water and Process Technologies, 2012) The filter modules are compact in design (45 cm x 45 cm x 188 cm), have a maximum peak flow rate of 42 L/min, and a continuous flow rate of 17 L/min.(GE Water and Process Technologies, 2012) This allows for an approximate maximum daily water production of 24,480 L, which is enough to serve 245 people for ideal drinking and hygiene needs (100 L/person/day) as recommended by the WHO.(Huang et al., 2011) The membrane filter has the potential to last 5 to 10 years when used with surface water, depending on the turbidity and mineral content in the water.(GE Water and Process Technologies, 2012) These systems require electricity for automatic backwashing, though manual backwashing is possible.(GE Water and Process Technologies, 2012)

In 2010, the Center for Global Safe Water (CGSW) conducted a literature review of the sustainability and performance of various decentralized membrane filtration systems in low-income settings, including the HomeSpring® system.(Center for Global Safe Water, 2010) They concluded that while the system operates automatically, requiring minimal care on a day-to-day basis, its high-tech system is regarded as a "black box" by many local communities, which may affect long term sustainability, especially if the system requires repair.(Center for Global Safe Water, 2010) Additionally, parts needed for replacements are produced in the US and may be difficult to obtain in low-income settings.(Center for Global Safe Water, 2010)

2.5 Sustainability

Sustainability is increasingly becoming the focus of water and sanitation provision discussions not only in low-income settings but in high-income settings as well.(Ugwu, Kumaraswamy, Wong, & Ng, 2006) While there is a greater emphasis on sustainability, a consensus has not been reached on its definition with regard to water and sanitation provision, nor is there a uniform method of evaluation.(Estes, 2010) An array of different definitions of sustainability and measurement methods were examined in this study.

2.5.1 Defining Sustainability

Sustainability is a multifaceted, dynamic concept made up of many interrelated components.(Harvey & Reed, 2004) Sustainability has been defined differently, depending on the central focus of the organization defining it. Often, sustainability is focused around two main themes: environmental sustainability and financial sustainability.(Estes, 2010)

Definitions of sustainability with regard to water service generally focus on finance, maintenance, and operations. Hodgkin in 1994 suggested that, "a sustainable water supply and sanitation project maintains, or expands, a flow of benefits at a specified level for a long period after external funding has been withdrawn"(Hodgkin, 1994) In 1999, Carter proposed that sustainability is the "continued delivery and uptake of services" over time and that "water continues to be abstracted at the same rate and quality as when the supply system was designed."(Carter, Tyrrel, & Howsam, 1999) Some definitions are even more precise, such as what Dayal recommended in 2000. She defined a sustained water supply as:

> a service that regularly and reliably provides enough water of an acceptable standard for at least domestic use. Breakdowns are rare and repairs rapid (within 48 hours), and local financing covers at least the regular costs of operation, maintenance, and repairs.(Dayal, Wijk, & Mukherjee, 2000)

While all definitions differ somewhat from one another, there is a focus on providing continuous service over time.

2.5.2 Importance of Sustainability

As the world focuses its efforts on meeting the MDG targets for water access, the importance of sustainability with regard to water service is becoming more apparent. Many projects that were initially successful have been shown to not last over time.(Batterman et al., 2009) Water for People estimated in 2010 that approximately 50,000 rural water points, or roughly 30%, are broken across Africa.(Breslin, 2010; Harvey & Reed, 2007) Another survey of 11 countries in sub-Saharan Africa in 2004 observed that functioning water systems in rural areas ranged from 30-80%.(Montgomery, Bartram, & Elimelech, 2009) These numbers are not much better than those observed two decades earlier in 1992 when the first formal global commitment to sustainability was made with the signing of UN Agenda 21.(Montgomery et al., 2009) Therefore, in order to meet and exceed the MDG targets in the future, emphasis needs to be focused on the sustainability of current and future projects.

However, there is a lack of literature surrounding the sustainability of water service projects in Latin America. It can be assumed that many of the same issues experienced in Africa relating to water service sustainability, such as lack of capacity and funding for maintenance and repairs, are also experienced in Latin America. This study may provide insight into the sustainability of water service projects in Honduras, which could enhance further research of the sustainability of water service projects throughout Latin America.

2.5.3 Issues Impacting Sustainability

In order to foster sustainability in water provision projects, it is essential to examine the issues impacting sustainability of these projects. Many definitions of sustainability include issues surrounding finances. Evaluations often cite heavy reliance on donor support as potential for decreased sustainability.(Batterman et al., 2009; Breslin, 2010; Harvey & Reed, 2007; Hodgkin, 1994) However, the lack of sustainability of water service problems is not just simply a lack of sufficient funding.(Batterman et al., 2009)

One of the major issues impacting sustainability of water provision projects is the lack of education and capacity building to complement the infrastructure.(Batterman et al., 2009; Hodgkin, 1994) This includes not only capacity strengthening for individuals maintaining and repairing the water system but also education about the importance of safe water practices and proper use for the general population using the water system.(Harvey & Reed, 2007) Without proper education, the target population may not value the water system which could lead to decreased sustainability.(Hodgkin, 1994; Moe & Rheingans, 2006) In addition to initial capacity strengthening for individuals maintaining and repairing the water system, a strategy needs to be implemented to train and replace these individuals should they no longer be capable of providing these services.(Harvey & Reed, 2007)

The sustainability of water service projects is also impacted by the design and timeline of projects. Often project time frames are short and emphasis is placed on short-term goals.(Batterman et al., 2009; Giné & Pérez-Foguet, 2008) While there has been a shift towards supporting monitoring and evaluation throughout the project timeline, if project timelines are not extended to provide evaluation over the long term, true sustainability cannot be evaluated.(Hodgkin, 1994) As it is often infeasible to have the donor organization evaluate their project indefinitely, it is essential to involve the local government or other institutional organization to provide the accountability necessary to make a project sustainable.(Harvey & Reed, 2007; Hodgkin, 1994)

In addition to a plan for long term monitoring and evaluation, plans for extended maintenance and repairs, including a plan for funding these long term components are necessary for sustainability.(Hodgkin, 1994) A sustainable source of long term funding and a plan for accessing this funding is necessary for successful long term maintenance and future repairs.(Hodgkin, 1994) On the other side, lack of proper capacity strengthening for individuals caring for the water system, with regard to not only long term maintenance but also repairs, will limit the sustainability of the water system.(Hodgkin, 1994)

Furthermore, short timelines often mean inflexible timelines. Sustainable projects demand flexibility, in that projects need to be capable of coping with changes in supply and demand.(Batterman et al., 2009; Gleick, 1998; Hodgkin, 1994) Demand includes the integration of local knowledge, skills, and traditions into the project. Without this integration, projects are much more likely to be unsustainable.(Batterman et al., 2009; Harvey & Reed, 2007; Hodgkin, 1994) Local knowledge is required for infrastructure selection in order to maximize its ease of maintenance and the durability within a particular community.(Batterman et al., 2009; Haysom, 2006; Hodgkin, 1994)

2.5.4 Assessing Sustainability

As there is a wide array of definitions of sustainability, there are also many ways to assess sustainability. When assessing sustainability, most research teams define key factors that affect sustainability and assess outcomes associated with each factor (Table 1). While there is not a "one-size fits all" solution to measuring sustainability, many key factors are seen repeatedly throughout the literature.(Parry-Jones, Reed, & Skinner, 2001) These factors include social or cultural issues, finance and cost recovery issues, technical or maintenance issues, environmental issues, and institutional organization and capacity.

As mentioned previously, sustainability consists of interrelated components, such that sustainability cannot be achieved solely by focusing on individual factors in isolation.(Harvey & Reed, 2004) Therefore, when assessing sustainability all key factors need to be assessed in conjunction with one another, with an important emphasis placed on the overall picture.(Harvey & Reed, 2004) Furthermore, sustainability and these key factors need to be incorporated throughout the project lifetime and beyond in order to ensure maximum impact of the water infrastructure being implemented.(McConville & Mihelcic, 2007)

Table 1. Key factors for assessing sustainability as defined in the literature.

	Carter, RC et al 1999	WELL 1998	Giné, R et al 2008	Slater, M et al 2002	Parry-Jones, S et al 2001	Breslin, ED 2010	Narayan, D 1993	Harvey, P 2004	Saboori, S et al 2011
Institutional\Organizational		X	X		X		X	X	
Training\Education\Human Capacity Development					X		X		
Communication					X				
Managerial			X	X					
Project Process					X				
Collaboration among Organizations							X		
Monitoring								X	
Accountability									X
Cultural				X					
Community Motivation and Acceptance	X								X†
Social\Community		X	X		X			X	X
Political\Policy Context				X	X			X	
Technical\Technology		X	X		X			X	X
Supply Chains\Spare Parts Supply					X			X	X
Maintenance	X							X	
Reliability of Systems						X*	X		
Financial/Economic		X	X	X	X		X	X	X
Cost Recovery	X				X				
Continuing Support from Donor or Government Body	X								
Environmental\Natural Environment		X	X	X	X			X	
Meets water quality standards						X			
Meet water quantity standards						X			
Number of users per water point meets host country government standards						X			

* Water system is inoperable for no more than 1 day per month
† Student engagement

2.5.5 Sustainability Metrics

While there has been substantial research surrounding the factors that influence sustainability, there has been much more limited research regarding the development of tools to quantitatively or qualitatively evaluate sustainability. The tools that do exist within the literature vary in both the complexity of factors incorporated and the calculation methods used. These complexities affect their overall usability and applicability to other projects.

USAID developed a tool based on a series of broad “yes” or “no” questions, which covered research-defined issues within the key factors used, in order to rate the overall sustainability of a system.(Hodgkin, 1994) An example of these questions is: are management committees functioning?(Hodgkin, 1994) While they included threshold values in some instances, most values were left undefined, because of the subjectivity of the data.(Hodgkin, 1994) Therefore, while the tool identifies problem areas affecting sustainability for a certain project, the tool is mostly qualitative in nature and focuses on more general issues affecting sustainability.(Hodgkin, 1994)

McConville and Mihelcic developed a more quantitative tool for assessing the sustainability of sanitation infrastructure in the form of a matrix scorecard. Each sustainability factor across each project stage was scored on a scale of zero to four.(McConville & Mihelcic, 2007) In this tool, the focus was placed not only on overall sustainability but also on sustainability at each stage of the project (from needs assessment to maintenance post-installation).(McConville & Mihelcic, 2007) Each score was given equal weight and summed across project stages and also across sustainability factors, allowing for a total overall score of 100.(McConville & Mihelcic, 2007) Scores were based on completion of four broad tasks defined by the researchers for each cell of the matrix.(McConville & Mihelcic, 2007) An example of a broad task in the preliminary needs assessment (cell 1.1) is to determine the level of health education in the community.(McConville & Mihelcic, 2007) Interview questions/observations were nested under each of these broad tasks in order to gauge completion.(McConville & Mihelcic, 2007) While this in-depth, detailed tool covers many important aspects of sustainability, it was designed to assess sustainability at each step of a program's timeline rather than to be used as a post-intervention assessment.

Another, more simplistic, scorecard was developed by Harvey and Reed specifically for handpump sustainability.(Harvey & Reed, 2004) This scorecard scores on a scale of one to three for each sub-issue defined within each factor impacting sustainability.(Harvey & Reed, 2004) While this scorecard is short and easy to use, it can only determine general problem areas and is explicitly only for assessing the sustainability of handpumps.(Harvey & Reed, 2004)

Hartman, working with Living Waters of the World, developed a sustainability metric, with a scoring system, to evaluate private water purification plants in Mexico.(Hartman, 2011) This metric scored particular broad questions on a scale of zero to four with a score of 2.5 being set as the cutoff for sustainability.(Hartman, 2011) As broad questions were grouped into subcategories and then into domains, un-weighted averages were calculated across each domain and could be compared among specific plants within the study.(Hartman, 2011) The data used were a mix of qualitative and quantitative data.(Hartman, 2011) Defining a range of zero to four allows for a more specific identification of issues impacting sustainability of these systems. However, this metric was specifically focused on private water purification plants, with an emphasis on the profits and repayments of the system, which are not relevant to this study.

Despite the variety of sustainability metrics available within the literature, none can be applied to institutional-level water treatment systems effectively. There is therefore a need for a metric to assess the sustainability of water provision at an institutional-level.

2.6 General Electric Foundation: The Developing Health Globally™ Initiative

GEF originally started their Developing Health Globally™ initiative in 2004 with the goal of increasing access to healthcare in underserved communities.(GE Citizenship, 2012) This program began in Ghana and has extended to include 14 countries in sub-Saharan Africa, Latin America, and South East Asia.(GE Citizenship, 2012) GEF strives to improve healthcare through their Developing Health Globally™ initiative by providing tools, technology, and training to hospitals and clinics most in need within the regions where they work.(GE Citizenship, 2012) The majority of the donations made to these hospitals and clinics have been biomedical equipment, though as the program has expanded, donations have grown to cover more basic necessities, such as providing electrical generators and water purification systems.(GE Citizenship, 2012) In collaboration with Assist International (AI), GEF has donated and installed HomeSpring® water treatment units in hospitals, clinics, and schools in various regions of Ghana, Kenya, Senegal, Rwanda, and Honduras.(Center for Global Safe Water, 2010)

3 METHODS

3.1 Research Design

This evaluation was undertaken to assess the sustainability of GEF-donated water purification systems in Honduran hospitals and to provide recommendations to GEF in order to improve their future donations of water treatment technology so they would have a more lasting impact. A mixed method approach was used to assess the enabling environments contributing to the sustainability of these systems. A combination of key informant interviews, KAP surveys, facility inspections, and water sampling and testing methods contributed to this assessment. A sustainability metric was developed by the research team based on conditions for sustainability derived from the literature, pilot testing, and criteria for sustainable WASH interventions identified in previous studies by CGSW.(Saboori et al., 2011) The mixed method data informed the development of the metric and the assessment of the sustainability of each hospital's water purification system. Data was also collected at two additional comparison hospitals in order to better assess the impact of the GEF-donated water purification systems. A total of 148 interviews and surveys were conducted, and 168 water samples were collected and analyzed. All data were collected during the summer of 2012. Each hospital site was visited twice over the course of a six-week period.

3.2 Study Sites

Figure 1. Name and location of the six public hospitals involved in this study, where blue represents the locations of the intervention hospitals and red represents the locations of the comparison hospitals.

3.2.1 Intervention Hospitals

All hospitals in Honduras that have GEF-donated water purification systems (a total of four) were involved in this study and will be referred to as intervention hospitals throughout this paper. These hospitals, referred to by the city in which they are located, are: La Esperanza, Gracias, San Lorenzo, and Olanchito. The four hospitals are public hospitals and are located in diverse regions of the country, including: the western highlands (Gracias and La Esperanza), the Pacific coast (San Lorenzo), and the Caribbean lowlands (Olanchito) (Figure 1). All water systems were donated by GEF between 2009 and 2011 (Table 2). All four hospitals have at least one centralized Amiad filter and a centralized chlorine dosing pump. The Amiad filter is a pre-treatment micro-filter that removes suspended solids and organic material present in the water before it passes through the HomeSpring® filters to decrease potential membrane fouling of the

HomeSpring® filters. The chlorine dosing pump adds chlorine solution (in the form of diluted bleach) to the water after the filtration process to protect against recontamination in the piped network. Three of the four hospitals have centralized filter systems before the chlorine dosing pump; whereas the fourth, San Lorenzo, has POU filters located only in four particular departments.

Table 2. Characteristics of GEF-donated water purification systems in Honduras.

Hospital Name	Location	Year Water Purification System Installed	Water Purification System Description
Enrique Aguilar Cerrato Hospital	La Esperanza, Intibuca	2009	Centralized: 1 Amiad filter, 16 filters, chlorine dosing pump
Juan Manuel Galvez Hospital	Gracias, Lempira	2009	Centralized: 2 Amiad filters, 16 filters, chlorine dosing pump
San Lorenzo Hospital	San Lorenzo, Valle	2011	Centralized: 2 Amiad filters, chlorine dosing pump POU: 4 filters (pediatrics, surgery, minor procedures, and kitchen)
Anibal Murillo Escobar Hospital	Olanchito, Yoro	2009	Centralized: 1 Amiad filter, 4 filters, chlorine dosing pump

3.2.2 Comparison Hospitals

The two hospitals used as comparison hospitals in this study were chosen through convenience sampling based off of logistical, budgetary, and "added value" considerations. Prior to data collection, the Ministry of Health (MOH) of Honduras was contacted and asked to recommend other public hospitals within Honduras that were roughly the same size and served similar patient populations as the four intervention hospitals and that would be willing to participate in this study. Two hospitals were recommended and, after being contacted by the study team through email and text messaging, both agreed to participate in the study. Both comparison hospitals (Roberto Suazo Cordova Hospital in La Paz, La Paz and Gabriela Alvarado Hospital in Danlí, El Paradiso) are located within the central highlands (Figure 1). Neither of these two hospitals have their own water purification system. However, the water cisterns at each of the comparison hospitals were chlorinated once per week by the municipality or hospital staff.

3.3 Instrument Development

3.3.1 Key Informant Interviews

Key informant interview tools were developed for the hospital director and the member of the maintenance staff who maintains each hospital's water system. Versions of these tools were adapted for intervention hospitals, as well as for the comparison hospitals. The final interview tool for the hospital directors had 74 questions (49 questions for comparison hospitals), and the interview tool for the maintenance staff members had 61 questions (32 questions for comparison hospitals). The final interview tools used can be found in Appendix 1.

The tools for intervention hospitals were created first and were based on a shorter key informant interview tool used by the CGSW in village health centers in Rwanda with GEF-donated water purification systems. This tool was tailored to Honduran hospitals and translated into Spanish. All subsequent versions of the tool were developed in Spanish. A member of the research team piloted this interview tool with hospital directors during an initial site visit in April 2012. After pilot testing, the tool was expanded with questions that were more directed toward issues surrounding sustainability and impact of the water purification systems specifically in Honduras. The revised tool was broken down into interview guides for the hospital director and a member of the maintenance staff. The final tools were reviewed and edited by a native Spanish speaker.

The interview tool for the director covered the following topics: hospital demographic information, sources of water and availability, water treatment, accountability, training, communication with other institutions, finance mechanisms, and satisfaction and perceived value. The interview tool for the member of the maintenance staff covered the following topics: hospital infrastructure, training, operations and maintenance, repairs and institutional support, and satisfaction. Questions specifically regarding the GEF water purification system were removed from the comparison hospital interviews, though otherwise, the interview questions remained similar. As the water systems in the two comparison hospitals were unknown prior to the first visit, no specific questions regarding these systems could be added.

All interviews with the hospital directors and maintenance staff were conducted during the first round of hospital visits (except for the director interview in Gracias); however, additional questions were developed for both the directors and the maintenance staff following the first round of interviews. During the second round of interviews, the directors were asked additional questions regarding donations and institutional oversight. Maintenance staff were asked additional questions about operations records and on-site capacity. All interviews were conducted in Spanish by the bilingual (Spanish and native English speaking) research team. A bilingual interpreter was present to provide clarification when needed.

3.3.2 Knowledge, Attitudes, and Practices Surveys

Three KAP surveys were developed for hospital clinical staff (doctors and nurses), other hospital staff, and patients and visitors respectively. All iterations of the surveys were developed in Spanish, and the final versions were reviewed and edited by a native Spanish speaker. Topics covered in the other staff surveys included: knowledge about the hospital's water source and treatment, opinion regarding the safety of hospital water, how the respondent used hospital water, and patients' practices and opinions of the hospital water. The final clinical staff survey had a total of 16 questions, and the other staff survey had 14 questions. Additional questions were asked of the laboratory (3 questions) and administrative (3 questions) staff regarding chlorine residual testing and finances, respectively. The patient and visitor survey included questions regarding the respondent's use of hospital water, their drinking water practices at home, and perceptions surrounding water quality in their community. The final patient and visitor survey had a total of 14 questions. The final KAP survey tools used can be found in Appendix 1.

After the first round of hospital visits, additional questions were added to clinical staff and other staff surveys specifically regarding the bottling of water purified on site using the GE water purification system (in Olanchito) and knowledge and use of POU filters (in San Lorenzo). The patient and visitor survey remained the same between hospital visits.

3.3.3 Facility Inspection Guides

Facility inspection guides were developed based on tools used by the CGSW in village health centers in Rwanda with GEF-donated water purification systems. The tools were translated into Spanish. One inspection guide was developed to look at hospital infrastructure, particularly the functionality of hospital sinks and the presence of soap at these sinks. Because the study hospitals were quite large, it was decided that the inspection should focus on only certain key areas within the hospital: the in-patient ward, pediatric ward, and patient and staff bathrooms. The other inspection guide focused on educational messaging within the hospital, specifically messages regarding safe water, hand-washing, and bathroom use. Information regarding locations, frequency, and creativity of the messages was recorded, and photos of the various messages were taken. The final facility inspection guides used can be found in Appendix 1.

3.3.4 Sustainability Metric

The data collected from the key-informant interviews, KAP surveys, facility inspections, and water quality testing fed into a sustainability metric developed by the research team. This metric was developed from information found in the literature, criteria for enabling environments based on the CGSW's prior research, and pilot field-work. The interview guides and KAP surveys were developed in conjunction with the sustainability metric, so that each hospital's capacity to provide safe water could be scored across four domains of sustainability. This scoring allowed for access and use of safe water with the hospitals to be compared and for specific areas of improvement and success at each hospital to be determined. The metric had several layers, as shown in Figure 2, which will each be explained further below. The complete sustainability metric can be found in Appendix 2.

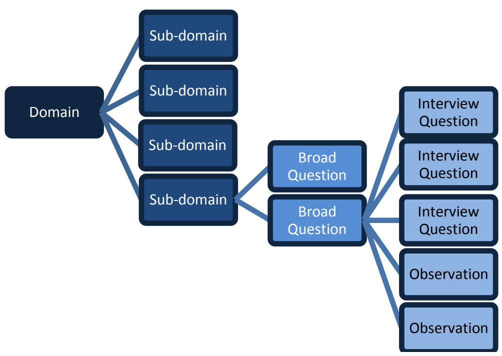

Figure 2. Structure of the sustainability metric.

Domains:

The four domains of sustainability used in this metric included: 1) technical feasibility, 2) on-site capacity, 3) accountability, and 4) institutional engagement and support. These domains were adapted from a CGSW study on sustaining water treatment programs in schools, where the domain of financial capacity was incorporated into accountability, and the domain of on-site capacity was added because of the greater technical skill required to manage the purification systems.(Saboori et al., 2011) These four domains were found to be appropriate for the evaluation of decentralized water purification systems, including GEF systems, after a review of the literature.

Sub-Domains:

Each of the four domains of sustainability was broken down into four sub-domains, to allow for the better grouping of questions within each domain.

Within the domain of technical feasibility, sub-domains included: 1) water sources and availability, 2) availability of local replacement parts, 3) current infrastructure, and 4) water quality information. Questions regarding water sources and availability asked about the water sources available to the hospital and the reliability of these sources. The sub-domain of availability of local replacement parts focused on the hospital's ability to procure replacement parts for the water purification system locally. Questions regarding current infrastructure centered mainly on facility inspections and maintenance of WASH infrastructure. Water quality information was gathered through water quality testing for *E. coli*, total coliforms, chlorine residual, and turbidity compared to WHO and CDC guidelines for safe water.(The Centers for Disease Control and Prevention, 2012; World Health Organization, 2011)

Within the domain of on-site capacity, sub-domains included: 1) communication and organization, 2) training and capacity strengthening, 3) maintenance, and 4) repairs. Questions regarding communication and organization focused on the hospital's organizational structure and task management surrounding WASH, as well as, communication among key parties within the hospital regarding the hospital's water system. Questions regarding training and capacity strengthening focused on the training of hospital staff members within management, laboratory, and maintenance departments about the water system. The sub-domain of maintenance focused on the hospital’s successful completion of all recommended regular maintenance procedures for the water system and the amount of regular downtime the water system experiences. Questions regarding repairs centered on the hospital’s capacity to repair the water system when and if it breaks.

Within the domain of accountability, sub-domains included: 1) monitoring performance, 2) oversight by another entity, 3) sources of funding, and 4) finances. The sub-domain of monitoring performance focused on the hospital’s ability and success at performing monitoring activities. Questions regarding oversight focused on the roles of communication with GEF and oversight by the MOH of Honduras, biosafety committees, and other entities. Questions regarding sources of funding centered on the hospital’s external sources of funding for its water system. Questions regarding finances focused on the hospital’s ability to pay reoccurring costs for the system and the maintenance of its finance records.

Within the domain of institutional engagement and support, sub-domains included: 1) demand and awareness, 2) satisfaction and perceived value, 3) engagement of hospital director and staff, and 4) educational messaging. The sub-domain of demand and awareness covered hospital staff’s, patients’, and visitors’ awareness of the water system and hospital water quality, the utilization of hospital water, and the demand for safe water within the community surrounding the hospital. Questions regarding satisfaction and perceived value focused on hospital staff’s satisfaction with the water system and commitment to the sustainability of the system. The sub-domain of the engagement of the hospital director and staff focused on their commitment to the provision of clean water within the hospital. The sub-domain of educational messaging focused on the observations made by the researchers on educational messaging within the hospital.

Broad Questions:

Each sub-domain was broken down into broad questions. Each broad question targeted a specific aspect of sustainability. These broad questions were derived from scientific literature addressing water system sustainability. An example of a broad question within the domain of on-site capacity was: Is there sufficient trained personnel to manage, maintain, and operate the water system? Each sub-domain had between one and three broad questions. The final metric contained 24 broad questions.

Interview and Survey Questions:

As each broad question could not be asked of study participants directly, interview and survey questions were developed to derive the answers to each broad question. Facility inspections and water quality testing were used to augment interview and survey questions to better answer each broad question. For example, to answer the broad question, "Is there sufficient trained personnel to manage, maintain, and operate the water system?," the researchers asked maintenance staff questions regarding the number of staff trained in the operation of the water purification system, the number of days in a week there was a staff member at the hospital who could manage the water system, and staff members' interest in further training about the water system.

Scoring:

The answers to each broad question were categorized on a scale of zero to four, where a four was defined as being most sustainable. This zero to four scale for scoring was based on work done by Janelle Hartman for Living Waters for the World on the sustainability of water purification plants in Mexico.(Hartman, 2011) The categorizations, however, were developed by the researchers, as most other sustainability tools cited in the literature did not have a specific scoring system to rate the answers to each broad question. Before any data collection occurred, preliminary descriptions were given to the lowest and highest categories (zero and four respectively) for each broad question. The other intermediary score responses were created following the second round of site visits. The iterative approach to developing the sustainability metric allowed the metric to be tailored to the context and circumstances identified during the two rounds of data collection.

A score of two was defined as the cut-off for sustainability, where a score below a two suggested that the system was likely to be unsustainable, and a score above two suggested that the system was likely to be sustainable. The responses to the interview questions and observations relevant for each broad question were used to derive a score for each hospital for each broad question. The broad question scores were then averaged within each domain to calculate the overall domain scores for each hospital. The four domain scores for each hospital were then averaged to give a final composite score for each hospital. Each domain was given equal weight when calculating the final composite score.

3.4 Interview and Survey Data Collection Process

3.4.1 Key Informant Interviews

Key informant interviews were held with each of the hospital directors during the first round of hospital visits, except for in the case of the hospital director at Gracias, as he was on vacation during the first visit. During the second visit to the hospital in Gracias, the researcher interviewed the interim director, as the director was still on vacation; however, the interim director was not able to answer specific questions regarding the water purification system, so the interview was repeated with the director in a telephone interview in early September. All other director interviews occurred in the directors' offices, were performed jointly by both researchers, and lasted about an hour and a half in intervention hospitals and about 45 minutes in comparison hospitals. During two of the director interviews (in La Esperanza and La Paz), members of the maintenance staff were present.

Key informant interviews with at least one member of the maintenance staff involved in managing the water system were held during the first round of hospital visits. These interviews either occurred outdoors near the water system or in the maintenance staff members' offices. During two of the maintenance interviews, more than one maintenance staff member was present and responded to the questions (in Gracias and San Lorenzo). These interviews were preformed jointly by both researchers and lasted about an hour in intervention hospitals and about 30 minutes in comparison hospitals.

All interview responses were hand written by both researchers during the interviews. Both researchers worked together to combine responses, translate the responses into English, and enter them into Excel (2007, Redmond, WA). All closed answer responses were coded and imported into SAS statistical software (version 9.3, Cary, NC) for analysis.

3.4.2 Knowledge, Attitudes, and Practices Surveys

At each hospital, KAP surveys were conducted with four clinical staff. In intervention hospitals, KAP surveys were conducted with seven additional staff members and 15 patients or visitors. In comparison hospitals, KAP surveys were conducted with five additional staff members and seven patients or visitors. While some surveys were conducted by both researchers together, most were conducted by the researchers individually. Surveys were conducted during both rounds of hospital visits (Table 3).

Table 3. Number of KAP surveys conducted during each hospital visit.

		Gracias	La Esperanza	Olanchito	San Lorenzo	Danlí	La Paz
Doctors	**Visit 1**	2	1	0	1	1	1
	Visit 2	1	0	1	1	1	0
Nurses	**Visit 1**	1	1	2	1	1	2
	Visit 2	0	2	1	1	1	1
Staff	**Visit 1**	3	4	5	3	2	3
	Visit 2	5	3	2	4	3	2
Patients	**Visit 1**	4	5	5	1	1	0
	Visit 2	3	3	4	5	2	3
Visitors	**Visit 1**	6	2	3	3	3	2
	Visit 2	2	4	3	6	1	2
Total		**27**	**25**	**26**	**26**	**16**	**16**

Participants for the KAP surveys were determined by convenience sampling, though the researchers tried to survey an equal number of patients and visitors within the in-patient ward and within the waiting areas. The researchers also tried to survey a diverse grouping of staff members, including (but not limited to) staff who worked in the laboratory, administration, the kitchen, and laundry. The researchers had intended to survey two doctors and two nurses at each hospital, however, labor strikes during the time of the study made this difficult in some hospitals. A member of the hospital maintenance staff was generally present during staff and care provider surveys and sometimes during patient and visitor surveys as well. All survey responses were hand written by the researcher, then translated, and entered into Excel. All closed answer questions were coded and imported into SAS for analysis.

3.5 Water Quality Testing Procedures

3.5.1 Sample Site Selection within each Hospital

Water samples were collected on the first day at each hospital site during both visits. Sample collection usually occurred in the morning. All samples were kept on ice in a cooler until they could be processed later the same day. Between 7 and 16 samples were collected at each hospital during each visit (Table 4). These samples were taken from various locations including: pre-treatment (such as from on-site cisterns), directly following treatment (spigots off of filter banks), hospital network (sinks and taps within and around hospital), purchased *botellones*, and hospital-filled *botellones*.

Table 4. Number of samples collected at each hospital on each visit, sorted by source type.

		Gracias	La Esperanza	Olanchito	San Lorenzo	Danlí	La Paz
Pre-Treatment	Visit 1	0	1	3	2	1	--
	Visit 2	0	1	0	0	1	--
Directly Following Treatment	Visit 1	1	1	1	0	--	--
	Visit 2	0	0	1	1	--	--
Hospital Network	Visit 1	10	11	6	11	8	9
	Visit 2	5	6	6	9	7	11
Purchased *Botellones*	Visit 1	2	2	2	1	2	1
	Visit 2	1	0	2	1	1	0
Hospital Filled *Botellones*	Visit 1	0	--	2	--	--	--
	Visit 2	3	--	2	--	--	--
Other*	Visit 1	0	1	1	0	0	0
	Visit 2	1	0	1	1	0	0
Total	**Visit 1**	**13**	**16**	**15**	**14**	**11**	**10**
	Visit 2	**10**	**7**	**12**	**12**	**9**	**11**

*Other included: bucket filter (Gracias), separate private well on-site (La Esperanza), ozone filter (Olanchito), clothing sterilizer (San Lorenzo)

While the researchers tried to collect samples from representative areas within each hospital and varying distances from the water purification plant, the sampling method used was not systematic. In each hospital, samples were generally taken from: the hospital cistern(s); a sink in the pediatric ward, labor and delivery, neonatal, and emergency departments; the kitchen; and the laboratory.

3.5.2 Sample Site Selection within the Community

Community water samples were collected on the first day of the first visit to each hospital site, though some additional community samples were collected on the first day of the second visit. Samples were generally collected in the afternoon. They were kept on ice in a cooler with the hospital samples until they could be processed later that day. Between three and six samples were collected in total from each community. Samples were taken from restaurants, gas station outdoor taps, hotels, purchased bottled water, and community members' houses. While the researchers tried to only collect household samples from taps, in many locations this was impossible as municipal water sources were often turned off. In these instances, water was collected from community members' stored water sources that were intended for cooking or drinking.

The method for selecting these community sources was convenience sampling, though the researchers tried to stay within neighborhoods close to the hospital. In some communities, a member of the maintenance staff traveled with the researchers to recommend sites, in other communities, the researchers relied on their own judgment to choose sampling sites. In the four cities that had intervention hospitals, the researchers visited either the municipal water treatment plant (La Esperanza and Olanchito) or the municipal water source and cistern (Gracias and San Lorenzo), and additional water samples were collected at each of these sites.

3.5.3 Sample Collection

For each sample, two WhirlPak® bags (one with sodium thiosulfate to halt chlorine disinfection) were filled with 100 mL of water each. For 10% of the samples, a second WhirlPak® bag with sodium thiosulfate was filled as a duplicate. Samples were directly filled from the faucet, except in the case of samples collected from cisterns or other water containers, which were filled by scooping water using the WhirlPak® bag from near the top of the container. In many cities, sachets of water (250 mL) were a common source of drinking water, so the researchers also collected samples from these sources. When a sample was collected from purchased sachets, the outside of the bag and a pocket knife were wiped with hand sanitizer and then the knife was used to open the bag. Samples taken from cisterns were generally collected by hospital maintenance staff or municipal workers, rather than by the researchers, as the water was often difficult to reach. Occasionally, other hospital samples were collected by hospital staff in areas of the hospital where the researchers were not allowed to enter (such as in the labor and delivery department). The researchers instructed these staff members how to properly fill the WhirlPak® bags, emphasizing the importance of not contaminating the bag.

Samples were labeled according to a simple coding system: the first letter represented the hospital site (G=Gracias, E=La Esperanza, O=Olanchito, S=San Lorenzo, D=Danlí, P=La Paz), the second letter was either an H (hospital) or C (community), followed by the sample number and an A or B for duplicates, if applicable. Information about each sample, including its location, time of collection, and flow rate (seconds required to fill a 100 mL bag) were recorded on paper and later entered into an Excel file.

3.5.4 Sample Processing

All samples were processed by the researchers on the same day as sample collection. The time between sample collection and sample processing ranged from 2-8 hours (Table 5). Temporary laboratories were set up in each city within the researchers' hotel room on a cleaned table or on the tops of the closed ActionPackers®. Sample processing consisted of 3 tests: biological testing for total coliforms and *E. coli*, chemical testing for free and total chlorine residual levels, and turbidity level testing. All results were recorded on paper laboratory results tables according to sample ID number and then later entered into Excel. Excel files from each of the hospitals were then merged and imported into SAS for analysis.

Table 5. The average number of hours between time of sample collection and time of sample processing for each hospital site during each visit.

	Visit 1 (hrs)	Visit 2 (hrs)
Gracias	2.5	2
La Esperanza	4	2.5
Olanchito*	6.5	8
San Lorenzo	3	3.5
Danlí	2.5	3
La Paz	4.5	2

*The time difference was greater in Olanchito as the researchers were staying overnight in a city 2 hours away rather than within the city like at the other sites.

Biological Testing:

Microbial analysis was performed using the IDEXX QuantiTray 2000 method (Westbrook, ME). Water samples collected in the WhirlPak® bags with sodium thiosulfate were tested for total coliforms and *E. coli* concentration. IDEXX Colilert-18 reagent was used as the selective media, except for the samples that were collected in Olanchito where Colilert-24 reagent was used. Samples were processed through the QuantiTray Sealer (model 2x) according to standard methods. All trays were incubated at 35 ^{o}C for 18 hours when Colilert-18 was used and for 24 hours when Colilert-24 was used. During the second visit to Olanchito, the power went off just after all samples had been processed and put into the incubator, and remained off for 2 hours. The internal temperature within the incubator read 33 ^{o}C when the power returned. Samples were read as scheduled the following morning.

Bottled water that had not previously been opened (either Dasani® or Aguazul®) was used as a negative control. Prior to use, it was determined that the purchased bottled water did not have detectable chlorine residual levels. There was one negative control per day of sample processing. If any of the negative controls had shown measurable levels of contamination, then all samples for that day would have been discounted and removed from analysis. A positive control was not used due to cold-chain limitations and limited laboratory capacity. However, there were no days in which all samples were negative.

Results for total coliforms were recorded as the number of large and small cells turning from clear to yellow after a 18 (or 24) hour incubation period, and these numbers were used to calculate the most probable number (MPN) of colony forming units in each sample, using the MPN chart provided by IDEXX. Results for *E. coli* were recorded as the number of large and small cells that fluoresced under UV light after a 18 (or 24) hour incubation period, and these numbers were used to calculate the MPN of colony forming units for each sample, again, using the MPN chart made available by IDEXX. The lower and upper detection limits were <1 and >2419.6 MPN / 100 mL, respectively.

Chlorine Residual Testing:

Samples from the WhirlPak® bags without sodium thiosulfate were tested for both total and free chlorine residual levels using a LaMotte Single Test Colorimeter Model 1200 (Loveland, CO) and recorded in mg/L. Vials were washed with both purchased bottled water and sample water before each sample was run. The colorimeter was zeroed between each measurement. If the reading was out of range (concentration over 4 mg/L), the sample was diluted with a 1:10 dilution using purchased bottled water.

Turbidity Testing:

Samples from the WhirlPak® bags without sodium thiosulfate were also tested for turbidity levels using a Hach 2100Q Potable Turbidimeter (Loveland, CO). At the beginning of each laboratory session, the calibration of the turbidimeter was tested using the 10 NTU STABLCAL® Stabilized Formazin Standards provided with the instrument. The sample was shaken well before being measured out into the vials in order to make sure that none of the sediment had settled. The vials were washed with both purchased bottled water and sample water before each new sample was read. Each vial was also wiped with silicone oil and shaken before each measurement.

3.6 Data Analysis

3.6.1 Comparisons between Hospitals

All data analyses for close answered questions and water quality data were performed using SAS. All graphs and tables based off of these analyses were created using Excel. Statistical analyses used an alpha value of 0.05.

Demographic Data:

Descriptive statistics (means, ranges, frequencies) were used to compare basic demographic data across the hospitals to determine whether or not intervention hospitals were statistically different demographically than the comparison hospitals. Pooled t-tests were used to compare the average distance traveled to the hospital by survey participants as well as the average time participants had spent in the hospital. Chi-squared tests were used to compare the percentage of participants who have taps in their homes and the percentage that drink tap water at home. Hospital demographic data, such as catchment populations and numbers of patients seen daily, hospital beds, doctors, and nurses, were compared statistically to ensure that the hospitals with GEF water purification systems and the comparison hospitals were comparable.

Knowledge, Attitudes, and Practices Surveys:

Descriptive statistics were used to compare the hospital staff's, patients', and visitors' KAPs within the four intervention hospitals and also between intervention hospitals and the comparison hospitals. Information regarding participants' knowledge included staff's awareness of the water purification system and whether they were knowledgeable about how the hospital water was treated. Data regarding participants' attitudes included the percentage of participants that believed hospital water to be safe and beliefs about community water quality. Data regarding participants' practices included the percentage of participants who drink hospital water and the percentage of patients and visitors that treat their water at home. Pooled t-tests or chi-squared tests were performed to determine if there was a statistical difference between the four intervention hospitals with regard to KAPs and also between those four hospitals and the two comparison hospitals.

Water Quality Data:

Water samples were categorized based on WHO and CDC drinking water guidelines, which define safe drinking water to have less than 1 CFU / 100 mL of *E. coli* or total coliforms and between 0.2 and 2.0 ppm of total and free chlorine residual.(The Centers for Disease Control and Prevention, 2012; World Health Organization, 2011) The percentages of water samples meeting at least one of these guidelines were broken down by source category (pre-treatment, hospital network, etc.) and compared across the intervention hospitals and between the intervention hospitals and the comparison hospitals using chi-squared tests. The percentages of hospital network samples meeting each of the two guidelines were incorporated into the sustainability metric. The log reduction in indicator bacteria concentration between pre-treatment water and hospital network water was also calculated for each hospital and compared across hospitals using a pooled t-test.

3.6.2 Sustainability Metric

All calculations relating to the sustainability scores were completed in Excel, and all subsequent graphs depicting sustainability scores were also produced in Excel.

At the end of the first round of site visits, preliminary scores were calculated for each of the broad questions for each of the hospitals based on the two score responses (0 and 4) that had been defined for each broad question. These responses were revised in an iterative process based on the data collected, where, as score responses were refined, it was necessary to go back and look at the scores previously given to hospitals and change their scores if necessary in order to improve the scoring consistency across the range of encountered conditions. After the second round of site visits, the remaining score responses (1-3) were filled in for each broad question. The preliminary scores for each hospital were reviewed and updated if necessary. Again, the refinement of the final score responses was an iterative process, where after each change was made to a score response, all previous scores given to the hospitals for that broad question had be reviewed and changed if necessary.

The un-weighted mean was calculated for all broad questions within a domain for each hospital. The overall score for each hospital was the un-weighted mean of the four domain scores.

3.7 Ethical Considerations and Confidentiality

The proposed study was submitted to the Emory Institutional Review Board (IRB) in April 2012 and in May 2012 was classified as exempt from further approval as it was deemed to be a minimal risk to study participants (IRB00057332). Despite being exempt by IRB, the researchers complied with all IRB guidelines throughout the study. All study participants were given the option to withdraw from the study at any time without consequence.

4 RESULTS

4.1 Demographic Data

All study hospitals were public, district-level hospitals. The four intervention hospitals were roughly equal in size, serving a mean catchment population of 240,000 people and treating between 130 and 225 patients per day (Table 6). The comparison hospitals had similar hospital-level demographic data, except for the number of patients served per day, where the comparison hospitals were found to serve slightly higher numbers of patients daily compared to the intervention hospitals (p-value=0.005).

Table 6. Sizes and capacities of the six study hospitals.

	Intervention Hospitals				**Comparison Hospitals**		**p-value**
	La Esperanza	Gracias	San Lorenzo	Olanchito	La Paz	Danlí	
Catchment Population	230,000	350,000	260,000	120,000	200,000	300,000	0.60
Patients/day	130	200	225	150	400	350	0.005
Beds	95	107	100	89	59	200	0.51
Doctors	25	42	20	36	23	unknown	0.53
Nurses	90	150	118	99	93	unknown	0.52

The patient and visitor population utilizing hospitals with and without GEF-donated water purification systems were similar (Table 7). The average patient or visitor interviewed spent 1.5 (±1.6) hours in transit to the hospital and had been in the hospital for 2.5 (±3.1) days. However, these times had a wide range, with transit times ranging from 5 minutes to 8 hours and time spent in the hospital ranging from 5 minutes to 12 days. Of all the patients and visitors interviewed, 87.7% had at least one water tap in their home, 56.2% drank tap water at home, 38.4% treated their tap water at home, and 30.1% believed water contamination to be a problem in their community.

Table 7. Patient and visitor populations at intervention hospitals and the comparison hospitals.

	Intervention Hospitals (N*=59)	Comparison Hospitals (N*=14)	p-value
Time to Hospital (hours) (mean, SD)	1.50 (1.5)	1.48 (2.1)	0.97
Time in Hospital (days) (mean, SD)	2.63 (3.3)	1.96 (2.3)	0.47
Patients who have a tap in their home (N, %)	52 (88.1)	12 (85.7)	0.80
Patients who drink tap water at home (N, %)	32 (54.2)	9 (64.3)	0.50
Patients who treat tap water at home (N, %)	20 (33.9)	8 (57.1)	0.11
Patients who believe water contamination is a problem in their community (N, %)	19 (32.2)	3 (21.4)	0.11

*where N equals the number of surveys conducted.

Over half of all patients and visitors surveyed across all hospitals stated that they drink tap water at least some of the time at home (Figure 3). The other major source of drinking water cited was bottled water (43.8% of all participants). Patients and visitors who traveled less than 30 minutes to the hospital were 4.6 times more likely to drink bottled water at home than those patients and visitors who traveled more than 30 minutes to the hospital (p-value=0.0002). A small percentage of the participants reported using well water (8.2%).

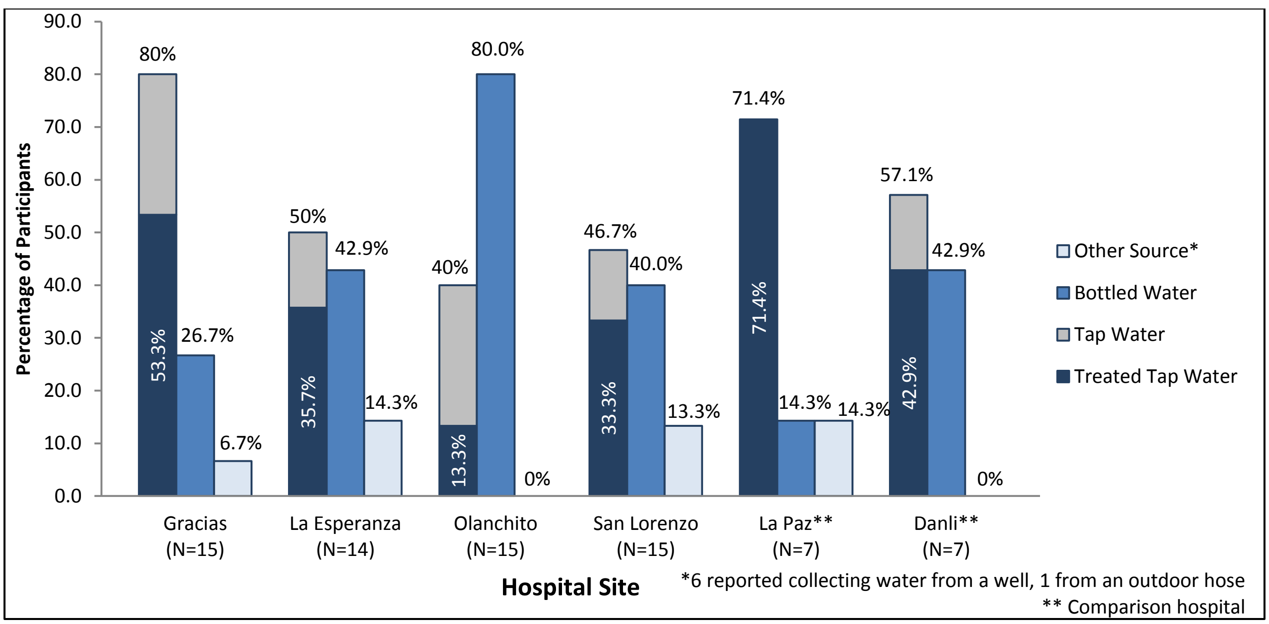

Figure 3. Sources of drinking water in the home of hospital patients and visitors interviewed. Percentages may add to more than 100% as some participants reported drinking from more than 1 source.

Of those patients and visitors who treated their water at home (61.6% of all patients and visitors interviewed), most reported either boiling or chlorinating their water (53.3% and 42.2% respectively) (Figure 4). Chlorination was more common in San Lorenzo and La Paz, and boiling was more common in Gracias, La Esperanza, Olanchito, and Danlí. Chlorination was most commonly used for large-scale disinfection of water stored in household-level water storage tanks. The most common filtration method cited was sand filtration, though only 6.7% of those interviewed reported using filtration methods. Other methods of treatment included solar disinfection (SODIS) and safe storage methods.

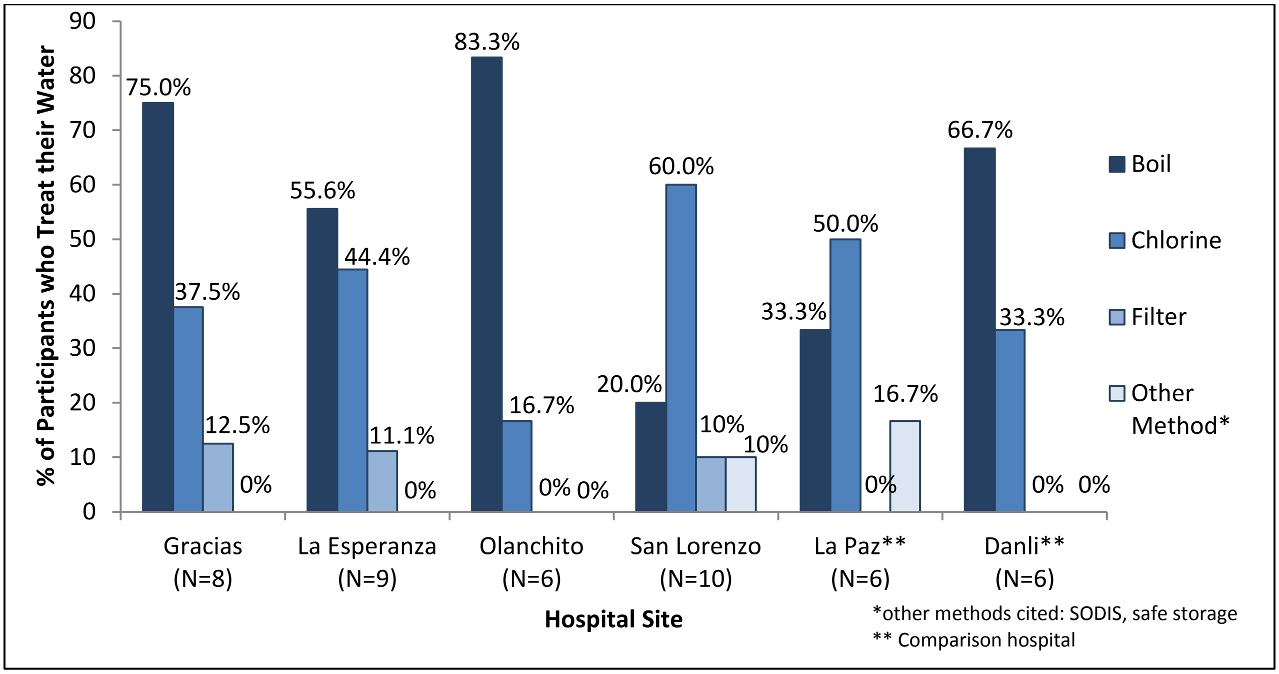

Figure 4. Water treatment methods used in the homes of hospital patients and visitors interviewed. Percentages may add to more than 100% as some participants reported using more than one treatment method.

4.2 Water Quality Data

4.2.1 Hospital Water Network Samples

All water samples taken within the treatment plant (directly post-filter) at any of the intervention hospitals (7 samples) that were found to have less than 1 MPN / 100 mL for both total coliforms and *E. coli*. However, recontamination was seen within the hospital water network, such that only 80-90% of all samples collected at POU taps within the hospital water network in Gracias, La Esperanza, and San Lorenzo had less than 1 MPN / 100 mL of total coliforms (Figure 5). Between 95 and 100% of all samples collected at POU taps within the hospital water network in these three hospitals had less than 1 MPN / 100 mL of *E. coli*. Water quality within the hospital water network in Olanchito was compromised because treated water from the GE water purification system was being mixed with untreated municipal water before entering the hospital network. Therefore, only 16.7% of samples collected at POU taps in the hospital network in Olanchito had less than 1 MPN / 100 mL of total coliforms and 42% of samples with less than 1 MPN / 100 mL of *E. coli*.

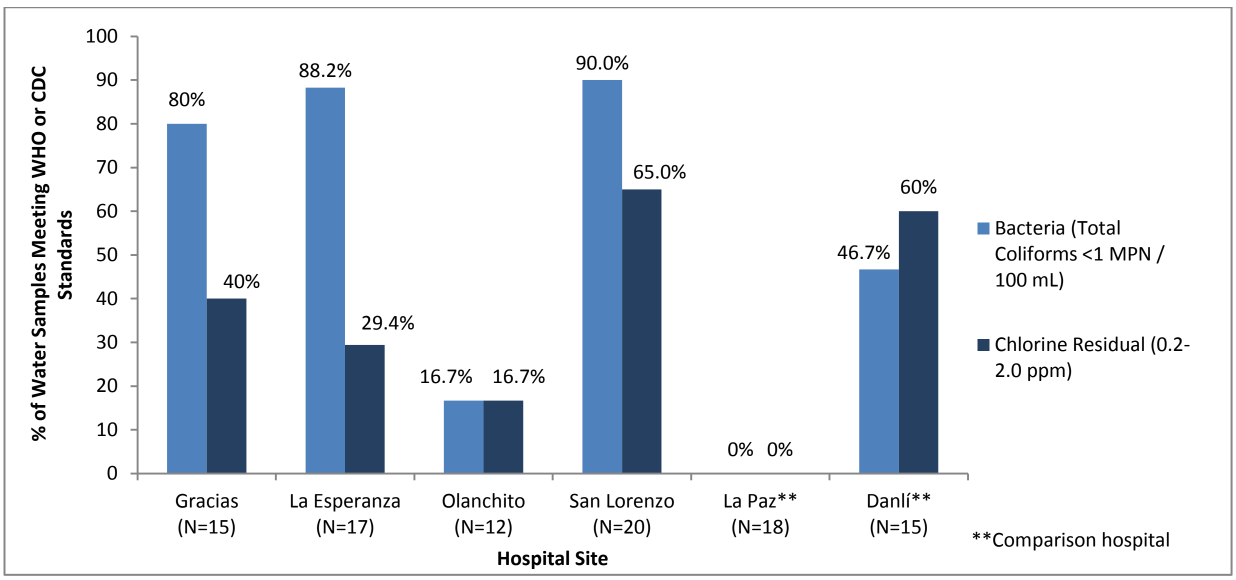

Figure 5. The percentage of water samples taken from POU taps within each hospital that met WHO guidelines for bacterial contamination or CDC guidelines for chlorine residual levels for safe drinking water.

Intervention hospitals had difficulty controlling chlorine residual levels within the hospital piped water networks. Between 16.7% and 65.0% of samples taken from POU taps within the hospital networks of intervention hospitals met the CDC guidelines for free chlorine residual levels between 0.2 and 2.0 ppm (Figure 5). These low numbers may be due to the installation of new chlorine dosing pumps in three of the hospitals (La Esperanza, Olanchito, and San Lorenzo) less than one week prior to the researchers' first site visit.

Both of the comparison hospitals chlorinated the water in their cisterns once per week, though neither measured chlorine residual levels post-treatment. In La Paz, chlorine was added to the cistern by the maintenance manager of the hospital, and in Danlí, chlorine was added by the municipality. In La Paz, none of the samples taken from POU taps during either visit met WHO guidelines for safe drinking water (Figure 5). Roughly half of the samples taken in Danlí were observed to have no detectable bacterial contamination. Positive samples were found to be clustered in certain locations in the hospital. The first set of samples taken in Danlí was collected the day after chlorine was added to the cistern, and therefore the water quality of those samples may not be representative of typical water quality at the hospital.

4.2.2 Bottled Water Samples

All hospitals had purchased water in *botellones* that were available for at least part of the staff, though none were explicitly available to patients. Purchased *botellón* water varied in quality depending on the brand of the water and the maintenance and cleaning of the kiosk that dispensed water into the *botellones* (Table 8). One water sample was taken from previously unopened *botellones* in Gracias, Olanchito, and La Paz. Both the unopened *botellones* in Olanchito and La Paz did not have any observed bacterial contamination. The sample taken from an unopened *botellón* in Gracias, however, had 58.3 MPN / 100 mL of total coliforms, suggesting that the bottling company may have been providing low quality water.

Table 8. Microbiological quality of samples collected from purchased *botellones* available in each hospital.

Location	N	Total Coliforms (MPN / 100 mL)	
		Mean	**SD**
Gracias	3	63.3	5.1
La Esperanza	2	<1.0	-
Olanchito	4	18.1	35.4
San Lorenzo	2	80.3	107.8
La Paz	1	<1.0	-
Danlí	3	270.9	289.5

Gracias and Olanchito had *botellones* available that were filled with water from the GE water purification system on site. Olanchito has been bottling its own water since the installment of the GE purification system 2 years previously. Gracias started bottling its own water in July 2012 after the researchers' first site visit, when data from the first collection showed that the water from the bottling company had low levels of contamination. All samples taken from hospital-filled *botellones* from both sites (a total of 7 samples) showed some level of total coliform contamination, with some of the samples having detectable levels of *E. coli* as well. The samples taken in Gracias had a mean of 120.9 (±117.7) MPN / 100 mL of total coliforms and 10.7 (±16.6) MPN / 100 mL of *E. coli*. The samples taken in Olanchito had a mean of 89.2 (±104.9) MPN / 100 mL of total coliforms and 5.2 (±9.8) MPN / 100 mL of *E. coli*. Contamination of these *botellones* was most likely due to improper cleaning of the *botellones* between refills. In fact, the researchers recommended improved cleaning techniques to the staff in Olanchito during the first site visit, and the mean observed total coliform levels in hospital-filled *botellones* decreased from 175.9 MPN / 100 mL during the first site visit to 2.6 MPN / 100 mL during the second visit.

4.2.3 Community Water Samples

The water quality of community samples varied greatly both by city and also by sample (Table 9). In the communities where intervention hospitals were located, the researchers visited either the source of the community's water supply (Gracias and San Lorenzo) or the municipal water treatment plant (La Esperanza and Olanchito). La Esperanza had a functioning water treatment plant that provided water that met WHO guidelines for microbiological quality, as well as CDC guidelines for chlorine residual levels. However, water samples collected within the community were found to have low levels of contamination, suggesting that recontamination was occurring within the municipal piped network. The water treatment plant in Olanchito was non-functional, and therefore the water within the community was found to be highly contaminated. High contamination levels were also seen in Gracias and San Lorenzo where raw source water, from surface and well sources, respectively, was piped directly to the community without treatment.

Table 9. Measured bacterial contamination and free chlorine residual levels of samples taken from the communities where each of the hospitals was located.

Location	**N**	**Total Coliforms (MPN / 100 mL)**		***E. coli* (MPN / 100 mL)**		**Free Chlorine Residual (ppm)**	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Gracias	3	184.9	73.2	2.4	0.64	0.12	0.07
La Esperanza	7	1.7	1.8	0.14	0.38	0.47	0.36
Olanchito	6	1,878.8	964.6	84.3	153.8	0.09	0.03
San Lorenzo	5	978.1	1316.0	196.1	438.5	0.03	0.02
La Paz	2	<1.0	-	<1.0	-	0.05	0.01
Danlí	3	33.7	45.9	4.1	5.9	0.15	0.12

4.3 Impact of GEF-Donated Water Purification System

None of the staff interviewed in the comparison hospitals believed that the hospital tap water was safe to drink compared to 24.4% of staff in intervention hospitals (p-value=0.02) (Figure 6). However, there was no difference between the percentage of staff who reported drinking tap water at the hospital at the intervention hospitals and the comparison hospitals (p-value=0.24). This similarity between intervention hospitals and comparison hospitals may be negligible because there was a lot of variability in the percentages of staff who reported drinking tap water at the intervention hospitals. In San Lorenzo, none of the staff reported drinking the hospital tap water, nor did any of them believe that the hospital tap water was safe to drink. Many cited the mineral content and poor taste as the rationale for these beliefs and practices. These reasons were also cited by staff workers in La Paz.

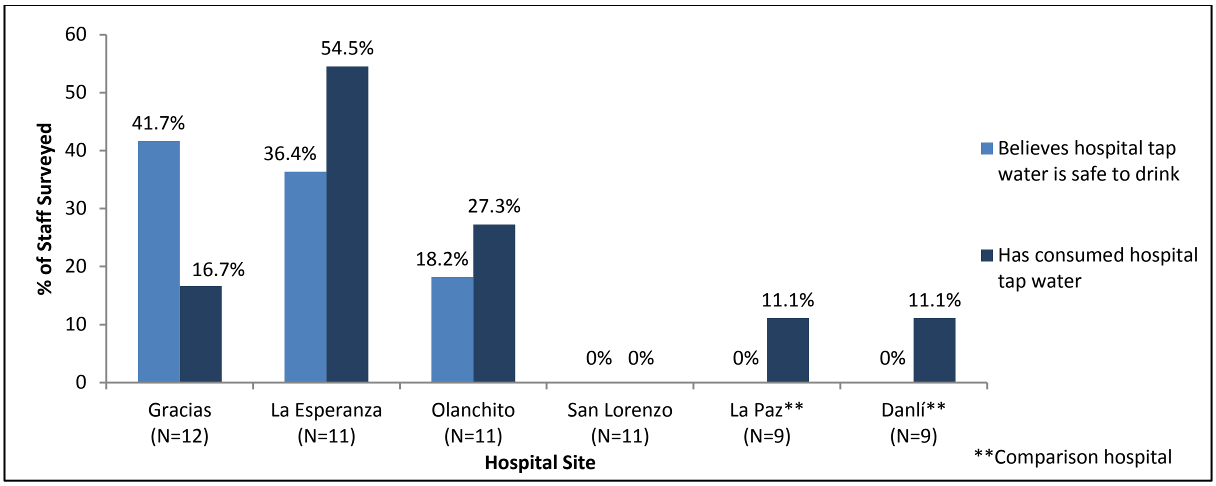

Figure 6. A comparison of the percentage of staff who believes that hospital tap water is safe to drink and the percentage of staff who reported drinking hospital tap water.

Furthermore, there was no difference between the percentages of patients and visitors interviewed who reported drinking hospital tap water at the intervention hospitals and the comparison hospitals (p-value=0.66) (Figure 7). When participants were asked why they had not consumed hospital tap water, the most common responses were: that the water was unsafe (26.2%), that they do not drink tap water outside of their house (23.1%), and that they do not know the quality of the tap water within the hospital (12.3%). Two participants from intervention hospitals (3.8%) said that someone had directly told them that the hospital tap water was unsafe to drink. Also, there was a notable difference between the percentage of staff who reported that patients drink hospital tap water and the percentage of patients and visitors who reported drinking hospital tap water.

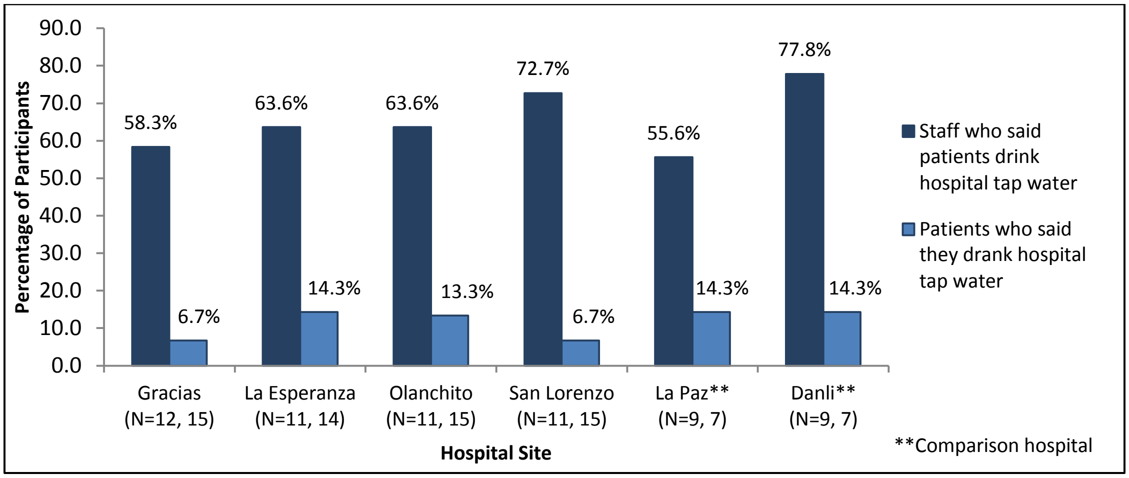

Figure 7. Percentage of staff who said that patients drink tap water in the hospital and the percentage of patients and visitors who reported drinking tap water in the hospital.

Staff were also asked if they believed hospital tap water to be better, worse, or the same as the water that they use at home (Figure 8). In Olanchito, 36% of the staff reported that they believed hospital tap water to be better than the water that they used at home, despite the fact that the water in the hospital was so poor. However, the staff in Olanchito were very aware that there was a purification system at the hospital and were also knowledgeable about the poor water quality in the community, which suggests that they believed the hospital water quality to be better than it actually was. The converse was true in San Lorenzo, where only 9% of the staff believed that hospital tap water to be better than the water that they used at home. Despite the high quality of the hospital tap water with regard to bacterial contamination and chlorine residual levels, the high mineral content of the hospital water was most likely the cause of this belief.

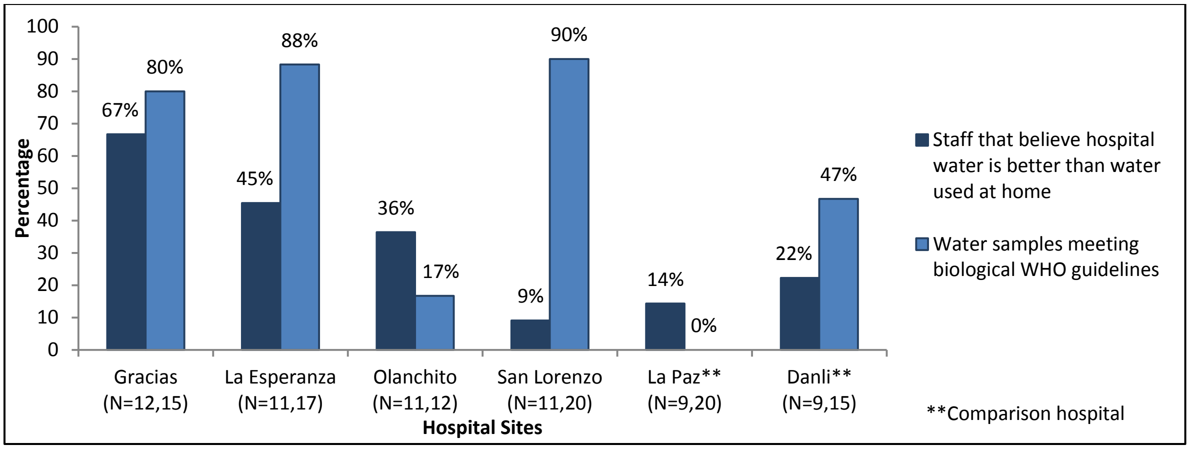

Figure 8. Percentage of staff who believe hospital tap water is better than the water they use at home and the percentage of water samples taken within the hospital that met WHO guidelines for total coliform levels.

Staff in intervention hospitals were more likely to believe that the water in their hospital was treated (61.9%) compared to staff in the comparison hospitals (20%) (p-value=0.005). However, there was very little awareness of the GE purification system among the staff. Only 9.8% of the staff in the intervention hospitals mentioned the GE system when asked how the water in their hospital was treated. Overall, 29% of staff in intervention hospitals believed that hospital water was treated on-site (either by chlorine, filter, or both), 7.3% said hospital water was treated by the municipality, and 31.7% did not know how the hospital water was treated.

The upkeep of hospital WASH infrastructure was similar between intervention hospitals and comparison hospitals. This data may have been skewed by the fact that the hospital in Danlí is a relatively new hospital (less than 7 years old). Of the observed taps, 90.8% of taps in intervention hospitals and 84.2% of taps in comparison hospitals were functional (p-value=0.35).

There was greater soap availability in the comparison hospitals (soap was present at 39.5% of observed sinks) than in intervention hospitals (soap was present at 21.1% of observed sinks) (p-value=0.04). Danlí had the greatest soap availability (57% of observed sinks), though the vast majority of sinks with soap in Danlí were only available to staff. In all hospitals, the availability of soap was very limited for patients and visitors. Many sinks had empty soap dispensers. As the director of the San Lorenzo Foundation (a foundation that funds repairs in the San Lorenzo Hospital) stated “the Foundation had purchased [soap] for patient sinks but it was all gone in 5 minutes,” and therefore they were not going to buy it again.

4.4 Sustainability Metric Scores

Overall, all four intervention hospitals had sustainability scores near the cut-off for sustainability (a score of 2) (Table 10). Two of the hospitals (San Lorenzo and Olanchito) had scores just below the cut-off (1.9 and 1.8, respectively) and the other two hospitals (La Esperanza and Gracias) had scores just above the cut-off (2.3 and 2.5, respectively). Each hospital had different strengths and challenges, creating high variability in scores within certain domains. Figure 9 shows the variability of each domain between hospitals in the form of radar plots. Figure 10 shows the variability within each domain for each hospital in the form of boxplots.

Table 10. Domain and sub-domain scores for each hospital, as well as each hospital's overall score. Scores below 2 (or below the cut-off for sustainability) are highlighted in red.

Domain	San Lorenzo	La Esperanza	Gracias	Olanchito	Average
Accountability	**1.8**	**1.8**	**1.8**	**1.6**	**1.8**
• Monitoring Performance	2	3	1	0	1.5
• Oversight by another entity	2	2	3	3	2.5
• Sources of Funding	2	1	1	1	1.3
• Finances	1	1	1	1	1.0
Technical Feasibility	**2.4**	**2.4**	**1.8**	**1.4**	**2.0**
• Water Source and Availability	1	4	1	2	2.0
• Local Access to Replacement Parts	1	1	1	1	1.0
• Current Infrastructure	4	3	2	4	3.3
• Water Quality Testing	3	2	2.5	0	1.9
On-Site Capacity	**2.2**	**3.2**	**3.2**	**1.3**	**2.5**
• Organization and Communication	3	3.5	4	1	2.9
• Training and Capacity Strengthening	2	3	3	1	2.3
• Maintenance	1	3	2.5	1	1.9
• Repairs	3	3	3	3	3.0
Institutional Engagement and Support	**1.3**	**2.0**	**2.9**	**2.8**	**2.3**
• Demand and Awareness	0.3	1.3	2.7	3	1.8
• Satisfaction and Perceived Value	2	2.3	2.7	2.3	2.3
• Engagement of Hospital Director and Staff	2	2	3	3	2.5
• Educational Messaging	2	3	4	3	3.0
Overall Score	**1.9**	**2.3**	**2.5**	**1.8**	**2.1**

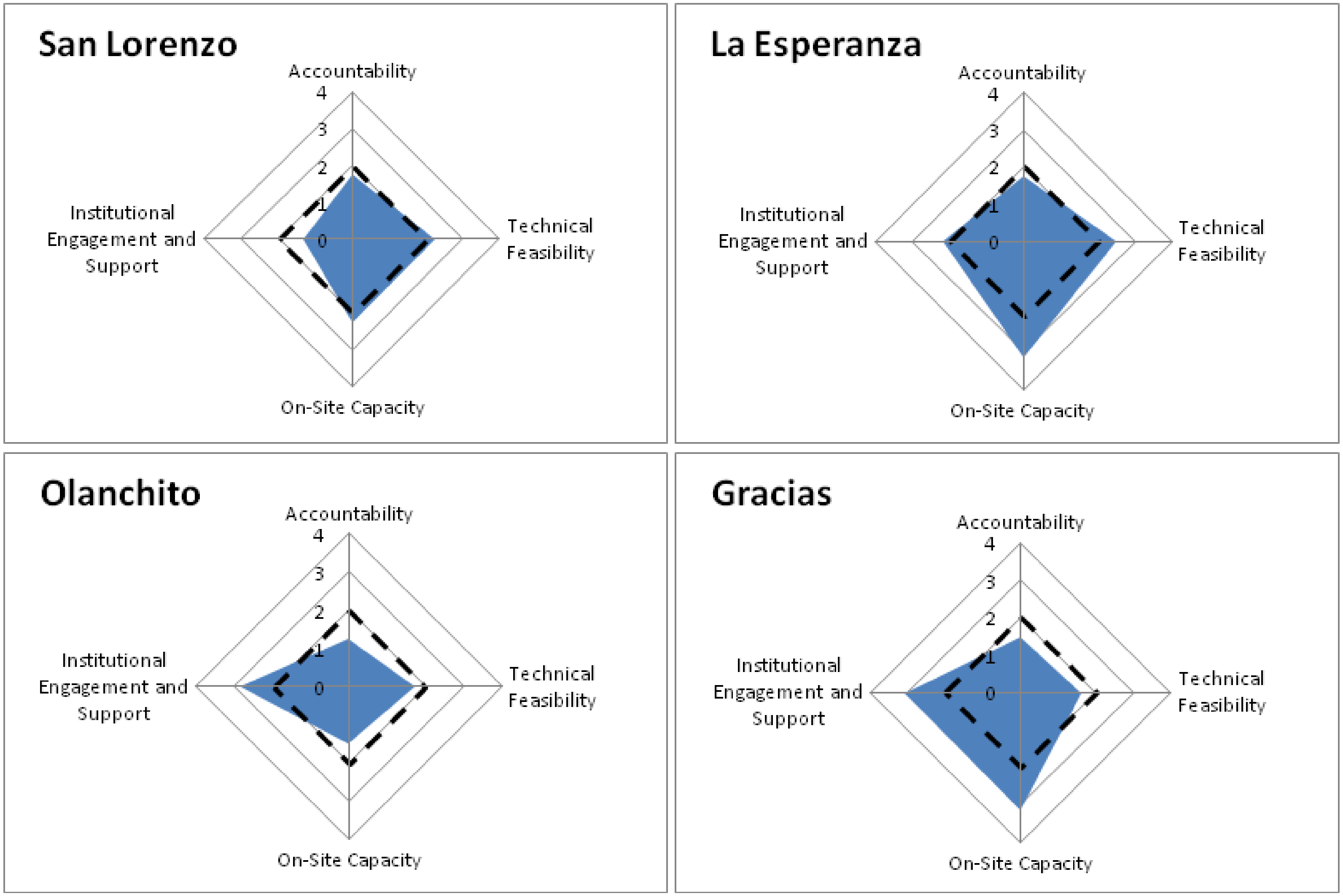

Figure 9. Average domain scores for each hospital. A score of 2 was defined as the cut-off for sustainability, where a score below 2 suggested that the system will likely be unsustainable.

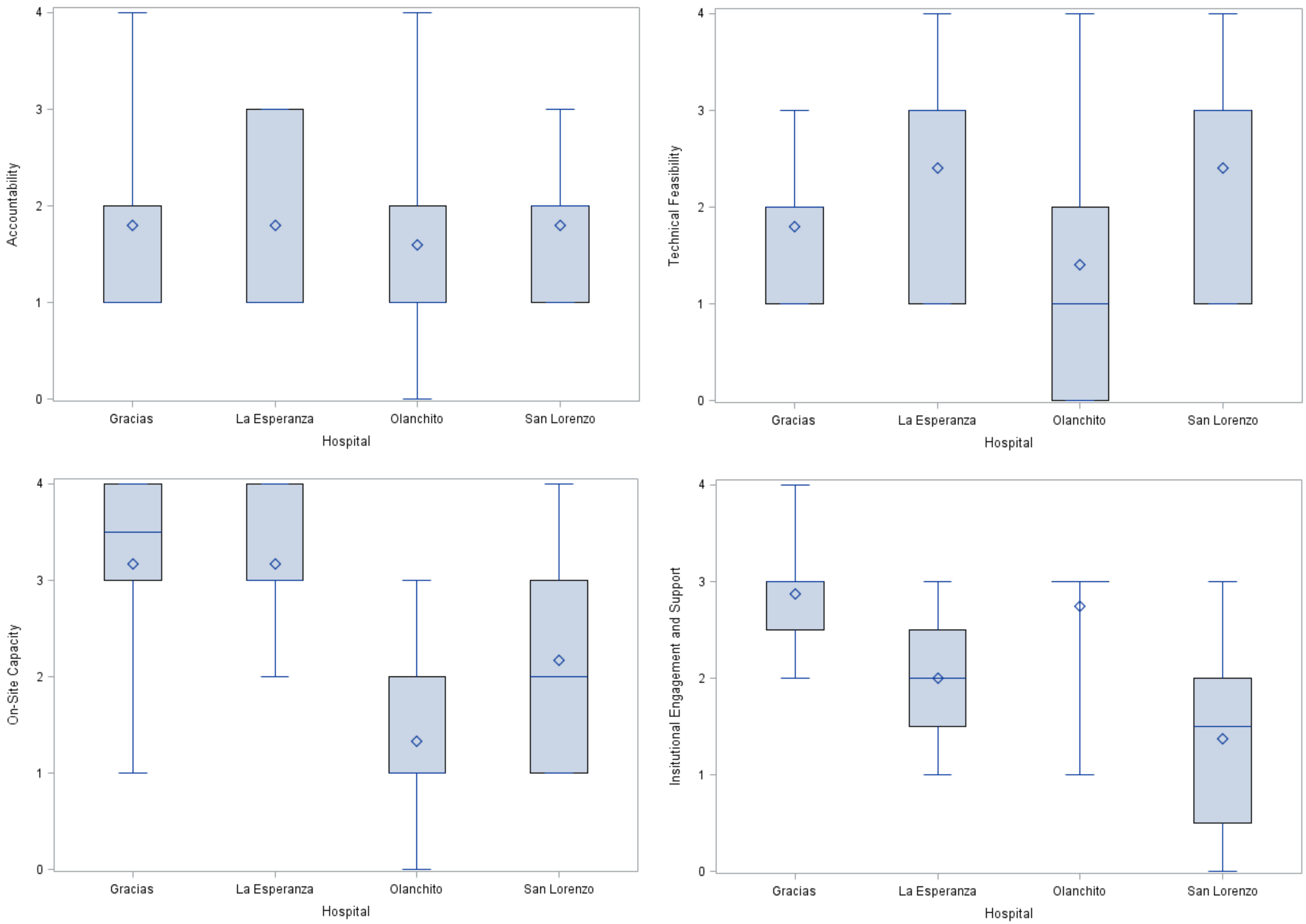

Figure 10. Distribution of scores for each hospital by sustainability domain.

4.4.1 Accountability

All hospitals scored below the cut-off of 2 in the domain of accountability. While there was a large amount of variation within certain sub-domains, others, relating to funding and finances, were similar between the hospitals.

There was great variation in the amount of monitoring performed within each hospital with regard to its water system. The laboratory staff in San Lorenzo and La Esperanza had very well maintained records of chlorine residual testing results. The laboratory staff in Gracias kept chlorine residual records on scraps of paper, and staff in Olanchito showed no signs of recording chlorine residual levels at all. The maintenance manager in La Esperanza also kept records of repairs performed on the water system, which none of the other maintenance teams in other hospitals had.

With regard to oversight, the MOH does not request any data on water quality from any of the hospitals. Nevertheless, the director of the hospital in Olanchito has talked to the MOH about water quality. In San Lorenzo, La Esperanza, and Gracias, the Inter-American Development Bank (*Banco Interamericano de Desarrollo,* BID) is monitoring water quality; however, most of the hospitals have not seen the results of this testing. The director in Gracias has received the results from BID, as well as twice monthly results from the local Environmental Health Department. Gracias and Olanchito have biosafety committees that discuss water quality within the hospital.

All hospital directors reported having regular communication with their GE ambassadors; however, they did not necessarily discuss the water system. Only in Gracias did the maintenance staff report that they communicate directly with their GE ambassador. The director in Gracias said that the ambassador is a “great problem solver” for them and connects them to technicians and other resources they need. Both the director in Gracias and in Olanchito said that they felt as though the ambassador is truly committed to improving the water system in their hospitals.

All hospitals reported having limited budgets and worrying about costs associated with the water system. Small tubing, valves, and chlorine can be purchased by the hospitals; however, more extensive repairs are cost prohibitive, and GE helps to cover these costs. The only exception was the hospital in San Lorenzo, which has the San Lorenzo Foundation that provides an additional source of funding. The San Lorenzo Foundation focuses on general hospital improvements, including water infrastructure.

All hospitals received a score of 1 with regard to finances. None of the hospitals maintained records of the expenditures specific to the water purification system. Moreover, none of the hospitals had a budget for purchasing chlorine for the water purification system. This may be partially due to the fact that the hospitals in San Lorenzo and Olanchito only started adding chlorine to their system during the week prior to the researchers' first site visit. The hospital in Gracias reported that there was a time when it did not purchase chlorine because of costs, though they said that it has become a higher priority since then.

4.4.2 Technical Feasibility

Technical feasibility scores varied greatly between hospitals. This was mainly due to the differences in source water (both quality and quantity) in each of the municipalities, as well as the aging infrastructure in the hospitals.

The source water supply for the hospitals in all of the cities was intermittent; however, the frequencies of these outages varied greatly, ranging from once a week for a few hours (La Esperanza) to the water only being on for a few hours a day (San Lorenzo). Despite these regular outages, the hospitals generally had sufficient storage capacity on site. Only San

Lorenzo has had to bring in water by tanker truck because the hospital water supply runs out occasionally. Source water quality also varied greatly between cities. In La Esperanza, municipal water was treated and arrived at the hospital with low chlorine residual levels. On the other end of the spectrum, the hospital in Gracias received raw river water, which after heavy rain has a yellow color and a great amount of debris in it.

All hospitals received a score of 1 with regard to local access to replacement parts. While all hospitals can purchase small parts, like tubing, valves, and glue, larger replacement parts are either not sold locally or are not within the hospital's budget. This is particularly a concern for the maintenance staff in San Lorenzo who cannot purchase replacement parts for the chlorine dosing pump, which has broken twice already since the water system was installed less than two years ago.

The hospitals in Gracias and Olanchito both have major problems with pressure and flow within the hospital water network. During times of high water demand, the water purification system is often by-passed. By-passing allows water to flow directly from the cistern to the hospital without losing pressure so that water can reach all departments within the hospital. The hospital in Olanchito currently by-passes the water system every day for most of the day. These issues may be the result of aging infrastructure within the hospital's pipe network.

4.4.3 On-Site Capacity

There was great variability in the scores for on-site capacity, though this domain had some of the highest scores, with an overall average score of 2.5.

The only hospital that really struggled with organizational structure was Olanchito. This may be because the chlorine dosing pump was installed just prior to the researchers' first visit, and a formal organizational structure had not been put in place. Because of the informal structure, certain key tasks were not always accounted for. Key tasks may also have been missed because there was a lack of communication among the staff. At the researchers' second visit, it was reported that chlorine had not been added to the system for two weeks because the maintenance staff member had failed to ask the administrator to purchase more. There were significant communication breakdowns regarding the addition, measurement, and provision of chlorine to the water system. The hospital in Gracias was the only hospital where staff had regularly scheduled meetings. In all other hospitals, communication between staff was informal and unscheduled. In the hospital in San Lorenzo, the maintenance manager was often busy and did not always have time to communicate key issues.

The hospitals in Gracias and La Esperanza had very strong maintenance and laboratory teams. There was always someone on staff in the maintenance department to take care of the water system. In the other two hospitals, maintenance staff trained in the upkeep of the water system were only on-site five days a week, though they were always accessible by phone. Laboratory and maintenance teams in Olanchito require additional capacity strengthening in order to plan and execute regular chlorine residual testing and supply appropriate chlorine levels.

The maintenance teams in the hospitals in Gracias and La Esperanza completed all recommended daily, weekly, and monthly tasks. The maintenance team in Olanchito completed all recommended daily, weekly, and monthly tasks not related to chlorine. Recommended tasks in San Lorenzo were completed irregularly. The maintenance staff member in charge of the water system knew what needed to be completed, but these tasks were not always carried out (as evidenced by the lack of backwashing of the filters, dirty equipment, and the rooms where the filters were stored were locked). However, there were also more daily tasks that needed to be completed in San Lorenzo, compared to the other hospitals, because the filters need to be backwashed manually.

Maintenance teams in all hospitals showed good capacity for completing repairs. Nevertheless, all maintenance teams said that they would benefit from additional capacity strengthening, particularly for system repairs. They were also all wary that they would not have the funding to make repairs should they be necessary.

4.4.4 Institutional Engagement and Support

While there was some variation in the levels of institutional engagement and support, most hospitals scored fairly well within this domain. The only sub-domain where the average score was below 2 was the sub-domain of demand and awareness, though this was mainly due to poor scores given to San Lorenzo and La Esperanza.

In all hospitals, awareness of the water system and the quality of hospital tap water was sub-optimal. In San Lorenzo, only 27% of staff interviewed said that the hospital water was treated in some way, though none knew how it was treated. Of the staff members in San Lorenzo who were asked (N=6), all knew that there were filters within the hospital; however, most guessed incorrect locations for these filters. Awareness among staff was also low in La Esperanza. While 67% of the staff knew the water was treated in some way, most (83%) were unfamiliar with the GE purification system. In the hospital in Gracias, staff were very aware of the water system; however, this was only after the meeting held by the researchers during the first site visit. There was a lot of interest in the meetings held by the researchers during each site visit to discuss the results of the water quality testing. In the hospital in Olanchito, there was high staff awareness about the GE purification system; however, there was very little specific knowledge. The staff were unsure of the quality of the hospital tap water and unsure whether the GE purification system was hooked up to the hospital water network.

With regard to water use, there was very little tap water consumption in any of the hospitals. In this study population, generally there is very little tap water consumption outside of the home, unless the person is too poor to purchase bottled water. Bottled water that was purified with the GE system and bottled on site was consumed by some staff and patients in Gracias and Olanchito. The hospitals in San Lorenzo and La Esperanza still purchased bottled water for drinking for staff. Patients either purchased their own water or consumed tap water. It is unlikely that the hospital in San Lorenzo would bottle their water on site in the future because of the poor taste, which the water purification system does not improve. The maintenance manager in La Esperanza, however, had begun consuming water purified with the GE system and recommended that other staff do the same.

The feasibility of the hospitals providing safe water to their surrounding communities was low. Bottling companies in each community deliver *botellones* to people's houses directly, and community members are not used to traveling to get water. Additionally, the director of the hospital in San Lorenzo said that selling water to the community would be illegal as they are a public hospital. Both the directors of the hospitals in Gracias and Olanchito were interested in selling water to the community; however, they were worried about the quantity of water that the system can provide, because they had problems supplying all departments of their hospitals with purified water currently.

The satisfaction of the directors regarding the water system varied greatly between the hospitals. Both the directors in San Lorenzo and La Esperanza were unsure whether the systems were worth the costs, upkeep, and reduced water availability in the hospital. The director of the hospital in San Lorenzo was worried about the future costs associated with the system, as he wished to become independent of GE in the future. He would also prefer a system similar to the other hospitals (centralized), whereas the director of the hospital in Olanchito would prefer a system similar to the one in San Lorenzo (POU filters). The directors in Olanchito and Gracias expressed concern about the quantity (and the resultant low pressure) of the water provided from the GE purification system.

Despite their varying levels of satisfaction, all the directors were committed to the sustainability of the water system. All of the hospital directors believed that the systems should provide clean water to 100% of the hospital, 100% of the time. The director in San Lorenzo hoped that in five years the water system will be completely owned by the hospital. While none believed that the water systems were working at their desired level yet, they were hopeful regarding their future collaboration with GE to get the systems running optimally.

Overall, the satisfaction of the maintenance staff was higher than that of the directors. Many were in agreement with the maintenance manager in La Esperanza who said that “[the system] is a really important resource for the hospital.” Most maintenance staff said that the system was easy to run and maintain. The maintenance manager in Gracias said “It does everything by itself. What could be easier?” However, they all worried about issues with water pressure within the hospital.

The commitment of staff varied greatly between hospitals. Staff in the hospitals in Olanchito and Gracias were very opinionated and interested in the water quality in the hospital. There were many staff members in each of these hospitals that were committed to providing safe water to the hospital. While staff in the hospital in San Lorenzo were interested in providing safe water, they did not believe that tap water would ever be safe enough to drink. Furthermore, they did not see the provision of safe water as a part of their role in the hospital. There was only cursory support among staff in the hospital in La Esperanza. This may be due to the fact that water in La Esperanza was of generally good quality even before the GE purification system.

All hospitals had some form of educational messaging relating to hand-washing. None of the hospitals had messaging specifically about safe water. The messages in San Lorenzo were the least engaging and were focused on hand-washing. Messages in La Esperanza and Olanchito were varied and posted over most of the sinks; however they mainly focused on hand-washing and hygiene behavior. Gracias had the most compelling messages, many of which were handmade. The messages in Gracias included ones about creating oral rehydration salts (ORS), water conservation, hygiene, diarrhea, and hand-washing.

5 DISCUSSION

This evaluation of the sustainability and impact of GEF-donated water purification systems in Honduran hospitals suggests that the provision and use of safe water in these hospitals is vulnerable to becoming unsustainable. This finding is based on the sustainability score each hospital received, showing that they are near the cutoff for sustainability (score of ≥ 2). Additionally, the benefits of these systems have not been maximized due to minimal engagement with hospital staff and patients. Increased staff and patient awareness, as well as targeted efforts focused on specific sustainability domains can improve the sustainability and impact of safe water provision within these hospitals. As each hospital has its own specific strengths and challenges, best practices from each hospital can be adopted to increase the impact and sustainability of the water purification systems in the other hospitals, as well as improve future donations of this nature.

This evaluation also provides a new method for evaluating the sustainability of institutional-level decentralized water treatment systems, through the use of a systematic sustainability metric. The use of mixed data collection methods, including interviews, facility inspections, and water quality analyses, provided a wealth of information that can be used to answer important questions about the sustainability and impact of the water purification systems and compare the impact and sustainability of water purification systems across different hospitals. While limitations and questions of external validity remain, the metric has effectively pointed out areas of success, improvement, and future research.

5.1 Impact of GEF-Donated Water Purification System

Data collected from the two comparison hospitals were used to evaluate the impact of the GE water purification systems on the hospitals where they were donated. While the water purification systems were found to improve water quality within the intervention hospitals, the overall benefit of the systems has not yet been maximized. Low hospital staff, patient, and visitor awareness of the water purification system has decreased the potential benefits of the donated water systems. Increases in awareness, as well as improved staff water practices, can help to maximize the benefits of these donations.

5.1.1 Impact on Water Quality and Hospital WASH Infrastructure

Water samples taken within the hospital networks at POU taps were found to be significantly cleaner in intervention hospitals compared to in the comparison hospitals. Of the samples taken within the hospital networks at POU taps, 73% of samples (87% if the hospital in Olanchito was not included) had less than 1 MPN / 100 mL of total coliforms within intervention hospitals compared to only 21% of samples collected within the comparison hospitals (p-value<0.0001). Additionally, 88% of samples taken at POU taps (98% if the hospital in Olanchito was not included) had less than 1 MPN / 100 mL of *E. coli* within intervention hospitals compared to only 64% of samples collected at POU taps within the comparison hospitals (p-value=0.006). These results suggest that the GE purification systems are indeed cleaning the tap water within the hospitals more effectively than weekly chlorination of cisterns, which is the treatment method used within the comparison hospitals.

Moreover, all samples taken directly after the treatment plant (housing the water purification system and chlorine dosing pump) had less than 1 MPN / 100 mL of total coliforms and *E. coli*. This suggests that recontamination in the pipes is occurring and that chlorine levels must be better regulated in order to provide safe water throughout the hospital on a continual basis. Only 41% of samples collected from POU taps in intervention hospitals met the CDC guidelines of having free chlorine residual levels between 0.2 and 2.0 ppm. Therefore, chlorine levels must be stabilized and monitored better in the future.

There was no significant difference in the upkeep of WASH infrastructure (as measured by the number of broken/leaking water taps) in intervention hospitals compared to the comparison hospitals (p-value=0.35). This suggests that improved water treatment technology has not led the hospitals to spend money or effort to improve other WASH infrastructure issues.

5.1.2 Impact on Staff's Beliefs and Practices

Staff in intervention hospitals were significantly more likely to believe that hospital tap water was safe to drink compared to staff in the comparison hospitals (24.4% and 0% respectively, p-value=0.02). Despite this significant difference, less than one quarter of the staff working in intervention hospitals actually believed the hospital tap water to be safe to drink, suggesting that there was very little awareness of, or trust in, the GE system. Furthermore, only 62% (±20%) of staff working in intervention hospitals were aware that the water in their hospital was being treated at all. Out of these staff, less than 10% of them mentioned the onsite purification system when asked how the water in their hospital was treated. These findings suggest that there was very little staff awareness of the GE purification systems within these hospitals.

Possibly because of this lack of awareness, there was no significant difference in the number of staff who drink hospital tap water in the intervention hospitals (24.4%) and in the comparison hospitals (11.1%) (p-value=0.24). As the filters produce high quality drinking water, and yet the staff are unaware that the system produces clean drinking water and therefore do not drink the water, the water system is not living up to its maximum potential. Increasing staff awareness of the water purification system on site, as well as the quality of the water being produced, would help to improve the benefits of the purification systems within these hospitals.

5.1.3 Impact on Patients' Beliefs and Practices

As there was very little staff awareness of the water purification system within intervention hospitals, there was also very little patient and visitor awareness. There was no significant difference between the number of patients who drank hospital tap water in intervention hospitals (10.2%) and in comparison hospitals (14.3%) (p-value=0.66). The hospital staff in intervention hospitals were not aware that the hospital tap water was safe to drink, and therefore they did not recommend that their patients drink the hospital tap water, which resulted in very little tap water consumption among patients. Two patients in intervention hospitals (3.4%) even stated that someone had directly told them that the hospital water was unsafe to drink. Drinking tap water in public locations was observed to be not the norm. When asked why they had not consumed hospital tap water, 23.1% of participants responded that they do not drink tap water outside of their home. Educational messaging is required to change water consumption habits among patients and visitors within the hospitals.

There was no difference between intervention hospitals and comparison hospitals in the proportion of patients who reported having taps in their homes (p-value=0.80), drinking tap water at home (p-value=0.50), treating tap water at home (p-value=0.11), or who believe that water contamination is a problem in their community (p-value=0.11). This suggests that there have been no positive effects on water KAPs in the community surrounding the hospital as a result of the donation of the GE water purification systems to the hospitals.

5.1.4 Importance of Comparison Hospital Data

The type of water system in the comparison hospitals was unknown before the researchers' first site visits; therefore data from these hospitals was limited. However, these two hospitals were found to be similar to the intervention hospitals across hospital-level demographic data, and they provided a useful benchmark for comparing the overall impact of the purification systems in the intervention hospitals. The comparison hospitals provided baseline information on water use and beliefs among hospital patients and staff, because surveys were not conducted in the intervention hospitals before the systems were installed. Having comparison values allowed the researchers to measure the effect of the donation of the water purification system on patients' and staff's KAPs.

5.2 Sustainability Metric

All intervention hospitals were found to border on the cutoff for sustainability as calculated using the sustainability metric. Each hospital was found to have different strengths and weaknesses in the four domains of sustainability defined in this evaluation: accountability, technical feasibility, on-site capacity, and institutional engagement and support. While this metric was designed specifically for evaluating GEF-donated water purification systems in hospitals in Honduras, it has the potential to be applied to other decentralized, institutional-level water treatment systems in low-income settings.

5.2.1 Successes and Areas of Improvement

Overall, hospitals performed the best within the domain of on-site capacity, though the hospital in Olanchito was an outlier in this group. The hospitals scored the poorest on the domain of accountability, particularly relating to funding and local access to replacement parts.

In many cases, the scores varied between hospitals because the hospitals had slightly different water systems, very different water sources, and were located in differing regions throughout the country. Some problems, such as access to replacement parts, are intrinsically a problem for any hospital in a low-income setting that uses equipment that is not sold in country. These problems will be difficult to resolve and will hinder the sustainability of these systems for the duration of their lifetime. Other issues, such as water quantity issues, will have to be solved by (external) technicians and engineers with specialized training, and they must be resolved before the water systems can truly be sustainable. Finally, some issues, such as staff awareness of the water system, can be resolved with basic capacity strengthening and have the potential to increase the sustainability of the water systems dramatically.

Accountability:

In general, hospitals scored poorly within the domain of accountability. The one major strength within this domain was each hospital's communication with the donor (GEF). Most of the hospitals had frequent and productive contact with their GE ambassadors. AI has provided successful technical support to all of the hospitals. These strong relationships should be used to enhance the sustainability of the water systems. However, there was a distinct lack of oversight by government entities (either the MOH or the Ministry of Environmental Health). These government agencies not only have the potential to provide important services, such as regular water quality testing, but also to provide in-country support in the long term. These relationships need to be expanded.

There was limited hospital initiated microbiological water quality monitoring as a result of either lack of capacity or resources within the hospital. Without regular monitoring of the water within the hospital water system, the quality of the water being provided at the POU cannot be assured. Some hospitals, such as in La Esperanza, have the capacity to complete regular microbiological testing on site. Onsite microbiological testing would be ideal and should be encouraged. However, if the hospital does not have the capacity to complete these tests on site, partnerships should be made with a government or private laboratory, such as the Ministry of Environmental Health, to conduct regular water quality testing.

The major area for improvement within the domain of accountability, however, relates to funding. None of the hospitals had a specific budget for their water system. All hospitals had limited budgets and many competing demands that needed to be resolved with limited resources. Funding to support water treatment not a priority and was allocated to other more pressing issues. Without involvement of the local or federal government (the source of funding for these public hospitals), funding specifically earmarked for the provision of safe water will most likely continue to be ignored. If the hospitals do not have the financial resources available to maintain the water system, they will not be able to sustain safe water provision using this technology.(Johnson, Hays, Center, & Daley, 2004)

Technical Feasibility:

Scores within the domain of technical feasibility varied widely between the hospitals because of the vast differences in source water at each hospital, as well as, differences in water infrastructure within each hospital. One of the major strengths was that the GE water purification systems produced high quality water. All water samples collected directly out of the filters met WHO and CDC guidelines for total coliforms, *E. coli*, chlorine residual, and turbidity. These laboratory results are in agreement with previous research studies about decentralized membrane filtration systems.(Huang et al., 2011; Lee & Schwab, 2005) However, varying levels of contamination were observed at POUs because of varying conditions of water infrastructure within each hospital.

Poor water infrastructure, including leaky pipes and broken pressure tanks, may have caused some of the pressure and flow issues, forcing the hospitals to by-pass the purification system. Poor water conservation practices, such as leaving sinks running while not in use, as well as intermittent water supply, may have exacerbated pressure and flow issues. If hospitals continue to by-pass the water system regularly, the quality of water provided within the hospital will be questionable and the sustainability of the water system will be poor. Providing the necessary quantity of water required to meet the demands of the hospital, will require intensive troubleshooting from a highly trained technician or engineer.

Another concern that affected all of the intervention hospitals and that will affect other hospitals in low-income settings that may receive GE purification systems was access to replacement parts. Hospitals were unable to buy replacement parts and supplies for the water systems locally, including items such as chlorine residual testing supplies and chlorine pump parts. Continual reliance on GEF to supply these parts to the hospitals will severely hinder the long term sustainability of these systems.(Harvey & Reed, 2004)

On-Site Capacity:

Overall, scores within the domain of on-site capacity were relatively high, with the exception of the hospital in Olanchito. All of the hospitals consistently and correctly carried out routine maintenance as recommended by AI. While organizational structure was not equally developed across hospitals, there was generally successful communication and strong relationships between the director, the administrator, laboratory staff, and maintenance staff. The organizational structure necessary for the water system operation and maintenance can be strengthened around these strong relationships. Organization and communication can also be enhanced though the scheduling of regular meetings between these key staff members to discuss issues relating to the water system.

Each hospital had varying capacity strengthening needs, such as maintaining appropriate chorine residual levels, limiting system downtime, and ensuring key tasks are accomplished and recorded. Further capacity strengthening could be facilitated by AI, CGSW, or during the quarterly trainings attended by hospital maintenance staff in Tegucigalpa. Additional capacity strengthening could be provided to the GE ambassadors so that they could, in turn, be able to advise the hospital staff to maintain the system.

Institutional Engagement and Support:

The second highest scoring domain overall was institutional engagement and support. One of the major areas for improvement within this domain, however, was the limited knowledge about the water system among staff and patients. Many of the staff members that the researchers interviewed had little to no awareness about the water system and the quality of the hospital water. As seen in the literature, overall impact of the system will remain minimal as long as knowledge and use of the system remains low.(Carter et al., 1999; Hodgkin, 1994) At each hospital, researchers encountered at least one staff member who was highly dedicated to the success of the water system. These safe water champions could be empowered to increase awareness and support among the staff. They could play an essential role in ensuring long term sustainability of the water system and should be encouraged to participate in future decisions about the water system.(Johnson et al., 2004)

Another major issue to overcome within the domain of institutional engagement and support was the strong distrust of hospital tap water and heavy reliance on bottled water. While increased awareness about the water system may decrease this distrust, influencing cultural norms, like the belief that drinking tap water is perceived as a sign of being poor, will be more challenging to overcome. However, many hospitals would prefer not to purchase water because of its additional cost and are interested in the idea of supplying their own drinking water to patients and staff. In San Lorenzo, this distrust of hospital tap water may be insurmountable due to the water's high mineral content and bad taste.

5.2.2 Sustainability Metric Application

This sustainability metric was designed to specifically evaluate the sustainability of the GE Homespring® filter system donated to hospitals in Honduras. While it was designed for a very specific purpose, it can serve as a prototype tool to evaluate other types of systems. By revising specific interview questions and reworking of the scoring scale to fit the context of the system, this metric could be applied to other decentralized water treatment systems in institutional low-income settings.

The metric was not particularly quantitative in nature, and therefore the results may lack precision. The main focus of this metric was to highlight areas for improvement and information gaps that require further research. There were a couple of key aspects that could be incorporated into future iterations of this metric to provide a deeper understanding of the successes and challenges within each hospital.

First, questions should distinguish between drinking hospital bottled water and drinking hospital tap water. As the researchers were unaware that hospital water bottling was taking place before they arrived in country, the interview tools did not include questions distinguishing the consumption of these two sources. Participants had varying opinions of the hospital bottled water versus hospital tap water, and many did not know that they came from the same source.

Consumption of hospital bottled water was seen as more acceptable than consumption of hospital tap water. Understanding this difference in perception is important for further work in these hospitals.

Second, many staff struggled with questions regarding their role in the provision of safe water. Most staff responded that they did not have a role or did not respond to the question. The question for staff about the importance of safe water yielded responses that were too broad to really be meaningful. The responses given to these questions did not meet the goal of the question, which was to determine the staff's perceived importance of safe water and their knowledge about safe water. During the second site visit, the researchers started asking the clinical staff about the recommendations that they give their patients about safe water and this question elicited more useful responses.

Finally, while the researchers asked about each hospital's biosafety committee, specific questions about the committee's role in the provision of safe water within the hospital would have provided more valuable information. Additionally, some hospitals mentioned their relationship with BID, however, most seemed unaware of their water quality results. The researchers did not incorporate questions about the role of BID in the provision of safe water in the assessment, so the extent of these relationships is not well known.

5.3 Study Limitations

There are several limitations to this study that must be considered when interpreting the results. First, very little information about the comparison hospitals was known, particularly regarding their water systems, before the researchers' first visit to these sites. Therefore, specific questions regarding the comparison hospitals' water systems could not be prepared beforehand.

This limitation may have hindered the researchers' ability to fully understand the workings of the water systems at the comparison hospitals.

A second limitation of this study was the small sample size. This was mainly the result of the fact that GEF had only donated water purification systems to four hospitals throughout Honduras. The researchers only recruited two hospitals to participate in this study as comparison hospitals. The number of surveys completed within each hospital was also limited to the amount of time the researchers could spend at each hospital site visit (1-2 days).

Third, while the researchers conducted all interviews in Spanish, the researchers were not fluent Spanish speakers. This may have affected the recorded results through either misinterpretation or mistranslation on the part of the researchers in understanding the participants' responses or on the part of the participants misinterpreting the researchers' questions.

Fourth, the overall sustainability scores were calculated as the simple average of each individual score. This calculation assumes that all categories were equally important, and that a good score in one category could outweigh a poor score in a different category. However, some issues, such as regular by-passing of the treatment system, have more influence on the provision of safe water compared to other factors. No matter how much staff support or maintenance capacity there is within a hospital, if the treatment system cannot supply enough water to the entire hospital, the continual provision of safe water cannot be met. Therefore, weighting of scores should be considered for future iterations of this metric.

6 RECOMMENDATIONS AND NEXT STEPS

6.1 Recommendations

One of the purposes of this study was to provide GEF with recommendations on how they can better maximize the benefits and improve the sustainability of their current donations of water purification systems, as well as, their future donations. Best practices from certain hospitals can be adapted for and applied to other hospitals in order for all of the hospitals to maximize the four domains of sustainability and sustain safe water provision over the long term. This study also provides recommendations for future researchers who may wish to adapt this sustainability metric for their own studies. GEF or the CGSW may wish to apply this metric in future research and can use these recommendations to improve this metric as well.

6.1.1 Recommendations for GEF and Study Hospitals

As the hospitals in Honduras with GEF-donated water purification systems are vulnerable to not being able to sustain the provision and use of safe water, steps need to be taken to ensure the continued use and oversight of these purification systems. Attention should be focused on maximizing the four domains of sustainability within each hospital.

1. Issues regarding pressure and flow in some of the hospitals need to be solved in order for the purification systems to be sustainable. GE technical assistance is needed to provide intensive troubleshooting in order to solve these problems.
2. Poor water conservation behaviors may be exacerbating current pressure and flow issues. The hospitals should improve water conservation throughout their facilities and fix any outstanding leaks.
3. There are no supply chains set up for hospitals to receive replacement parts and other consumables required for the water purification systems without the

assistance of GEF and AI. GEF and AI should strengthen the mechanisms for obtaining supplies and parts for foreseeable needs (including routine maintenance and repairs).

4. While there was generally good communication between hospital staff with regard to the water system, occasionally key issues were not communicated. The hospitals should set up regularly scheduled meetings between the director, administrator, laboratory staff, and maintenance staff to discuss the water system and ensure that key issues are communicated.
5. Good communication is necessary for the completion of key tasks. It was observed that occasionally key tasks were overlooked. In addition to improving communication, the completion of key tasks can be ensured through the improvement of record keeping for these tasks, including: measured chlorine residual levels, system by-pass events, maintenance procedures, system repairs, and supply ordering.
6. The hospitals struggle to maintain proper chlorine levels throughout the water network. The CGSW or AI should provide additional capacity strengthening to the laboratory and maintenance staff in order to maintain recommended chlorine residual levels at all POU taps.
7. None of the hospitals maintain specific budgets or financial records associated with their water systems, which suggests that sustainable funding for the purification systems is neglected. The hospitals should create a specific budget for the operation, maintenance, and repair of the water system.

8. Involvement from the local government is necessary over the long term, as a more sustainable form of oversight. The CGSW and GEF should work with hospitals to enhance partnerships with environmental health departments and the MOH in order to increase oversight and monitoring.
9. There was very little staff and patient awareness of the water system, which decreases the use of the water purification system for drinking water. If hospital staff and patients are unaware of the system, they may not use the purified water to its full potential (i.e. drink the tap water). The hospitals should work to increase staff and patient awareness of the purification system and of the water quality throughout their facilities.
10. While most hospital staff members knew that safe water is important, many were not certain of their role in the provision of safe water at the hospital. The hospitals should work to enhance staff knowledge about the importance of safe water and their role in the provision and use of safe water at the hospital. Hospital staff could be a valuable resource for increasing patient and visitor awareness of the water quality of their hospital's tap water and of the importance of safe water for health. Hospital staff could also serve as advocates of safe water within the hospital, holding the hospital administration responsible for the continued provision of safe water.
11. Many staff did not trust the hospital tap water because they were unaware of the quality of the hospital tap water. The CGSW should work with the hospitals to increase staff trust of hospital tap water through regular water testing and public

sharing of results. Signage at hospital faucets could increase staff awareness of water quality.

6.1.2 Recommendations for the Design and Use of the Sustainability Metric

The sustainability metric successfully identified strengths, weaknesses, and future areas of study in each of the hospitals with regard to the sustainability of safe water provision. However, there are improvements that can be made to the metric for it to be more precise and generalizable.

1. This metric was specifically designed for use with GEF-donated water purification systems in Honduran hospitals. By reworking some broad questions and response scales, this metric could be made more generalizable and be applied to any decentralized water purification system donated to an institution in a low-income setting.
2. Many of the interview questions used in this metric provided qualitative responses. It was up to the researcher, therefore, to determine how to categorize and score those responses. More closed-answer questions that elicit specific responses could be included in order to make the metric less qualitative and the analyses less subjective.
3. In this study, the researchers did not interview local or national government officials. However, the role of government is often perceived as being very important to long term sustainability. The researchers did interview hospital staff about their relationship with the government regarding water systems, but it would be useful to add specific interview questions for government officials into the metric.

6.2 Next Steps

The data collected in this study – on the sustainability of the GEF-donated purification systems and the provision and use of safe water in the hospitals that received these systems – can be used in the future as baseline data to measure against any improvements that are made. There are also many opportunities for the future use of the sustainability metric developed in this study, particularly for other GEF donation sites.

6.2.1 Next Steps with GEF and Study Hospitals

This study identified areas of success and areas for improvement within each hospital with regard to the sustainability of safe water provision and use. The CGSW can now work with GEF and the study hospitals to maximize the areas of success identified and manage the improvements that are necessary to increase the performance, use, and sustainability of the GE water purification systems.

1. The results of this study have been shared with both GEF and the study hospitals. These results will also be shared with the MOH in order begin the dialogue between local government and these hospitals about hospital water quality.
2. The CGSW will work with both GEF and the four hospitals in order to maximize the four domains of sustainability.
    a. Capacity strengthening will be conducted through raising staff awareness about the water system, as well as improving capacity for regular maintenance tasks (such as chlorine regulation).
    b. Technical assistance will be provided to mitigate pressure and flow issues experienced in some of the hospitals.

c. Water use mapping will be used to better understand how water is used in the hospital and how the purification system can be improved to meet the hospitals' needs.

d. Actor analyses will be conducted in order to determine where communication breakdowns are occurring so that identified weak relationships can be strengthened.

e. Independent governance and accountability systems will be developed to ensure high-quality water in hospitals without hospital dependence on GEF or other outside donors.

6.2.2 Next Steps in the Design and Use of the Sustainability Metric

Because of the increased focus on sustainability in the WASH sector, there are many opportunities for applying the sustainability metric developed in this study. However, before this metric can be used widely, it must first be validated in other study sites and then made more generalizable for technologies other than the GE water purification system.

1. The four domains for an enabling environment identified in this study (technical feasibility, on-site capacity, accountability, and institutional engagement and support) will be validated at other sites where GEF has donated water purification systems (in Ghana and Kenya) in 2013-2014.
2. The metric will be re-oriented to reflect sustainable access to and use of safe water in health facilities as a whole, rather than being technology specific.

7 CONCLUSIONS

The goal of this research study was to evaluate the impact and sustainability of water purification systems donated by the General Electric Foundation to hospitals in Honduras. In the process of meeting this goal, a sustainability metric was developed to systematically measure the sustainability of these water purification systems. The impact of these water systems was assessed by comparing KAPs reported by hospital staff, patients, and visitors, as well as water quality within the hospitals, among hospitals with water purification systems donated by GEF to hospitals without water purification systems donated by GEF.

This evaluation provided a new method for evaluating the sustainability of institutional-level decentralized water treatment systems through the use of a sustainability metric. The metric enabled a systematic evaluation through the use of a scoring system in order to identify areas of success, areas needing improvement, and areas of future research, regarding the provision and use of safe water in Honduran intervention hospitals. However, there are limitations to this metric, and the external validity and predictive power have yet to be tested.

Overall, the four intervention hospitals were determined to be near the cut-off for sustainability as defined by the sustainability metric (score of ≥ 2). These findings suggest that the provision and use of safe water in these hospitals is vulnerable to becoming unsustainable. Best practices seen in some hospitals can be used to increase domain scores in other hospitals, in order to increase the overall sustainability of the water purification systems. Finally, the use of the GEF-donated water purification systems for drinking water has not been maximized, despite the high quality of water being produced by the systems. Increased staff, patient, and visitor awareness of the systems and improved staff water-use practices can help increase the beneficial use of the water purification systems.

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Appendix 1. Interview Tools

AH1	Date		AH4	Hospital Name	
AH2	Start Time		AH5	Name of Investigator(s)	
AH3	End Time				

General Information		
Demographics		
A1	How big is the catchment area of this hospital?	Area: Population:
A2	What are the most common reasons for hospitalization?	
A3	How many patients are attended daily at this hospital?	
A4	How many beds does this hospital have?	
A5 A6	How many doctors are employed in this hospital? Nurses?	__________ doctors __________ nurses
A7	In general, what is the average distance patients travel to get to this hospital?	Distance: Time:
A8	Does the catchment population of this hospital have access to safe water?	1) Yes 2) No 99) I do not know Comments:
A9	How often are there water outages or is the water service intermittent from the municipal water source?	______times a day/week/month 1) Never Comments:
Water Sources, Availability, and Demand		
A10 A10a	What water sources are available in this hospital? (Mark all that apply, specifying if necessary)	1) Tap (public) **Source:** 1) Well 2) Surface Water 88) Other 2) Tap (private) 3) Tanker Truck 88) Other (specify):
A11	What is the principle source of drinking water in this hospital?	1) Tap (public) 2) Tap (private) 3) Tanker Truck 88) Other (specify):
A12	Are there times when water from this principle source is not available?	1) Yes 2) No→SKIP a A14
A13	**If yes**, why is it not available? (select all options that apply)	1) Season (dry or rainy) 2) Other reason (specify):
A14	Is potable water available in every department today? [If not, why not?]	1) Yes 2) No 99) I do not know Comments:

GEF Hospital Director

A15	Are there times when water is stored before using? Why?	1) Yes 2) No 99) I do not know Comments:
 A16 A17 A18 A19	Who drinks water directly from the tap? **Staff** **Patients** **Visitors/Care Takers** **Others**	 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know Specify:____________
A20	What are other sources of drinking water in this hospital?	1) bottled treated water 2) purchased water 88) other, specify:_____________
A21	Who drinks from these other sources that you just mentioned?	Source____________ Users_______________ Source____________ Users_______________ Source____________ Users_______________ Source____________ Users_______________ Comments:
A22	**Observation**: Describe the type of container and mechanism used to obtain water from the tap or bottle.	1) Plastic bottle 2) Cup from home 88) Other, specify:_____________
A23 A24	Are there times when people collect water from the hospital to take home with them? **If yes**, approximately how many people each day?	1) Yes 2) No →SKIP to A25 99) I do not know →SKIP to A25 ________ people/day
A25 A25a A25b A25c A25d	What source of water do staff use to: A. Wash their hands B. Cook C. For laundry D. Wash medical equipment	 A. 1) treated water 2) un-treated water B. 1) treated water 2) un-treated water C. 1) treated water 2) un-treated water D. 1) treated water 2) un-treated water Comments:
On-Site Capacity		
Water Treatment		
A26 A26a A26b A26c A26d A26e	Is there a person responsible for: A. Ensuring there is water available in every department B. Ensuring water gets to all toilets and sinks C. Ensuring there are hygiene and cleaning supplies (soap, toilet paper) D. Ensuring there is chlorine E. Ensuring the water is clean	 A. 1) Yes 2) No [Name/Role_________________] B. 1) Yes 2) No [Name/Role_________________] C. 1) Yes 2) No [Name/Role_________________] D. 1) Yes 2) No [Name/Role_________________] E. 1) Yes 2) No [Name/Role_________________]

GEF Hospital Director

A27	What is your personal role in the provision of safe water in this hospital?	
A28	How long have you worked here as the director?	
A29	What are your goals for the water system? Do you feel as though you are achieving those goals? Why or why not?	
A30	Where do you see the water system in 5 years? Where would you like to see it?	
A65	In your opinion, What type of intervention would increase access to safe water in the community?	
A66	How can the hospital's water system improve access to safe water in the community?	
A67	If the hospital had the ability to sell safe water, do you think people would buy it? Why or why not?	1) Yes 2) No 99) I do not know Comments:
Accountability		
A31	Does this hospital have a written record for any of the following activities? Who is responsible for each?	
A31a	Availability of water	1) Yes 2) No 3) N/A ________________________
A31b	Water treatment	1) Yes 2) No 3) N/A ________________________
A31c	Cleaning water containers	1) Yes 2) No 3) N/A ________________________
A31d	Cleaning water cisterns	1) Yes 2) No 3) N/A ________________________
A31e	Cleaning the toilets or latrines	1) Yes 2) No 3) N/A ________________________
A31f	Restocking soap for hand-washing	1) Yes 2) No 3) N/A ________________________
A31g	Repairing taps and broken sinks	1) Yes 2) No 3) N/A ________________________
A31h	Other	Specify:
A32	What information regarding water, sanitation, and hygiene does the MOH collect in audits?	
A33	What information does GE ask for?	
A62a A62b A62c	How frequently do you talk to maintenance staff about the water system? What did you talk about the last time you spoke? Does the maintenance staff inform you when they shut of the water system?	

GEF Hospital Director

A63a A63b	How frequently do you talk to laboratory staff about the water system? What did you talk about the last time you spoke?	
A64a A64b	How frequently do you talk to the administrator (bookkeeper) about the water system? What did you talk about the last time you spoke?	
Institutional Support (the MOH and GE)		
Training and Capacity Building		
A34	Who was trained in using the water system?	Name: ______________ Role: ________________ Name: ______________ Role: ________________ Name: ______________ Role: ________________ Name: ______________ Role: ________________
A35	Has GE made any follow-up visits? How many?	________ visits
A36	Has GE held any follow-up trainings? How many? What was the content?	______ trainings Comments:
Support for Operations and Maintenance, Repairs, and Replacements		
A37 A37a A37b A37c A37d A37e	Does GE or the MOH offer: A. Funds for water treatment B. Funds for infrastructure (tubing, sinks) C. Staff training D. Recognition of your achievements in the provision of safe water E. Other (Specify):	 A. 1) Yes 2) No 99) Don't know **Who:** 1)GE 2)MOH B. 1) Yes 2) No 99) Don't know **Who:** 1)GE 2)MOH C. 1) Yes 2) No 99) Don't know **Who:** 1)GE 2)MOH D. 1) Yes 2) No 99) Don't know **Who:** 1)GE 2)MOH E. Describe: **Who:** 1) GE 2) MOH
Feedback Mechanisms between Donors, Government, Institutions, and Community		
A38	Do you have communications with either GE or the MOH about the water system? How often? What do you discuss? [Probe for specific examples]	
A39	How often do you talk to GE? What do you talk to them about?	____ times per month/year 99) I do not know Comments:
Finance Mechanisms		
A40	How much does chlorine cost on a monthly basis for the water system?	
A41	Is there a specific budget for the water system? [if not, please explain the system used to obtain consumables and parts]	1) Yes 2) No 99) I do not know Comments:

GEF Hospital Director

A42	Is there a record of the costs associated with the water system? [ask to see it]	1) Yes 2) No 99) I do not know Comments:
A43	To whom do you report your costs?	
A44	Has there been a time when chlorine was not bought for the water system? Why?	1) Yes 2) No 99) I do not know Comments:
Satisfaction and Perceived Value		
A45	In your opinion, what are the benefits of having a safe water source here in the hospital?	
A46	For who in the hospital is safe water most important? For what purpose? Can you give me an example?	
A47	What actions does the hospital take to promote the availability and awareness of safe water for staff and patients?	
A48	How is the water quality in the hospital compared to the water you use at home? Why?	1) Worse 2) Equal 3) Better 99) I do not know Comments:
A49	Is the taste of the water satisfactory? [If no, why not?]	1) Yes 2) No 99) I do not know Comments:
A50	Is the water pressure satisfactory? [If no, why not?]	1) Yes 2) No 99) I do not know Comments:
A51	Is the maintenance cost of the water system satisfactory? [If no, why not?]	1) Yes 2) No 99) I do not know Comments:
A52	In general, does the water system satisfy your needs? [explain]	1) Yes 2) No 99) I do not know Comments:
A53	Would you recommend this water filtration system to other hospitals? Why or why not?	1) Yes 2) No 99) I do not know Comments:
A54	In your opinion, what distinguishes this hospital from other public hospitals?	

GEF Hospital Director

A55 A56 A56a A56b A56c A56d A56e	What methods do you use to protect immuno-compromised patients? Do you use treated water for: A) Direct observation therapy for tuberculosis? B) Medications for persons with HIV/AIDS? C) The preparation of oral rehydration salts? D) In the preparation for surgical and maternal procedures? E) Other specific uses: Specify: ________________	 A] 1) Yes 2) No 99) I do not know B] 1) Yes 2) No 99) I do not know C] 1) Yes 2) No 99) I do not know D] 1) Yes 2) No 99) I do not know E) Describe: ________________
Personal Information (Observations)		
A57	Sex of the director:	1) Male 2) Female
A58	Age of the director:	1) ≤ 30 years 2) >30 years 3) ≥ 60 years
 A59 A59a A59b A59c A59d	**Opinion of the investigator:** On a scale of 1-5, 5=very committed 1=not committed: A. How committed was the participant to respond to the questions asked? B. What was the participant's level of knowledge about the practices at this hospital? C. How willing was the participant to give examples and additional information? D. What was the participant's level of commitment to the provision of clean water?	 A. 1 2 3 4 5 B. 1 2 3 4 5 C. 1 2 3 4 5 D. 1 2 3 4 5 Comments and observations:

GEF Hospital Clinical Staff

BH1	Date		BH4	Hospital Name	
BH2	Start Time		BH5	Name of Investigator(s)	
BH3	End Time				

B1	Role of Participant:	1) Doctor 2) Nurse 88) Other, specify:
B2	Sex of Participant:	1) Male 2) Female
B3	Age of Participant:	1) ≤ 30 years 2) >30 years 3) ≥ 60 years
B4 B5 B6	Where does the water in this hospital come from? Is it treated before use? How?	Source: Treated: 1) Yes 2) No 99) I do not know Method of treatment: Comments:
B7	In your opinion, is the water from the tap safe to drink? Why or why not? [Probe for more information]	1) Yes 2) No 99) I do not know Comments:
B8	How is the water quality in the hospital in comparison to the water you use at home?	1) Worse 2) Equal 3) Better 99) I do not know Comments:
B9	Is contaminated water a problem for the population living near this hospital? Why or why not?	1) Yes 2) No 99) I do not know Comments:
B10 B10a B10b B10c B10d	Who drinks water directly from the tap? **Staff** **Patients** **Visitors/Care Takers** **Others**	 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know Specify:____________
B11	What do the patients say regarding water quality? [explain]	
B12	What are the benefits of having safe water for your job?	
B13	For who is this hospital is safe water most important? For what purpose?	
B14 B14a B14b B14c B14d	Do you use tap water for: **Washing your hands** **Drinking** **Washing medical equipment** **Other use**	 1) Yes 2) No 1) Yes 2) No 1) Yes 2) No 1) Yes 2) No Specify:____________________

GEF Hospital Clinical Staff

B15	What methods do you use to protect immuno-compromised patients? Do you use treated water for:	
B15a	A) Direct observation therapy for tuberculosis?	A] 1) Yes 2) No 99) I do not know
B15b	B) Medications for persons with HIV/AIDS?	B] 1) Yes 2) No 99) I do not know
B15c	C) The preparation of oral rehydration salts?	C] 1) Yes 2) No 99) I do not know
B15d	D) In the preparation for surgical and maternal procedures?	D] 1) Yes 2) No 99) I do not know
B15e	E) Other specific uses: Specify: _________________	E) Describe: ________________
B16	What is your role in the provision of safe water in the hospital?	
B17	Opinion of the investigator: On a scale of 1-5, 5=very committed 1=not committed:	
B17a	A. How committed was the participant to respond to the questions asked?	A. 1 2 3 4 5
B17b	B. What was the participant's level of knowledge about the practices at this hospital?	B. 1 2 3 4 5
B17c	C. How willing was the participant to give examples and additional information?	C. 1 2 3 4 5
B17d	D. What was the participant's level of commitment to the provision of clean water?	D. 1 2 3 4 5 Comments and observations:

GEF Hospital Staff

CH1	Date		CH4	Hospital Name	
CH2	Start Time		CH5	Name of Investigator(s)	
CH3	End Time				

C1	Role of Participant:	1) Receptionist 2) Laboratory Technician 3) Cook 4) Administrator (bookkeeper) 88) Other, specify:
C2	Sex of Participant:	1) Male 2) Female
C3	Age of Participant:	1) ≤ 30 years 2) >30 years 3) ≥ 60 years
C4 C5 C6	Where does the water in this hospital come from? Is it treated before use? How?	Source: Treated: 1) Yes 2) No 99) I do not know Method of treatment: Comments:
C7	In your opinion, is the tap water safe to drink? Why or why not?	1) Yes 2) No 99) I do not know Comments:
C8	How is the water quality in the hospital in comparison to the water you use at home?	1) Worse 2) Equal 3) Better 99) I do not know Comments:
C9 C9a C9b C9c C9d	Who drinks water directly from the tap? **Staff** **Patients** **Visitors/Care Takers** **Others**	 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know Specify:____________
C10	What are the benefits of having safe water for your job?	
C11 C11a C11b C11c C11d C11e C11f C11g	Do you tap water for: **Washing your hands** **Cooking** **Drinking** **Washing dishes** **Washing medical or laboratory equipment** **For laboratory analysis** **Other use**	 1) Yes 2) No 1) Yes 2) No 1) Yes 2) No 1) Yes 2) No 1) Yes 2) No 1) Yes 2) No Specify:
C12	For who is this hospital is safe water most important? For what purpose?	
C13	Is contaminated water a problem for the population living near this hospital? Why or why not?	1) Yes 2) No 99) I do not know Comments:

GEF Hospital Staff

C14	What is your personal role in the provision of safe water in the hospital?	
C15	**[for laboratory technicians]** How often do you measure chlorine residual levels? Where do you measure them?	
C16	**[for laboratory technicians]** How often do you give advice (feedback) to the maintenance staff to adjust the chlorine levels in the water system? How do they react?	
C18	**[for laboratory technicians]** When was the last time you talked to the director about the chlorine levels?	
C19	**[for the administrators]** What influences your decision to buy (or not buy) chlorine for the water system?	
C20	**[for the administrators]** What influences your decision to finance (or not finance) repairs for the water system?	
C21	**[for the administrators]** What influences your decision to finance (or not finance) the maintenance of infrastructure for the hospital's water system, for example repairs or substitutions of broken sinks and taps?	
C17	**Opinion of the investigator:** On a scale of 1-5, 5=very committed 1=not committed:	
C17a	A. How committed was the participant to respond to the questions asked?	A. 1 2 3 4 5
C17b	B. What was the participant's level of knowledge about the practices at this hospital?	B. 1 2 3 4 5
C17c	C. How willing was the participant to give examples and additional information?	C. 1 2 3 4 5
C17d	D. What was the participant's level of commitment to the provision of clean water?	D. 1 2 3 4 5 Comments and observations:

GEF Hospital Patients and Visitors

DH1	Date		DH4	Hospital Name	
DH2	Start Time		DH5	Name of Investigator(s)	
DH3	End Time				

D1	Role of Participant:	1) Patient 2) Visitor 88) Other ______________
D2	Sex of Participants:	1) Male 2) Female
D3	Age of Participant:	1) ≤ 30 years 2) >30 years 3) ≥ 60 years
D4	How much time did it take you to get to the hospital today?	___hours ___minutes
D5	How long have you been here in the hospital this visit?	___hours ___minutes
D6	Have you used a sink in the hospital to wash your hands today?	1) Yes 2) No 3) I do not remember
D7	Have you consumed hospital tap water today?	1) Yes 2) No 3) I do not remember
D8	**If they have children**, have your children consumed hospital tap water today?	1) Yes 2) No 99) I do not know
D9	**If they have consumed hospital tap water**: How does the hospital tap water compare to the water you use in your house? Flavor? Security?	1) Worse 2) Equal 3) Better 99) I do not know Comments:
D10	**If they have not consumed hospital tap water**, why have you not consumed hospital tap water?	
D11	In your house, do you drink tap water, purchased water, or both?	1) Tap 2) Purchased water 3) Both
D12	Do you have a tap in your house?	1) Yes 2) No
D13 D13a	Do you treat your drinking water in your house? **If yes**, How?	1) Yes 2) No →SKIP to D14 99) Don't know→SKIP to D14 Comments: Treatments [in the affirmative case] 1) Boil 2) Filter 3) Chlorine 88) Other
D14	Is contaminated water a problem in your community? Why or why not?	1) Yes 2) No 99) I do not know Comments:

GEF Hospital Maintenance Staff

HH1	Date		HH4	Hospital Name	
HH2	Start Time		HH5	Name of Investigator(s)	
HH3	End Time				

Cisterns (ask to see all cisterns, including those not in use)			
Ha	**1st cistern**	Hb	**2nd cistern**
H1a	Describe the cistern site:	H1b	Describe the cistern site:
H2a	Financed by:	H2b	Financed by:
H3a	Year constructed:	H3b	Year constructed:
H4a	Capacity:	H4b	Capacity:
H5a	Is the cistern in use? 1) Yes 2) No	H5b	Is the cistern in use? 1) Yes 2) No
H6a	What type of cistern is it? 1) Above ground 2) Below ground	H6b	What type of cistern is it? 1) Above ground 2) Below ground
H7a	What is the cistern made of? 1) Cement 2) Plastic 88) Other: _____________	H7b	What is the cistern made of? 1) Cement 2) Plastic 88) Other: _____________
H8a	Does the cistern leak? 1) Yes 2) No	H8b	Does the cistern leak? 1) Yes 2) No
H9a	Is there a screen to prevent the entry of debris and insects into the cistern? 1) Yes 2) No	H9b	Is there a screen to prevent the entry of debris and insects into the cistern? 1) Yes 2) No
H10a	Is there a tap on the cistern? 1) Yes 2) No→SKIP to H12a	H10b	Is there a tap on the cistern? 1) Yes 2) No→SKIP to H12b
H11a	If there is a tap, does it work? 1) Yes 2) No	H11b	If there is a tap, does it work? 1) Yes 2) No
H12a	Is the cistern connected to the piped water supply? 1) Yes 2) No	H12b	Is the cistern connected to the piped water supply? 1) Yes 2) No
H13a	Is the water in the cistern filtered? 1) Yes 2) No	H13b	Is the water in the cistern filtered? 1) Yes 2) No
H14a	Is the water in the cistern chlorinated? 1) Yes 2) No→SKIP to H1b 99) Don't Know	H14b	Is the water in the cistern chlorinated? 1) Yes 2) No→SKIP to H16 99) Don't Know
H15a	**If yes**, what is the chlorine residual level? _________________	H15b	**If yes**, what is the chlorine residual level? _________________
Electricity			
H16	In the last week, how many times has the electricity gone out?	_________ times	

GEF Hospital Maintenance Staff

Sanitation		
H17	What types of toilets are available in the hospital?	1) Toilet 2) Pour flush toilet 3) Tap flush toilet 4) Latrine 88) Other (specify):
H18	What are the common maintenance problems associated with toilets in the hospital? [probe for specific examples]	1) Low water pressure 2) Broken ceramic parts 88) Other (specify): Comments:
Maintenance and Financing for Sanitation		
H19	Who cleans the bathrooms?	Name: _______________ Role: _______________
H20	How often are the bathrooms cleaned?	______ times per day/week/month
H21	Where does the wastewater from the hospital go?	1) Municipal sewer system 2) Wastewater pond 88) Other (specify): 99) I do not know
H22	Is the wastewater treated before being returned to the environment?	1) Yes 2) No 99) I do not know

GEF Hospital Maintenance Staff

On-Site Capacity		
Training		
H23	Who was trained by GE in the operations and maintenance of the water system? Do they all still work here?	Name __________ Role___________1) Yes 2) No Name __________ Role___________1) Yes 2) No Name __________ Role___________1) Yes 2) No Name __________ Role___________1) Yes 2) No Name __________ Role___________1) Yes 2) No
H24	Who is responsible for the GE water system?	
H25	Normally, how many people complete maintenance tasks associated with the water system?	
H26	How many days a week is there someone here that knows how to operate the water system?	
H27	How many days in the last two months have you not used the water system? Why?	
H28	Do you communicate with GE or the MOH about safe water? How often? What do you discuss? [Probe for specific examples]	
H29	What is your role in the provision of safe water within the hospital?	
H61a H61b H61c	How often do you talk to the director about the water system? What did you discuss the last time you talked? Do you inform the director when you shut of the water system?	1) Yes 2) No 99) I do not know
H62a H62b H62c H62d	How often do you talk to the laboratory staff about the water system? What did you discuss the last time you talked? Do you inform the laboratory when you shut off the water system? Do you inform the laboratory when you change to a new chlorine level?	1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know
Regular Maintenance		
If any of the below responses are "never," Why never? Is it not necessary? Is it too difficult? Does it cause too much stress on the equipment? Is there not enough time?		
H30	**[For manual systems]** How often is a backwash performed?	_______times per day/week/month 1) Never

GEF Hospital Maintenance Staff

H31	**[For PLC systems]** How often are the filters checked to make sure the backwash is functioning?	_______times per day/week/month 1) Never
H32	How often are chlorine levels checked?	_______times per day/week/month 1) Never
H33	How often is more chlorine added to the system?	_______times per day/week/month 1) Never
H34	How often are the chlorine supplies inventoried?	_______times per day/week/month 1) Never
H35	How often is the pressure at the entrance and exit checked to see if there is a significant drop in pressure across the filters?	_______times per day/week/month 1) Never
H36	How often are the Amiad filters scrubbed and backwashed?	_______times per day/week/month 1) Never
H37	How often is the chlorine tank checked to make sure it has an acceptable level of chlorine?	_______times per day/week/month 1) Never
H38	How often is the flow from the dosing pump through the clear line to the water pipes checked?	_______times per day/week/month 1) Never
H39	How often are all hand valves checked to assure that they are in the proper position for filtration, not by-pass?	_______times per day/week/month 1) Never
H40	How often is the outside of the equipment wiped down?	_______times per day/week/month 1) Never
H41	How often is the area around the system checked to make sure it is not being used as storage for non-filter related items?	_______times per day/week/month 1) Never
H42	How often are the filters checked to make sure there are no leaks and that any leaks that exist are fixed?	_______times per day/week/month 1) Never
H43	How often are the tops of the filter housing removed and filters inside rinsed?	_______times per day/week/month 1) Never
H44	What do you do when there is a drop in pressure? [Probe about backwashing]	
Repairs and Institutional Support		
H45	Who do you call when there is a problem with the system?	
H46	Have you ever sought external help for repairs? [explain]	
H47	Can you buy important parts for the water system locally?	1) Yes 2) No 99) I do not know Comments:

GEF Hospital Maintenance Staff

H48 H48a H48b H48c H48d	Have any of the parts of the system been repaired or replaced? Which part? When? By who? Where did you get the parts for the repair?	 ____/____/______ Name: ________________ Role:_____________
H49	Are there parts of the water system that have been successfully repaired or replaced in the last year?	1) Yes 2) No 99) I do not know ***Describe specific examples*:**
H50	Are there parts of the water system that function poorly or are broken currently because the responsible person cannot fix them?	1) Yes 2) No 99) I do not know ***Describe specific examples*:**
Satisfaction		
H51	What is the most difficult part of the system? Why?	
H52	What is the easiest part of the system? Why?	
H53	What can GE do to improve the water system?	
H54	Would you recommend the water system to other hospitals? Why or why not?	
H55	What advice would you give others who operate the same water filtration system that you have here?	
Demographic Information		
H56	Sex of Participant:	1) Male 2) Female
H57	Age of Participant:	1) ≤ 30 years 2) >30 years 3) ≥ 60 years
H58	What is the highest education level you have completed?	
H59	How long have you been working here at this hospital?	________months/years

GEF Hospital Maintenance Staff

Other (opinion of the investigator)		
H60	**Opinion of the investigator:** On a scale of 1-5, 5=very committed 1=not committed:	
H60a	A. How committed was the participant to respond to the questions asked?	A. 1 2 3 4 5
H60b	B. What was the participant's level of knowledge about the practices at this hospital?	B. 1 2 3 4 5
H60c	C. How willing was the participant to give examples and additional information?	C. 1 2 3 4 5
H60d	D. What was the participant's level of commitment to the provision of clean water?	D. 1 2 3 4 5 Comments and observations:

Control Hospital Director

AH1	Date		AH4	Hospital Name	
AH2	Start Time		AH5	Name of Investigator(s)	
AH3	End Time				

General Information		
Demographics		
A1	How big is the catchment area of this hospital?	Area: Population:
A2	What are the most common reasons for hospitalization?	
A3	How many patients are attended daily at this hospital?	
A4	How many beds does this hospital have?	
A5 A6	How many doctors are employed in this hospital? Nurses?	__________ doctors __________ nurses
A7	In general, what is the average distance patients travel to get to this hospital?	Distance: Time:
A8	Does the catchment population of this hospital have access to safe water?	1) Yes 2) No 99) I do not know Comments:
A9	How often are there water outages or is the water service intermittent from the municipal water source?	_______times a day/week/month 1) Never Comments:
Water Sources, Availability, and Demand		
A10 A10a	What water sources are available in this hospital? (Mark all that apply, specifying if necessary)	1) Tap (public) Source: 1) Well 2) Surface Water 88) Other 2) Tap (private) 3) Tanker Truck 88) Other (specify):
A11	What is the principle source of drinking water in this hospital?	1) Tap (public) 2) Tap (private) 3) Tanker Truck 88) Other (specify):
A12	Are there times when water from this principle source is not available?	1) Yes 2) No→SKIP a A14
A13	**If yes**, why is it not available? (select all options that apply)	1) Season (dry or rainy) 2) Other reason (specify):

Control Hospital Director

A14	Is potable water available in every department today? [If not, why not?]	1) Yes 2) No 99) I do not know Comments:
A15	Are there times when water is stored before using? Why?	1) Yes 2) No 99) I do not know Comments:
 A16 A17 A18 A19	Who drinks water directly from the tap? **Staff** **Patients** **Visitors/Care Takers** **Others**	 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know Specify:___________
A20	What are other sources of drinking water in this hospital?	1) bottled treated water 2) purchased water 88) other, specify:____________
A21	Who drinks from these other sources that you just mentioned?	Source__________ Users___________________ Source__________ Users___________________ Source__________ Users___________________ Source__________ Users___________________ Comments:
A22	**Observation**: Describe the type of container and mechanism used to obtain water from the tap or bottle.	1) Plastic bottle 2) Cup from home 88) Other, specify:____________
A23 A24	Are there times when people collect water from the hospital to take home with them? **If yes**, approximately how many people each day?	1) Yes 2) No →SKIP to A25 99) I do not know →SKIP to A25 _______ people/day
A25 A25a A25b A25c A25d	What source of water do staff use to: A. Wash their hands B. Cook C. For laundry D. Wash medical equipment	 A] 1) treated water 2) un-treated water B] 1) treated water 2) un-treated water C] 1) treated water 2) un-treated water D] 1) treated water 2) un-treated water Comments:

Control Hospital Director

On-Site Capacity		
Water Treatment		
A26 A26a A26b A26c A26d A26e	Is there a person responsible for: F. Ensuring there is water available in every department G. Ensuring water gets to all toilets and sinks H. Ensuring there are hygiene and cleaning supplies (soap, toilet paper) I. Ensuring there is chlorine J. Ensuring the water is clean	A. 1) Yes 2) No [Name/Role_________________] B. 1) Yes 2) No [Name/Role_________________] C. 1) Yes 2) No [Name/Role_________________] D. 1) Yes 2) No [Name/Role_________________] E. 1) Yes 2) No [Name/Role_________________]
A28	How long have you worked here as the director?	
A60	What would be the value of a water treatment system in this hospital?	
A61	Do you have plans for providing treated water in this hospital in the future?	1) Yes 2) No 99) I do not know Comments:
Accountability		
A31	Does this hospital have a written record for any of the following activities? Who is responsible for each?	
A31a	Availability of water	1) Yes 2) No 3) N/A ________________________
A31b	Water treatment	1) Yes 2) No 3) N/A ________________________
A31c	Cleaning water containers	1) Yes 2) No 3) N/A ________________________
A31d	Cleaning water cisterns	1) Yes 2) No 3) N/A ________________________
A31e	Cleaning the toilets or latrines	1) Yes 2) No 3) N/A ________________________
A31f	Restocking soap for hand-washing	1) Yes 2) No 3) N/A ________________________
A31g	Repairing taps and broken sinks	1) Yes 2) No 3) N/A ________________________
A31h	Other	Specify:
Institutional Support (the MOH)		
Support for Operations and Maintenance, Repairs, and Replacements		
A37 A37a A37b A37c A37d A37e	Does the MOH offer: A. Funds for water treatment B. Funds for infrastructure (tubing, sinks) C. Staff training D. Recognition of your achievements in the provision of safe water E. Other (Specify):	A. 1) Yes 2) No 99) Don't know B. 1) Yes 2) No 99) Don't know C. 1) Yes 2) No 99) Don't know D. 1) Yes 2) No 99) Don't know E. Describe:
Feedback Mechanisms between Donors, Government, Institutions, and Community		
A38	Do you have communications with the MOH about the water system?	

Control Hospital Director

Finance Mechanisms		
A41	Is there a specific budget for the water system? [if not, please explain the system used to obtain consumables and parts]	1) Yes 2) No 99) I do not know Comments:
A42	Is there a record of the costs associated with the water system? [ask to see it]	1) Yes 2) No 99) I do not know Comments:
A43	To whom do you report your costs?	
Satisfaction and Perceived Value		
A54	In your opinion, what distinguishes this hospital from other public hospitals?	
A55 A56 A56a A56b A56c A56d A56e	What methods do you use to protect immuno-compromised patients? Do you use treated water for: A) Direct observation therapy for tuberculosis? B) Medications for persons with HIV/AIDS? C) The preparation of oral rehydration salts? D) In the preparation for surgical and maternal procedures? E) Other specific uses: Specify: ____________	A] 1) Yes 2) No 99) I do not know B] 1) Yes 2) No 99) I do not know C] 1) Yes 2) No 99) I do not know D] 1) Yes 2) No 99) I do not know E) Describe: ________________
Personal Information (Observations)		
A57	Sex of the director:	1) Male 2) Female
A58	Age of the director:	1) ≤ 30 years 2) >30 years 3) ≥ 60 years
A59 A59a A59b A59c A59d	**Opinion of the investigator:** On a scale of 1-5, 5=very committed 1=not committed: A. How committed was the participant to respond to the questions asked? B. What was the participant's level of knowledge about the practices at this hospital? C. How willing was the participant to give examples and additional information? D. What was the participant's level of commitment to the provision of clean water?	A. 1 2 3 4 5 B. 1 2 3 4 5 C. 1 2 3 4 5 D. 1 2 3 4 5 Comments and observations:

Control Hospital Clinical Staff

BH1	Date		BH4	Hospital Name	
BH2	Start Time		BH5	Name of Investigator(s)	
BH3	End Time				

B1	Role of Participant:	1) Doctor 2) Nurse 88) Other, specify:
B2	Sex of Participant:	1) Male 2) Female
B3	Age of Participant:	1) ≤ 30 years 2) >30 years 3) ≥ 60 years
B4 B5 B6	Where does the water in this hospital come from? Is it treated before use? How?	Source: Treated: 1) Yes 2) No 99) I do not know Method of treatment: Comments:
B7	In your opinion, is the water from the tap safe to drink? Why or why not? [Probe for more information]	1) Yes 2) No 99) I do not know Comments:
B8	How is the water quality in the hospital in comparison to the water you use at home?	1) Worse 2) Equal 3) Better 99) I do not know Comments:
B9	Is contaminated water a problem for the population living near this hospital? Why or why not?	1) Yes 2) No 99) I do not know Comments:
B10 B10a B10b B10c B10d	Who drinks water directly from the tap? **Staff** **Patients** **Visitors/Care Takers** **Others**	 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know Specify:____________
B11	What do the patients say regarding water quality? [explain]	
B12	What would be the benefits of having safe water for your job?	
B13	For who is this hospital is safe water most important? For what purpose?	
B14 B14a B14b B14c B14d	Do you use tap water for: **Washing your hands** **Drinking** **Washing medical equipment** **Other use**	 1) Yes 2) No 1) Yes 2) No 1) Yes 2) No 1) Yes 2) No Specify:____________________

Control Hospital Clinical Staff

B15 B15a B15b B15c B15d B15e	What methods do you use to protect immuno-compromised patients? Do you use treated water for: A) Direct observation therapy for tuberculosis? B) Medications for persons with HIV/AIDS? C) The preparation of oral rehydration salts? D) In the preparation for surgical and maternal procedures? E) Other specific uses: Specify: __________	 A] 1) Yes 2) No 99) I do not know B] 1) Yes 2) No 99) I do not know C] 1) Yes 2) No 99) I do not know D] 1) Yes 2) No 99) I do not know E) Describe: _______________
B18	What types of information do you offer your patients regarding safe water?	
 B17 B17a B17b B17c B17d	Opinion of the investigator: On a scale of 1-5, 5=very committed 1=not committed: A. How committed was the participant to respond to the questions asked? B. What was the participant's level of knowledge about the practices at this hospital? C. How willing was the participant to give examples and additional information? D. What was the participant's level of commitment to the provision of clean water?	A. 1 2 3 4 5 B. 1 2 3 4 5 C. 1 2 3 4 5 D. 1 2 3 4 5 Comments and observations:

Control Hospital Staff

CH1	Date		CH4	Hospital Name	
CH2	Start Time		CH5	Name of Investigator(s)	
CH3	End Time				

C1	Role of Participant:	1) Receptionist 2) Laboratory Technician 3) Cook 4) Administrator (bookkeeper) 88) Other, specify:
C2	Sex of Participant:	1) Male 2) Female
C3	Age of Participant:	1) ≤ 30 years 2) >30 years 3) ≥ 60 years
C4 C5 C6	Where does the water in this hospital come from? Is it treated before use? How?	Source: Treated: 1) Yes 2) No 99) I do not know Method of treatment: Comments:
C7	In your opinion, is the tap water safe to drink? Why or why not?	1) Yes 2) No 99) I do not know Comments:
C8	How is the water quality in the hospital in comparison to the water you use at home?	1) Worse 2) Equal 3) Better 99) I do not know Comments:
C9 C9a C9b C9c C9d	Who drinks water directly from the tap? **Staff** **Patients** **Visitors/Care Takers** **Others**	 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know Specify:____________
C10	What would be the benefits of having safe water for your job?	
C11 C11a C11b C11c C11d C11e C11f C11g	Do you tap water for: **Washing your hands** **Cooking** **Drinking** **Washing dishes** **Washing medical or laboratory equipment** **For laboratory analysis** **Other use**	 1) Yes 2) No 1) Yes 2) No 1) Yes 2) No 1) Yes 2) No 1) Yes 2) No 1) Yes 2) No Specify:
C12	For who is this hospital is safe water most important? For what purpose?	
C13	Is contaminated water a problem for the population living near this hospital? Why or why not?	1) Yes 2) No 99) I do not know Comments:

Control Hospital Staff

C17	**Opinion of the investigator:** On a scale of 1-5, 5=very committed 1=not committed:	
C17a	A. How committed was the participant to respond to the questions asked?	A. 1 2 3 4 5
C17b	B. What was the participant's level of knowledge about the practices at this hospital?	B. 1 2 3 4 5
C17c	C. How willing was the participant to give examples and additional information?	C. 1 2 3 4 5
C17d	D. What was the participant's level of commitment to the provision of clean water?	D. 1 2 3 4 5 Comments and observations:

Control Hospital Patients and Visitors

DH1	Date		DH4	Hospital Name	
DH2	Start Time		DH5	Name of Investigator(s)	
DH3	End Time				

D1	Role of Participant:	1) Patient 2) Visitor 88) Other _____________
D2	Sex of Participants:	1) Male 2) Female
D3	Age of Participant:	1) ≤ 30 years 2) >30 years 3) ≥ 60 years
D4	How much time did it take you to get to the hospital today?	__hours __minutes
D5	How long have you been here in the hospital this visit?	__hours __minutes
D6	Have you used a sink in the hospital to wash your hands today?	1) Yes 2) No 3) I do not remember
D7	Have you consumed hospital tap water today?	1) Yes 2) No 3) I do not remember
D8	**If they have children**, have your children consumed hospital tap water today?	1) Yes 2) No 99) I do not know
D9	**If they have consumed hospital tap water**: How does the hospital tap water compare to the water you use in your house? Flavor? Security?	1) Worse 2) Equal 3) Better 99) I do not know Comments:
D10	**If they have not consumed hospital tap water**, why have you not consumed hospital tap water?	
D11	In your house, do you drink tap water, purchased water, or both?	1) Tap 2) Purchased water 3) Both
D12	Do you have a tap in your house?	1) Yes 2) No
D13 D13a	Do you treat your drinking water in your house? **If yes**, How?	1) Yes 2) No →SKIP to D14 99) Don't know→SKIP to D14 Comments: Treatments [in the affirmative case] 1) Boil 2) Filter 3) Chlorine 88) Other
D14	Is contaminated water a problem in your community? Why or why not?	1) Yes 2) No 99) I do not know Comments:

Control Hospital Maintenance Staff

HH1	Date		HH4	Hospital Name	
HH2	Start Time		HH5	Name of Investigator(s)	
HH3	End Time				

Cisterns (ask to see all cisterns, including those not in use)			
Ha	**1st cistern**	Hb	**2nd cistern**
H1a	Describe the cistern site:	H1b	Describe the cistern site:
H2a	Financed by:	H2b	Financed by:
H3a	Year constructed:	H3b	Year constructed:
H4a	Capacity:	H4b	Capacity:
H5a	Is the cistern in use? 1) Yes 2) No	H5b	Is the cistern in use? 1) Yes 2) No
H6a	What type of cistern is it? 1) Above ground 2) Below ground	H6b	What type of cistern is it? 1) Above ground 2) Below ground
H7a	What is the cistern made of? 1) Cement 2) Plastic 88) Other: _____________	H7b	What is the cistern made of? 1) Cement 2) Plastic 88) Other: _____________
H8a	Does the cistern leak? 1) Yes 2) No	H8b	Does the cistern leak? 1) Yes 2) No
H9a	Is there a screen to prevent the entry of debris and insects into the cistern? 1) Yes 2) No	H9b	Is there a screen to prevent the entry of debris and insects into the cistern? 1) Yes 2) No
H10a	Is there a tap on the cistern? 1) Yes 2) No→SKIP to H12a	H10b	Is there a tap on the cistern? 1) Yes 2) No→SKIP to H12b
H11a	If there is a tap, does it work? 1) Yes 2) No	H11b	If there is a tap, does it work? 1) Yes 2) No
H12a	Is the cistern connected to the piped water supply? 1) Yes 2) No	H12b	Is the cistern connected to the piped water supply? 1) Yes 2) No
H13a	Is the water in the cistern filtered? 1) Yes 2) No	H13b	Is the water in the cistern filtered? 1) Yes 2) No
H14a	Is the water in the cistern chlorinated? 1) Yes 2) No→SKIP to H1b 99) Don't Know	H14b	Is the water in the cistern chlorinated? 1) Yes 2) No→SKIP to H16 99) Don't Know
H15a	**If yes**, what is the chlorine residual level? _________________	H15b	**If yes**, what is the chlorine residual level? _________________
Electricity			
H16	In the last week, how many times has the electricity gone out?	_________ times	

Control Hospital Maintenance Staff

Sanitation		
H17	What types of toilets are available in the hospital?	1) Toilet 2) Pour flush toilet 3) Tap flush toilet 4) Latrine 88) Other (specify):
H18	What are the common maintenance problems associated with toilets in the hospital? [probe for specific examples]	1) Low water pressure 2) Broken ceramic parts 88) Other (specify): Comments:
Maintenance and Financing for Sanitation		
H19	Who cleans the bathrooms?	Name: _______________ Role: _______________
H20	How often are the bathrooms cleaned?	______ times per day/week/month
H21	Where does the wastewater from the hospital go?	1) Municipal sewer system 2) Wastewater pond 88) Other (specify): 99) I do not know
H22	Is the wastewater treated before being returned to the environment?	1) Yes 2) No 99) I do not know

Control Hospital Maintenance Staff

On-Site Capacity		
Repairs and Institutional Support		
H45	Who do you call when there is a problem with the system?	
H46	Have you ever sought external help for repairs? [explain]	
H47	Can you buy important parts for the water system locally?	1) Yes 2) No 99) I do not know Comments:
H48 H48a H48b H48c H48d	Have any of the parts of the system been repaired or replaced? Which part? When? By who? Where did you get the parts for the repair?	 ____/____/______ Name: ________________ Role: _______________
H49	Are there parts of the water system that have been successfully repaired or replaced in the last year?	1) Yes 2) No 99) I do not know ***Describe specific examples*:**
H50	Are there parts of the water system that function poorly or are broken currently because the responsible person cannot fix them?	1) Yes 2) No 99) I do not know ***Describe specific examples*:**
Demographic Information		
H56	Sex of Participant:	1) Male 2) Female
H57	Age of Participant:	1) ≤ 30 years 2) >30 years 3) ≥ 60 years
H58	What is the highest education level you have completed?	
H59	How long have you been working here at this hospital?	________months/years
Other (opinion of the investigator)		
H60 H60a H60b H60c H60d	**Opinion of the investigator:** On a scale of 1-5, 5=very committed 1=not committed: A. How committed was the participant to respond to the questions asked? B. What was the participant's level of knowledge about the practices at this hospital? C. How willing was the participant to give examples and additional information? D. What was the participant's level of commitment to the provision of clean water?	A. 1 2 3 4 5 B. 1 2 3 4 5 C. 1 2 3 4 5 D. 1 2 3 4 5 Comments and observations:

Water Samples

MH1	Date		MH4	Hospital Name	
MH2	Start Time		MH5	Name of Investigator(s)	
MH3	End Time				

Sample 1		
M1.1	Is the water flowing today?	1) Yes 2) No →SKIP
M1.2 M1.3	Collect two water samples	ID 1: _______ _______ _______ ID 2: _______ _______ _______
M1.4	Describe the location of the tap	
M1.5	Measure the flow	_____sec to fill 100 mL with the tap totally open
M1.6	Is the water filtered? Select all that apply.	1) Membrane 2) Amiad 3) No 88) Other (specify):
Sample 2		
M2.1	Is the water flowing today?	1) Yes 2) No →SKIP
M2.2 M2.3	Collect two water samples	ID 1: _______ _______ _______ ID 2: _______ _______ _______
M2.4	Describe the location of the tap	
M2.5	Measure the flow	_____ sec to fill 100 mL with the tap totally open
M2.6	Is the water filtered? Select all that apply.	1) Membrane 2) Amiad 3) No 88) Other (specify):
Sample 3		
M3.1	Is the water flowing today?	1) Yes 2) No →SKIP
M3.2 M3.3	Collect two water samples	ID 1: _______ _______ _______ ID 2: _______ _______ _______
M3.4	Describe the location of the tap	
M3.5	Measure the flow	_____ sec to fill 100 mL with the tap totally open
M3.6	Is the water filtered? Select all that apply.	1) Membrane 2) Amiad 3) No 88) Other (specify):

Water Samples

Sample 4		
M4.1	Is the water flowing today?	1) Yes 2) No →SKIP
M4.2 M4.3	Collect two water samples	ID 1: _______ _______ _______ ID 2: _______ _______ _______
M4.4	Describe the location of the tap	
M4.5	Measure the flow	_____ sec to fill 100 mL with the tap totally open
M4.6	Is the water filtered? Select all that apply.	1) Membrane 2) Amiad 3) No 88) Other (specify):
Sample 5		
M5.1	Is the water flowing today?	1) Yes 2) No →SKIP
M5.2 M5.3	Collect two water samples	ID 1: _______ _______ _______ ID 2: _______ _______ _______
M5.4	Describe the location of the tap	
M5.5	Measure the flow	_____ sec to fill 100 mL with the tap totally open
M5.6	Is the water filtered? Select all that apply.	1) Membrane 2) Amiad 3) No 88) Other (specify):
Sample 6		
M6.1	Is the water flowing today?	1) Yes 2) No →SKIP
M6.2 M6.3	Collect two water samples	ID 1: _______ _______ _______ ID 2: _______ _______ _______
M6.4	Describe the location of the tap	
M6.5	Measure the flow	_____ sec to fill 100 mL with the tap totally open
M6.6	Is the water filtered? Select all that apply.	1) Membrane 2) Amiad 3) No 88) Other (specify):

Observations

EH1	Date		EH4	Hospital Name	
EH2	Start Time		EH5	Name of Investigator(s)	
EH3	End Time				

Sinks									
Number	Functions	Soap	Staff	Patients	Number	Functions	Soap	Staff	Patients
1					42				
2					43				
3					44				
4					45				
5					46				
6					47				
7					48				
8					49				
9					50				
10					51				
11					52				
12					53				
13					54				
14					55				
15					56				
16					57				
17					58				
18					59				
19					60				
20					61				
21					62				
22					63				
23					64				
24					65				
25					66				
26					67				
27					68				
28					69				
29					70				
30					71				
31					72				
32					73				
33					74				
34					75				
35					76				
36					77				
37					78				
38					79				
39					80				
40					81				
41					82				

Observations

FH1	Date		FH4	Hospital Name	
FH2	Start Time		FH5	Name of Investigator(s)	
FH3	End Time				

Taps					
Number	Functions	Handle Present	Soap	Staff	Patients
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

Educational Messages		
G1	Were any messages about safe water observed?	1) Yes 2) No →SKIP to G3 99) Don't Know → SKIP to G3
G2	Where were the messages about safe water observed?	
G3	Were any messages about hand-washing observed?	1) Yes 2) No →SKIP to G5 99) Don't Know → SKIP to G5
G4	Where were the messages about hand-washing observed?	
G5	Were any messages about bathroom use observed?	1) Yes 2) No →SKIP to H1a 99) Don't Know → SKIP to H1a
G6	Where were the messages about bathroom use observed?	

G7: Message(s):

Appendix 2. Sustainability Metric

Technical Feasibility

Topic	Broad Question	Code	Survey Questions and Metrics	0	1	2	3	4
Water Source and Availability	Is there a reliable water source that provides the quantity and availability of water needed to meet demand?	A10	What water sources are available in this hospital?	The principle source of water is intermittent and it is necessary for water to be stored. Stored water is relied upon every day. Water is not available in more than two departments. Having to bring in water from another source (tanker truck) is common.	The principle source of water is intermittent and it is necessary for water to be stored. Stored water is relied upon during most days of the week in at least one season but they rarely run out of water. Water is not available in more than two departments.	The principle source of water is intermittent and it is necessary for water to be stored. However, most days of the week, stored water is not relied upon. Water is not available in fewer than two departments.	The principle source of water is intermittent and it is necessary for water to be stored. However, most days of the month, stored water is not relied upon. Water is available in all departments.	The principle source of water is dependable and while water may be stored it is sufficient to meet demand. Potable water is available in every department within the hospital.
		A11	What is the principle source of drinking water?					
		A12	Are there times when water from this principle source is not available?					
		A13	If yes, why?					
		A20	What are other sources of drinking water in this hospital?					
		A15	Are there times when the water is stored before using? Why?					
		A9	How often are there water outages or is the water service intermittent from the municipal water source?					
Local Access to Replacement Parts	Are replacement parts for foreseeable issues during the life of the filtration system available locally?	H47	Can you buy important parts for the system locally?	All replacement parts for the water system are produced and sold in the US exclusively.	Replacement parts for minor repairs can be purchased locally (tubes, glue, valves) but no parts for major repairs can be purchased within Honduras.	All replacement parts for minor repairs can be purchased locally (tubes, glue, valves) and some parts for major repairs can be purchased within Honduras (replacement parts for chlorine doser or filters).	All replacement parts for minor repairs can be purchased locally (tubes, glue, valves) and many parts for major repairs can be purchased locally (replacement parts for chlorine doser or filters).	All replacement parts for the water system can be purchased within Honduras, most of them locally.
		GE3	Are all of the parts for the water filtration system manufactured within the US? Are there any parts that can be purchased in Honduras?					

Technical Feasibility, continued

Topic	Broad Question	Code	Survey Questions and Metrics	0	1	2	3	4
Current Infrastructure	Is the hospital committed to routine maintenance of infrastructure of water, sanitation, and hygiene?	E	Sinks	Hospital infrastructure relating to water, sanitation, and hygiene is not maintained. The majority of the sinks observed were non-functional.	Hospital infrastructure is not consistently maintained. At least 65% of sinks observed were functional.	Hospital infrastructure relating to water, sanitation, and hygiene is moderately maintained. At least 75% of all sinks observed were functional.	Hospital infrastructure relating to water, sanitation, and hygiene is mostly maintained. At least 85% of all sinks observed were functional.	Hospital infrastructure relating to water, sanitation, and hygiene is well maintained. At least 95% of all sinks observed were functional.
		H1-15	Cistern					
		H16	In the last week, how many times has the electricity gone out?					
		H17	What types of toilets are available?					
		H18	What are the common maintenance problems associated with the toilets?					
		H21	Where does the sewage go?					
		H22	Is the sewage water treated before it is returned to the environment?					
Water Quality Testing	Does the tap water throughout the hospital meet WHO standards for microbial water quality?	M		Fewer than 40% of all samples met WHO standards for microbial water quality.	Between 40-59% of all samples met WHO standards for microbial water quality.	Between 60-79% of all samples met WHO standards for microbial water quality.	Between 80-99% of all samples met WHO standards for microbial water quality.	100% of all samples met WHO standards for microbial water quality.
	Does the tap water throughout the hospital meet standards for chlorine residual?	M		Fewer than 20% of samples met standards for chlorine residual.	Between 20-39% of samples met standards for chlorine residual.	Between 40-59% of samples met standards for chlorine residual.	Between 60-79% of samples met standards for chlorine residual.	More than 80% of samples met standards for chlorine residual.

On-Site Capacity

Topic	Broad Question	Code	Survey Questions and Metrics	0	1	2	3	4
Organization and Communication	Is there a clearly defined organizational structure? Are all key tasks accounted for?	A26	Who is responsible for:	There is no organizational structure for activities related to the water system within the hospital. Most key tasks are not accounted for or responsibility for each task is uncertain.	There is little organizational structure for activities related to the water system. While people may know their role, the task are not accomplished.	There is a loose organizational structure in place but most key tasks are accounted for and most people know their role.	There is basic organizational structure in place at the hospital, and all key tasks are accounted for and the majority of people know their roles.	There is a clear organizational structure within the hospital, everyone knows their specific roles with regard to the water filtration system, and all key tasks are accounted for.
		A26a	Ensuring that there is water available in every department					
		A26b	Ensuring that water gets to all toilets and sinks					
		A26c	Ensuring that there are hygiene and cleaning supplies (soap, toilet paper)					
		A26d	Ensuring that there is chlorine					
		A26e	Ensuring the water is clean					
		A27	What is your (director's) personal role in supplying potable water to this hospital?					
		H29	What is your (maintenance staff) role in the supply of safe water in this hospital?					
		H24	Who is responsible for the GE water system?					
	Is there successful communication between the hospital director, the maintenance staff, and the laboratory staff?	A62a	How often do you (the director) talk to the maintenance staff about the water system?	There is very little to no communication between the director, maintenance staff, and laboratory staff about the water system. The maintenance staff does not inform anyone when they shut the system off.	There is some communication between the director, maintenance and laboratory staff but it is unscheduled and there is evidence of a lack of communication regarding key issues.	There is a loose schedule for communication between the three parties but communication happens intermittently and some key issues are not communicated.	There is regular and scheduled communication between all three parties; however, a few key issues are not communicated OR there are not scheduled meetings; however, all key issues are communicated.	There is regular and scheduled communication between all three parties about the water system. All key issues are communicated. The maintenance staff informs the director and the laboratory staff before shutting down the water system.
		A62b	What did you (the director and maintenance staff) talk about the last time you spoke about the water system?					
		A62c	Does the maintenance staff inform you (the director) when the system is shut down?					
		A63a	How often do you (the director) talk to the laboratory staff about the water system?					
		A63b	What did you (the director and laboratory staff) talk about the last time you spoke about the water system?					

On-Site Capacity, continued

Topic	Broad Question	Code	Survey Questions and Metrics	0	1	2	3	4
Organization and Communication, **continued**	Is there successful communication between the hospital director, the maintenance staff, and the laboratory staff? **[continued]**	A64a	How often do you (the director) talk to the administrator about the water system?	There is very little to no communication between the director, maintenance staff, and laboratory staff about the water system. The maintenance staff does not inform anyone when they shut the system off.	There is some communication between the director, maintenance and laboratory staff but it is unscheduled and there is evidence of a lack of communication regarding key issues.	There is a loose schedule for communication between the three parties but communication happens intermittently and some key issues are not communicated.	There is regular and scheduled communication between all three parties; however, a few key issues are not communicated OR there are not scheduled meetings; however, all key issues are communicated.	There is regular and scheduled communication between all three parties about the water system. All key issues are communicated. The maintenance staff informs the director and the laboratory staff before shutting down the water system.
		A64b	What did you (the director and the administrator) talk about the last time you spoke about the water system?					
		C18	When was the last time that you (the laboratory technician) spoke to the director about the chlorine levels?					
		H61a	How often do you (the maintenance staff) talk to the director about the water system?					
		H61b	**Repeat question to maintenance staff:** What did you (the director and maintenance staff) talk about the last time you spoke about the water system?					
		H61c	Do you (the maintenance staff) inform the director when the water system is shut down?					
		H62a	How often do you (the maintenance staff) talk to the laboratory staff about the water system?					
		H62b	What did you (the maintenance staff and laboratory staff) talk about the last time you spoke about the water system?					
		H62c	Do you (the maintenance staff) inform the laboratory when the water system is shut down?					
		H62d	Do you(the maintenance staff) inform the laboratory when you change to a new chlorine level?					

On-Site Capacity, continued

Topic	Broad Question	Code	Survey Questions and Metrics	0	1	2	3	4
Training and Capacity Strengthening	Are there sufficient trained personnel to manage, maintain, and operate the water system?	A28	How long have you been working here as the director?	There are not enough trained personnel to maintain the water system and there have not been any efforts made to increase the number of trained personnel. The hospital will always rely on GE for operations and maintenance support.	Rudimentary management and operations are accomplished. However, additional capacity building is needed in at least two of the following areas: lab, management, maintenance. The hospital is self-reliant for some operation and maintenance; however, they depend on GE for the majority of it.	Essential management and operations are accomplished. However, additional capacity building is needed in one of the following areas: lab, management, maintenance. The hospital is self reliant for many operation and maintenance issues; however, they do not have any plans to be self-reliant in the next 5 years.	There are a sufficient number of trained personnel to manage, maintain, and operate the water system. However, additional capacity building would be beneficial to sustainably manage and operate the system. The hospital is on the road to being able to maintain and operate the water system without support from GE within the next 5 years.	There are a sufficient number of trained personnel to manage, maintain, and operate the water system. The hospital is capable of holding their own follow-up trainings. The hospital can operate and maintain the water system without support from GE.
		H59	How long have you (maintenance staff member) been working in this hospital?					
		H58	What is your (the maintenance staff member's) highest level of education?					
		A34	Who was trained in using the water filtration system?					
		H23	**Repeat question to maintenance staff:** Who was trained in using the water filtration system?					
		A35	Has GE held any follow-up trainings? How many? What was the content?					
		H25	Normally, how many people do maintenance work on the water system?					
		H26	How many days a week is there someone present who knows how to manage the water system?					
		H65	Do you feel as though you need (or want) more training in order to better maintain the water system?					
		GE4	How often do you visit each hospital for operations and maintenance checkups? Do you foresee a time when these checkups will no longer be necessary?					
		GE7	What do you see as GE's role in the management, operations, and maintenance of these water filtration systems in 5 years? 10 years?					
		GE5	Have you revisited any of the hospitals for further training sessions? How frequently does this occur? Do you foresee a time when hospitals will be able to conduct their own training sessions?					

On-Site Capacity, continued

Topic	Broad Question	Code	Survey Questions and Metrics	0	1	2	3	4
Maintenance	Are daily, weekly, and monthly recommended maintenance procedures followed?	H30	How often do you run the backwash? (if manual)	The daily, weekly, and monthly recommended tasks are often not completed and some have never been completed.	The daily, weekly, and monthly recommended tasks are completed irregularly. Daily tasks are generally completed at least once a week, and weekly tasks at least once a month.	The daily, weekly, and monthly recommended tasks are generally completed but not as frequently as is recommended. Daily tasks often may not be completed during non-peak times (like on the weekends).	All daily, weekly, and monthly recommended tasks are usually completed, but are occasionally forgotten.	All daily, weekly, and monthly recommended tasks are completed as recommended, if not more frequently.
		H31	How often do you check to make sure the backwash is running (if automated)?					
		H32	How often do you check the chlorine levels?					
		H35	How often do you check the pressure at the entry and exit to see if there is a significant pressure drop between the filters?					
		H36	How often do you scrub and backwash the Amiad filters?					
		H37	How often do you check the chlorine tank to make sure that there are acceptable levels of chlorine?					
		H33	How often do you add more chlorine to the system?					
		H34	How often do you inventory chlorine supplies?					
		H40	How often do you wipe down the equipment?					
		H41	How often do you verify that the area around the filter is not being used as storage for non-filter related items?					
		H42	How often do you check for leaks and repair the ones that exist?					
		H44	What do you do when there is a pressure drop?					
		H43	How often do you remove the top of the filter housing and rinse the filters?					

On-Site Capacity, continued

Topic	Broad Question	Code	Survey Questions and Metrics	0	1	2	3	4
Maintenance, **continued**	Is there limited downtime in the operation of the water system?	A14	Is potable water available in every department today (if no, why not?)	The water system has experienced downtime for at least 30 days within the past 2 months.	The water system has experienced downtime for at least a few hours multiple times a week OR maintenance issues make the system unreliable.	The water system has experienced downtime less than once a week, for no more than a couple hours at a time.	The only downtime the water system has experienced in the past 2 months has been due to repairs being made to the system and these have been minimal.	The water system has experienced no downtime within the past 2 months.
		H27	How many days in the last 2 months have you not used the water system? Why?					
Repairs	Does the hospital maintain the capability to repair the water system when needed?	H46	Who do you call when there is a problem with the system?	The maintenance staff are not knowledgeable as to how to repair the water system or who to contact for help OR the water system is currently broken and there has been no effort made to repair it.	The maintenance staff have demonstrated the capacity to make minor repairs; however, there are currently broken parts and their capacity for major repairs is low or unknown.	The maintenance staff have demonstrated the capacity to make repairs of various complexity; however, broken parts remain and they do not feel comfortable that they can resolve most problems.	The maintenance staff have demonstrated the capacity to make repairs of various complexity; however, the staff do not feel comfortable that they can solve all issues that arise. However, no unresolved repairs exist. The maintenance staff do not feel like they understand the inner workings of the filtration system.	The maintenance staff knows how to repair the water system and feels capable that they could resolve any issues that arise. Any parts that have broken within the past year have been repaired or replaced successfully.
		H47	Has there been a time when you have sought external help for repairs? Explain.					
		H48	Has any part of the system been repaired or replaced? Which part? When? By whom? Where did the parts come from?					
		H49	Have there been parts of the water system that have been successfully repaired or replaced in the past year?					
		H50	Are there parts of the water system that work poorly or are broken currently that the responsible person cannot fix?					
		H64	If part of the system were to stop working, would you (or your team) be capable of repairing the system without external help?					

Accountability

Topic	Broad Question	Code	Survey Questions and Metrics	0	1	2	3	4
Oversight by another entity	Is there oversight by another entity?	A32	What information about water, sanitation, and hygiene does the MOH collect in audits?	There are no outside organizations that monitor water quality in the hospital. The hospital does not have a biosafety committee OR the biosafety committee has never discussed safe water.	There is an outside organization that could monitor water quality and may have done so in the past but there is no formal relationship established. The biosafety committee (if there is one) may discuss water on occasion but no efforts have been made to improve or monitor water quality.	There are outside organizations that occasionally monitor water quality. The biosafety committee regularly discusses water quality and has made efforts to improve or monitor water quality, however, they may not have accomplished improvements.	There are outside organizations that monitor water quality on a regular basis, but they may not share results or have a collaborative relationship. The biosafety committee regularly discusses water quality and has made efforts to improve or monitor water quality.	An outside organization regularly monitors water quality within the hospital. The hospital and the outside organization have a collaborative relationship. The biosafety committee in the hospital is devoted to keeping the hospital water clean.
		A43	To whom do you report your costs?					
		A64	Is there an organization or institution that has monitored the quality of water in the hospital?					
		A67a	Does the hospital have a biosafety committee?					
		A67b	If so, is water one of the themes they discuss?					
	Do the hospital and GE successfully communicate with each other?	A35	Has GE made any follow-up visits? How many?	The hospital and GE do not communicate with each other. GE has not made any follow up visits.	The director and the ambassador communicate semi-regularly but they rarely discuss the water system.	The director and the ambassador discuss the water filtration system occasionally, but key issues are not brought to the attention of GE. If key issues are brought up, they may not be adequately addressed.	The director and the ambassador discuss the filtration system regularly; however, key issues may not adequate be addressed and laboratory and maintenance staff are not involved when applicable.	The hospital and GE regularly communicate specifically about the water filtration system. When applicable, maintenance and laboratory staff also speak with the ambassador.
		A39	How often do you talk to GE? What do you talk to them about?					
		A33	What information does GE ask for?					
		A38	Do you have communication with GE about the water system? How often? What do you discuss?					
		H28	**Repeat question for maintenance staff:** Do you have communication with either GE about the water system? How often? What do you discuss?					
		GE1	Do you have a written agreement with the hospitals where you have donated water filtration systems? If so, what does it include?					
		GE6	How often do GE ambassadors communicate with the hospital directors? Is there a set agenda for communication between the ambassadors and hospital directors? Is there a set schedule for communication?					

Accountability, continued

Topic	Broad Question	Code	Survey Questions and Metrics	0	1	2	3	4
Monitoring Performance	Does the hospital perform monitoring activities?	H63	Does this hospital have a written record for any of the following activities? Who is responsible?	The hospital has no written records of activities regarding safe water, sanitation, and hygiene.	The hospital has some records but they are not well maintained and are out of date.	The hospital maintains some records of activities regarding safe water, sanitation, and hygiene but does not do so consistently or are missing key items.	The hospital maintains records of important activities regarding water, sanitation, and hygiene, but there is room for improvement in maintaining them or including additional items.	The hospital keeps well maintained, up to date records of activities regarding safe water, sanitation, and hygiene.
		H63a	By-passing the system					
		H63b	Measuring chlorine levels					
		H63c	Cleaning of water containers					
		H63d	Repairing taps and broken sinks					
Sources of Funding	Does the hospital rely on external funding for its water system?	A37	Does GE or the MOH provide:	If GE stopped providing funding, the hospital could not maintain the fixed costs associated with the provision of safe water. There is no evidence that the hospital has invested in the provision of safe water.	The hospital is able to cover some of the costs associated with the system but relies on GE for the majority.	The hospital has allocated funding toward the recurring costs but not fixed costs. If GE stopped providing funding, the hospital would struggle to maintain the provision of safe water. There may be an outside organization/ foundation that can support fixed costs.	The hospital has allocated funding for recurring and fixed costs; however, the funding may not be sufficient and is uncertain.	The hospital has allocated funding to both the recurring costs and fixed costs associated with the provision of safe water. There is evidence that the hospital has invested in the provision of safe water.
		A37a	Funds for water treatment					
		A37b	Funds for infrastructure (piping and sinks)					
		A37c	Staff training					
		A37d	Recognition of your achievements in potable water supply					
		A37e	Other					
		A65	Is there any part of the water system that was donated by a company, organization, or international government?					
		A66	Are there other organizations or institutions that finance infrastructure for the provision of water and sanitation in the hospital?					
		GE2	Do you anticipate a time when the hospitals will fund repairs on the water filtration system without GE support?					

Accountability, continued

Topic	Broad Question	Code	Survey Questions and Metrics	0	1	2	3	4
Finances	Is the hospital able to pay reoccurring costs for the system and does it maintain a record of their finances regarding the water system?	A40	How much do chlorine cost on a monthly basis for the water system?	The hospital does not have a specific budget for the water system, it does not keep a record of expenses relating to the water system, and the hospital often cannot pay for chlorine.	The hospital does not have a specific budget for the water system, it does not keep a record of expenses relating to the water system, but it is able to pay for chlorine.	The hospital has a specific budget for chlorine related to the water system and expenses related to chlorine are recorded. However, the budget for the water system does not include other parts or consumables.	The hospital has a specific budget beyond chlorine procurement; however, it does not include all consumables and parts necessary for the system. The vast majority of the time, the hospital has enough chlorine for the system.	The hospital has a specific budget for the water system and keeps a well maintained written record of it. The hospital always has enough chlorine for the water system.
		A41	Is there a specific budget for the water system? (if not, please explain the system used to obtain consumables and parts)					
		C22	**Repeat question for administrator:** Does a specific budget exist for the provision of water in the hospital?					
		A42	Is there a record of the costs associated with the water system?					
		C19	What influences your (the administrator's) decision to buy (or not buy) chlorine for the water system?					
		A44	Has there been a time when chlorine was not bought for the system? Why?					

Institutional Engagement and Support

Topic	Broad Question	Code	Survey Questions and Metrics	0	1	2	3	4
Demand and Awareness	Are staff and patients aware of the water system and the water quality?	B4-6, C4-6	Where does the water in this hospital come from? Is it treated before use? How?	Staff and patients are not aware of the water treatment plant and are generally incorrect in their understanding of the hospital water quality.	There is a limited amount of awareness regarding the water system. Some people drink water from the plant, though not necessarily because they know it is safe.	There is some awareness of the water system among staff, though the knowledge is limited or vague. Some participants drink water from the plant because they believe it to be safe.	The majority of staff are aware of the water system and some are knowledgeable about the process. Over half the participants believe the water from the plant is safe to drink.	Staff are knowledgeable about the water treatment plant. Everyone knows water from the plant is safe to drink.
		B7, C7	In your opinion, is the water from the tap safe to drink?					
		D7, D10	Have you (the patient) drunk from the tap in the hospital? If not, why not?					
	Is treated water accessible and utilized by the population within the hospital?	A16	Does the staff drink water from the tap?	No one (with the exception of those who have no other option) drinks water filtered in the hospital, everyone brings their own drinking water or purchases water.	Few people drink water from the treatment plant. Botellones are still being purchased but are not always available.	While some people drink water filtered in the plant, they are not the majority. Botellones are still being purchased.	While staff has access to filtered water from the plant and they know it is safe, patients and visitors have more limited access or are not generally aware that the tap water is safe. The hospital no longer purchases botellones.	Staff, patients, and visitors alike drink filtered water from the plant (either from the tap or in botellones).
		A17	Do patients drink water from the tap?					
		A18	Do visitors drink water from the tap?					
		A19	Do others drink water from the tap?					
		A21	Who drinks from the other sources mentioned?					
	Is there a demand for the hospital to supply safe water to the community?	A23	Are there times when people collect water at the hospital to take home with them?	People do not take water home with them from the hospital and there is no demand for the hospital to supply safe water to the community or if there is community demand, the hospital could never meet this demand.	A few staff members may take water home with them, however, the hospital could not meet the needs of the community or there is not community demand. Furthermore, there is not institutional support to supply water for the community.	A few staff members may take water home with them, however, the hospital could most likely not meet he needs of the community, even though there is demand for an alternative safe water supply. There may be some institutional support to supply water to the community.	There are a few staff members who take water home with them regularly. The hospital could meet the community's need for an alternative safe water supply. There is some institutional support to supply water to the community.	People regularly take water home from the hospital and may be willing to pay for it, as the hospital could meet the community's need for an alternative safe water supply. There is institutional support to supply water to the community.
		A24	if yes, approximately how many people per day?					
		A8	Does the population living near this hospital have access to safe water?					
		B9, C13, D14	Is contaminated water a problem for the population living near this hospital? Why or why not?					
		A65	In your (director's) opinion, what type of intervention would increase access to safe water in the community?					
		A66	How can the hospital's water filtration system improve access to safe water in the community?					
		A67	If the hospital had the ability to sell safe water, do you think people would buy it? Why?					

Institutional Engagement and Support, continued

Topic	Broad Question	Code	Survey Questions and Metrics	0	1	2	3	4
Satisfaction and Perceived Value	Is the director of the hospital satisfied with the water system?	A48	How is the water quality in this hospital when compared to the water you (the director) use in your house?	The hospital director is completely unsatisfied with water filtration system and would not recommend to another hospital.	The hospital director is mostly unsatisfied with the water filtration system. He would probably not recommend the system to other hospitals.	The hospital director is somewhat satisfied with the water filtration system. He knows it has its problems but he would probably recommend the system to other hospitals.	The hospital director is mostly satisfied with the water filtration system. He would recommend the system to other hospitals.	The hospital director is completely satisfied with water filtration system and would definitely recommend the system to other hospitals.
		A49	Is the taste of the water satisfactory?					
		A50	Is the water pressure satisfactory?					
		A51	Are the maintenance costs for the system satisfactory?					
		A52	In general, does the water filtration system satisfy your hospital's needs?					
		A53	Would you recommend this water system to other hospitals? Why or why not?					
	Is the maintenance staff satisfied with the water system?	H54	**Repeat question for the maintenance staff:** Would you recommend this water system to other hospitals? Why or why not?	The maintenance staff is completely unsatisfied with water filtration system and would not recommend to another hospital.	The maintenance staff is mostly unsatisfied with the water filtration system. They would probably not recommend the system to other hospitals.	The maintenance staff is somewhat satisfied with the water filtration system. They know it has its problems but they would probably recommend the system to other hospitals.	The maintenance staff is mostly satisfied with the water filtration system. They would recommend the system to other hospitals.	The maintenance staff is completely satisfied with water filtration system and would definitely recommend the system to other hospitals.
		H51	What is the hardest part about this water system?					
		H52	What is the easiest part about this water system?					
		H53	What can GE do to improve this water system?					
	Is the hospital director committed to the sustainability of the water system?	A29	What are your (director's) goals for the water filtration system? Do you feel like you are achieving them? Why?	The hospital director does not see a future for the water filtration system in his hospital.	The hospital director is unsure of the future of the water filtration system in the hospital. He has goals but has not taken steps to achieve them.	The hospital director has goals for the water filtration system and has set plans in motion for some of them.	The hospital director has both short-term and long-term goals for the water filtration system and has set plans in motion for some of them.	The hospital director is committed to maximizing the water filtration system's full potential.
		A30	Where do you (the director) see the water filtration system in 5 years? Where would you like to see it?					

Institutional Engagement and Support, continued

Topic	Broad Question	Code	Survey Questions and Metrics	0	1	2	3	4
Engagement of Hospital Director and Staff	Are the hospital director and staff committed to the provision of clean water?		On a scale of 1-5 where 5=very committed and 1=not committed:	Neither the hospital director nor the hospital staff are engaged or committed to the provision of safe water. (1)	There are a few hospital staff engaged or committed to safe water; however, they are the minority. (2)	The director and some staff are engaged and committed to the provision of safe water in the hospital, but they are not the majority. (3)	The director and most hospital staff are engaged and committed to the provision of safe water in the hospital. (4)	Both the hospital director and the staff are devoted to improving the provision of safe water within their hospital. (5)
		A57a, B17a, C17a, H59a	How committed was the participant to respond to questions asked?					
		A57b, B17b, C17b, H59b	What was the participant's level of knowledge about the practices at this hospital?					
		A57c, B17c, C17c, H59c	How willing was the participant to give examples and additional information?					
		A57d, B17d, C17d, H59d	What was the participant's level of commitment to the provision of clean water?					
		A47	What actions do you take for the hospital to promote availability and knowledge about safe water to staff and patients?					
Educational Messaging	Does the hospital provide educational materials regarding safe water, sanitation, and hygiene practices?	G1	Did you observe any messages regarding safe water?	No educational messaging regarding safe water, sanitation, or hygiene practices were visible during the hospital visit.	Educational messaging regarding safe water, sanitation, or hygiene practices were observed infrequently and not in both staff and patient areas.	Educational messaging regarding safe water, sanitation, or hygiene practices were observed in several locations and were visible to both patients and staff. However, the messages were not catchy or engaging.	Educational messaging regarding safe water, sanitation, or hygiene practices were observed in several locations and were visible to both patients and staff. Some messages were engaging/catchy but most were not.	Compelling educational messaging regarding safe water, sanitation, and hygiene practices were very visible in places where both patients and staff can see them.
		G2	Where did you observe these messages regarding safe water?					
		G3	Did you observe any messages regarding hand washing?					
		G4	Where did you observe these messages regarding hand washing?					
		G5	Did you observe any messages regarding bathroom usage?					
		G6	Where did you observe these messages regarding bathroom usage?					
		G7	Messages observed:					