Distribution Agreement

Signature:

________________________________ _______________

Ledor Sira-Idee Igboh Date

Evaluation of the Sustainability and Impact on Water Quality of Decentralized Water Treatment Systems Installed by the General Electric (GE) Foundation in Six Government-run Hospitals in Ghana.

By

Ledor Sira-Idee Igboh
Master of Public Health

Department of Global Environmental Health

Christine Moe, PhD
Committee Chair

Paige Tolbert, PhD
Committee Member

Evaluation of the Sustainability and Impact on Water Quality of Decentralized Water Treatment Systems Installed by the General Electric (GE) Foundation in Six Government-run Hospitals in Ghana.

By

Ledor Sira-Idee Igboh

B.A.
University of Minnesota, Twin Cities
2007

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
in partial fulfillment of the requirements for the degree of
Master of Public Health
in Department of Global Environmental Health
2014

Evaluation of the Sustainability and Impact on Water Quality of Decentralized Water Treatment Systems Installed by the General Electric (GE) Foundation in Six Government-run Hospitals in Ghana.

By: Ledor Sira-Idee Igboh

Background: Little is known about water availability, quality and use in health care facilities in developing countries. Decentralized water purification technology is increasingly available and is being applied in low-resource settings to address the need for safe, affordable, and reliable access to clean drinking water in public settings such as school, hospitals, and churches. In 2005, the General Electric Foundation (GEF) donated and installed decentralized membrane filtration systems (DMFS) in six government-run district-level hospitals in Ghana. Research is needed to understand the feasibility, performance and sustainability of institution-based DMFS in institutional settings in low-resource settings.

Significance: Safe water in healthcare facilities is vital for positive health outcomes. Due to the lack of water source reliability and inadequate centralized treatment processes in Ghana, DMFS have the potential to improve water quality in health care settings. Therefore, it is essential to evaluate the ability of these water treatment systems to sustainably provide safe water for consumption, hygiene and medical purposes.

Objective: To evaluate the use, performance, and sustainability of DMFS in six government-run district hospitals in Ghana. This study assessed factors that impeded or enabled the sustainability of the DMFS, identified gaps in capacity, and recommended areas for improvement.

Methods: Knowledge, attitudes, and practices *(*KAP) surveys were conducted with hospital staff, patients, and visitors. To assess water quality, over 200 water samples were analyzed for *E. coli*, total coliforms and *Pseudomonas aeruginosa* using the IDEXX Quanti-Tray 2000 method. A sustainability metric was used to quantitatively evaluate four sustainability domains: accountability, technical feasibility, on-site capacity, and institutional engagement and support.

Results: Awareness of the water treatment system on hospital grounds did not influence drinking water practices among patients and staff. Of the 78 water samples collected at the point of use (POU) in all six study hospitals, 48% met WHO standards for total coliforms, 58% met the standards for *E. coli* and less than 10% met the CDC guidelines for free chlorine residual. Geometric mean *E. coli* concentrations in POU samples by hospital ranged from 0.5 to 20.6 MPN/100 mL. Geometric mean *P. aeruginosa* concentrations in POU samples by hospital ranged from 76.5 to 933.8 MPN/100 mL. Water samples collected from sink taps within the hospital were more likely to meet WHO standards for water quality than samples collected from storage bucket taps within the hospital. The sustainability assessment showed each hospital with unique strengths and challenges in relation to the provision and use of safe water. However, all the hospitals faced major challenges in the domains of Accountability and Technical Feasibility. Overall, most hospitals did not meet the basic requirements for sustainability in all four sustainability domains.

Discussion: Targeted solutions are needed to improve the sustainability of the water treatment systems and address unique challenges within each hospital. Appropriate governing and monitoring entities to improve the technical capacity of the maintenance staff and monitor the operation and performance of the DMFS would promote the sustainability of these water treatment systems and improve hospital water quality.

Evaluation of the Sustainability and Impact on Water Quality of Decentralized Water Treatment Systems Installed by the General Electric (GE) Foundation in Six Government-run Hospitals in Ghana.

By

Ledor Sira-Idee Igboh
B.A.
University of Minnesota
2007

Thesis Committee Chair: Christine Moe, PhD

A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements for the degree of
Master of Public Health
in the Department of Global Environmental Health
2014

Acknowledgements

At the outset, I would like to express my heartiest gratitude to the Center for Global Safe Water (CGSW) for the opportunity to be a part of this research study.

I am especially grateful to have had the chance to work with and learn from my thesis advisor, Dr. Christine Moe. Thank you for always pushing me to do my very best.

I am greatly indebted to Kate Robb who has assisted and guided me throughout this journey. Your patience and positivity continues to inspire me enormously. Additional thanks to Mia Gallegos and Samantha Lie-Tjauw for being my comrades in and off the field.

This Global Field Experience (GFE) was also made possible with the support of the Eugene J. and Rose Salamone Gangarosa GFE funding. For this I am very grateful.

I would also like to thank the General Electric Foundation for funding, and Assist International (Jim Stunkel) their support on this project.

I would particularly like to thank the directors, staff and patients of all the study hospitals in Ghana for their generosity in sharing their valuable time and knowledge with the CGSW research team and me.

Lastly, humble thanks to my family for continuing to believe in me and supporting my aspirations. I will keep marching on.

Table of Contents

Acknowledgements ... *i*
List of Tables ... *v*
Glossary of Terms ... *vi*

1 INTRODUCTION ... 1
1.1 Problem Statement ... 2
1.2 Purpose ... 3
1.3 Significance ... 4
1.4 Scope of Research ... 5
1.4.1 Study sites ... *5*
1.4.2 Site Overviews ... *5*
1.5 Definitions ... 6

2 REVIEW OF THE LITERATURE ... 7
2.1 Global Perspective on Safe Water Access ... 7
2.2 Safe Water versus Improved Water ... 7
2.3 Water, Sanitation and Hygiene Disease Burden ... 8
2.4 Microbiological Water Quality ... 8
2.5 *Pseudomonas aeruginosa* in Water: Important in Hospitals ... 9
2.6 Drinking Water Guidelines ... 9
2.7 Water, Sanitation and Hygiene in Healthcare Facilities ... 10
2.8 Access to Improved Water in Ghana ... 11
2.9 Reliability of Water Sources and Quality in Ghana ... 11
2.10 Institutional Structure for Water Supply in Ghana ... 12
2.11 Ghana's Health Ministry Priorities ... 13
2.12 General Electric Foundation (GEF) Project Objectives and Goals ... 14
2.13 Decentralized Water Distribution Systems ... 15
2.14 Water Treatment Technologies ... 15
2.14.1 Advantages and Disadvantages of Membrane-based Systems ... *16*
2.14.2 Previous Research on Homespring® Filters ... *16*
2.15 Sustainability ... 17
2.15.1 Sustainability Definitions ... *17*
2.15.2 Importance of Sustainability ... *18*
2.15.3 Issues Impacting Sustainability of Water-related Interventions ... *19*
2.15.4 Measuring and Assessing Sustainability ... *20*

3 METHODS ... 23
3.1 Research design ... 23
3.1.1 Hospitals with GEF donated water treatment systems in Ghana ... *24*
3.2 Study sites ... 24
3.3 Data collection tools ... 25
3.3.1 In-depth interviews ... *25*
3.3.2 Knowledge, attitudes, and practices (KAP) surveys ... *26*
3.3.3 Water-use survey ... *27*
3.3.4 Facility inspection guide ... *27*
3.3.5 Maintenance info graphic survey ... *28*
3.3.6 Maintenance supply checklist ... *28*
3.4 Sustainability metric ... 29
3.4.1 Domains ... *29*
3.4.2 Sub-domains ... *29*

3.4.3 Broad questions ... 31
3.4.4 Scoring ... 32
3.5 Data collection process ... 32
3.5.1 In-depth interviews ... 32
3.5.2 Knowledge, attitudes, and practice (KAP) surveys ... 33
3.5.3 Water-use surveys ... 33
3.5.4 Facility inspection guide ... 34
3.5.5 Maintenance supply checklist ... 34
3.6 Water quality testing procedures ... 34
3.6.1 Water sample site selection within each hospital ... 34
3.6.2 Sample collection ... 35
3.6.3 Sample processing ... 35
3.7 Data Analysis ... 38
3.7.1 Analysis of demographic data ... 38
3.7.2 Knowledge, attitudes and practices data ... 38
3.7.3 Water quality ... 38
3.7.4 Sustainability metric ... 39
3.8 Ethical considerations and confidentiality ... 39

4 RESULTS ... 40
4.1 Hospital demographic data ... 40
4.2 Key Maintenance Tasks and Hospital Infrastructure ... 41
4.3 Water Quality ... 44
4.4 Knowledge, Attitudes, and Practices Related to Hospital Water ... 48
4.5 Sample Collection Points and POU Water Quality ... 52
4.6 Sustainability Metric Scores ... 57
4.6.1 Accountability ... 58
4.6.2 Technical Feasibility ... 65
4.6.3 On-site Capacity ... 65
4.6.4 Institutional Engagement ... 66

5 DISCUSSION ... 68
5.1 Impact of the GEF- donated DMFS ... 68
5.1.1 Impact of DMFS on Water Quality and Hospital Infrastructure ... 68
5.1.2 Impact of DMFS on Staff's Knowledge, Attitudes and Practices ... 69
5.1.3 Impact of DMFS on Patients' Knowledge, Beliefs, and Practices ... 70
5.2 Sustainability Evaluation ... 71
5.2.1 Successes and Areas of Improvement ... 71
5.3 Strengths and Limitations of the Study ... 77

6 RECOMMENDATIONS AND NEXT STEPS ... 79
6.1 Recommendations ... 79
6.1.1 Recommendations for GEF and Study Hospitals ... 79
6.2 Next Steps ... 82
6.2.1 Next Steps for GEF and Study Hospitals ... 82

7 CONCLUSIONS ... 83
References ... 84
Appendix A: Interview Tools ... 87
Appendix B: Sustainability Metric Tool ... 142
Appendix C: Institutional Review Board Documentation ... 169

List of Figures

Figure 1: Hospital Water and Health 4
Figure 2: Institutional Structure for the Water Sector in Ghana 13
Figure 3: GE donated Homespring, amiad, and membrane filter, with chlorine doser 24
Figure 4: Locations of the study sites in the their respective regions within the country. Source: Google Maps 25
Figure 5: A schematic of the sustainability metric structure. 31
Figure 6: Reported frequency of routine maintenance tasks 42
Figure 7: Reported occurrences of common system problems. 42
Figure 8: Observation of functional sink taps and presence of soap. 44
Figure 9: Percentages of water samples collected from point-of-use taps within each study hospital that met WHO guidelines of <1MPN/100mL of *E. coli*, total coliforms concentration and CDC guidelines for free chlorine residuals. 46
Figure 10: Distributions of total coliforms, *E. coli*, and *P. aeruginosa* concentrations (MPN/100mL) in samples from point-of-use taps within all hospitals. *E. coli* and total coliforms (N=78), *P. aeruginosa* (N=75). 47
Figure 11: Percentage of staff that are aware of the water treatment system, believe water is safe and drink water from the hospital taps. 49
Figure 12: Percentage of patients who drink hospital tap water, and believe water safe compared to percentage of hospital point-of-use tap water that met WHO guidelines for *E. coli* and total coliforms. KAP surveys (N=58), *E. coli* and total coliforms (N=78). 50
Figure 13: Use of water for medical purposes by clinical staff in hospitals 51
Figure 14: Percentage of staff who thinks patients drink water from taps, and patients who reported that they drink water from hospital taps. 52
Figure 15: A veronica bucket used for water storage and hand washing within hospital wards. 54
Figure 16: Sink taps within the hospital. 54
Figure 17: Radar plots depicting the variability in average sustainability domain scores across hospitals. Scores below the cut-off for sustainability (2) are highlighted in red. 60
Figure 18: Radar plots of average scores for subdomains of *Accountability* by hospital. Scores below the cut-off for sustainability (2) are highlighted in red. 61
Figure 19: Radar plots of average scores for subdomains of *Technical Feasibility* by hospital. Subdomain scores below the cut-off for sustainability (2) are highlighted in red. 62
Figure 20: Radar plots of average scores for subdomains of *On-site Capacity* by hospital. Subdomain scores below the cut-off for sustainability (2) are highlighted in red. 63
Figure 21: Radar plots of average scores for subdomains of *Institutional Engagement* by hospital. Subdomain scores below the cut-off for sustainability (2) are highlighted in red. 64

List of Tables

Table 1: An outline of the four sustainability domains and subdomains within each domain. 29
Table 2: Sample incubation temperatures 37
Table 3: Total number of surveys administered in each hospital. 40
Table 4: Hospital demographic data. 40
Table 5: Distance traveled to access replacement parts, staff trained, parts accessed and cost of consumables. 43
Table 6: Mean and standard deviation for *E. coli*, total coliforms and free chlorine residual before filtration, after filtration and at point-of-use taps within the hospital. 45
Table 7: P. aeruginosa concentration in samples collected from point-of-use taps within the hospital wards. 48
Table 8: Mean and standard deviation for *P. aeruginosa* before filtration, after filtration, and at point-of-use taps within the hospital. 48
Table 9: Number and percentage of samples from buckets and taps within the hospital that met WHO total coliforms and *E. coli* guidelines for drinking water (<1MPN/100 mL). 53
Table 10: Number and percentage of samples collected from taps and buckets, and percentages of samples from both locations that met guidelines for free chlorine and turbidity. 53
Table 11: Association between samples meeting microbiological guidelines for safe drinking water and meeting guidelines for free chlorine residual and turbidity. 55
Table 12: Association between location of sample collection points and whether or not sample met WHO standards for *E. coli* and total coliforms concentration in drinking water. 56
Table 13: Association between detection of E. *coli*, total coliforms, and free chlorine, controlling for sample collection points (buckets vs. taps). 57

Glossary of Terms

AI: Assist International
CDC: Centers for Disease Control and Prevention
CFU: Colony Forming Units
CGSW: Center for Global Safe Water
DHG: Developing Health Globally
GE: General Electric
GEF: General Electric Foundation
GSB: Ghana Standards Board
GWCL: Ghana Water Company Limited
***E. coli**: Escherichia coli*
EPA: Environmental Protection Agency
IRB: Institutional Review Board
JMP: Joint Monitoring Program for Water Supply and Sanitation
KAP: Knowledge, Attitudes, and Practices
MDG: Millennium Development Goals
MF: Ministry of Finance
MLGRDE: Ministry of Local Government, Rural Development, and Environment
MoH: Ministry of Health
MPN: Most Probable Number
MWRWH: Ministry of Water Resources Works and Housing
NGO: Non-Governmental Organizations
NTU: Nephelometric Turbidity Unit
POU: Point –of-Use
RO: Reverse Osmosis
SD: Standard Deviation
UF: Ultrafiltration System
UNICEF: United Nations Children's Fund
USAID: US Agency for International Development
UV: Ultra-violet
WASH: Water, Sanitation and Hygiene
WHO: World Health Organization
WRC: Water Resource Committee

1 INTRODUCTION

The mission of the General Electric Foundation (GEF) is to make an impact on the health care systems of developing nations by building capacity in clinical practice and service delivery in the areas of maternal and infant care, emergency care, surgical care, and biomedical practice. To achieve this mission, GEF's Developing Health Globally™ (DHG) program is strengthening partnerships with ministries of health, governments, and academic institutions in various countries across the globe to provide medical equipment, such as incubators, x-ray machines, and generators.[20] DHG also provides technical expertise to facilitate the appropriate utilization of these resources.

In addition to the DHG's program reach in over fourteen countries and 222 hospitals, the GEF foundation recognizes the need to improve access to safe water particularly for health facilities.[10] DHG has responded to this need by installing water treatment technologies to district hospitals, community clinics, and birthing centers to improve water quality for drinking and use for medical needs.

The objective of this project is to evaluate the use, impact on water quality, and sustainability of Decentralized Membrane Filtration Systems (DMFS) donated by the GEF to six government-run district hospitals in Ghana. Recently, decentralized institutional-level water purification systems, such as decentralized water filtration systems, have been used in schools and hospitals in low-resource settings to address the need for safe, affordable, and reliable access to clean drinking water. Despite their potential, the effectiveness and long-term sustainability of these systems is not known.[28, 45] Long-term integration of DMFS technology into these settings requires evidence-based strategies to improve sustained safe water access and use at the institutional level.[19,40,47] Recommendations from this study will inform future DMFS donations by GEF.

1.1 Problem Statement

Water-related illnesses, such as diarrhea, dysentery, and typhoid, are endemic and contribute to 70% of disease in Ghana.[51] WHO estimates that 88% of diarrheal diseases globally are attributed to unsafe drinking water, inadequate sanitation, and poor hygiene. [2, 62]

The 2013 *Progress on Sanitation and Drinking Water Update* reports that 53 percent of the total population in Ghana has access to an improved drinking water source, [64] a minimal improvement from 42.3 percent in 2012.[62,64] While incremental successes in increased access to water have been documented, large proportions of the Ghanaian population still lack access to safe water sources.

Drinking water in developing countries often exceeds the accepted World Health Organization (WHO) guidelines for *E. coli* (<1 CFU/100mL sample[*]) and total coliform bacteria.[3, 12] Both *E. coli* and total coliforms are traditional indicator organisms used to measure drinking water quality.[40] In low-resource settings water quality is not guaranteed. Even in water sources that are considered to be "improved,"[+] the water quality may not be safe due to resource constraints and lack of sustainable treatment.[10] For this reason, household point-of-use water treatment is often promoted to improve the quality of water used in homes.

In parts of Ghana, some government-run hospitals have access to piped water through a municipal supply, while others rely on water tanker trucks and harvested rainwater. Intermittent source reliability, inadequate treatment processes, and vulnerable piping infrastructure showcase the need for decentralized treatment technology on site. However, the aforementioned constraints result in many point-of-use treatments not being feasible at the institutional level.

---

[*] The WHO guideline is that *E. coli* and thermo tolerant (fecal) coliform bacteria "must not be detectable in any 100-mL sample of water intended for drinking.

[+] "Improved" drinking water sources as defined by UNICEF include sources that, by the nature of their construction or through active intervention, are protected from outside contamination, particularly fecal matter. Examples of improved water sources include piped water into a dwelling or yard, boreholes and tubewells, protected springs, and rainwater collection systems.

Recognizing the inconsistency in municipal water supplies, supply, and lack of appropriate treatment technologies, the GEF (in collaboration with Assist International and Ghana Ministry of Health) installed six DMFS at six government-run district-level hospitals in 2005 in Ghana. DMFS have been found to be useful in removing microorganisms like *E. coli* (an indicator for fecal contamination from animals and humans) from drinking water at the point of use.[28] The pore size of the membrane is small enough to remove most pathogens including parasites, bacteria, and most viruses.[28, 47]

The GEF has contracted the Center for Global Safe Water (CGSW) at Emory University to assess the impact and sustainability of the DMFS donated to these hospitals in Ghana. Data collected from the evaluations at each of the six project sites will be used to provide recommendations for both the study hospitals and the GEF. NGOs and other private organizations have installed donated water treatment technologies in public institutions, such as hospitals, without assessing the impact and sustainability of these systems. With little context-specific data available to attest to the capabilities of DMFS to function as intended, and their impact on water quality (considering their environment and geographical climate), the utility of DMFS for sustained provision of safe water in health care settings remain unexplored.

1.2 Purpose

The purpose of this project is to evaluate the use, impact on water quality (performance) and sustainability of DMFS donated by the GEF to six Ghanaian hospitals and recommend areas for improvement. The evaluation includes the following specific aims:

1. Evaluate microbiological and physiochemical water quality at the six beneficiary hospitals.
2. Evaluate knowledge, attitudes and practices of hospital staff regarding safe water provision and use.
3. Evaluate the sustainability of safe water provision at each hospital using a metric to assess four domains of sustainability: accountability, on-site capacity, institutional engagement and support, and technical feasibility.

4. Identify and evaluate key stakeholders that could facilitate water system oversight and sustainability

1.3 Significance

The effects of inadequate water quality in health care settings cannot be understated, especially for health care settings in low-resource areas that serve vulnerable populations. Health service delivery in underserved populations has the added challenge of inefficient technologies and inadequate infrastructure capacity to cater to high service demands. Safe water for medical use is vital for the health benefit of its patients and workers in healthcare facilities The links between hospital water quality and health of its consumers is depicted in *Figure 1*.[5, 4] Water quality in hospitals is not only important for drinking, but also for other medical uses such as, sterilizing medical equipment and cleaning environmental surfaces.

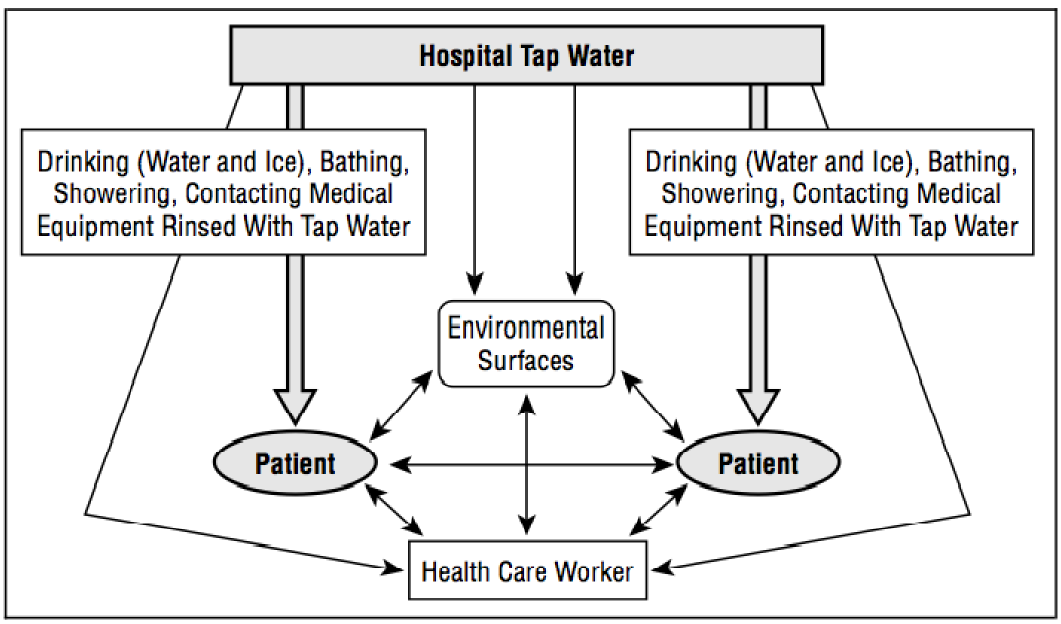

Figure 1: Hospital Water and Health[1]

The WASH sector have been focused on assessing treatment methods for drinking water quality at homes, in schools, and communities, with no particular focus on healthcare settings and other institutions. The utility of decentralized water treatment technologies in healthcare settings in low-resource countries is currently unknown. Research is needed to fully understand the feasibility, performance and sustainability of DMFS in institutional settings.

Based on the assertion that DMFS have the potential to provide safe drinking water in low-resource settings, [26,47] this project will evaluate the sustainability of these systems, identify and promote factors that create enabling environments for sustaining and maintaining DMFS in institutional settings.

1.4 Scope of Research

1.4.1 Study sites

The DMFs are currently installed in six government-run district hospitals across six regions in Ghana (*Figure 4*): Bole District Hospital in the Northern Region, Kintampo District Hospital in the Brongo-Ahafo Region, Mampong-Asante District Hospital in the Ashanti Region, Kete-Kratchi Government Hospital in the Volta Region, Apam Catholic Hospital the Central Region, and Axim Hospital in the Western Region. These district-level hospitals serve both urban and rural populations of between 100,000 and 200,000 people and use a centralized water distribution systems provided by their respective municipalities.

1.4.2 Site Overviews

Mampong District Hospital is located in Mampong-Asante district of the Ashanti region. It serves a population of approximately 100,000 people, and it is the only referral hospital in the region apart from Konfo-Anokye Teaching Hospital, which is located in Kumasi, the district capital.[54] The water treatment system in Mampong-Asante district hospital serves the hospital, maternity center, and midwifery school.

Kete-Kratchi West District Hospital is located in the Kratchi West District of the Volta region. Kete-Kratchi hospital first began as a health center in 1958, but it matured into a district hospital ten years later. The hospital currently serves a population of more than 100,000 people. Kete-Kratchi hospital has a wide catchment area, which includes many island communities, such as the Sene district, as well as some northern communities situated along the Volta Lake and Ashanti region.

Kintampo Municipal Hospital is located in the Kintampo North district in the Brongo-Ahafo Region and serves an estimated population 130,000. Kintampo hospital is the only hospital that uses a sand filtration water treatment system, instead of a DMFS. The water treatment system in Kintampo serves the hospital and the Health Science College.

Bole District Hospital is located the district capital of Bole in the northern region, and serves a population of approximately 70,000 people. It is the only hospital in the district, and thus serves a wide catchment area.

Apam Catholic Mission Hospital is a non-profit health facility located in Apam, a coastal town in the central region of Ghana. Two Dutch catholic nuns established the Apam Catholic Missions hospital in 1959.[1] Over the years, the hospital has expanded to become a district hospital that currently serves a population of approximately 200,000 and aspires to becoming a referral hospital for the region. Apam Catholic Hospital receives financial donations and some infrastructure support from various international organizations to strengthen the facilities infrastructure.

Axim Government Hospital is located in Axim, the capital of the Nzema East District in the Western region of Ghana, and serves approximately 100,000 people in Axim and surrounding towns. The Axim Government hospital was initially established as a Catholic missions hospital in 1925 but later became a district government-run hospital. [59]

1.5 Definitions

- ***Tro tro*** – are privately owned minibuses or shared transportation vehicles, typically operated by a driver and conductor.
- **Sachet water –** is a common type of bagged water privately vended and highly patronized for drinking in Ghana.
- **Veronica bucket** – are buckets used to store water for hand washing stationed within hospital wards. They are typically installed with basins at the bottom to collect water used.

2 REVIEW OF THE LITERATURE

This literature review presents global perspectives on safe water access, institutional structure for water supply in Ghana, and the sustainability and impact of water quality of decentralized water treatment technology in low-resource settings.

2.1 Global Perspective on Safe Water Access

In 2010, an estimated 5.8 billion people used improved water sources, and 1.8 billion people (about 28% of the global population) utilized unsafe water.[42] The following year in 2011, 89% of the world's population gained access to an improved drinking-water source, with estimates that 768 million people still used unimproved water sources.[64] Furthermore, the World Health Organization (WHO) and United Nations Children's Education Fund (UNICEF) Joint Monitoring Program announced in 2012 that goal 7, target C of the Millennium Development Goals (MDG), which calls for "reducing by half the proportion of people without sustainable access to safe drinking water and basic sanitation" by 2015 had been met for drinking water.[62] While incremental successes in access to water have been reported globally, large proportions of the population in sub-Saharan Africa still do not have access to safe water sources. For example, the 2013 progress on Sanitation and Drinking Water Update report indicates that only 53% of Ghana's total population has access to an improved drinking water source.[64]

2.2 Safe Water versus Improved Water

The Joint Monitoring Program (JMP) report defines improved[*] water sources as those that are protected from outside contaminants, specifically fecal matter. [64] Based on the definition of improved water sources, the proportion of the population reported to have gained access to improved water sources may be an overestimation.[42] Furthermore, the classification of water sources as "improved" or "unimproved" as described in the WHO/UNICEF report does not include the components mentioned

[*] "Improved" drinking water sources as defined by UNICEF include sources that, by the nature of their construction or through active intervention, are protected from outside contamination, particularly fecal matter. Examples of improved water sources include water piped into a dwelling or yard, boreholes and tubewells, protected springs, and rainwater collection systems.

above. Currently, there is a continuing debate over the accuracy of this achievement since progress measured by the MDG targets does not consider the quality or quantity of the improved water source.. To address the quality component of worldwide access, the JMP will use a water quality goal of <10 CFU of *E. coli*/100 mL when evaluating the post-2015 drinking water targets. [64]

2.3 Water, Sanitation and Hygiene Disease Burden

Water-related diseases are a leading cause of death around the world. Improving access to safe drinking water and sanitation is vital to improving health and prevention of Water, Sanitation and Hygiene (WASH) - related disease burden.[2] WHO estimates that 88% of diarrheal diseases globally are attributed to unsafe drinking water, inadequate sanitation, and poor hygiene.[2, 62] Every year, more than 3.4 million people die as a result of water-related diseases.[62] The global burden of WASH related illness is felt greatly in developing countries. This is evidenced by high rates of child morbidity and mortality concentrated in sub-Saharan Africa, where water-related illnesses, such as diarrhea, dysentery, and typhoid among others are endemic and contributes to 70% of disease in Ghana.[51] In 2012, 5,193 deaths were attributed to diarrhea in Ghana, but this is likely to be an underestimate in a country where enteric infection rates have remained consistently high.[8] Ongoing assessments of existing water interventions and their impacts on health are essential in order to identify better strategies for implementation for the desired impact on health. Addressing water quality at both the community and institutional level is an important step in reducing the global WASH disease burden.

2.4 Microbiological Water Quality

Microbiological water quality is determined by the presence or absence of particular indicator bacteria and enteric pathogens. Types of pathogens include viruses, bacteria, and parasites. Examples of waterborne pathogens are norovirus, shigella, *Vibrio cholera*, cryptosporidium, giardia, and *Pseudomonas aeruginosa.*[3] Enteric pathogens that pose public health threats in drinking water are transmitted through a fecal-oral route. These pathogens can cause illnesses like gastroenteritis, paralysis, meningitis, hepatitis, and respiratory illnesses and diarrhea.[24] Total coliforms are common indicator bacteria used to evaluate the efficacy of drinking water treatment.[3] *E. coli* bacteria indicate the presence of human or animal fecal contamination.[24] *P. aeruginosa* are especially important in healthcare settings because they opportunistic pathogens and capable of surviving and thriving in water distribution systems.

2.5 *Pseudomonas aeruginosa* in Water: Important in Hospitals

P. aeruginosa are a recognized cause of hospital-acquired infections transmitted not only through drinking water but also through contact.[1] Since water is identified as a point source for outbreaks of *P. aeruginosa,* measuring *P. aeruginosa* contamination in healthcare settings is important.[29] *P. aeruginosa* are known for their tendency to form biofilms[†] on environmental surfaces, especially plastic.[28] This is important to consider since water treatment technologies have plastic fittings that would be suitable for *P. aeruginosa* bacteria to colonize. Although, these bacteria are persistent and ubiquitous, they can be controlled with appropriate disinfection interventions and hygiene practices. Appropriate hygiene and water treatment interventions are especially critical in hospitals because *P. aeruginosa* can become pervasive in hospital settings and hospitals have vulnerable populations of immunocompromised patients.[28, 39] The case for appropriate treatment interventions to tackle *P. aeruginosa* is evidenced in a baseline study conducted by Huang et al that assessed suitable water purification methods developed for low income country applications and found that point-of-use filtration using 0.2μm filtration units was associated with significant reductions in chronically endemic microbiological contamination.[28, 29, 39]

2.6 Drinking Water Guidelines

Drinking water guidelines provide a basis for regulating and evaluating water safety. There are internationally recognized drinking water guidelines for *E. coli* and total coliforms, however guidelines for acceptable levels of *P. aeruginosa* concentrations in drinking water are yet to be internationally agreed upon. WHO water quality guidelines recommend that *E. coli* or thermotolerant coliforms should not be detectable in any 100 mL sample of drinking water.[1] Drinking water in healthcare facilities must also

---

[†] Biofilm can be defined as structured microbial communities of single or multiple species attached to a surface and surrounded by a matrix of extracellular polymers or ‘slime’.

meet WHO guidelines for chemicals and radiological parameters. Another important drinking water guideline is the Center for Diseases and Prevention (CDC) Safe Water Systems guideline, which recommends a free chlorine residual level in drinking water between is 0.2 – 2.0ppm.[1,12]

For *P. aeruginosa*, the U.S. Environmental Protection Agency (EPA) recommends that concentrations in drinking water should not exceed 500 colony forming units (CFU) per mL; however, this recommendation is not enforced.[48] However, in Europe and Australia the drinking water regulations state that *P. aeruginosa* of any quantifiable amount must not be detectable in a 250mL sample of bottled water.[26] While there is general consensus that high oral doses of *P. aeruginosa* would be considered a health hazard, internationally-vetted guidelines about acceptable *P. aeruginosa* concentrations in drinking water do not exist.

To implement and enforce guidelines for drinking water quality in hospital settings, appropriate management at the national, regional, district, and local levels, and support from international intergovernmental and non-governmental agencies such as the (WHO) and (UNICEF), are essential.

2.7 Water, Sanitation and Hygiene in Healthcare Facilities

Unsafe healthcare environments cause infections that contribute to morbidity and mortality worldwide. [1] Safe water has an impact on health outcomes; therefore it is important for health facilities to have safe water for drinking and medical use. In order to decrease the WASH disease burden, policy and standardized guidelines that address water supply, quality, quantity, and access in the health facilities need to be created.

Eleven environmental health guidelines for healthcare facilities have been developed by WHO. The guidelines include specific indicators that can be measured. Although there are 11 of these guidelines in total, only three focus on water. The water-related guidelines include: water quality, water quantity, and water facilities and access to water. These guidelines were specifically designed to inform national standards and facilitate the development of relevant, context-specific standards for healthcare settings.[1]

WHO has also contributed to a newly instituted *Hand Hygiene Self-Assessment Framework* for use by healthcare professionals to improve hygiene in healthcare facilities.[67] The WHO guidelines for health facilities state that hospitals should: a) provide safe drinking water from a protected groundwater source, or from a treated water supply, which must be kept safe through the point of use, and b) healthcare settings must also provide basic sanitation facilities that enable patients, staff, and service providers to utilize the latrine without contaminating the healthcare setting or water resources. [1]

Coordination for water-related guidelines is the responsibility of key entities within institutions. An important coordinating body for WASH promotion and other aspects of infection control is the "infection control committee".[1] In Ghana, although infection control committees (also termed "Biosafety Committees") could ensure that hospital water resources meet recommended guidelines from the Ministry of Health (MoH), their coordinating presence is lacking at the district-level hospitals.

2.8 Access to Improved Water in Ghana

In Ghana, water is abundant, however, drinking water of good quality is limited by geography, demography, temporality, and affordability.[3, 38] Although access to improved water continues to increase in Ghana's rural and urban communities, Ghana continues to face economic and structural constraints that prevent improved water and adequate sanitation. Research indicates that 51% of Ghana's urban sectors have access to improved water supply; however, urban water coverage by the Ghana Water Company Limited (GWCL) could not be determined.[7,2] According to the 2005 WaterAid report, approximately 50% of water produced by the GWCL does not reach its intended consumers due to leakages and breakages in the piping systems. Thus, Ghana experiences widespread rationing and intermittent supply of water. [2]

2.9 Reliability of Water Sources and Quality in Ghana

In Ghana, decentralized water treatment technology is needed on site. Constant interruptions to the municipal water supply have caused reduced reliance on centralized water. Over the last few years, sachet (bagged) water has become a primary drinking water source for many Ghanaians. Several studies have examined the microbiological water quality and potential for disease transmission from sachet water.[58] Some studies identified high contamination with common pathogens found in drinking water, [18] whereas others found no bacterial contamination in sachet water.[15] Although evidence demonstrates varying water quality, sachet water remains a popular alternative to poor source reliability in households and communities.[16]

One GWCL official stated, “the problem does not lie in the amount of water available, but in the purification systems being inadequate”. [6] Interrupted distributions from municipal water sources contributes to poor quality of water delivered within the piped network. A study conducted by Arnold et al used the IDEXX Quanti-Tray® and Petrifilm™ enumeration methods to assess water quality by sources in communities in the Ashanti Region of Ghana.[2] This study found that piped water was available in several villages, but the systems were not always functional and did not provide water during several visits by the research team. This finding highlights the fact that the piped water sources were not functioning about 50% of the time.[2] The Arnold et al study also showed that boreholes provided higher water quality than other sources that were tested. *E. coli* was not detected in any borehole samples, and only one of ten boreholes was positive for total coliforms. Similar studies looking at water source types and microbiological water quality in Ghana could not be found.

Recognizing that water source reliability and quality are compounding issues in Ghana, the government of Ghana, has partnered with donors and non-governmental organizations (NGO), and has made renewed commitments to tackle this challenge by strengthening partnerships to provide good quality water for all Ghanaians.[51]

2.10 Institutional Structure for Water Supply in Ghana

In the past, urban water supply was the responsibility solely of the government. Recently, reforms instituted through partnerships with the private sector have allowed for the operation, management, and regulation of water supply and sanitation.[8] *Figure 2* illustrates the hierarchical structure and institutional key players in the water supply sector in Ghana.

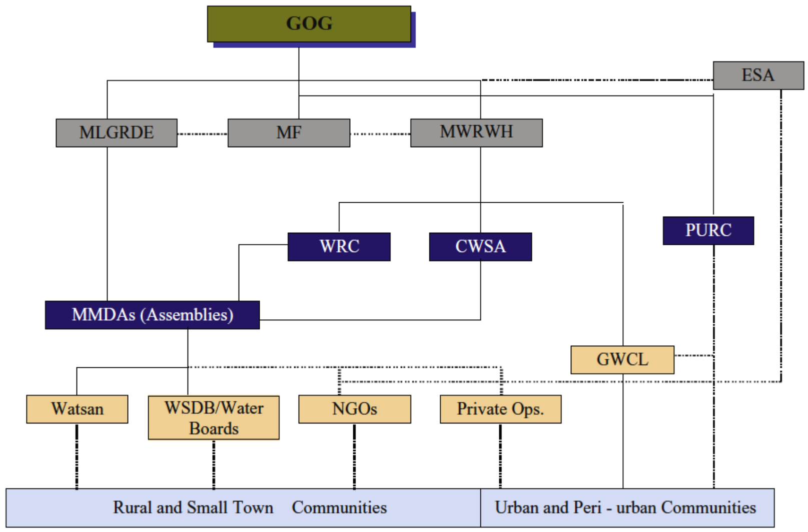

Figure 2: Institutional Structure for the Water Sector in Ghana[8]

At the policy level, the Ministry of Water Resources Works and Housing (MWRWH) formulate policies and coordinate solicitation for funding from a variety of External Support Agencies (ESA) through Ghana's Ministry of Finance (MF). Regulation of water resources, licenses, and abstraction (i.e. the removal or diversion of water), is the mandate of Water Resource Committees (WRC). These committees rely on the Ghana Standards Board (GSB) to set national standards for drinking water quality. [8] The sole responsibility of GWCL is to ensure provision, distribution, and management of water supply for the urban and Peri-urban communities. The Community Water Sanitation Association, under the MWRWH oversees water development in rural areas and small towns. The Environmental Protection Agency (EPA) is also expected perform the important function of enforcing laws to control pollution of water resources in Ghana. These various governing bodies for water are imbedded within the Ministry of Local Government, Rural Development, and Environment (MLGRDE). [8] Though it is clear that the structures to deal with water supply and quality issues exist, there remains a gap in using the structures in place to address water-related priority health issues identified by the health ministry.

2.11 Ghana's Health Ministry Priorities

The overarching mission of Ghana's Ministry of Health (MoH) is to improve the health status and reduce health inequalities of all people living in Ghana. The ministry seeks to identify groups in society that should be given priority in health and to determine the relative importance of these groups to guide budget decisions.[30] To understand where water-related illnesses fit within the ministry's intervention priorities, a study was conducted to assess how cost-effectiveness, severity of disease, and poverty reduction priorities determined the inclusions of specific interventions to national priorities. The study revealed that child interventions such as improved complimentary feedings, immunization expansion programs, and management of childhood illnesses like diarrhea ranked above the 90 percentile for likelihood of being included as a priority area for intervention.[30]

Another health priority of the MoH in Ghana is to address inadequate access to water supply in order to reduce disease, as outlined in the Ghana Poverty Reduction Strategy I and II.[34] Based on the many water-related challenges that Ghana faces, it is clear that sustainable, context-specific water treatment technologies can support the achievement of Ghana's water-related national health priorities.

2.12 General Electric Foundation (GEF) Project Objectives and Goals

The GEF is the philanthropic branch of General Electric (GE) and focused its work in health, education, the environment, and disaster relief in order to address some of the world's most difficult problems. Since the 1950s, the GEF has committed hundreds of millions of dollars to these diverse efforts. The Foundation currently works through four major programs: Developing Futures in Education, Disaster Relief, Developing Health US and Developing Health Globally™ (DHG).[20] Program efforts are undertaken through partnerships with NGOs, academic institutions, and think tanks. The GEF's DHG program launched in 2004 and works in 14 countries in 222 hospitals in Sub-Saharan Africa, Latin America, and Southeast Asia to improve healthcare access and provision.[20]

Safe water provision has recently become a focus for the GEF's philanthropic branch. To further this goal, the GEF has donated Decentralized Membrane Filtration Systems (DMFS) to hospitals and community clinics in at least five countries, including Ghana. Other aspects of the safe water projects include the development and dissemination of simple water quality analysis protocols and visual tools to help build capacity, and improve the management of safe water.[20] In Ghana the DHG™ water project is implemented by the GEF in collaboration with Assist International (AI) and Emory University where AI functions as the technical arm. The Center for Global Safe Water at Emory University (CGSW) is an academic institution that conducts applied research, trains students and WASH professional, and evaluates WASH programs. The GEF has engaged the CGSW to evaluate the feasibility, performance and sustainability of the water treatment systems provided by the GEF.[20] GE and AI installed six DMFS that utilize Homespring® filters in healthcare facilities in 2005 in Ghana and have conducted follow up site visits intermittently between 2006 and 2013.

2.13 Decentralized Water Distribution Systems

Drinking water distribution systems often contain a diversity of microbial growth, pipe corrosion, declining quality of water. [44, 55, 66] Piped distribution systems also provide a suitable environment for biofilm formation of *E. coli*, and *P. aeruginosa.*[66] Where centralized water supply systems exist, renovation and implementation of decentralized treatment technologies can be introduced as solutions to improve the quality of the water closer to the point-of-use.[44] Decentralized water treatment solutions have the potential to improve water quality from municipal water source supplies, and also from alternative sources, like groundwater or rainwater.

2.14 Water Treatment Technologies

Decentralized water treatment technology is increasingly available and is being applied in low-resource settings by a variety of organizations to address the need for safe, affordable, and reliable access to clean drinking water in public settings such as school, hospitals, and churches.[44] Suitable treatment options in developing countries can be provided as decentralized, community based, or Point-of-Use (POU) household approaches.[52] Other treatment technologies considered suitable for developing countries due to infrastructural reasons and failed water distribution systems are decentralized filtration systems such as Sand Filtration (SF), Ultraviolet (UV) light disinfection, and Ultrafiltration (UF) methods. Some treatment technologies are better than others at removing or destroying microbial, chemical, or physical contaminants.[52] Membrane-based treatment technologies include Reverse Osmosis (RO), Nano filtration (NF), Ultrafiltration (UF), and Micro-filtration (MF).[40]

Membrane-based systems vary based on investment costs and capacity to remove viruses and inorganic contaminants from water. Advantages and disadvantages of membrane-based systems, specifically UF technologies, for health facilities in a low-resource setting will be discussed.

2.14.1 Advantages and Disadvantages of Membrane-based Systems

UF-based systems are highly efficient at removing bacterial pathogens such as *E. coli*. The systems are also efficient in removing suspended particles in water to a level as low as 0.1NTU, an indication of effective removal of feed water particles.[28] UF is not recommended for use at household level filtration of drinking water because of the high servicing costs.[28, 44] Although UF-based systems are not recommended for use in households, they require significantly less pressure than their counterparts (i.e. RO systems). The most widely used type of UF systems are the Homespring® UF systems.

2.14.2 Previous Research on Homespring® Filters

Homespring® filters are an example of highly effective membrane-based filters that can remove >99.999% of bacteria and viruses and operate at an efficiency rate of 95% with a life span of five to ten years. [40, 46] Out of over 28 GE Homespring® Filters that have been commissioned and installed by GEF in hospitals, clinics, and schools globally, 20 are in Ghana. Homespring® filters are considered high-tech treatment technologies and require highly trained technicians to maintain uninterrupted operations, replacement of parts, and general upkeep. [40] They are also known for their suitability for filtering any type of water without pre-treatment which makes Homespring® systems appropriate for use in resource limited settings with poor water source quality.[44] UF Homespring® systems can be used with the existing pressures from the main source; however, annual maintenance are key to long-term functionality.[28, 44]

Although decentralized water treatment technologies are being implemented in low-resource settings like Ghana, sustaining the long-term functionality and operations of such systems is still a challenge in the WASH sector.

2.15 Sustainability

NGOs and other private organizations have donated water treatment technologies to public institutions, such as hospitals, without assessing their impact and long-term sustainability.[8, 19, 62] There is an immense need in the water and sanitation sector to ensure long-term sustainability of water-related interventions.[62] Moving forward, governments, as well as private and public entities must create cohesive and context-specific strategies to sustain water-related interventions and/or donations of water point technologies. Additionally, the WASH sector would benefit from utilizing systematic sustainability metrics that can be tailored to sector-specific challenges. In the succeeding sections key components of sustainability are defined and assessed for their utility. A variety of sustainability metrics that have been used to assess water-related projects are also reviewed to identify gaps and areas of strength.

2.15.1 Sustainability Definitions

Definitions and principles of sustainability vary, as they are based on the sector and country context. General perspectives on sustainability include: maintenance of health benefits over time, institutionalization of a program or program components, and community capacity building.[25] A variety of sustainability literature such as the *environmental sustainability index*, *corporate sustainability index*, and indices for *water resource sustainability* have been developed to guide decision-makers and stakeholders in achieving sustainability.[32] The utility of sustainability indicators goes beyond evaluating performances and providing information on trends in improvement. Sustainability indicators can also be used to warn decision-makers of declining trends in order to formulate strategies to reverse the situation.[56]

Hanson defined a sustainable initiative as one that would remain in the community, supported by the community, and would entail expenses and volunteers that could be provided by the community. Additionally, the program would stay in the community, either as it was initiated, or as a variation of it depending on progress made.[25] Alternatively, Hodgkin presents a water-related definition which states that sustainable water-related programs should include a consistent water supply as well as a sanitation component in order to continue or build upon project objectives.[27] Furthermore, truly sustainable projects should also continue over an extended period of time once external funding ceases to exist.[27] Few water and sanitation projects have been able to achieve success by these definitions.[25, 27, 10] While the importance of sustainability is acknowledged, designing sustainable programs can be complex due to the numerous components that demand extensive considerations.

2.15.2 Importance of Sustainability

The importance of sustainability as a concept is widely documented, but evidence for the application of sustainable WASH interventions in health facilities are sparse. This is of concern, because increasing the number of people with access to better quality water will require more focus on long-term impact and sustainability.[10, 62] Targeted program design and implementation, based on research, as well as continued monitoring and evaluation are essential for sustainable long-term health program effectiveness.[25] Unfortunately, dysfunctional water technologies and water points are prevalent in the WASH sector. Sustainability-centered research on demand, cost recovery, failure management, maintenance of water sources, and water treatment will inform future sustainable development.[19, 52,62]

Water point failures have become common in developing countries. In sub-Saharan Africa, between six to eight million hand pumps have been installed, but they have a failure rate of 30%. In Ghana, it is estimated that 58% of existing water points are in need of repair.[10] Though very little success is evident in water programs, Ghana is making strides to address safe water provision challenges as evident in the Decentralized Safe Water Kiosk project.[51] The Decentralized Safe Water Kiosk project in collaboration with Water Health Ghana (WHG) uses a sustainable model which incorporates best practices from the private sector with a focus on establishing local sustainability (environmental, operational, and economical), and scale.[51] The project partnered with the John Hopkins University to undertake independent evaluations of the impact of improved water supplies on local health outcomes and possible models to inform scale up and transition of the water kiosks to local ownership. Programs such as this, with clearly outlined guiding principles for sustainability development, can increase the potential for sustainable WASH interventions.

2.15.3 Issues Impacting Sustainability of Water-related Interventions

To assess factors hindering sustainable development, it is necessary to understand the issues affecting sustainability of water-related projects. Sustainability of well-intended projects becomes at risk when roles and responsibilities of management, donors, partners, stakeholders and beneficiaries are not clearly outlined.[10] The likelihood of sustainable of water programs decreases when organizations make limited efforts to quantitatively, and qualitatively measure core indicators of sustainability. Poorly measured indicators that impact sustainability include: quality of water, maintenance of water systems, cost of operations, rate of adoption, accountability, available economic and human resources, operational capacity, and ownership.[25, 27,50,51]

Another critical issue impacting the sustainability of WASH programs is the removal of donors from financial, operational, and management support roles within short and inflexible time frames. Untimely donor pullout without adequate preparations of the intervention beneficiaries to assume full capability, can render donations unsustainable.[10] Furthermore, lack of locally-available alternative technologies that are feasible for the communities to maintain over time has a negative impact on the sustainability of interventions.[10, 27] For these reasons, institutional capacity strengthening is needed at the onset of program planning to properly implement the strategies of donor and funding organizations. Failure to involve communities and beneficiaries in the decisions to implement water interventions that suit their specific needs increases the chances of inappropriate interventions and unsustainable outcomes.[46] Another issue impacting sustainability is the inability to rally political will at all levels of the government to dedicate the necessary resources needed to promote and create demand for WASH services and interventions.[46, 56]

Lastly, inadequate monitoring and evaluation systems of water interventions to inform good policies or future donations affect the sustainability of water-related interventions.[9] Poor forethought with regard to the financial sustainability of water interventions also contributes to decreased sustainability. Implementing organizations tend to focus on the hardware components of projects, rather than resolving software challenges such as payment issues or long-term funding for system malfunctions, and this can result in inevitable failure of programs.[10] Failure to consider software issues is an important barrier to sustainability because communities need to understand the cost implications of maintaining and operating their water systems over time.[10]

2.15.4 Measuring and Assessing Sustainability

A variety of sustainability measurement tools with recurring factors and indicators have been used to measure sustainability outcomes of WASH interventions. Some studies have promoted the application of a "triple bottom" approach to sustainability principles. This approach embodies environmental (economic), institutional, and social issues as key factors for assessing the sustainability of water interventions.[32]

Alternatively, the International Water and Sanitation Centre suggests evaluating technical, administrative, resource evaluation, sociological, and health factors to assess functionality, utilization, and impact of water facilities.[19] A review of sustainability assessment tools currently in use for program monitoring of WASH interventions reflects a comprehensive use of financial, institutional, environmental, technical, and social indicators, while others also include service delivery, management, knowledge, and capacity indicators.[9, 19] Evidence suggests that application of a purely technical approach to assess sustainability is no longer sufficient because it underplays the complexity of issues surrounding WASH. Considering the preceding points, it is important however, to note that the sector has moved toward a more inclusive and holistic approach to assess sustainability using both qualitative and quantitative evaluation approaches. The utility, application, and adaptability of these identified sustainability assessment tools will be discussed.

AGUASAN, a Swiss organization, developed a sustainability assessment tool (SAT) to assess rural water schemes in Kosovo, Nepal, and Mali in 2010. Semi-structured interviews of key informants were used for data collection, field observations, and a review of policy and program documents were also applied.[9] The scoring for this tool involved taking an average of the indicator scores. This tool exhibited limited application in institutional settings.

USAID-Rotary developed and utilized a sustainability index tool (SIT) to evaluate institutional, management, financial, technical, and environmental factors of water projects conducted under the USAID-Rotary international partnerships in Ghana, Philippines, and the Dominican Republic in 2012.[9,65] The selection of indicators was based on internationally recognized principles and standards for WASH services.[9, 65] Data collection methods used included site inspections, focus group discussions, and household and key informant interviews. An example of an institutional indicator question asked for community-managed hand pump intervention is: 1) Are there formalized roles and responsibilities for the service authority? and 2) Are the roles and responsibilities of the service authority understood by all in the service authority involved in overseeing the water system? [65] Scores were aggregated based on intervention type, as well as for each of the five indicators. The results were presented graphically with low-medium-high likelihood ranking of sustainability levels. Based on the limited application of this tool, it cannot be determined if results from this evaluation have impacted program planning. An assessment of the SIT tool showed that it was predominantly developed by donors, and lacked ownership by all levels of government and beneficiaries of the project interventions.

In 2011, the CARE USA Water Team used five indicators to assess the functionality of water points in Northern Mozambique. The factors for functionality were: accountability, transparency, participation, and inclusivity of community members in local water governance.[11] Surveyed communities were assigned a score of low, medium, and high using a number scheme of 1, 2, and 3 for respective sub-indictors under indicators of accountability, which reflected the potential functionality of water points. Examples of sub-indicators for accountability are water committee existence, and committee meetings.[11] Sub-domains of transparency included: financial matters, record keeping, process of elections and existing laws.[11]

The sustainability assessment tools and indices discussed have been focused on water point functionality, program implementation, delivery of water, as well as sanitation and hygiene interventions at the community level. Although sustainability tools now have expanding utility, there is sparse data available on their applicability for WASH interventions in institutional healthcare settings - thus, the relevance of this research study which uses a sustainability metric to evaluate the water treatment technologies donated by the GEF to healthcare facilities. The findings of this research will contribute to the recent initiative by WHO and UNICEF to promote improved WASH interventions in healthcare facilities.

3 METHODS

3.1 Research design

Various methodological approaches were used to evaluate the sustainability and impact on water quality of decentralized membrane filtration systems (DMFS) donated by the General Electric Foundation (GEF) to six district-level hospitals in Ghana. To assess the impact of the water filtration systems, we collected water samples from six hospital sites in Ghana to determine water quality before and after filtration, as well as at the point of use. Hospital taps, sinks, water distribution mechanisms, water management, and storage capacities were inspected. In-depth interviews as well as knowledge, attitudes, and practices (KAP) surveys were also administered to key staff in order to comprehensively evaluate the provision and use of safe water at each study site. To measure sustainability of safe water provision, a sustainability metric (previously utilized in baseline assessment of hospital water purification systems in Honduras, Roguski, 2012) was adapted and refined.

The domains of sustainability as outlined in the sustainability metric were: *accountability, on-site capacity, institutional engagement and support, and technical feasibility*. Each domain score was calculated using the results of the KAP surveys, in-depth interviews, facility inspections, and water quality testing to make intra-site, cross-site and cross-national comparisons.

Water-use-mapping survey tools were used to identify water use practices by administrative, clinical, and maintenance staff, as well as, patients, visitors, and caregivers. Information about water use practices help researchers understand the uses of treated vs. untreated water within the study hospitals as well as highlighting areas of need for capacity strengthening related to water use. A maintenance supply checklist was administered at each hospital in order to understand the accessibility of major and minor parts required for repairs. The tool was also used to ascertain if distance to purchase replacement parts and availability of parts led to interrupted maintenance and operation of the filtration system at each hospital. This baseline impact assessment was conducted over eight weeks throughout June and July of 2013 in Ghana.

3.1.1 Hospitals with GEF donated water treatment systems in Ghana

Five hospitals were beneficiaries of the GE Homespring® membrane filter (*Figure 3*). 1 hospital, Kintampo used a sand filter. The water treatment systems in six hospitals were all included in the study.

Figure 3: GE donated Homespring, amiad, and membrane filter, with chlorine doser

3.2 Study sites

The DMFS are currently installed in six government-run district hospitals across six regions in Ghana (*Figure 4*): Bole District Hospital in the Northern Region, Kintampo District Hospital in the Brongo-Ahafo Region, Mampong-Asante District Hospital in the Ashanti Region, Kete-Kratchi Government Hospital in the Volta Region, Apam Catholic Hospital the Central Region, and Axim Hospital in the Western Region. These district level hospitals serve both urban and rural populations of between 100,000 and 200,000 people.

Figure 4: Locations of the study sites in the their respective regions within the country. Source: Google Maps

3.3 Data collection tools

3.3.1 In-depth interviews

At each study site, key informants, such as the director, maintenance personnel, administrator, and laboratory technicians, were interviewed in depth. The director's interview tool was comprised of 84 questions, the maintenance interview tool 59 questions; the administrator interview tool included a total of 33 questions, and there were twenty-four questions in the interview tool for the lab technician.

The in-depth interview tool for each key informant was based on previous versions of an interview tool that was developed for evaluating similar water filtration systems in four Honduran hospitals in 2012. The tools were revised to be contextually specific to the study sites in Ghana. Additional revisions were made based on background information on the water purification systems in

Ghana and site reports developed by CGSW and Assist International (AI). A member of the CGSW research team then piloted the revised tool in April 2013. Further revisions were made after piloting to better understand the system of accountability amongst key managerial staff regarding financing of system repairs, water sources, and practices surrounding safe water provision at the hospital. Other issues of interest were to identify communication channels within the institutional structure, operation, maintenance and satisfaction with the system. The interview tools also included questions about general demographic information for each hospital. Most of the data from the in-depth interviews were used in the estimation of the sustainability metric score.

Although data collection began with a finalized interview tool for each key informant, the tools were continuously revised in the field. Questions that were not applicable or difficult to understand were omitted before the next site. Questions were also added in the field in order to clarify and/or follow-up on responses provided by the key informants. All in-depth interviews were conducted in English.

3.3.2 Knowledge, attitudes, and practices (KAP) surveys

KAP surveys were administered to clinical staff, other staff, laboratory staff, as well as patients, visitors, and caregivers. Examples of personnel in clinical staff positions include: midwives, doctors, nurses, and pharmacists. Other staff includes: staff members working in the finance and records departments, customer service officers, janitors, and orderlies.

The purpose of administering the KAP surveys was: 1) to gain insight into attitudes, beliefs, demand, and satisfaction of staff and patients that may hinder or encourage acceptance and sustainability of the water filtration systems as well as safe water use practices and hygiene behaviors; 2) to assess medical care; and 3) to assess community and household water sources. The clinical staff survey had 17 questions, the staff survey had 18 questions, and the patient and visitor survey had a total of 17 questions.

Minimal edits were made to the KAP surveys during data collection at Mampong, and Kete-Kratchi hospitals. After the first two hospital sites, questions regarding educational messaging, and how and what patients, visitors, staff, clinical staff and community members would like to learn about safe water were removed. The question "do you live on hospital grounds" was added to the staff survey in order to fully understand the question "How would you rate the water quality in the hospital as compared to the water in your house". Most KAP surveys were conducted in English. However, at each site, an interpreter who was proficient in English and the local dialect was utilized to conduct patient and visitor surveys. All translations were done orally, and responses were recorded in English.

3.3.3 Water-use survey

The water-use survey tool was used to identify water use patterns of staff, clinical staff, maintenance staff, patients, visitors and caregivers to understand the uses of different water sources for hygiene and medical purposes within the study hospitals. The results of this survey contributed to the goal of strengthening capacity at the hospital sites by identifying problems regarding water equity and proposing site-specific solutions.

Water use surveys were conducted at the end of each in-depth interview and KAP survey. Type of water source, water source availability, and a list of daily activities applicable to the role of the interviewee (i.e. hand washing before surgery, gardening, mixing of reagents for laboratory technician, sponge-bathing to reduce fever, and reconstitution of medications for pharmacy technicians) were asked in the water use survey tool. Blank boxes were added to the end of the tool to allow the interviewer write in water sources that were not listed.

3.3.4 Facility inspection guide

The research team based their facility inspection tool on the tool used by the CGSW research team in 2012 for the baseline evaluation of similar systems in Honduras. The facility inspection tool focused on the functionality and maintenance of hospital infrastructure, such as sinks, taps (which included showers, and scrub basins for surgeons), and the general hygiene of the hospital environment. The tool also included questions regarding safe water educational messaging observed by the researchers throughout the facilities. Printed educational messages found within the hospitals were photographed and evaluated for engagement and the potential to promote safe water and hygiene behaviors surrounding water sanitation and hygiene.

3.3.5 Maintenance info graphic survey

The maintenance info-graphic survey was designed to quantify the water storage capacity of each institution. This tool was used to quantify and characterize cisterns, polytanks, or other types of water storage containers present, including the physical construction material of the storage container (cement, plastic, or otherwise). In addition, the info-graphic survey included questions about water quantity in the filtered cistern, water source supply connected to the cisterns (e.g. piped, borehole, or tanker truck), and the proximity of the storage containers to each department. The locations of the polytanks, cistern, and other water sources and the connections were mapped in order to understand the water distribution systems within the hospital. The map and info-graphic helped to identify possible contamination routes post-filtration, including length of water storage in the event of water supply interruptions. The maintenance info-graphic survey was generally administered following the in-depth maintenance interviews.

3.3.6 Maintenance supply checklist

The maintenance supply checklist was developed in the field, after conducting in-depth interviews with maintenance staff at Mampong and Kete-Kratchi. The research team realized that maintenance staff had difficulty understanding names of parts in English. The new tool was created to accurately assess the ability of the maintenance personnel to correctly identify the parts of the water filtration system, their function, and the difficulty and/or ease of buying replacement parts. The process of developing the supply checklist involved taking photographs of selected parts and using a local technician to identify the English and local name for each part. Finally, a list of these items was created and questions regarding the local availability of each part, the location where the part was purchased previously, and distance traveled to acquire parts for minor and major system repairs were added to the checklist.

3.4 Sustainability metric

The sustainability metric used for this baseline study was based on a similar metric used for research conducted previously in Honduras in 2012. The sustainability metric incorporated data from in-depth interviews, KAP surveys, water quality samples, facility inspections, the info-graphic survey, and the supply checklist. A scoring system was used to measure areas of success and areas for improvement for within each hospital, while also allowing for comparisons to be made between hospitals. The domains, and sub-domains in the metric were identified based on a literature review of factors related to sustainability of water systems and WASH interventions

3.4.1 Domains

The sustainability metric was used to quantitatively evaluate the sustainability of the water treatment systems in four domains: On-Site Capacity, Accountability, Technical Feasibility, and Institutional Engagement. Domains were scored from 0 to 4 (4 being the most sustainable) based on interview responses and laboratory results. A score of 2 was defined as the cutoff for sustainability. Domains scores were compared across hospitals to identify common strengths and weaknesses.

3.4.2 Sub-domains

Within each domain of sustainability, there are topic areas, which are categorized as sub-domains (*See table 1*).

Table 1: An outline of the four sustainability domains and subdomains within each domain.

Technical Feasibility	**On-Site Capacity**
Water Sources and Availability Local Access to Replacement Parts Current Infrastructure Water Quality Testing	Organization and Communication Training and Capacity Strengthening Maintenance Repairs
Accountability	**Institutional Engagement**
Monitoring Performance Oversight by Another Entity Financial Ownership Finances	Demand and Awareness Satisfaction and Perceived Value Engagement of Hospital Director and Staff Educational Messaging

The subdomains of Accountability included: monitoring of performance, oversight by another entity apart from GE and the CGSW, financial ownership, and finances. This subdomain focused on structures that monitor key activities required for the successful operation of the system. These included: measuring chlorine residual levels, cleaning of water containers, regular backwash operation, and repairs of broken parts. Questions were asked about finance mechanisms for water and the treatment system, recurring and fixed costs, as well as the financial infrastructure relating to the water treatment system. Questions about the budget for the water treatment system were asked and available records of municipal water use were collected.

The domain of On-site Capacity included subdomains of: organization and communication, training and capacity strengthening, maintenance, and repairs. Questions were asked about the capacity of the managerial staff to manage, maintain, and operate the water system and the capabilities of the maintenance staff to troubleshoot and complete major repairs to measure the facility’s level of on-site capacity. Additionally, questions were asked about the capacity of the hospital to perform microbiological water quality testing and to learn about the functioning and non-functioning parts of the system.

The domain of Institutional Engagement and Support included sub-domains of: demand and awareness, satisfaction and perceived value, engagement of hospital director and staff, and educational messaging. The subdomains of institutional engagement identified which key stakeholders were engaged in oversight of the water system maintenance and upkeep of the water system. Furthermore, the awareness of hospital staff, patients, and visitors about the water treatment system was also measured with specific questions. Questions regarding the commitment of key managerial staff to the provision of safe water as well as data on the frequency and quality of educational messaging observed by the researcher within the facilities, were included under this sub-domain.

The final domain of Technical Feasibility included sub-domains of water source and availability, local access to replacement parts and consumables, current infrastructure, and water quality testing. Questions about the intermittent nature of hospital water supply and the methods in place to ensure water availability, storage, and management were asked. Microbiological and physiochemical laboratory tests were conducted to assess if the water in the hospital met WHO standards[‡] for microbial water quality and CDC chlorine residual standards (0.2 – 2.0ppm). Lastly, questions about the infrastructure in the hospital, such as broken sinks and taps, uncovered polytanks and cisterns, and electricity outages were asked.

3.4.3 Broad questions

Interview and survey questions were grouped under broad questions. Within each domain of the sustainability metric there were between five to six broad questions pertaining to the domain and subdomain (*Figure 5*). For example, under the domain of technical feasibility, the sub-domain was water source and availability, and the corresponding broad question was: Is there a reliable water source that provides the quantity and availability of water needed to meet demand? The sustainability metric has a total of twenty-four broad questions accompanying the sub-domains of the metric.

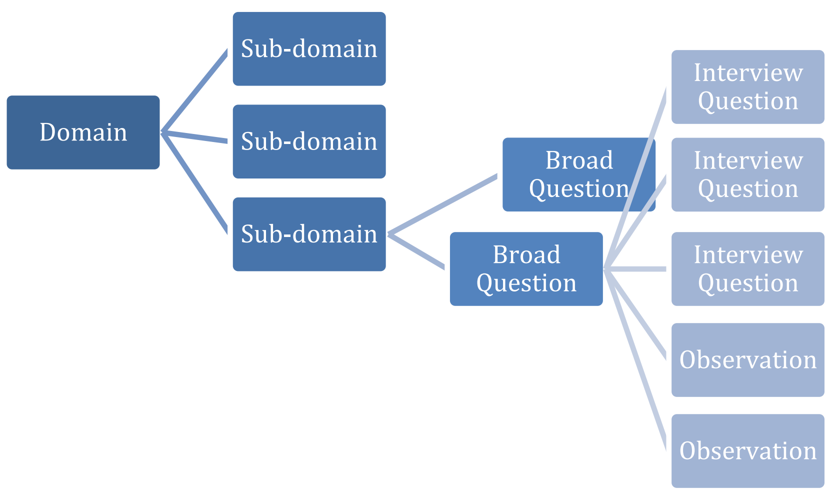

Figure 5: A schematic of the sustainability metric structure.

3.4.3.1 Interview and survey questions

The interview and survey questions were more definitive, task specific and used to elicit responses, whereas the broad questions related directly to the sub-domains required multiple inputs from the surveys, in-depth interviews, water quality results and observations to answer. Hospital-specific sustainability scores were calculated based on the scores assigned to the broad questions.

---

‡ The WHO guideline value is that *E. Coli* and thermotolerant (fecal) coliform bacteria "must not be detectable in any 100-mL sample of water intended for drinking.

3.4.4 Scoring

Sustainability was measured using a scoring system of 0-4 on a numeric scale. In this scale, a score of four was the most sustainable and a score of two was considered to be the cutoff for sustainability. Any score below two would indicate little to no evidence for sustainability of the water treatment systems and the provision of safe water within these hospitals. The score descriptions were pre-defined and used consistently across all the study hospitals. Each hospital's score for the broad questions were averaged to calculate sub-domain and domain scores. Data collected from each hospital site was entered into an Excel database. The scores for broad questions within each subdomain were calculated from multiple scores (from specific questions, observations, and measurements), and all four domains were weighted equally.

3.5 Data collection process

3.5.1 In-depth interviews

Although the goal for the research team was to administer most of in-depth interviews with the directors and maintenance personnel on the first day of the site visit, this could not be achieved consistently at all the sites. All the directors were interviewed except for the director of Axim Government Hospital. Each director interview lasted approximately two hours. In-depth interviews were conducted in the director's offices by two researchers, except for the interview conducted in Mampong hospital, which was conducted by one researcher. During these interviews, both researchers took turns asking questions, and each took detailed notes, either by hand or typed directly onto a soft copy of the survey.

In-depth interviews were conducted with one or both maintenance personnel responsible for the maintenance of the water treatment system. When possible, an in-depth interview was administered to each maintenance staff separately in order to prevent external influences on each of their responses. The in-depth interviews for the maintenance staff were usually conducted in a private room or occasionally near the water treatment systems if clarification was needed about specific comments or parts mentioned. After the in-depth interviews were conducted, one of the researchers conducted the maintenance info-graphic survey with one or more of the maintenance personnel. A thorough tour of the hospital grounds was conducted to enumerate water storage at the facilities. The maintenance info-graphic tool was also utilized to identify additional water sources used in the hospital and their connection to the water treatment system. The tool also recorded which wards in the hospital were not connected to the water treatment system.

After data collection, the combined responses from the in-depth interviews were entered into the database and secured. During data entry, clarifications were sought where needed to ensure accuracy, consistency, and unbiased entry of the information gathered.

3.5.2 Knowledge, attitudes, and practice (KAP) surveys

Clinical staff such as dentists, midwives, nurses, nurses in training, pharmacists, and optometrists, were selected for clinical staff interviews. Examples of other hospital staff selected for administrative interviews included: kitchen staff, janitorial staff, procurement officers, and desk clerks. Patient surveys were conducted in the wards and in-patient waiting areas. The team selected patients who had spent a few nights at the hospital; however, some outpatients were also interviewed. Visitors and caregivers were often at the bedside of a patient or could be found in common waiting areas on hospital premises. In order to collect a diverse range of responses, hospital wards were pre-selected, and interviewees were randomly selected. KAP surveys were collated and entered into the database and secured for analysis.

3.5.3 Water-use surveys

Water use surveys were conducted at every hospital. There were a few instances when only the water use surveys were completed with hospital staff without KAP without surveys in order to get more information on water use within the hospitals.

3.5.4 Facility inspection guide

Tap Observation Tools were utilized on the first evening of the site visit in conjunction with the collection of water samples, or on the last day of data collection at the site. Researchers sought permission from the hospital administrator and unit heads before entering the wards, pharmacies, laboratories, and consulting rooms. In cases where the research team was not allowed to enter private areas or isolated patient rooms, hospital staff conducted the inspection and reported the information to researchers. The inspection included, turning on sink taps (surgical scrub basins included) and shower heads to observe flow and functionality. The availability or lack of soap (both liquid and solid) around the sink was observed and noted. The hospital theater often required sterile and protective gear; in this case one of the researchers wore the hospital-approved footwear and gown provided by the hospital staff in order to conduct the inspection.

3.5.5 Maintenance supply checklist

The maintenance supply checklist was administered in four of the six hospitals (Kintampo, Bole, Apam and Axim). The availability of parts, where the part was found previously, and distance traveled to acquire parts for minor and major system repairs were recorded. Initially, at the Kintampo Government Hospital, maintenance staff on duty were shown photographs of the individual parts and then asked to identify the part in the system and indicate its accessibility and distance travelled to acquire the part. Subsequent supply checklists did not include photographs. Maintenance supply checklists were carried out on the same day of the info-graphic survey or on the final day of data collection for the site.

3.6 Water quality testing procedures

3.6.1 Water sample site selection within each hospital

Water sample collection sites were identified before sample collection. Water samples were collected upon arrival at each site, usually in the late afternoon before the first full day of data collection. At least one maintenance personnel accompanied the research team during sample collection. At minimum, 24 water samples were collected from each hospital and tested for *P. aeruginosa*, *E. coli* and Total Coliforms, free chlorine residual levels, and turbidity. Some water samples were collected before and after treatment and from several points within the hospital wards. Other samples were taken from staff quarters and hospital-associated school taps, some of which were also connected to the water treatment system.

3.6.2 Sample collection

For each tap tested, three WhirlPak® bags were filled with 100 mL of water and stored in a cooler in preparation for processing. Two of the sample bags contained sodium thiosulfate to neutralize the chlorine in the water samples; the last sample bag was used to test chlorine residual and turbidity and did not contain sodium thiosulfate. Researchers collected most of the water samples except in cases where maintenance staff expressed a desire to learn the procedure. In such instances, the researcher collected a duplicate sample in order to minimize contamination. The exact locations of sample collection (ward, name and a brief description of source, such as veronica bucket or tap), flow rate, and filtration status (operational, or not) were recorded on the water sample collection form.

3.6.3 Sample processing

Water samples were processed in a temporary field laboratory in the hotel rooms of CGSW staff within 2 – 3 hours of sample collection. Laboratory equipment set up in preparation for sample processing included the IDEXX Quanti-Tray Sealer®, an incubator, a Hach 2100P portable Turbidimeter®, and a LaMotte Single Test Colorimeter® (model 1200).

3.6.3.1 Biological testing

The IDEXX Quanti-Tray® 2000 method was used to measure concentrations of Total Coliforms, *E. coli* and *P. aeruginosa* in water samples. In preparation for processing, water samples for Total Coliforms, *E. coli* and *P. aeruginosa* coliforms were mixed with Colilert® and Pseudalert™ reagents, respectively, to facilitate bacterial growth. Antifoam was used to settle the Pseudalert ™ in the samples tested for *P. aeruginosa*. Each sample was then poured into an IDEXX Quanti-Tray®, sealed using the DEXX Quanti-Tray® Sealer Model 2X, incubated at 38°C for 18 hours for E. *coli* and Total Coliforms, and 24 hours for *P. aeruginosa*. A negative control was used for each batch of processed samples. Distilled water brought from the laboratory at Emory University was used as a negative control.

After incubation, the wells of the IDEXX trays turned yellow if total coliforms were present. Ultraviolet (UV) light was used to determine the number of cells that fluoresced blue indicating the growth of *E. coli* or *P. aeruginosa*. A MPN chart was used to convert the number of positive cells into most probable number (MPN) of *E. coli* or total coliforms, and *P. aeruginosa* per 100mL. The assay limits of detection for undiluted samples were: 1 MPN/100mL for the lower detection and 2419.6 MPN/100mL for the upper detection limits.

The reliability of electricity and availability of generators determined the location of the incubator. The incubator was usually set up on hospital grounds, except on two occasions (Kintampo and Axim Hospitals) where the incubator was used in the hotel room. Incubation temperatures fluctuated due to power voltage surges. At Bole Hospital, the temperature of the incubator was 38.8°C at the beginning of incubation, but rose to 42.4°C 18 hours later. Similarly in Apam Catholic hospital, the incubator was at 40.9°C when all samples were inserted into the incubator, and 38.3°C when the water samples were read (*see table 2*).

Table 2: Sample incubation temperatures

Hospital Site	Sample Type	Temp at incubation (°C)	Maximum Temperature (°C)	*E. coli*/TC) Temp at 18 hours (°C)	*P. aeruginosa* Temp at 24 hours (°C)
Apam	*E. coli*/TC	38.4	40.9	38.3	38.0
	P. aeruginosa				
Axim	*E. coli*/TC	37.6	-	41.0	39.0
	P. aeruginosa				
Bole	*E. coli*/TC	38.8	41.9	42.4	42.4
	P. aeruginosa				
Kete-Kratchi	*E. coli*/TC	-	-	-	-
	P. aeruginosa				
Kintampo	*E. coli*/TC	33.6	46.7	37.6	37.6
	P. aeruginosa				
Mampong	*E. coli*/TC	38.0	38.0	38.0	38.0
	P. aeruginosa				
	P. aeruginosa				

3.6.3.2 Chlorine residual testing

Total and free chlorine residual levels were tested using the LaMotte Single Test Colorimeter® (model 1200). Two samples were collected and tested for free and total chlorine. Water was collected using a WhirlPak® bag that did not contain sodium thiosulfate. The target range for chlorine residual in drinking water, as defined by the Centers for Disease Control was 0.2 – 2.0 mg/L or ppm. Between samples, the vials were rinsed with non-chlorinated, bottled water.

3.6.3.3 Turbidity testing

Turbidity levels of water samples were measured using the Hach® 2100P Turbidimeter which was calibrated once at each study site with STABLCAL® Stabalized Formazin Standards. Water samples used to assess turbidity did not contain sodium thiosulfate. Turbidity measurement procedures were in accordance with the manufacturer's instructions. WhirlPak® bags were shaken before being placed in the turbidimeter.

3.7 Data Analysis

Data analyses for this study were performed using Statistical Application Software (SAS 9.3) for analysis of both water quality and survey data. Tables and graphs were created in Microsoft Excel 2011.

3.7.1 Analysis of demographic data

Demographic data from the study hospitals such as populations served, number of doctors, number of clinical and other staff, out patients served weekly/daily and number of beds available were compared. Descriptive analyses, such as frequencies, geometric means, standard deviations, and distributions were calculated.

3.7.2 Knowledge, attitudes and practices data

Descriptive statistics such as frequencies were used to describe and compare beliefs of clinical staff, other staff, and patients regarding safety of hospital tap water, use of water for medical and non-medical purposes, and knowledge of the water treatment system. Variables of interest from the maintenance and water quality data were examined using univariate and descriptive analyses. Chi-square tests for association were used to examine associations between staff who were aware of the water treatment system and staff who believed the water from hospital tap was safe to drink. Chi-square tests for associations were used to examine relationships between samples that met WHO standards for drinking water quality, locations of sample collection points, and free chlorine residual levels.

3.7.3 Water quality

Water quality was defined using the WHO standards for safe drinking water (<1CFU /100mL of water), and the CDC standards for free chlorine residual (0.2 – 2.0ppm). Percentages of water samples tested at the water treatment system (both pre-treatment and after treatment) and at Point-of-Use (POU) taps within the hospital that met these standards were compared. Water quality data also informed sustainability scores of each hospital. Furthermore, the standard error of the mean of the bacterial levels detected was also calculated. A value of zero chlorine residual was assigned to samples from hospitals that were not chlorinating their water or a portion of water in the hospitals. The WHO guideline recommending <5 NTU for turbidity of drinking water was used as the standard for turbidity calculations. To calculate odds ratios, values of zero were replaced with 0.5.

3.7.4 Sustainability metric

Analyses and calculation of sustainability scores were conducted using excel. Sustainability scores were assigned to each broad question under the respective subdomains. Broad questions were previously defined and ranked with a score from 0 – 4. Responses from survey questions, water quality, and observations were reviewed in order to assign appropriate scores. Sustainability scores were adjusted as necessary after considering all data inputs and observations. After all scores had been assigned, the means were calculated using multiple scores for all broad questions under each subdomain for each hospital. Overall sustainability scores for the domains in each hospital were weighted equally.

3.8 Ethical considerations and confidentiality

Institutional Review Board (IRB) approval 0000031237 was obtained before conducting this research. Permission was sought from the hospital administration prior to interacting with staff, clinical staff, patients, visitors and caretakers. Informed verbal consent was obtained from each participant in accordance with the ethical requirements of the IRB.

4 RESULTS

4.1 Hospital demographic data

At ach study hospital, a total of five KAP surveys were administered to clinical staff and administrative staff, and ten KAP surveys were administered to patients, visitors and caregivers. A total of 6 administrator, 7 laboratory, 33 clinical staff, 35 other staff, and 58 patients and visitor surveys were collected in all the hospitals (*Table 3).*

Table 3: Total number of surveys administered in each hospital.

Site	Director	Administrator	Maintenance	Laboratory	Clinical Staff	Staff	Patient &Visitor
Apam	1	1	2	1	6	4	10
Axim	0	1	1	1	6	6	10
Bole	1	1	1	1	5	6	9
Kete-Kratchi	1	1	1	1	5	6	10
Kintampo	1	1	2	1	5	5	9
Mampong	1	1	2	2	6	7	10
Total	**5**	**6**	**9**	**7**	**33**	**34**	**58**

The estimated population served by the six study hospitals ranged from 67,000, to 221,000 (*Table 4*). The mean population served by the study hospitals was 120,888. The hospitals served between 200 and 250 patients per day.

Table 4: Hospital demographic data.

	Apam	Axim	Bole	Kete-Kratchi	Kintampo	Mampong
Population Served	221,000	54,337	67,000	122,105	140,000	-
Doctors	3	1	1	1	2	11
Nurses	52	27	13	50	65	83
Other Admin Staff	70	65	81	140	100	310
Patients/day	250	-	-	375	200	209
Beds	NA*	70	100	NA*	128	139

* Information was not available.

The main sources of drinking water reported by staff, patients and visitors were bottled and sachet water, followed by tap water. Of all patients and visitors interviewed, 38% thought contaminated water is a problem in their communities, 16% used any water treatment method at home, and only 7% of all patients interviewed drank water from the hospital tap. The majority of patients who did not drink water from hospital tap indicated that they preferred to buy sachet water for drinking, or did not consider the hospital sinks hygienic enough to drink from. About 16% of patients reported that they used a water treatment method at home. Boiling and filtration were the most common water treatment methods used equally at 44%. None reported using a chlorination method of treatment.

4.2 Key Maintenance Tasks and Hospital Infrastructure

According to the maintenance staff, common system problems included frequent breakdowns, low water pressure issues, and bypassing the water treatment system, all of which led to distribution of unfiltered water to taps within the hospital. *Table 5* summarizes distance traveled to access replacement parts, number of staff trained, where replacement parts were accessed and cost of consumables. The median distance travelled by maintenance staff to access replacement parts for system repairs was 58 miles and required approximately 1.5 hours of travel time. Other key maintenance tasks discussed during the surveys are indicated in *Figure 6a*. Each study hospital had challenges at varied levels with routine maintenance tasks such as: chlorine addition to the treatment system, and performance of backwash. All hospitals, except for Kintampo who did not have a functioning chlorine doser, reported adding chlorine to the treatment system on average 1.07 times a week. However chlorine residual levels were not detected in post-filtration samples collected in three out of four hospitals.

Daily backwashing of the water treatment system was performed twice as much on a weekly basis by maintenance staff in Mampong Hospital in comparison to other study sites (*Figure 6*). Only two of the study sites, Mampong and Apam, reported routine pressure checks at the entrance and exit of the system.

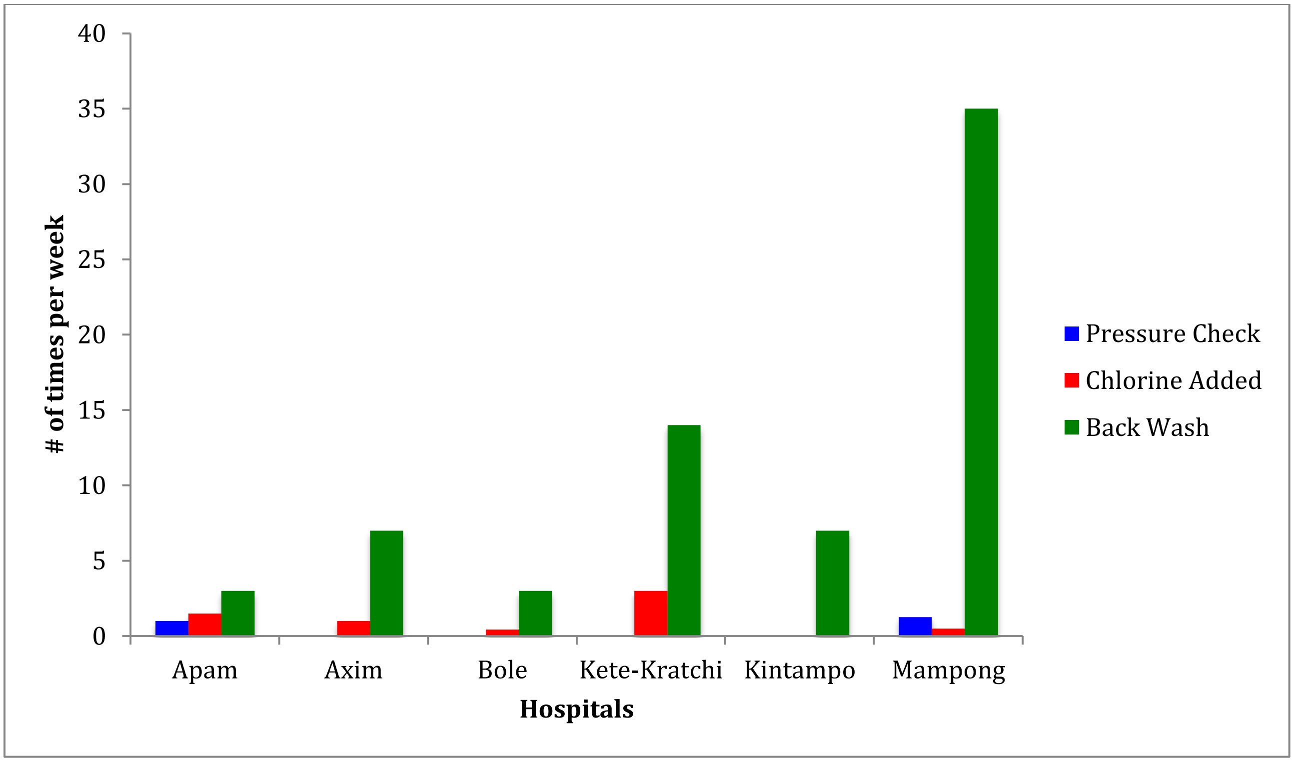

Figure 6: Reported frequency of routine maintenance tasks

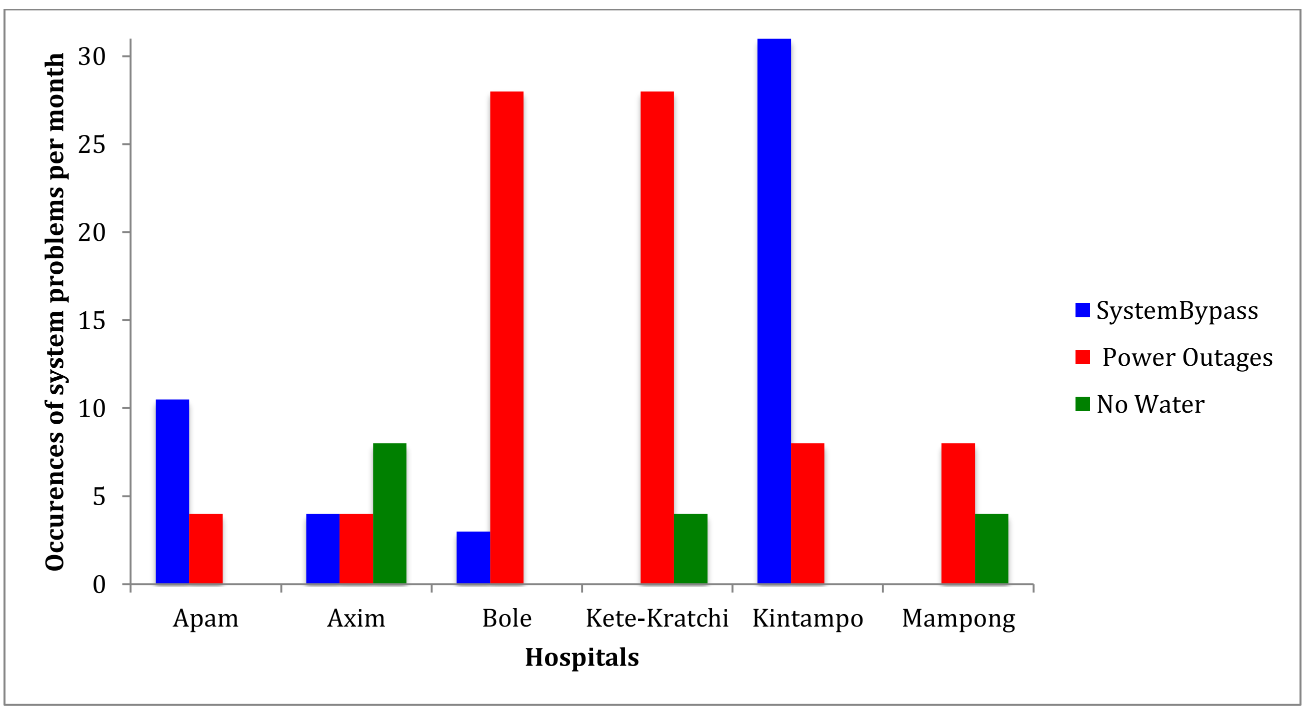

Figure 7: Reported occurrences of common system problems.

Bypassing of the water treatment system occurred almost daily in Kintampo, significantly more than in any other study site (*Figure 7*). Apam, Axim, and Bole hospitals also reported bypassing the system due to system breakdowns and long inoperable periods of the water treatment system. Power outages were a common problem in all of the study sites; however the challenge of frequent power outages was greatest at Bole and Kete-Kratchi. Interrupted water flow was not a reported challenge in Apam, Bole, and Kintampo.

Table 5: Distance traveled to access replacement parts, staff trained, parts accessed and cost of consumables.

Hospital	**Apam**	**Axim**	**Bole**	**Kete-Kratchi**	**Kintampo**	**Mampong**
Maintenance Employed (years)	22	3.5	3	5	8	7.8
Trained staff	2	2	2	1	1	3
City parts Located	Accra	Takoradi	Wa	Kumasi	Kintampo	Kumasi
Travel Time (hr.)	1.50	1.50	.30	9.0	0.30	1.50
Distance (km)	62.1	54.5	127.0	548.0	-	-
Consumables (monthly cost)	20.0	-	250.0	100.0	-	112.5
Mean distance traveled to access replacements parts is 131.92 kilometers, and 81.96 miles, and mean time traveled is 2.35 hours. Average monthly cost of consumables for the water treatment system is \$318/month. Tenure of maintenance staff at their respective posts range from 3 to 22 years.						

The functionality of hospital infrastructure varied greatly among hospitals *(Figure 8*). At Axim, Kete-Kratchi and Kintampo, over 85% of taps were functional, compared to Mampong hospital that had only 28% of the taps functional. Overall, only 56% of the hospital sinks had soap at the time of the survey. Five of the hospitals used large polytanks for water storage. The number of polytanks per hospital ranged from 1 – 21.

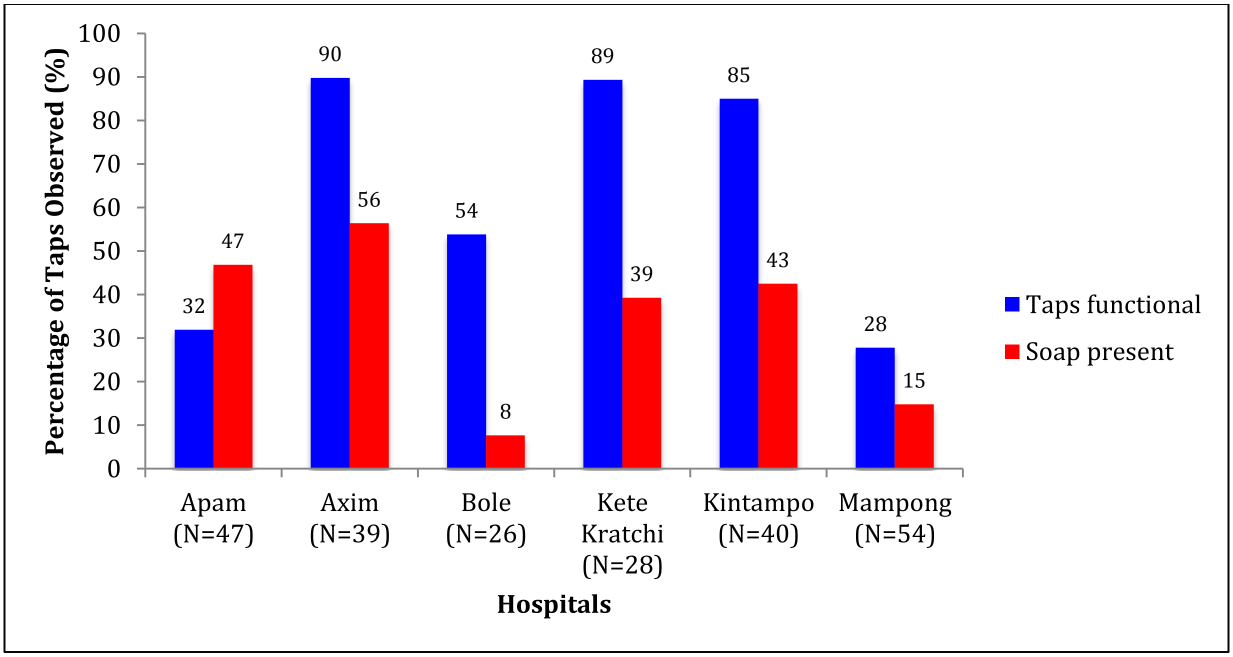

Figure 8: Observation of functional sink taps and presence of soap.

4.3 Water Quality

A total of 220 water samples were collected, tested, and analyzed for microbiological contamination and physiochemical properties. Four out of five water samples collected pre-filtration and chlorination tested positive for *E. coli* and total coliform bacteria except for the sample collected from Axim hospital, which had <1MPN/100 mL of both *E. coli* and total coliforms. All samples collected post-filtration at all the water treatment systems had < 1MPN/100 mL of *E. coli*, and total coliform bacteria contamination, except the sample from Kintampo hospital, which had 38.8 MPN/ 100 mL of total coliforms post-filtration (*Table 6*). *P. aeruginosa* bacteria were detected in five out of six systems post-filtration.

Table 6: Mean and standard deviation for *E. coli*, total coliforms and free chlorine residual before filtration, after filtration and at point-of-use taps within the hospital.

Hospitals	Raw Water (Before Filtration)		Finished Water (Post-Filtration & Chlorination)		N	Points-of-Use (POU) Samples		
	total coliforms MPN/100 mL	*E.coli* MPN/100 mL	total coliforms MPN/100 mL	*E.coli* MPN/100 mL		*E.coli* MPN/100 mL Mean* (SD)	total coliforms MPN/100 mL Mean* (SD)	Free Chlorine Residual Mean + (SD)
Apam	>2419.6	>2419.6	<1	<1	13	20.57 (98.18)	161.55 (329.19)	0.04 (0.03)
Axim	<1	<1	<1	<1	11	0.5 (0)	0.5 (0)	0.20 (0.07)
Bole	95.6	<1	<1	<1	10	17.00 (30.63)	77.80 (93.51)	0 (0)
Kete-Kratchi	119.8	22.6	<1	<1	13	0.15 (3.08)	1.13 (41.40)	0.02 (0.41)
Kintampo	95.5	2	38.8	<1	12	1.09 (1.69)	16.51 (23.36)	0 (0)
Mampong	-	-	0.5	<1	19	0.61 (0.99)	1.26 (518.72)	0.23 (1.22)

* Geometric mean
+ Arithmetic mean

Over 80% of samples collected from taps within the hospital at Mampong and Kete-Kratchi met the WHO standards of <1MPN/100mL for *E. coli* and total coliforms (*Figure 9*). Only 23% of samples in Apam, 25% of samples in Kintampo, and 10% in Bole met the CDC recommended guidelines for free chlorine residual level in drinking water. All water samples collected from Axim hospital both at the system and at the hospital taps had no detectable *E. coli* and total coliforms in 100 mL. However, *P. aeruginosa* was detected from two water samples tested, one at the water treatment system post filtration (tap #5), and the other from the sink tap of the theatre ward.

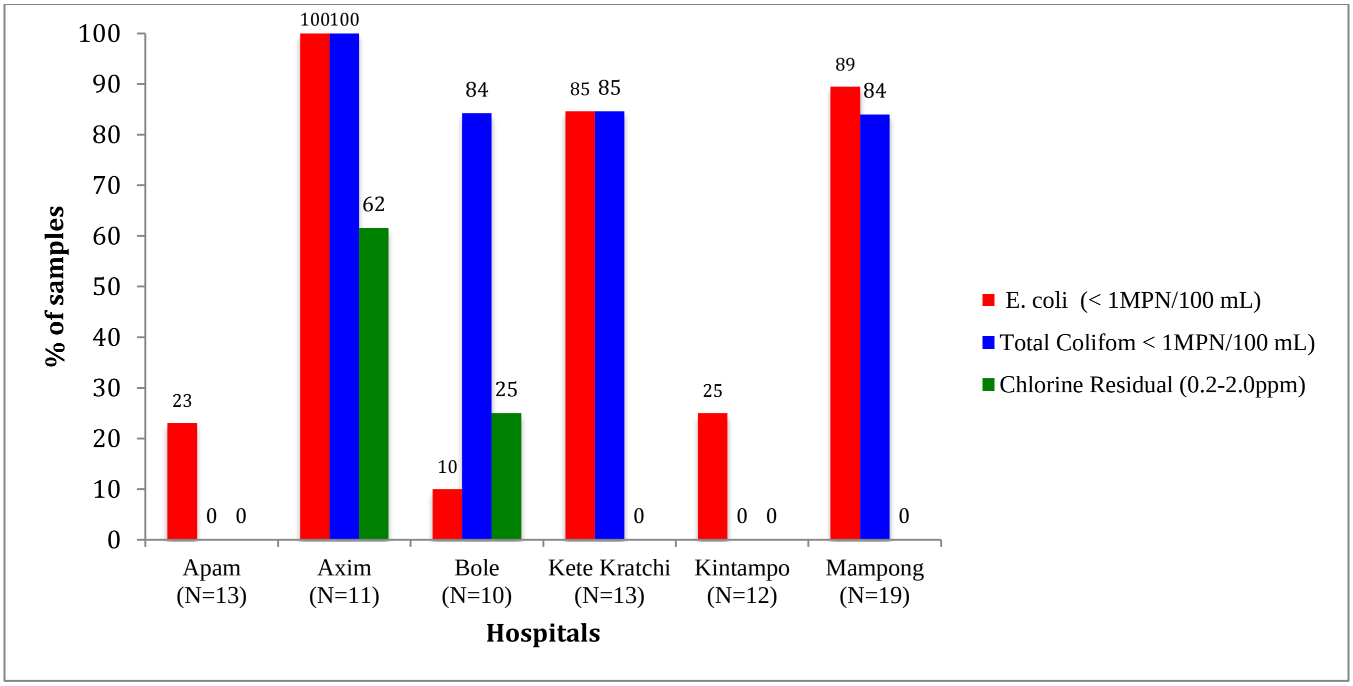

Figure 9: Percentages of water samples collected from point-of-use taps within each study hospital that met WHO guidelines of <1MPN/100mL of *E. coli*, total coliforms concentration and CDC guidelines for free chlorine residuals.

Overall, more than 90% of water samples tested in all hospitals did not meet CDC recommendations for free chorine residual (between 0.2 and 2.0ppm), but there were two samples that had free chlorine residual levels above 2.0 ppm. About 62% of water samples in Axim and 25% of samples in Bole had chlorine residual levels within the CDC guidelines for safe drinking water (*Figure 9*). Axim hospital added chlorine to both the cistern (pre-filtration) and at the water treatment system (post-filtration) once a week, and 62% of samples met the CDC guidelines. Whereas Kete-Kratchi reported adding chlorine to the system 3 times a week, and 0% of samples tested met the CDC guidelines for free chlorine residual.

Since sachet water was available throughout the hospitals, and was reported to be a preferred option for drinking water, selected water sachet brands were tested for bacterial contamination. All of these had non-detectable levels of both *E. coli* and total coliform bacteria.

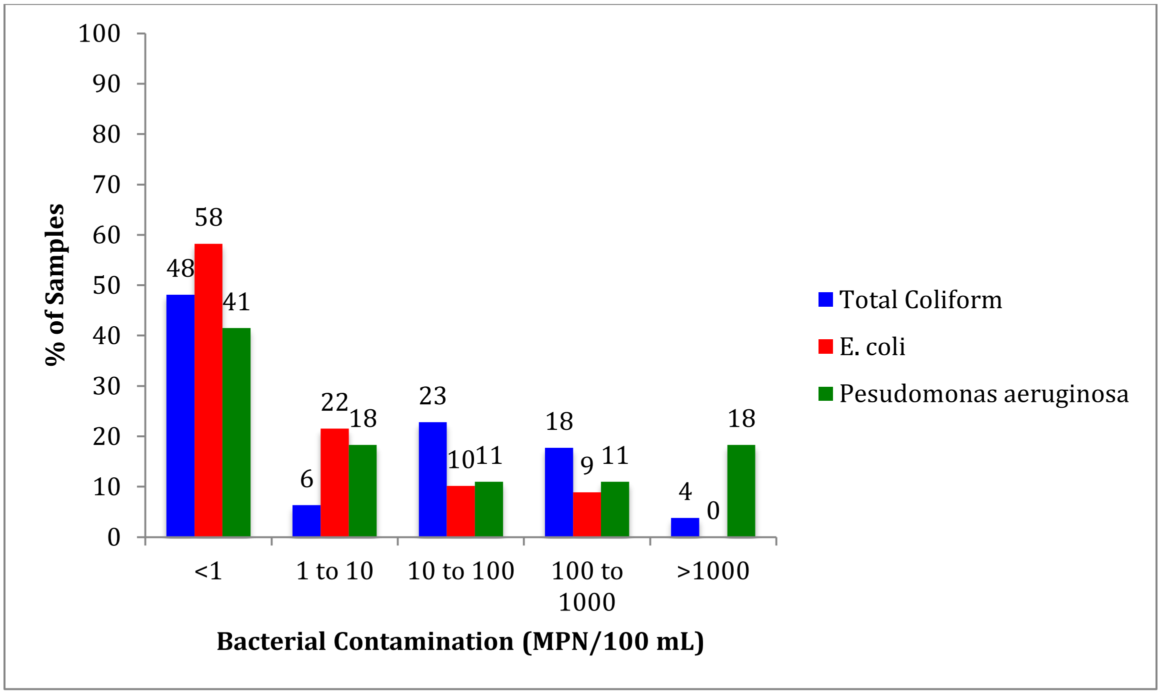

Figure 10: Distributions of total coliforms, *E. coli*, and *P. aeruginosa* concentrations (MPN/100mL) in samples from point-of-use taps within all hospitals. *E. coli* and total coliforms (N=78), *P. aeruginosa* (N=75).

Figure 10 summarizes the distribution of *E. coli*, total coliforms, and *P. aeruginosa* concentrations in the water samples collected at taps within the hospitals. Most of the water samples tested had <1MPN/100 mL of *E. coli*, total coliforms, and *P. aeruginosa* (58%, 48%, and 41%, respectively). About 18% of samples tested for *P. aeruginosa* had concentrations >1000 MPN/100 mL.

Table 7 summarizes the distribution of *P. aeruginosa* concentrations measured in water samples collected after filtration and from taps within the hospital. High levels of *P. aeruginosa* were observed at critical points in the hospital (i.e. surgical, labor and delivery, and outpatient department).

Mean *P. aeruginosa* concentrations were between 0.09 and 933 MPN/100 mL, with wide confidence intervals (*Table 7*). The mean *P. aeruginosa* concentrations in samples from all taps within the hospital that tested positive for *P. aeruginosa* was 450.53 MPN/100 mL (p-value<0.0005) which was significantly higher than the mean concentrations of *E. coli* and total colifoms. Three hospitals had very high levels of *P. aeruginosa*. Water samples tested for *P. aeruginosa* in Apam had a mean of 933.79 MPN/ 100mL. Samples tested for *P. aeruginosa* in Bole had a mean of 970.62 MPN/100mL.

Table 7: *P. aeruginosa* concentration in samples collected from point-of-use taps within the hospital wards.

Hospital	N	Geometric Mean MPN/100 mL	SD
Apam	14	933.79	1168.16
Axim	11	202.13	698.32
Bole	10	970.62	1120.38
Kete-Kratchi	17	76.51	259.38
Kintampo	13	535.60	995.67
Mampong	20	257.87	740.51

Table 8 summarizes *P. aeruginosa* contamination in samples collected before and after filtration and at taps within hospital wards. High levels of *P. aeruginosa* bacteria were detected at five hospitals post-filtration, and. >2419 MPN/100 mL of *P. aeruginosa* bacteria was detected in finished water samples at Axim and Kintampo hospitals.

Table 8: Mean and standard deviation for *P. aeruginosa* before filtration, after filtration, and at point-of-use taps within the hospital.

Hospitals	**Raw Water (Before filtration)**		**Finished water (Post-filtration & chlorination)**		**POU (Taps within hospital)**	
	N	**MPN/100 mL**	**N**	**MPN/100 mL**	**N**	***MPN/100 mL* (SD)**
Apam	1	>2419.6	2	195.5*	13	59.94* (1131.44)
Axim	2	0.5	1	>2419.6	12	0.5 (0.00)
Bole	1	77.6	1	113.7	10	126.49 (1130.49)
Kete-Kratchi	2	324.02	4	646.81*	14	2.05 (20.37)
Kintampo	1	261.3	1	>2419.6	9	30.18 (788.84)
Mampong	0	-	1	0.5	19	2.49 (758.52)

* Geometric mean

4.4 Knowledge, Attitudes, and Practices Related to Hospital Water

Of all the staff interviewed (both clinical and administrative staff), an average of 42% of staff believed that water from hospital taps was safe to drink, compared to an average of 51% of patients interviewed that believed water from the hospital was safe to drink. In four out of the six hospitals with the GEF-donated water treatment system showed, over 50% of the staff reported that they were aware of the water treatment system at the hospital. There is a wide variation in the proportion of staff that reported drinking water from hospital taps (*Figure 11*). In Apam, Mampong, and Bole, less than 20% of staff reported drinking water from hospital taps, and 0% of staff in Kintampo hospital reported drinking from hospital taps.

Most staff reported drinking from water dispensaries, coolers, and purchasing bottled water for drinking. There was a significant association between staff who were aware of the water treatment system, and staff who believed that hospital water was safe (*p*-value<0.0034).

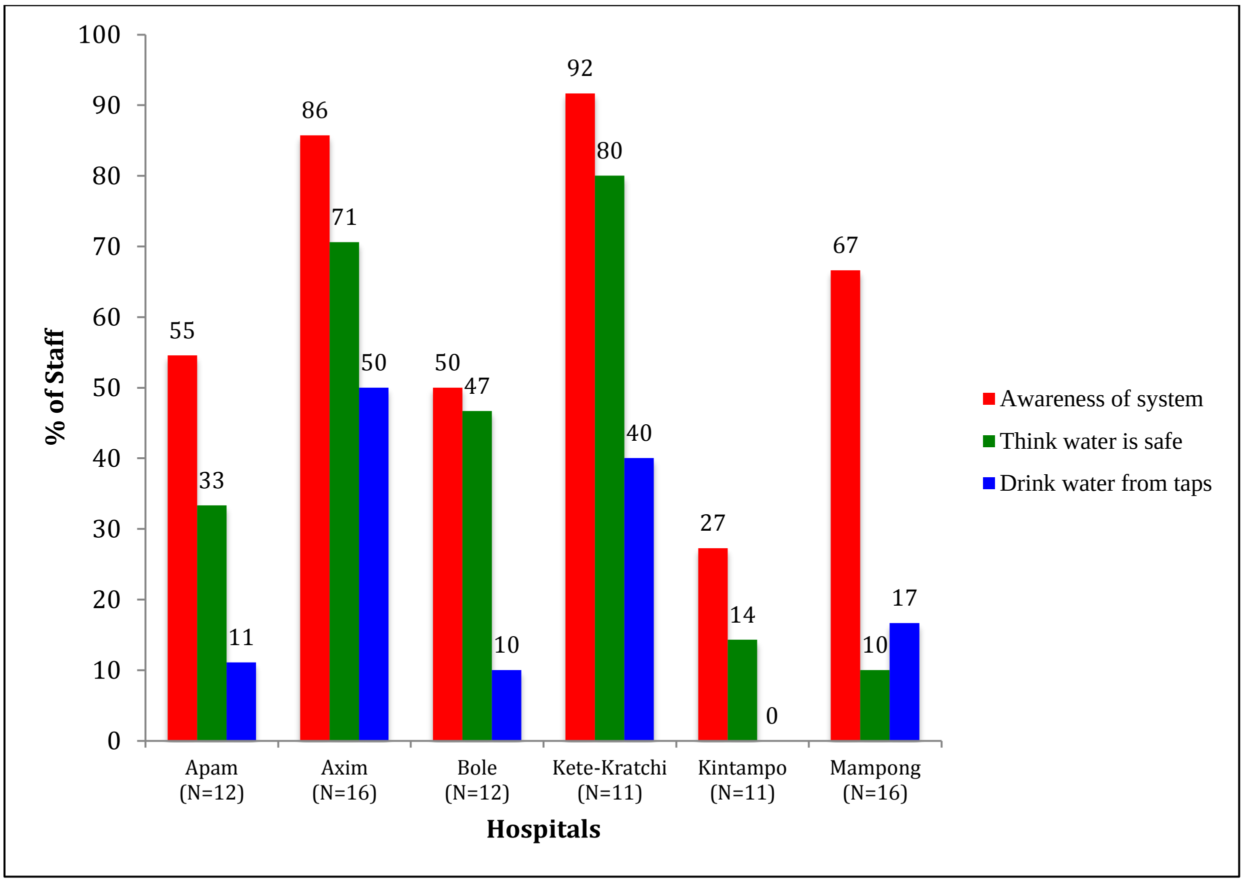

Figure 11: Percentage of staff that are aware of the water treatment system, believe water is safe and drink water from the hospital taps.

Beliefs and attitudes about water within the hospital did not vary greatly among patients and visitors. Few patients in Kete-Kratchi, Bole, and Kintampo reported that they drank hospital water (20%, 11%, 11%, respectively), compared to no patients that reported drinking water from taps within the hospital in Mampong, Axim, and Apam hospitals (*Figure 12*). Although no patients and visitors in Mampong, Axim, and Apam hospitals reported that they drank the hospital water; significant percentages of patients and visitors believed the water was safe to drink.

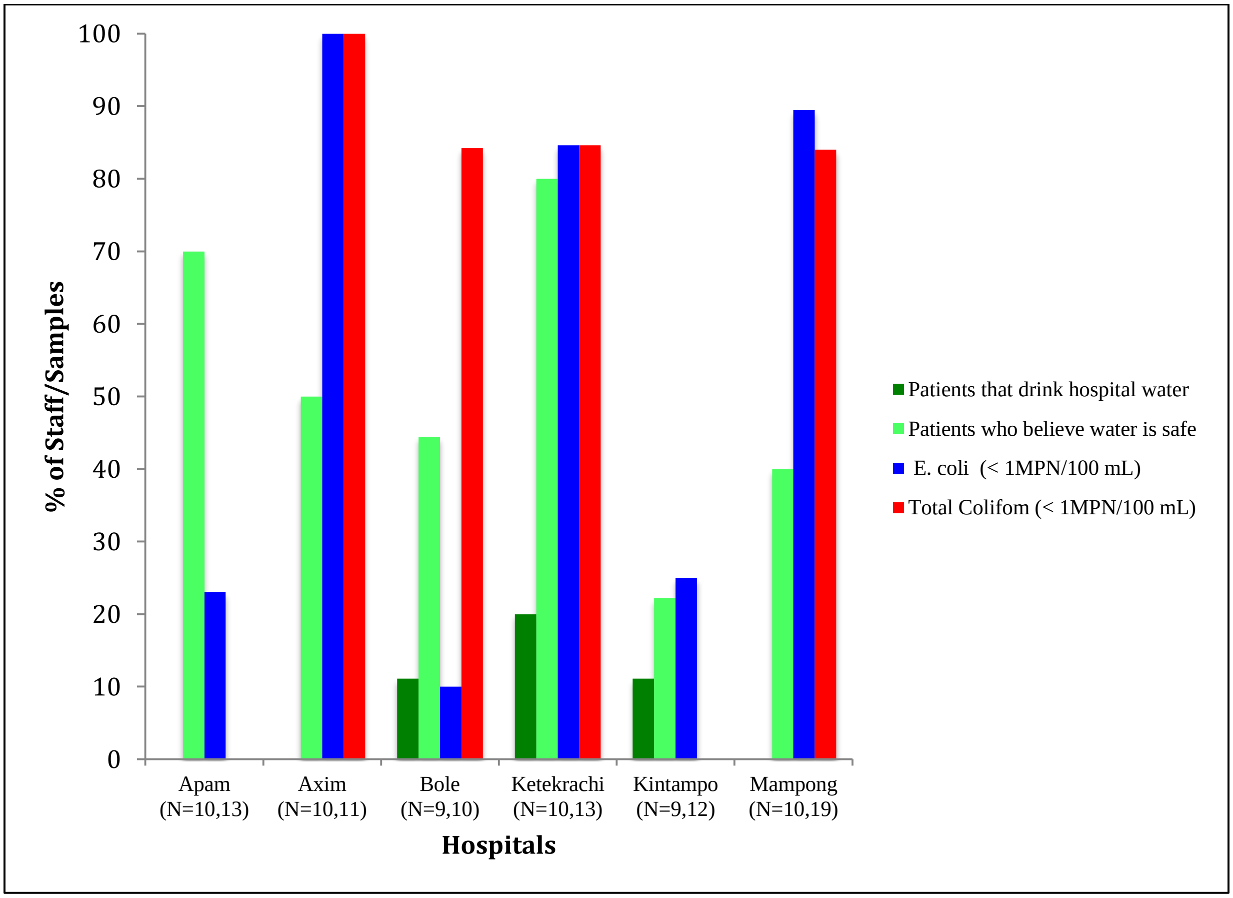

Figure 12: Percentage of patients who drink hospital tap water, and believe water safe compared to percentage of hospital point-of-use tap water that met WHO guidelines for *E. coli* and total coliforms. KAP surveys (N=58), *E. coli* and total coliforms (N=78).

There was no association between staff beliefs that hospital water was safe and the proportion of water samples with non-detectable levels (<1MPN/100 mL) of Total Coliform bacteria (p-value<0.5989). However, there was a significant association between the proportion of staff who believed that the hospital water was safe and detection of *E. coli* levels >1MPN/100 mL in the hospital water (p-value<0.0004).

Most clinical staff used treated tap water, bottled water, or better ("better water" was either sterile saline, or other sterile forms of liquid) for important medical purposes. Use of safe water for medical purposes in Ghana varied depending on the specific task conducted (*Figure 13*). The use of bottled water or water of better quality for giving medications, cleaning wounds, and caring for burns did not vary significantly at (86%, 86% and 89%). At least 20% of staff reported that they used bottled water or higher quality water for cleaning wounds 5% reported using tap water for burn care. A least 14% of staff reported that they used tap water when giving medications to patients, and 100% of clinical staff reported using both untreated tap and treated water for hand washing.

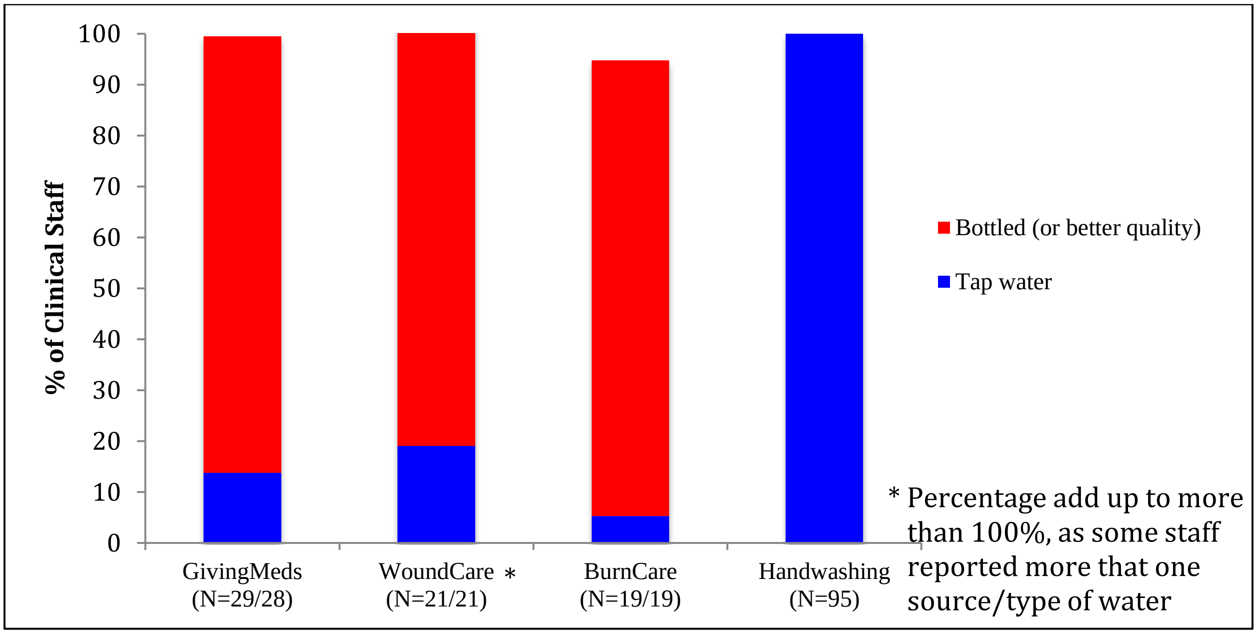

Figure 13: Use of water for medical purposes by clinical staff in hospitals

There was a large difference between the percentages of staff that believe patients and visitors drink from taps within the hospital and percentages of patients who reported actually drinking from taps within the hospital (*Figure 14*). Taps within the hospitals were generally located in places perceived by patients not to be hygienic or accessible.

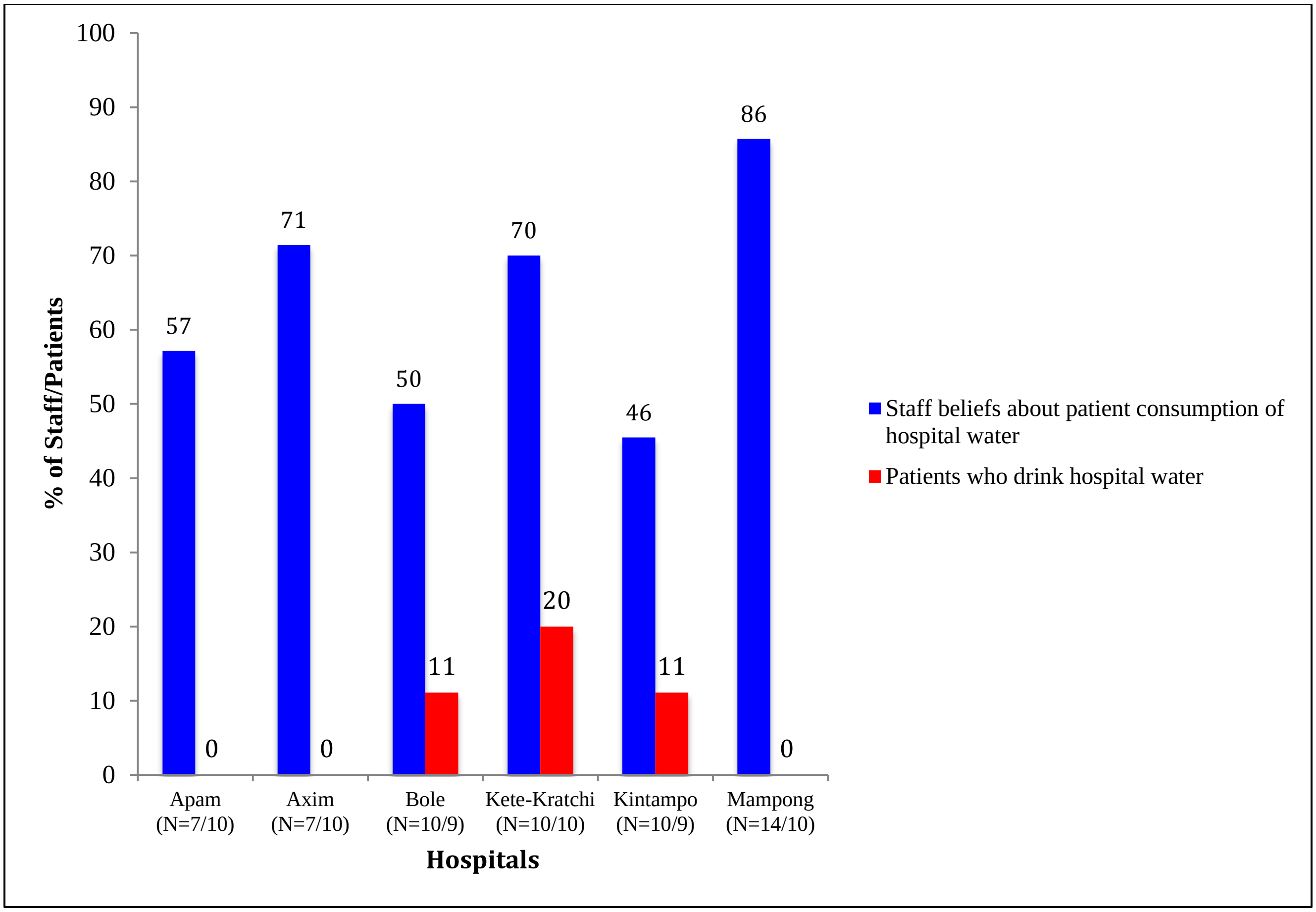

Figure 14: Percentage of staff who thinks patients drank water from taps, and patients who reported that they drink water from hospital taps.

4.5 Sample Collection Points and POU Water Quality

Locations where water samples were collected at point-of-use were also an important factor in determining microbiological water quality. All of the hospitals had buckets (also termed veronica buckets) with lids available within each ward including patient waiting areas (*Figure 15*). Veronica buckets were used to store water within hospital wards and were mostly used by clinical staff for hand washing before and after attending to patients. About 83% of samples collected and tested were from taps. Only 20% of samples collected from taps, and 0% of samples collected from buckets met the CDC free chlorine residual guidelines for safe drinking water. There was a significant difference in the percentage of samples collected from taps that met guidelines for free chlorine residual, as compared to samples taken from buckets ($p<0.0297$, $p<0.2635$), respectively.

Table 9: Number and percentage of samples from buckets and taps within the hospital that met WHO total coliforms and *E. coli* guidelines for drinking water (<1MPN/100 mL).

Hospital	*E. coli*		Total coliforms	
	Taps (% <1 *MPN/* 100 mL) N (%)	Buckets (%<1 MPN/ 100 mL) N (%)	Taps (% <1 MPN/100 mL) N (%)	Buckets (%<1 MPN/100 mL) N (%)
Apam (N=13	11 (27.3)	2 (0.0)	11 (0.0)	2 (0.0)
Axim (N=11)	11 (100)	0 (-)	11 (100.0)	0 (-)
Bole (N=9)	5 (0.0)	4 (25.0)	5 (0.0)	4 (0.0)
Kete-Kratchi (N=14)	14 (84.6)	0 (-)	14 (84.6)	0 (-)
Kintampo (N=12)	9 (33.3)	3 (0.0)	9 (0.0)	3 (0.0)
Mampong (N=17)	13 (92.3)	4 (75.0)	13 (84.6)	4 (75.0)
Total	63(56.2)	13(16.6)	63 (44.8)	13(12.5)

Frequency Missing = 3

At point-of-use, more samples collected from taps met WHO guidelines for both *E. coli* and total coliforms than samples collected from buckets (*Table 9*). Overall, out of 63 tap samples 56%, and 45% met drinking water guidelines for *E. coli* and total coliforms, respectively. Out of 13 samples collected from buckets, only17%, and 12% met drinking water guidelines.

Table 10: Number and percentage of samples collected from taps and buckets, and percentages of samples from both locations that met guidelines for free chlorine and turbidity.

Hospitals	N	Bucket samples (%)	Tap samples (%)	Chlorine (0.2-2.0ppm) (%)	Turbidity (<5 NTU)
Apam	13	15.4	84.6	0.0	76.9
Axim	11	0.0	100.0	72.7	90.9
Bole	9	44.4	55.6	0.0	100.0
Kete-Kratchi	14	0.0	100.0	0.0	100.0
Kintampo	12	25.0	75.0	0.0	33.3
Mampong	17	23.5	76.5	31.6	57.9
Total	76	17.1	82.9	17.4	76.5

** Frequency missing=3

The highest percentages of samples collected from buckets were in Bole hospital (44.4%). All samples collected from Axim and Kete-Kratchi were from taps. Turbidity levels were highest in Bole and

Kete-Kratchi (*Table 10*). At four hospitals, none of the point-of-use samples had adequate free chlorine residual. At Bole and Kete-Kratchi all of the point-of-use samples had low turbidity.

Figure 15: A veronica bucket used for water storage and hand washing within hospital wards.

Figure 16: Sink taps within the hospital.

Table 11: Association between samples meeting microbiological guidelines for safe drinking water and meeting guidelines for free chlorine residual and turbidity.

	Sample met Free Chlorine residual guidelines (Yes= 0.2-2.0ppm, No=<0.2 - >2.0ppm)				Significance	OR 95% CI
	Outcome	**Yes**	**No**	**Total**		
Sample met WHO guidelines for total coliforms	Yes	13 (34.2)	25 (65.8)	38	p<0.0004*	19.2 (2.37,156.5)
	No	1 (2.6)	37(97.4)	38		
	Total	14	62	76		
Sample met WHO guidelines for *E. coli*	Yes	14 (30.4)	32 (69.6)	46	p<0.0014*	27.1 (1.55,475.4)
	No	0.5 (0.0)	31 (100.0)	31.5		
	Total	14.5	63	77.5		
	Sample met WHO Turbidity guidelines (Yes= <5 NTU, No= > 5 NTU)					
	Outcome	**Yes**	**No**	**Total**		
Sample met WHO guidelines for total coliforms	Yes	31(81.6)	7 (18.4)	38	p<0.2011	2.0 (0.68,6.02)
	No	24 (68.6)	11 (31.4)	35		
	Total	55	18	73		
Sample met WHO guidelines for *E. coli*	Yes	36(81.8)	8 (18.2)	44	p<0.1386	2.3 (0.77,6.62)
	No	20 (66.7)	10 (33.3)	30		
	Total	56	18	73		

The presence of free chlorine residual between 0.2 – 2.0 ppm was a critical factor in determining microbiological water quality. There was a significant association between water samples that met WHO guidelines for total coliform and samples that met CDC guidelines for free chlorine (p<0.0004). Water samples that met free chlorine guidelines were 19.2 times more likely to meet WHO guidelines for drinking water at the 0.05 confidence level (*Table 11*). There was no association between samples that met WHO guidelines for total coliforms and samples that met WHO guidelines for turbidity (p<0.2011).

Water samples that met WHO guidelines for *E. coli* were strongly associated with having free chlorine residual levels that met CDC guidelines (p<0.0014). Water samples that met chlorine residual guidelines were 27.1 times more likely to meet WHO guidelines for *E. coli* in drinking water quality. There was no association between *E. coli* presence and turbidity level (p<0.1386).

Table 12: Association between location of sample collection points and whether or not sample met WHO standards for *E. coli* and total coliforms concentration in drinking water.

	Location of Sample Collection				Significance	OR 95% CI
	Outcome	**Tap**	**Bucket**	**Total**		
Sample met WHO guidelines for TC	Yes	33 (91.7)	3 (8.3)	36	p<0.0436*	4.0 (0.98,15.69)
	No	28 (73.7)	10 (26.3)	38		
	Total	61	13	74		
Sample met WHO guidelines for *E. coli*	Yes	40 (90.9)	4 (9.1)	44	p<0.0256*	4.1 (1.13,14.82)
	No	22 (71.0)	9 (29.0)	31		
	Total	62	13	75		
	Outcome	**Bucket**	**Tap**	**Total**		
Sample met WHO guidelines for total coliforms	Yes	3 (8.3)	33(91.7)	38	p<0.0436*	0.3 (0.06,1.02)
	No	10 (26.3)	28 (73.7)	38		
	Total	13	61	74		
Sample met WHO guidelines for *E. coli*	Yes	4 (9.09)	40 (90.91)	44	p<0.0256*	0.2 (0.07,0.89)
	No	9 (29.0)	22 (71.0)	31		
	Total	13	62	75		

The location of sample collection was a strong indication of microbiological water quality There was an association between samples that met WHO guidelines for total coliforms and samples collected from taps at (p<0.0436) (*Table 12*). Samples collected from taps were 4.0 times more likely to meet water quality standards for total coliforms compared to samples taken from buckets. At the 0.05 significance level, there was an association between samples that met WHO guidelines for *E. coli* and samples collected from taps (p<0.0256). Samples collected from taps were 4.1 times more likely to meet WHO guidelines for *E. coli* compared to samples taken from buckets.

Table 13: Association between detection of E. *coli*, total coliforms, and free chlorine, controlling for sample collection points (buckets vs. taps).

	Sample met guidelines for chlorine residual Controlling for taps=Yes				Significance	OR 95% CI
	Outcome	**Yes**	**No**	**Total**		
Sample met WHO guidelines for total coliforms	Yes	12 (36.4)	21 (63.6)	33	*p*<0.0019*	15.4 (1.86, 128.3)
	No	1 (3.6)	27(96.4)	28		
	Total	13	48	61		
Sample met WHO guidelines for *E. coli*	Yes	13 (32.5)	27 (67.5)	40	*p*<0.0056*	21.2 (1.19, 377.4)
	No	0.5 (0.0)	22 (100.0)	22		
	Total	13.5	49	62.5		

A stratified analysis of free chlorine levels and detection of *E. coli* and total coliforms, controlling for sample collection site, showed a significant associations at (*p*<0.0019) and (*p*<0.0056, respectively). Water samples collected from taps that met CDC free chlorine residual guidelines were 15.4 times more likely to meet drinking water quality standards for total coliforms. Samples collected from taps were 21.2 times more likely to meet drinking water standards for *E. coli* (*Table 13*). About 32.5% and 36.4% of samples collected from taps met both free chlorine residual and WHO standards for total coliforms and *E. coli*, respectively. There was not sufficient data to examine the relationship between microbiological water quality and free chlorine residual in samples collected from buckets.

4.6 Sustainability Metric Scores

The results from the sustainability evaluation indicate that most hospitals in Ghana did not meet the cut off score (2) for sustainability. Overall average sustainability scores ranged from 0.4 to 3.2 out of a maximum possible score of 4.0. Apam, Bole, and Kintampo hospitals had the lowest overall scores and ranged from 0.4 – 0.6 (*Table 14*). The hospitals were located in different regions of the country, experienced unique challenges, and showed variations in areas of strength and potential for sustainability as seen in the range of scores. Overall domain scores are presented in *Figure 17*, whilst *Figures 18, 19,* *20, and 21* exhibit the results from each subdomain of sustainability and demonstrate problems and areas of strength.

4.6.1 Accountability

Subdomains for accountability include: monitoring performance, oversight by another entity, sources of funding and finances (*Table 14*). Subdomain scores for oversight by another entity were calculated from questions about oversight by another entity and successful communication between GEF and the hospital. In the subdomain of accountability, none of the six hospitals met the sustainability cut-off (2). Axim, Mampong, Kete-Kratchi, and Bole met the sustainability cut off (2) in the subdomains related to sources of funding and finances whereas Apam and Kintampo had a score of 0 in both of these subdomains (*Figure 16*). All the hospitals maintained inadequate records of water availability, water treatment, and cleaning of storage containers. Axim and Bole hospitals kept records of backwashing, however backwashing was not being performed appropriately as the system demands. Axim hospital kept the most up to date records of key routine maintenances tasks, however records for bypassing the water treatment system, cleaning of cisterns, and other water storage containers were not kept or maintained. All of the hospitals relied on internally generated for funding to ensure sustained and long-term functionality of the water treatment system.

Table 14: Domains, subdomains and overall sustainability scores for all hospitals. Scoring was based on a range of 0-4, a score of 2 was considered as the cut-off for sustainability. Scores below 2 in the plots are highlighted in RED.

Domain	*Sub-domains*	Apam	Axim	Mampong	Kete-Kratchi	Kintampo	Bole
Accountability (AC)							
	Monitoring Performance	1	3	1	1	0	1
	Oversight by another entity	1	1	1	0	1	1
		0	0	1	0	1	0
	Sources of Funding	1	2	2	2	0	2
	Finances	1	2	2	2	0	2
Average AC		0.8	1.60	1.4	1.0	0.40	1.2
Technical Feasibility (TF)							
	Water Source and Availability	1	4	1	1	1	1
	Local Access to Replacement Parts	2	2	2	2	2	2
	Current Infrastructure	0	3	1	2	1	0
	Water Quality Testing	0	3	0	2	0	0
		0	3	1	0	0	0
Average TF		0.6	3.2	1.2	1.4	0.8	0.6
On-Site Capacity (OC)							
	Organization and Communication	3	3	1	1	1	1
		2	2	1	1	1	0
	Training and Capacity Strengthening	2	3	1	1	1	0
	Maintenance	2	3	1	1	1	0
		1	3	1	4	4	0
	Repairs	1	2	1	1	1	1
Average OC		1.8	2.6	1.0	1.5	1.5	0.5
Institutional Engagement (IE)							
	Demand	2	2	2	2	0	1
	Satisfaction and Perceived Value	4	3	3	3	2	3
		2	3	2	3	0	1
		2	3	1	3	1	2
	Engagement of Hospital Director and Staff	3	2	3	3	3	2
	Educational Message and Awareness	2	2	1	2	1	1
		3	1	1	1	2	1
Average IE		2.5	2.3	1.9	2.4	1.3	1.6

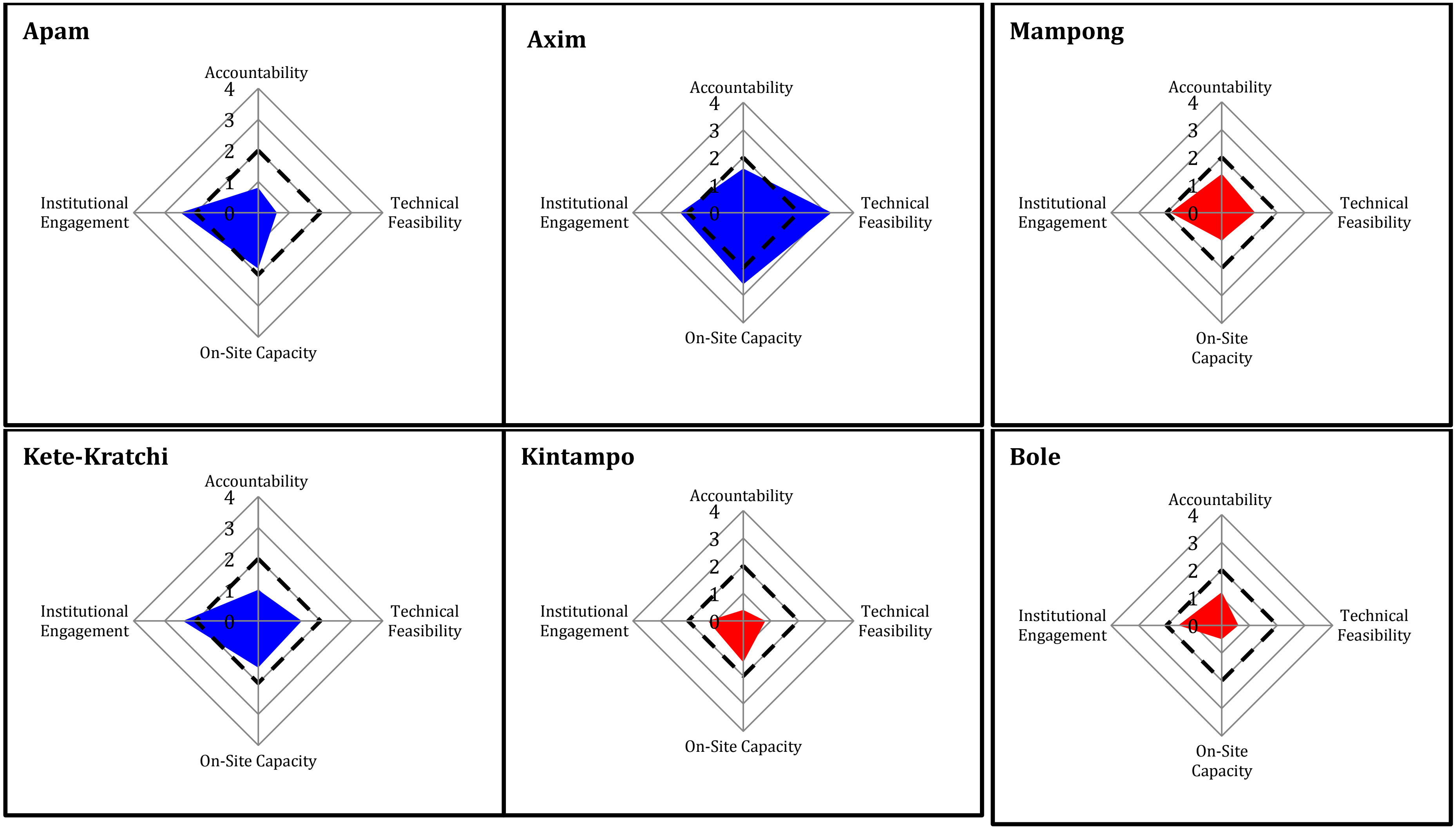

Figure 17: Radar plots depicting the variability in average sustainability domain scores across hospitals. Scores below the cut-off for sustainability (2) are highlighted in red.

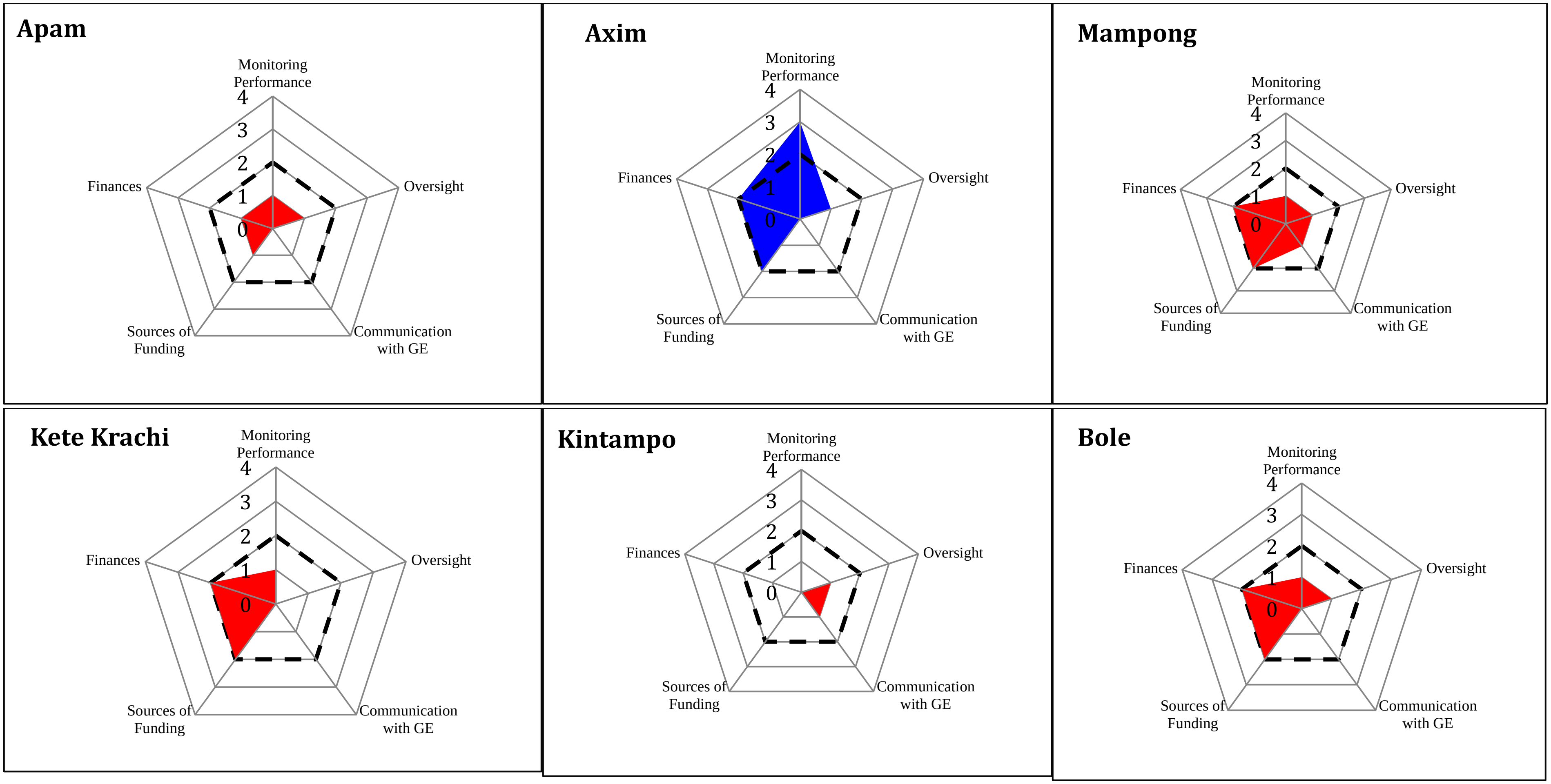

Figure 18: Radar plots of average scores for subdomains of *Accountability* by hospital. Scores below the cut-off for sustainability (2) are highlighted in red.

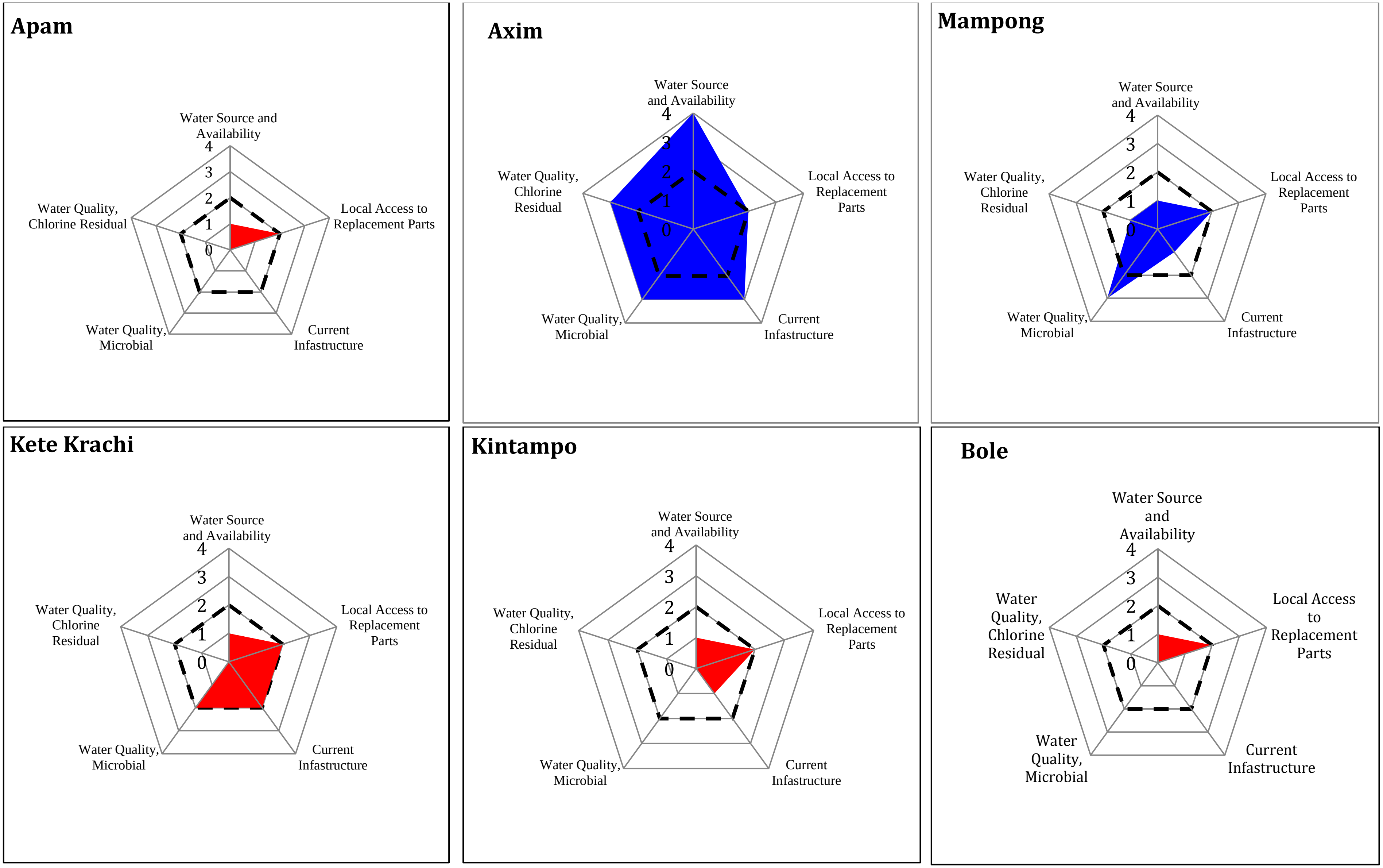

Figure 19: Radar plots of average scores for subdomains of *Technical Feasibility* by hospital. Subdomain scores below the cut-off for sustainability (2) are highlighted in red.

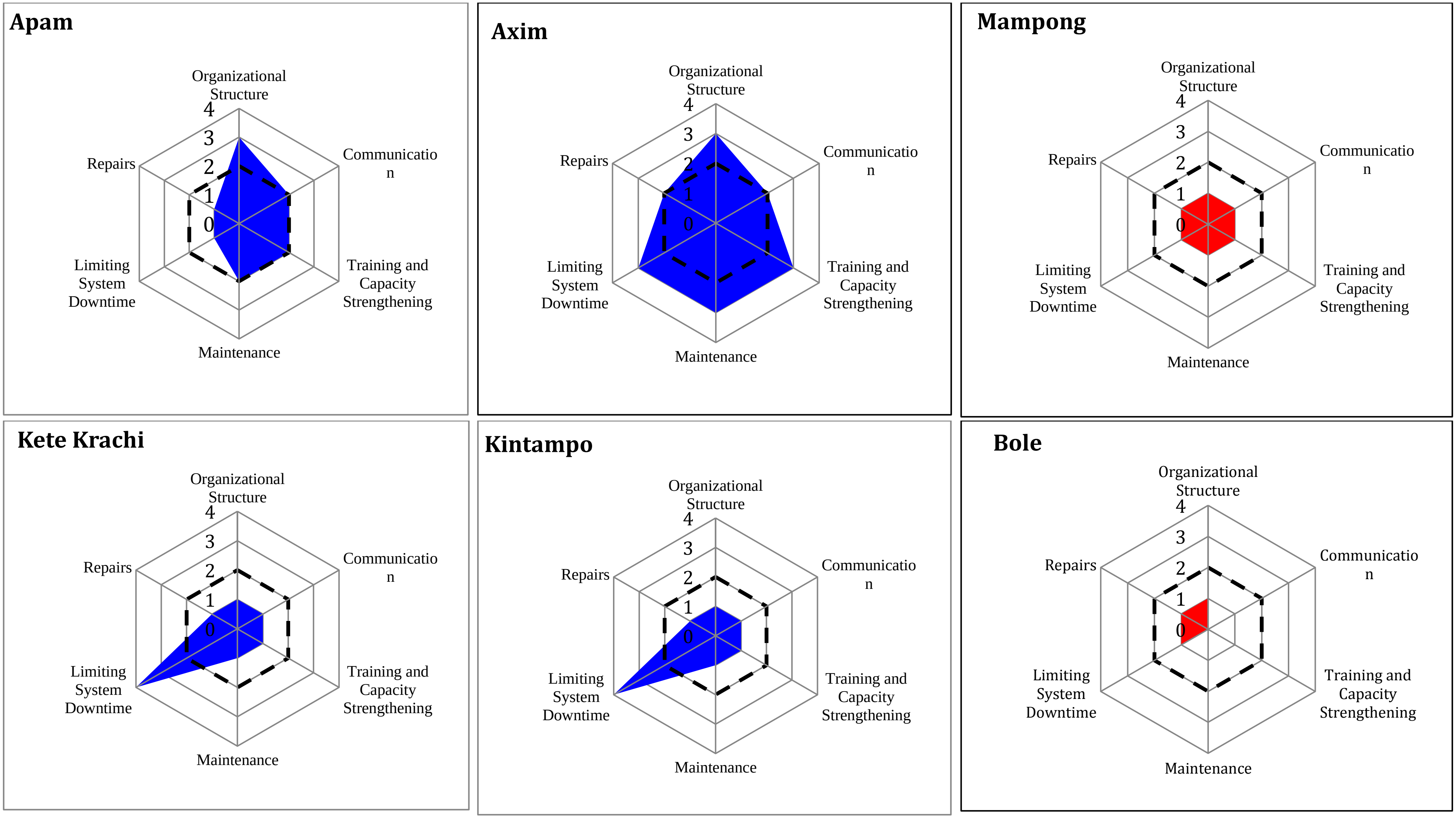

Figure 20: Radar plots of average scores for subdomains of *On-site Capacity* by hospital. Subdomain scores below the cut-off for sustainability (2) are highlighted in red.

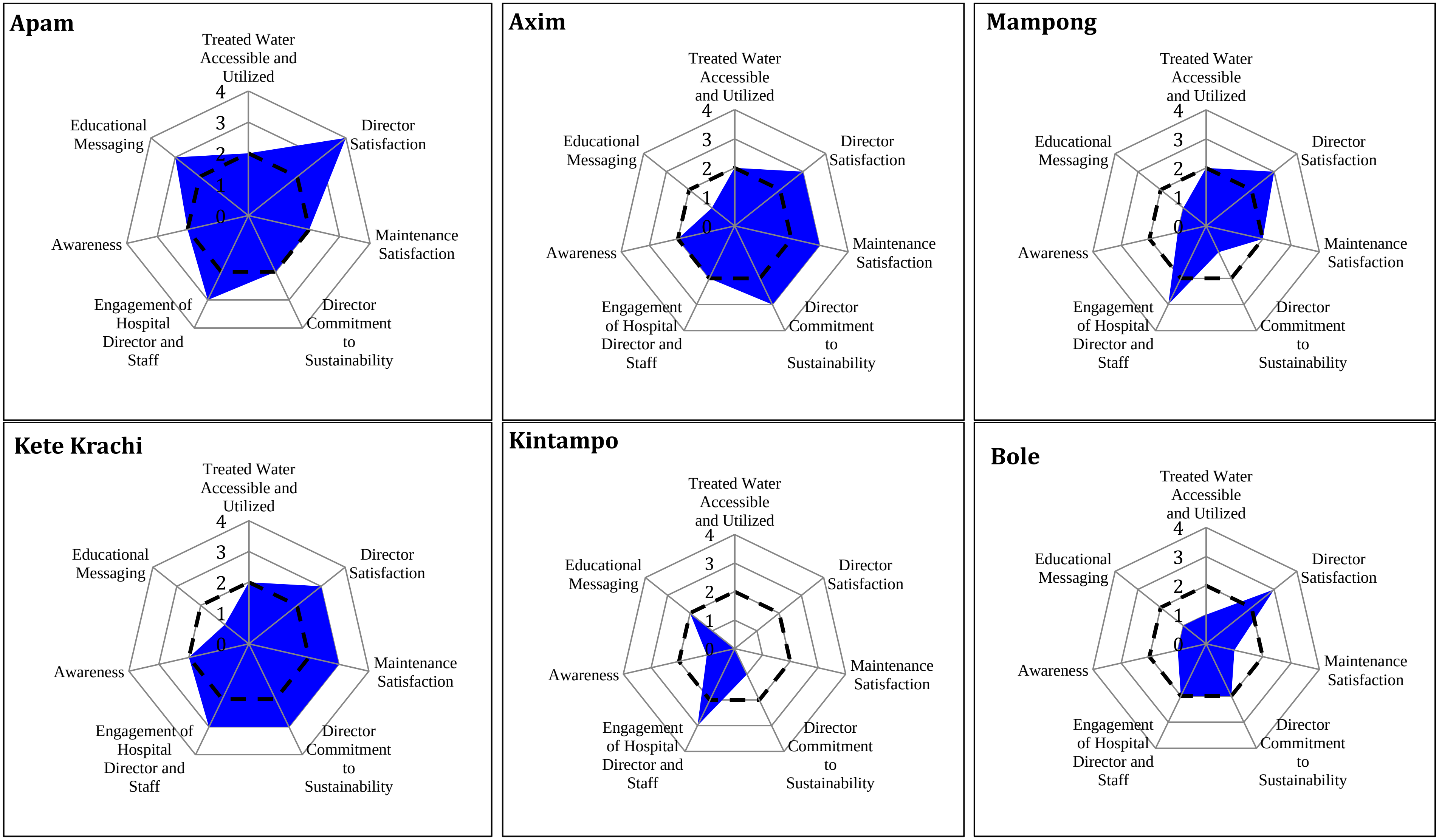

Figure 21: Radar plots of average scores for subdomains of *Institutional Engagement* by hospital. Subdomain scores below the cut-off for sustainability (2) are highlighted in red.

4.6.2 Technical Feasibility

Subdomains for technical feasibility included water source and availability, local access to replacement parts, current infrastructure, and water quality and testing (*Figure 19*). For this subdomain, only one hospital (Axim) exceeded the cut off for sustainability 3.2. Technical feasibility average scores ranged from 0.6 to 3.2. Axim had the highest score of 3.2, Kete-Kratchi scored 1.4, and Mampong followed closely at 1.2. Apam and Bole had the lowest scores of 0.6. Water source supply was intermittent, but did not vary significantly among the hospitals. All hospitals had a sustainability score of 1 for the water source and supply subdomain.

All hospitals received a sustainability score of 2 for local accessibility to replacement parts. Although tubings, connectors, elbows, pipefittings, and reducers were available locally, the distance traveled by each hospital to access parts when the system broke down varied significantly.

Almost all hospitals did not meet the sustainability cut off of for water quality and testing. Axim was the only hospital to score 3 for the percentage of samples tested that met WHO and CDC guidelines for safe drinking water.

4.6.3 On-site Capacity

Subdomains for on-site capacity include organization and communication, training and capacity strengthening, maintenance, and repairs (*Figure 20*). Sustainability ratings for on-site capacity showed variability with average scores ranging 0.5 to 2.6. Overall, Axim hospital was the only hospital to meet to cut off for sustainability with an average score of 2.6. Whereas, Apam scored 1.8, followed closely by Kintampo and Kete-Kratchi with scores of 1.5. Lastly, Mampong had an average score of 1.0, and Bole had the lowest average score of 0.5. Scores for organization and communication were calculated using multiple scores on the presence of clearly defined organizational structure and successful communication between the key hospital staff and the director. Similarly, the subdomain scores for maintenance were calculated from routine maintenance procedures and limited downtime of the water system. This low score in Bole hospital was due to confusion about responsibilities and gaps in capacity to repair and maintain the water treatment system. The chlorine doser in Kintampo was broken during the study period,, and no one was in charge of ensuring adequate chlorine was added to the treatment system.

4.6.4 Institutional Engagement

Subdomains for institutional engagement include demand, satisfaction and perceived value, engagement of hospital director and staff, and educational message and awareness (*Figure 21*). Three out of six hospitals met the cut off for sustainability in the domain of institutional engagement. Apam had the highest average at 2.5, Kete-Kratchi scored 2.4, and Axim had a score of 2.3. Mampong hovered close to the cut off at 1.9, Bole had a score of 1.6, and Kintampo had the lowest average score of 1.3. Scores for satisfaction and perceived value were calculated from multiple scores relating to director and maintenance staff satisfaction with the system and the commitment of the director to the sustainability of the water system. Scores for educational message and awareness were also calculated from multiple scores relating to staff and patient awareness of the water system, and the presence of educational messages on water and sanitation. Subdomain scores were relatively high showing strengths in satisfaction, perceived value of the treatment system, and in engagement of hospital director and staff. All hospitals had low scores in the subdomain for visibility of educational messages in the hospital and awareness of the water treatment system.

Educational messages regarding safe water were only observed in Apam hospital. Educational messages regarding hygiene practices were observed in all six hospitals. In three hospitals, educational messages about hygiene were visible to the staff, but not to the patients.

Ratings of perceived value and satisfaction about the system by the hospital directors varied across all hospitals. The hospital directors reported overall satisfaction with pressure, color of water, and costs of maintaining the system, but mentioned concerns about water quality within the hospital wards, and poor capacity of maintenance staff to carryout of major system repairs. Hospital directors also had varying levels of commitment to the sustainability of the water treatment system and safe water provision.

5 DISCUSSION

Qualitative and quantitative methods were utilized to evaluate the performance of decentralized water treatment systems, water use, and the sustainability of safe water provision in six hospitals in Ghana. The results from the evaluation of the DMFS in Ghana indicate that the water treatment systems were not sustainable in five out of the six of the Ghanaian district hospitals. While the water treatment systems provided safe water at the point of treatment, there was minimal on-site capacity of maintenance staff and technical feasibility to sustain safe water provision throughout the hospital. Targeted solutions for improvements in the domains of accountability, technical feasibility, on-site capacity, and institutional engagement are needed to improve the potential for sustainability of the water treatment systems. Although the hospitals have context and facility-specific challenges, appropriate governing and monitoring entities could increase the technical capacity of the maintenance staff and facilitate the sustainability of the water treatment systems.

5.1 Impact of the GEF- donated DMFS

The study found that the water treatment systems were indeed performing as designed, to improve the microbiological quality of the water. However, challenges with accountability, technical feasibility, on-site capacity, and institutional engagement issues undermined the potential benefit of the systems for the hospitals.

5.1.1 Impact of DMFS on Water Quality and Hospital Infrastructure

While the water treatment system proved effective at improving microbiological water quality, water samples collected at taps and veronica buckets within the hospital showed evidence of re-contamination. Compromised water quality within the hospital wards is the result of mixing filtered and unfiltered water within the piped networks and inconsistent performance of key maintenance tasks. Of all the water samples collected, 55% and 58% met WHO standards for *E. coli* and total coliforms, respectively. Of the water samples collected from taps within all hospitals, only 20% met the free chlorine standards of having free chlorine residual between 0.2 – 2.0 ppm.

Low chlorine residual detection in samples collected within the hospitals was due to inconsistent addition of chlorine at the hospital water treatment system post-filtration. Non-detectable chlorine levels in Kintampo were the result of a non-functioning chlorine doser at the sand filtration system, whereas low levels of chlorine in other hospitals were due to inadequate chlorine dosing per water volume and problems with powdered chlorine sinking to the bottom of the chlorine doser. In addition, as less than 50% of functional taps observed had soap present, materials for proper hand washing were not a priority for the hospital. Furthermore, *P. aeruginosa* was detected in 83% of water samples collected at the water treatment system after filtration, suggesting that a colonization of the bacteria in the system within the distribution pipes was highly likely. This result is confirmed by two research studies on disease-causing pathogens transmitted through drinking water which found, that *P. aeruginosa* in water was not always directly linked to the organic matter content but can also develop in clean water.[24]

5.1.2 Impact of DMFS on Staff's Knowledge, Attitudes and Practices

In all hospitals, 54% of all staff was aware of the DMFS on site, and 42% of these staff believed that water from hospital taps was safe to drink. Of all staff who believed hospital water was safe, only 21% reported drinking water from the taps. There was a strong association between staff who were aware of the system, and staff that believed the water from hospital taps was safe for consumption (p-value<0.0034). There was no association between staff who believed that water from the hospital tap was safe and those who actually drank water from hospital taps.

Some staff cited the brownish color of water as a deterrent from drinking the hospital water, whereas others mentioned rusty taps as a concern for water safety. Few staff mentioned debris particles and slippery consistency of water after storage as reasons for not drinking the hospital water. These comments highlight the lack of trust in the performance of the water treatment system for those who were aware of the system. Most hospital staff reported preference for drinking water from the dispensaries[§] or purchasing sachet water for drinking.

The lack of correlation between staff who thought the water was safe and staff who actually drank the water represents an opportunity for increased educational messaging about water treatment systems and the treated water quality Variations between awareness of the water treatment system within the hospital and staff who drink from hospital tap may be explained by the order in which the questions about awareness of the water treatment system, and practice of drinking hospital water were asked. For instance, the questions about being aware of a water system on site may have influenced the staff to response positively about believing the water was safe to drink.

5.1.3 Impact of DMFS on Patients' Knowledge, Beliefs, and Practices

The inconsistency between staff beliefs about patient practices, and reported patient practices were notable. Although 64% of staff believed that patients drink from hospital taps, only 7% of patients reported drinking water from hospital taps, and less than 50% of patients believed that the hospital water was safe to drink. Patients also reported that the locations of taps in the hospital were not hygienic and were inaccessible for them to use. The results indicated that some patients perceived the water on hospital premises to be safe, albeit not easily accessible to patients and their visitors. This discrepancy between the percentages of patients that reported that the drinking hospital water and the percentage of patients who staff reported drinking hospital water could be caused by under reporting by patients who drank hospital tap water or the staff's lack of knowledge about patient consumption of tap water in the hospital. Possible reasons for under-reporting by patients are that patients may have accurately recollected instances when they drank

---

[§] A water dispensary is a device that dispenses both cool and warm water.

hospital water, or they may not have felt comfortable reporting drinking from hospital taps, since it is expected by the hospital that patients and visitors bring their own water to the hospital.

Visible educational messages targeted at patients and visitors regarding the presence and effectiveness of the water treatment system could increase patients' knowledge and trust in the DMFS within the hospitals. The availability of the inexpensive and preferred option of sachet water also contributes to the low demand and trust of hospital drinking water by patients and visitors.

5.2 Sustainability Evaluation

The sustainability evaluation indicates that the water treatment systems are vulnerable to becoming unsustainable in five out of the six hospitals. The evaluation also highlighted exemplary areas where some hospitals were taking initiatives to maintain the water system without the support of GE ambassadors and the GEF. Using a variety of data sources to assess the water treatment systems, gaps in accountability, technical feasibility, on-site capacity, and institutional engagement were identified. The sustainability metric used in this study was robust and could be applied to evaluate a variety of water treatment systems in healthcare settings.

5.2.1 Successes and Areas of Improvement

All the study hospitals faced unique challenges in all four domains used to assess the sustainability of the water treatment system. In order for the water treatment systems to be sustainable significant improvements in the areas of accountability, technical feasibility, on-site capacity, and institutional engagement are required. The contexts in which the water treatment systems have been donated present many challenges, as the hospitals have both existing infrastructure and economic issues that remain long-term challenge at the country level. In order to overcome issues such as power fluctuations, compromised pipe integrity and mixing of treated and untreated water, both country and hospital-level solutions must be employed to promote the sustainability of the water systems.

Another area for improvement was ownership of the water treatment system. To foster a sense of ownership of the system, a specific budget line needs to be dedicated to support the water treatment system. This would facilitate easy and timely acquisition of parts needed to maintain the system and encourage institutional ownership.

Accountability:

In all the study hospitals, administrators and maintenance staff did not communicate with Ministry of Health (MoH) or Ghana Health Service (GHS), nor did they benefit from oversight by another entity monitoring water quality except GEF. One hospital, Axim hospital had identified an outside laboratory within the GWCL as an organization that could monitor water quality within the hospital and had engaged this lab by sending a water sample for testing. This relationship should be strengthened and institutionalized long-term. Biosafety committees or quality assurance committees were operational at all six hospitals by mandate of the Ministry of Health. However, none of these committees were functional or actively monitoring the water treatment system performance or water quality.

Bio-safety committees could play a significant role to ensure that the hospital infrastructure is up to standard and that the DMFS continues to provide safe water for the hospitals. Biosafety committees could also monitor the performance of the water system to assure quality. Research evidence on previous assessments of water point sustainability in 86 communities found that the existence of water committees were associated with a 30% increase in uninterrupted functionality of water systems [11] This study finding further highlights the potential impact that biosafety committees in institutions could have on the sustainability of the GEF donated water treatment systems in Ghana.

None of the six study hospitals relied on external sources of funding for their water bills or water-related infrastructure costs. In all hospitals, Internally Generated Funds (IGF) contributed to the general maintenance budget, which did not specifically include the water treatment system. All hospitals had a process for procurement, but there was evidence that the system in place was neither efficient nor standardized for the acquisition of supplies for safe water provision. Allocation of funds for replacement parts for the water treatment systems was not a high priority for any of the hospitals, as there were competing financial demands within the facilities. To improve accountability, allocation of funds to purchase supplies and replacement parts for the water treatment system should be more transparent. This will increase the likelihood that available funds for water treatment will be identified and released as needed. Findings from a sustainability assessment of water point functionality that was conducted by CARE in Mozambique highlights the influence that transparent and systematic financial systems can have on raising the priority of water systems. [11]

Technical Feasibility:

Only two hospitals, (Apam and Axim) met and exceeded the cut-off for sustainability in the subdomains for technical feasibility. All six hospitals met the cut-off (2) in at least one subdomain. Maintaining good microbiological water quality and adequate chlorine residual were challenges in all hospitals except Axim. Poor water quality scores were due to: inconsistent chlorination at the water treatment system, mixing of treated and untreated water within hospital piping networks, lack of routine cleaning of water storage containers, and poorly performance of routine maintenance tasks. Water quality was a key area for improvement in all study sites as the water in most of the hospitals was currently not safe to drink.

The hospitals relied on several water source supplies, but only one water source was connected to the water treatment system at a time. When the municipal supply was functioning, water was available only after peak hours, and treated water stored in overhead cisterns did not last more than two days due to high demand. In the past, tanker trucks were brought in to supplement the intermittent water supply, but now this water was used mostly for gardening and grounds work. Although these sites had the necessary infrastructure to distribute water to most taps within the hospital, the taps were either not functioning or water was unavailable during the time of the study visit. Another challenge with water source availability at the hospitals was due to the fluctuating electrical power supply. Although water delivery to wards after filtration was gravity fed, power outages made it difficult to pump water treated water for distribution. Faulty pumps in Apam and Kete-Kratchi hospitals also affected water distribution. In addition, power fluctuations or surges in electrical voltage can damage the electrical component of the water treatment system, making it unable to pump raw water into the system.

One hospital (Axim) performed well in the subdomain of water availability. This was mainly due to the fact that this hospital had a borehole on site that consistently provided sufficient quantity and quality of water. Water flowed regularly from all taps within the hospital, and the hospital also had the capacity to collect rainwater if needed. Axim hospital did not utilize polytanks for water storage, so there was less opportunity for the water quality to degrade during storage. Kintampo, Bole, and Apam had the most problems with water quality, and water infrastructure – even when treated water was available, the water could not be distributed to the various wards due to non-functional taps.

Purchasing of replacement parts for the water treatment system was not a priority for most hospitals. Minor replacement parts were easily accessible for all the hospitals. However, overall lack of funding and low prioritization of funding for supplies related to the water system, made it difficult for parts to be bought and used for repair in a timely manner. Most hospitals depended on the GE technical ambassador to facilitate the procurement of major parts needed to repair the system. This dependence will affect the sustainability of the water system when the GEF no longer provides technical support to the hospitals.

On-Site Capacity:

Axim was the only hospital that met and exceeded the cut-off for sustainability in this domain. Most hospitals struggled with the subdomains related to on-site capacity. In Bole hospital, the maintenance staff did not have the technical knowledge to repair the water treatment system therefore system repairs were outsourced. Outsourcing system repairs can undermine the sustainability of the water system because this requires additional hospital funds. Additionally, outsourcing maintenance repairs does not allow the maintenance staff to develop institutional knowledge. However, as a last resort, having access to external technical support for water system repairs can be critical for hospitals that do not have that capacity on site.

Though the maintenance staff in most hospitals is adequately trained, they do not fully understand their roles and are incapable of carrying out major repairs for the system without frequent help from the GE technical ambassador. As evidenced by the research conducted by Saboori et al. on sustaining school hand washing and water treatment programs in Kenya, easy accessibility of parts for needed repairs and increased knowledge of major system repairs are needed to ensure uninterrupted operations and sustained use of water systems. [50]

In all hospitals, inconsistencies were observed between capacity and training, and existing organizational structures. In Mampong for example, there appeared to be a clear organizational structure, but the structure is not reflected in the capacity and training of those responsible for the upkeep of the water treatment system was still inadequate. In all hospitals, meetings between maintenance staff, administrators and directors were not regularly scheduled and often happened informally. Therefore key issues were not always communicated and follow-through on assigned responsibilities rarely occurred. The laboratory technicians in all six hospitals were trained multiple times on how to perform chlorine residual testing and provide feedback on chlorine levels to maintenance and administrative staff. However, this did not occur on a routine basis.

The directors in all hospitals believed that their staff had the knowledge and capacity to perform basic repairs. However, communication between the administrator, director, and maintenance staff was not streamlined, and there was a lack of follow-through by administrators to ensure key system repairs are completed.

Maintaining water pumps and adequate water pressure were additional challenge areas. Although low water pressure was a common problem in all six study sites, pressure checks at inflow and outflow points were not checked consistently because the pressure gauges on the water treatment system had not been functional.

Institutional Engagement and Support:

The benefits of safe water for medical and hygiene purposes were recognized by all of the hospital directors, but they had varying levels of commitment to the sustainability of the water treatment system and safe water provision. Directors in Kete-Kratchi, Kintampo, and Mampong district hospitals showed strong commitment to sustaining the operation of the water treatment system, and did not expect GEF to remain in Ghana for an unlimited amount of time. These directors displayed foresight to ensure that the maintenance staff received the appropriate training to learned how to make major repairs on the water treatment system without the assistance of GEF. The director in Bole district hospital recognized the lack of capacity of the current designated maintenance staff and was open to hiring a committed and technically skilled staff member to complete maintenance operations.

Some hospitals (Kintampo and Apam) preferred for GEF continue to provide both technical and financial support for an unlimited amount of time. It was evident that both maintenance staff and directors wished to be empowered to oversee and maintain the system, however, there remained a strong reliance on the GEF as the overseeing body to continue to provide regular training for the necessary staff. Previous research conducted on philanthropic giving strategies that have informed water interventions in Africa, Asia, and Latin America, re-iterates the importance of institutional ownership of water system donation in order to promote long-term sustainbility.[10, 27]

All directors reported that they would recommend the treatment system based on perceived value and expected utility, although none were entirely confident about the system's performance. The hospital directors also had reservations about the systems because of the many maintenance and operational challenges. The ability of the water treatment system to improve water quality did not influence the directors trust and ownership of the system.

5.3 Strengths and Limitations of the Study

Study Strengths

A notable strength of the study was the tool used to evaluate the sustainability of the DMFS within the study hospitals achieved the intended objective. Domains and sub-domains were clearly defined in order to incorporate the necessary indicators of sustainability of the GEF-donated water treatment systems. The metric successfully identified challenge areas that would benefit from targeted efforts for improvement. This tool goes beyond highlighting where improvements can be made, but also identifies specific components that can be strengthened further through responses to pointed questions from the surveys.

Another important strength is that the study was able to systematically collect information on water quality and use for different purposes in a hospital setting in sub-Saharan Africa. Lastly, the sustainability tool was relatively easy to use and can be easily replicated and applied to evaluate water-related interventions in hospitals in other low-resource countries.

Study Limitations

The limitations of the study should be considered when using the results for programmatic decision- making and comparisons across hospitals. All surveys were conducted in English, and when needed, an interpreter was used. The language barrier may have affected the responses we received either through misunderstanding of the finer points of the questions by staff and patients, misinterpretations of the questions by the interpreters, or the researcher's misunderstanding of what the interpreters were conveying to us.

The sustainability metric rated each hospital on a range of situations, ranging from ideal to dire under each subdomain. This rating system assumed that the ideal situations would be similarly perceived at each hospital regardless of existing organizational or hierarchical structures. For future assessments, the sustainability metric should be adjusted to consider existing organizational structures within each hospital. For example, because of existing hierarchical structures, the maintenance staff may not have frequent and easy access to hospital directors. Thus, the sustainability rating of successful communication between maintenance staff and directors should be adjusted to reflect established communication practices within the hospital. In addition, some broad questions in the tool should be re-evaluated for their relevance to the sustainability of the water treatment system in the context of the beneficiary hospitals.

Another limitation of the study is the sample size. Only six hospitals received the GEF-donated DMFS. Although we believe the number of surveys administered with staff, patients and visitors were sufficient to get an accurate picture of beliefs and practices at each hospital, no power calculations were conducted. Surveys for maintenance staff were limited in terms of what types of analyses could be performed to assess predictors of issues affecting routine maintenance tasks, and their effects on water quality, and the long-term sustainability of the water treatment systems.

Lastly, the researchers did not return to each site for a second round of visits to follow-up on unresolved issues at the site. Therefore, any adjustments or improvements made after the visit of the researchers could not be taken into consideration when evaluating each hospital's capacity to troubleshoot and resolve problems with the system.

6 RECOMMENDATIONS AND NEXT STEPS

6.1 Recommendations

6.1.1 Recommendations for GEF and Study Hospitals

The findings from this research study have identified gaps and areas for improvement and provide the basis for recommendations to the GEF and study hospitals. To increase the sustainability of the DMFS in Ghanaian hospital, these domain-specific recommendations should be considered.

Recommendations to improve Accountability:

1. Standardize record-keeping tools for maintenance staff across all hospitals in order to increase compliance in maintaining adequate records of system operations and maintenance. AI and CGSW should continue to use these records to evaluate the competencies of the maintenance staff. The hospital directors should also add summaries of these records to general hospital reports submitted to the ministry of health.
2. Increase accountability and ownership of the water treatment, by developing a specific budget for all water-related consumables (i.e. pumps, chlorine, tubing, PVC pipes).
3. A transparent source of funding should be identified by the hospitals for long-term financial support of the water treatment system. A consistent revenue stream would ensure that the long-term operating costs of the water treatment systems are covered.[11, 65]

Recommendations to improve Technical Feasibility:

1. Ensure all wards within the hospital receive safe water. GEF and AI should oversee the excavation of the distribution network at each of the facility to ensure that all water sources are connected to the water treatment system.

2. Encourage the development of a supplier inventory for chlorine, chlorine test kits and their reagents, and locally-available parts for the water treatment system. This list will also encourage hospitals to develop strong relationships with suppliers.
3. GEF should continue to provide technical support for major system repairs in order to sustain the water treatment systems until the maintenance staff are able to demonstrate the technical capacity required to maintain the system.
4. Laboratory and maintenance staff should undergo quarterly training on appropriate chlorine residual and microbiological water testing of hospital water to build institutional capacity. This training would empower hospital administrators, maintenance, and laboratory staff to conduct these tests if other local reputable entities cannot be identified to monitor water quality, and in anticipation of GEF withdrawal.
5. Standardized cleaning protocols for cisterns and polytanks should be instituted in each hospital.

Recommendations to improve On-site Capacity:

1. GEF and CGSW should support acquisition of appropriate laboratory equipment's to conduct microbiological and physiochemical tests to assess water quality within each hospital.
2. Because all the study hospitals were concerned about low water pressure and low pump rates, strengthen the capacity of maintenance staff to repair pumps and check pressure gauges in the water treatment system without the assistance of GEF. All hospitals were concerned about pressure issues and low pump rates.
3. Discourage any bypassing of the water treatment system to ensure uninterrupted safe water provision.
4. Conduct quarterly trainings for the maintenance staff and administrators on operations and routine maintenance of the water treatment system to improve their

long term self-efficacy. These trainings would facilitate accurate knowledge transmission to future staff.

Recommendations to improve Institutional Engagement:

1. Streamline communication among governing bodies of the water treatment system such as, director, administrators, maintenance staff, laboratory staff, unit heads, the GE technical ambassador(s), and AI at each hospital.
2. The hospitals should focus on building relationships with outside entities that could monitor water quality within the hospital.
3. CGSW and GEF should help the hospitals in identify outside entities and stakeholders who could invest in the success and sustainability of the water treatment systems.
4. The health promotion department at the MoH should be engaged to develop key health education messages regarding safe water and hygiene practices for staff, patients and visitors. Educational messages should be developed at the country level to ensure appropriate, culturally relevant messages are communicated and ownership of the water system is fostered.
5. Awareness campaigns about the water treatment systems should be held quarterly to build the knowledge of hospital staff and increase trust in hospital water.

6.1.2 Recommendations for the Design and Use of the Sustainability Metric

1. For future assessments, the sustainability metric should be adjusted to consider existing organizational structures within each hospital.
2. Some broad questions under the subdomains should be re-evaluated for their relevance to the sustainability of the water treatment system in the context of the beneficiary hospitals.

6.2 Next Steps

6.2.1 Next Steps for GEF and Study Hospitals

1. To ensure safer water, GEF should consider the installation of POU filters in critical wards (such as surgical, labor and delivery wards) to provide an additional treatment and ensure good water quality at the point of use.
2. The GEF should collaborate with the beneficiary hospitals to devise a transition plan that would prepare the hospitals to take full management control and ownership of their water treatment systems to increase the potential for sustainability. [51]
3. Governing bodies for the water treatment system at each hospital should be constituted and engaged in a comprehensive training on the maintenance of the water systems *before* their installation.
4. Further research should be conducted to investigate the colonization of *P. aeruginosa* in the water treatment system, and at wards where this bacteria was detected.
5. Based on this complex structure of *P. aeruginosa*, a follow-up study should be conducted to access, and identify appropriate control measures for water systems. [3, 29]
6. Hospital directors, maintenance staff and administrators from each hospital should meet yearly to discuss challenges with the water system, share best practices and recommend hospital-led solutions.
7. AI and CGSW should continue to encourage and support the acquisition of technically skilled staff to be in charge of the water treatment system.

7 CONCLUSIONS

The purpose of this research project was to evaluate the performance, use, and sustainability of DMFS donated by the GEF to six Ghanaian hospitals and recommend areas for improvement. To accomplish this objective, a sustainability metric was used to assess four domains of sustainability: accountability, on-site capacity, institutional engagement and support, and technical feasibility. To assess the impact of the water treatment systems on water quality of microbiological and physiochemical water quality were examined. Using KAP surveys, the knowledge, attitudes and practices of hospitals staff and patients, gaps in awareness, and knowledge about the water system were evaluated.

The study found that the water treatment systems were not sustainable in most of the evaluated domains at each of the district hospitals in Ghana. Frequent training of maintenance staff may be necessary to empower them to perform basic system repairs and maintain uninterrupted operations of the system without the support of GEF in the near future. To promote the sustainability of these water systems for the long-term, further training and capacity strengthening is needed in the areas of accountability, technical feasibility, and on-site capacity.

In conclusion, the impact of the DMFS in each hospital has not been maximized due to both pre-existing infrastructure barriers and lack of technical capacity to promote sustainability of the DMFS. Moving forward, extensive assessments of the beneficiary environment should be undertaken by GEF before installation of complex water treatment technologies in healthcare facilities in developing countries. Stakeholders at the MoH should be involved to advocate for improved water, sanitation and hygiene in healthcare facilities and to facilitate for the sustainability of DMFS in district hospitals.

References

1. Adams, J., Bartram, Jamie., Chartier, Yves. (2008). "<Essential environmental health standards in health care.pdf>."

2. Arnold, M., VanDerslice, J. A., Taylor, B., Benson, S., Allen, S., Johnson, M., . . . Ansong, D. (2013). Drinking water quality and source reliability in rural Ashanti region, Ghana. *J Water Health, 11*(1), 161-172. doi: 10.2166/wh.2013.104.

3. Ashbolt, N. J. (2004). "Microbial contamination of drinking water and disease outcomes in developing regions." Toxicology **198**(1-3): 229-238.

4. A.J. Bates. Water as Consumed and Its Impact on the Consumer – Do we Understand the variables? Journal of Food and Chemical Toxicology. 38 (2000) S29-S38. Published by Elsevier Science Ltd.

5. Anaissie J. Elias, MD. (ND). Penzak R. Scott PharmD; Dignani M. Cecilia, MD. The Hospital Water Supply as Source of Nosocomial Infections: A Plea for Action

6. Atlantic Rising. Saltwater Poisoning threatens Ghana. 2009-2011.Retrieved: Jan, 2013. Retrieved from: http://www.atlanticrising.org/case-studies/view.asp?id=26

7. Atipoka, F. A. (2009). "Water supply challenges in rural Ghana." Desalination **248**(1-3): 212-217.

8. Awuah, E., et al. (2009). "Water and sanitation in Ghana." Desalination **248**(1-3): 460-467.

9. Boulenouar, J., Scweitzer R., Lockwood Harold. (Octobe 2013). "<Mapping sustainability assessment tools to support sustainable water and sanitation service delivery.pdf>." Aquaconsult.

10. Breslin, D. E. (2010). "<Rethinking-hydrophilanthropy: Smart Money for Transformative Impact.pdf>." Water for People.

11. CARE, U. W. T. (2011). "<Assessing Water oint Sustainability in Northern Mozambique.pdf>." 13.

12. Centers for Disease Control and Prevention (CDC). (December 2010). Microbiological Indicator Testing in Developing Countries: A Fact Sheet for the Field Practitioner. Version 1.

13. Clasen, T. F. (2012). "Millennium Development Goals water target claim exaggerates achievement." Trop Med Int Health **17**(10): 1178-1180.

14. Crosby, B. (1991). "<Stakeholder Analysis A Vital Tool for Strategic Managers USAID 1991.pdf>."

15. D. K, D., J. Kambo., V. Headley (2007). "Quality of "Sachet" Water in the Cape Coast." Journal of Environmental Science and Health **41**(3): 329-342.

16. Dada, A. C. (2011). "Packaged water: optimizing local processes for sustainable water delivery in developing nations." Global Health **7**: 24.

17. EWB, E. w. b. (2012). "<Failure Report 2012.pdf>."

18. G. Kwakye - Nuako, B., P.B., Mensah-Attipoe, I., Asmah, R.H., Ayeh-Kumi, P.F. (2007). "<Sachet Drinking Water in Accra- The potential Threats of Transmission of Enteric Pathogenic Protozoan Organisms.pdf>." Ghana Medical Journal **41**(2).

19. Garandeau, R. (2009). "<Evaluating and Improving the WASH setcor- Strengthening WASH Governance, Learning about Complexity, Assessing Change.pdf>." International Water and Sanitation Centre(23): 109.

20. General Electric Foundation. Developing Health Globally™. Retrieved from: http://www.gecitizenship.com/dhg/

21. Ghana SWA Compact. (April 2010). Sanitation and Water for ALL: A global Framework for Action. Government of Ghana: Ministry of Water Resources, Works and Housing. Retrieved, Feb, 20, 2013 from: http://www.sanitationandwaterforall.org/files/The_Ghana_Compact.pdf

22. Gleick H, Peter. (2007). The Human Right to Water. Pacific Institute

23. Goodman, J., et al. (2013). "System Life Cycle Evaluation(SM) (SLiCE): harmonizing water treatment systems with implementers' needs." J Water Health **11**(2): 199-209.

24. H. Leclerc, L. S., E. Dei-Cas (2002). "<Microbial Agents Associated with Waterbourne Diseases.pdf>." Critical Reviews in Microbiology(4): 371-409.

25. Hanson, M. H., Salmoni, W. Alan., Volpe, Richard (2009). "<Defining Program Sustainability - Differing view of Stakeholders.pdf>." Canadian Journal of Public Health **100**(3): 304-309.

26. Herdalo, C., Edberg C. Stephen (1997). "<Pseudomonas aeruginosa- Assessment of Risk from Drinking Water.pdf>." Clinical Reviews in Microbiolgy **23**(1): 47-75.
27. Hodgkin, J., USAID (1994). "<The Sustainability of Donor-Assisted Rural Water Supply Projects.pdf>." Water and Sanitation for Health Project(94).
28. Huang, H., Jacengelo G. Joseph., Schwab J. Kellog (2011). "<Decentralized Membrane Filtration System for Sustainable and Safe Drinking Water Supply in Low-Income Countries- Baseline Study.pdf>." Journal of Environmental Engineering(137): 981-989.
29. Jefferies, J. M., et al. (2012). "Pseudomonas aeruginosa outbreaks in the neonatal intensive care unit--a systematic review of risk factors and environmental sources." J Med Microbiol **61**(Pt 8): 1052-1061.
30. Jehu-Appiah, C., et al. (2008). "Balancing equity and efficiency in health priorities in Ghana: the use of multicriteria decision analysis." Value Health **11**(7): 1081-1087.
31. Jowitt, P. W. (2009). "Water infrastructure, the UN MDGs and sustainable development." Desalination **248**(1-3): 510-516.
32. Juwana, I., et al. (2012). "Indicator-based water sustainability assessment - a review." Sci Total Environ **438**: 357-371.
33. Kiehn, T. E. (1989). "Bacteremia and fungemia in the immunocompromised patient." Eur J Clin Microbiol Infect Dis **8**(9): 832-837.
34. Kweku, G. A. (2010). "<Urban Water Politics and Water Security in Disadvantaged Urban Communities in Ghana.pdf>." African Studies Quarterly **11**(4): 23.
35. L. Hens, E. K.-B. (1999). "<Institutional, Legal, and Economic Instruments in Ghana's Environmental Policy.pdf>." Envronmental Management **24**(3): 337 - 351.
36. Labite, H., et al. (2010). "Quantitative Microbial Risk Analysis to evaluate health effects of interventions in the urban water system of Accra, Ghana." J Water Health **8**(3): 417-430.
37. Marlow, D. R., et al. (2010). "A pathway to a more sustainable water sector: sustainability-based asset management." Water Sci Technol **61**(5): 1245-1255.
38. McGarvey, S. T., et al. (2008). "Community and household determinants of water quality in coastal Ghana." J Water Health **6**(3): 339.
39. Minogue, E., et al. (2013). "Diagnostics method for the rapid quantitative detection and identification of low-level contamination of high-purity water with pathogenic bacteria." J Ind Microbioly Biotechnology **40**(9): 1005-1013.
40. Moe, C., Huttinger, Alexandra., Smith, Emily., Harshfiel, Eric., Thomas, Joan (2010). "<Evaluation of Membrane Filtration Systems for Water Purification in Low-Resource Settings: Lessons Learned from Implementation Strategies-GE 2010.pdf>."
41. Moe, C., Rheinhans, Richard. (2006). "<Global challenges in water, sanitation and health.pdf>." J Water Health **4**(Supp 1): 41-57.
42. Onda, K., et al. (2012). "Global access to safe water: accounting for water quality and the resulting impact on MDG progress." Int J Environ Res Public Health **9**(3): 880 - 894.
43. Opryszko, M. C., et al. (2013). "Impact of water-vending kiosks and hygiene education on household drinking water quality in rural Ghana." Am J Trop Med Hyg **88**(4): 651-660.
44. Peter-Varbanets, M., et al. (2009). "Decentralized systems for potable water and the potential of membrane technology." Water Res **43**(2): 245-265.
45. Robertson, W., Stanfield, G., Howard, G., Bartram, J. Monitoring The Quality of Drinking Water During Storage and Distribution. Retrieved Feb 06, 2013 from: http://www.who.int/water_sanitation_health/dwq/9241546301_chap6.pdf
46. Roguski, K. (2012). "<Evaluation of Impact and Sustainability of Hospital Water Purification Systems in Honduras.pdf>."
47. Rossiter, H. M., et al. (2010). "Chemical drinking water quality in Ghana: water costs and scope for advanced treatment." Sci Total Environ **408**(11): 2378-2386.
48. Rusin, A. P., Rose B. Joan., Haas, N. Charles., Gerba, P. Charles (1997). "Risk Assessment of Opportunistic Bacterial Pathogens in Drinking Water." Review of Environmental Contamination and Toxicology **152**: 57-83.
49. S. Kyei-Faried, E. A.-D., D. Brenya, Abenaa Akuamoa-Boateng, L. Visser (2006). "<The Role of Community-based Survielance in Health Outcomes Measurement.pdf>." Ghana Medical Journal **40**(1).

50. Saboori, S., et al. (2011). "Sustaining school hand washing and water treatment programmes: Lessons learned and to be learned." Waterlines **30**(4): 298-311.
51. Safe Water Network (2012). SafeWaterNetwork-WorkingTowardaSustainableModelinGhana.pdf.
52. Schäfer, A. I., et al. (2009). "Physico-chemical water quality in Ghana: Prospects for water supply technology implementation." Desalination **248**(1-3): 193-203.
53. SidHARTe: Systems Improvement at District Hospitals and Regional Training of Emergency Care. Retrieved from: http://www.sidharte.org/site/content/kintampo
54. SidHARTe: Systems Improvement at District Hospitals and Regional Training of Emergency Care. Retrieved from: http://www.sidharte.org/site/content/mampong
55. Sima, L. C. and M. Elimelech (2013). "More than a drop in the bucket: decentralized membrane-based drinking water refill stations in southeast Asia." Environ Sci Technol **47**(14): 7580-7588.
56. Singh, R. K., et al. (2012). "An overview of sustainability assessment methodologies." Ecological Indicators **15**(1): 281-299.
57. Stawicki, A. S. (2012). "<Assessing Water Scheme Functionality and Governance in South Gondar, Ethiopia.pdf>." 39.
58. Stoler, J., et al. (2013). "Drinking Water in Transition: A Multilevel Cross-sectional Analysis of Sachet Water Consumption in Accra." PLoS One **8**(6): e67257.
59. The Jaxim Trust. Retrieved May 2013. Retrieved from: http://www.jaximtrust.com/AximHospital.html
60. Trautmann, M., et al. (2009). "[Reservoirs of Pseudomonas aeruginosa in the intensive care unit. The role of tap water as a source of infection]." Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz **52**(3): 339-344
61. UNICEF, W. (2010). Progress on Drinking Water and Sanitation. Progress Update.
62. UNICEF, W. (2012). "<Progress on Drinking Water and Sanitation.pdf>." Progress Update.
63. UNICEF, W. (2012). "<Rapid Assessment of Drinking-water Quality: A Handbook for Implementation.pdf>."
64. UNICEF, W. (2013). "<Progress on SANITATION and DRINKING - WATER .pdf>." 40.
65. USAID, R. "<Sustainability Index of WASH Intervention- Global Findings and Lessons Learned.pdf>.
66. Ustun P, Annette., Bos, Robert., Gore, Fiona., Bartram, Jamie. (2008). SAFE WATER, BETTER HEALTH: Costs, benefits and sustainability of interventions to protect and promote health.
67. WHO (2010). "<Hand Hygiene Self-Assessment Framework 2010- Introduction and user instructions.pdf>."
68. Wingender, J. and H. C. Flemming (2011). "Biofilms in drinking water and their role as reservoir for pathogens." Int J Hyg Environ Health **214**(6): 417-423.
69. Yang, H., et al. (2013). "Sanitizing effectiveness of commercial "active water" technologies on Escherichia coli O157:H7, Salmonella enterica and Listeria monocytogenes." Food Control **33**(1): 232-238.
70. Yu, J., et al. (2010). "Microbial diversity in biofilms on water distribution pipes of different materials." Water Sci Technol **61**(1): 163-171.

Hospital Director In-depth Interview Tool

Appendix A: Interview Tools

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

General Information		
Demographics		
	Ask director or administrator for annual report.	
A1	How long have you worked here as the director?	
A2a A2b	What is the population of the town surrounding the hospital? **Only ask in Honduras	Area: Population:
A3	How many patients are attended to daily at this hospital? (in annual report)	
A4 A5 A6	How many doctors are employed in this hospital? Nurses? Other staff? (in annual report)	________ doctors ________ nurses ________ other staff
A7 A7a A7b A7c	What is the primary drinking water source for the population in A) This town? B) The rural communities surrounding this town? To the best of your knowledge, what is a common household water treatment method used in this town and rural communities surrounding this town?	A) __________ 99) I do not know B) __________ 99) I do not know Comments:
A8	How often does water not flow from the taps in the hospital in the average week?	_____times a week/month/year 99)I do not know Comments:
A9 A9a A9b A9c A9d A9e A9f	What causes the water to stop flowing?(circle all that apply, specifying if necessary)	*1)* Electrical issues *2)* Construction issues *3)* Water rationing *4)* Faulty pumps *5)* Dry season *88)* Other _______________
Water Sources, Availability, and Demand		
A10 A10a A10b A10c A10d	What water sources are available in this hospital? (circle all that apply, specifying if necessary)	*1)* Municipal water *2)* Well water from improved source *3)* Tanker truck water *4)* Surface water

A10e A10f A10g		*5)* Rain water *6)* Bottled water *88)* Other ______________
A11	Are there any wards/sections of the hospital that do not have running water today? [Why not?] Which ones?	1) Yes 2) No 99) I do not know Comments:
A12	Are there any wards/sections of the hospital that are not connected to the water filtration system? [Why not?] Which ones?	1) Yes 2) No 99) I do not know Comments:
A13a A13b	A) Typically how much unfiltered/untreated water do you store? B) Typically how much filtered/treated water do you store?	A) _____ 99) I do not know Comments: B) _____ 99) I do not know Comments:
A14	How often is unfiltered/untreated water pumped into the elevated tank/cistern? **N/A for Honduras	_____times a day/week/month 1) Never 99) I do not know Comments:
A14a	How often is filtered/treated water pumped into the clean side of the elevated tank/cistern? **N/A for Honduras	_____times a day/week/month 1) Never 99) I do not know Comments:
A14b	When the elevated tank/cistern is full of treated water, how long does it take to empty? **in Honduras, ask about untreated water	________ Hours ________ Days ________ Weeks ________ Months
A14c	When the polytanks are full of treated water, on average, how long do they take to empty? **N/A for Honduras	________ Hours ________ Days ________ Weeks ________ Months
A14d	Are the elevated tanks/cisterns cleaned? If yes, how often?	1)Yes 2)No 99) I do not know Comments:
A14e	Are the polytanks cleaned? If yes, how often? **N/A for Honduras	1)Yes 2)No 99) I do not know Comments:
A15 A15a	Have you ever had to bring in water from a tanker truck due to lack of water? If yes, how often in the past year? Where is the water from the tanker – truck usually stored?	1) Yes 2) No 99) I do not know Comments: Location: ____________ 1) Before filtration 2) After filtration

	(specify location, check if location is before or after filtration system)	99) I do not know
A15b A15b.1 A15b.2 A15b.3 A15b.4 A15b.5	What is the water brought in from the tanker truck used for? (circle all that apply, specify if necessary)	1) Grounds and maintenance uses 2) Hospital taps 3) Laundry 4) Staff/student quarters 88) Other_______________ 99) I do not know Comments:
A16	What are sources of drinking water in the hospital? (circle all that apply, specify if necessary)	1) Bottled/sachet (provided by the hospital) 2) Bottled/sachet(purchased by patient/staff) 88) Other ___________________
 A17a A17b A17c A17d	Who drinks the tap water? **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:__________
A18 A18a A18b A19 A20 A21	Are there times when people collect water from the hospital to take home with them? **If yes**, approximately how many people each day? Are they staff or patients/visitors? When people do take water home with them, from which collection points within the hospital do people collect the water? Does the hospital support or discourage people collecting water from the hospital taps? How much do people pay (per liter) when they purchase water from vendors for household purposes?	 1) Yes 2) No →SKIP to Ax 99) I do not know →SKIP to Ax ________ people/day Comments: 1) Staff 2)Patients/Visitors 3) Both 99) I do not know 1) Support 2) Discourage 99) I do not know Comments: _________ Ghc/L
On-Site Capacity		
Water Treatment		

A22 A22a A22b A22c A22d A22e A22f A22g	Is there a person responsible for: *A.* Maintaining the filtration system *B.* Repairing the filtration system *C.* Ensuring there is chlorine available to treat the water *D.* Purchasing chlorine to treat the water *E.* Testing the chlorine residual levels *F.* Ensuring that storage tanks and bucket taps are filled with water when the taps are not flowing *G.* Shutting off the filtration system when necessary	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______________] F. 1) Yes 2) No [Name/Role______________] G. 1) Yes 2) No [Name/Role______________]
A23	Who assigns and ensures the above responsibilities are completed? (A22)	
A24 A24a A24b	When the treatment system is shut off or bypassed, are you informed? Before or after shut off? Who informs you?	1) Yes 2)No 99)I do not know 1) Before 2)After 99) I do not know Comments:
A25	Do you believe your hospital staff have the (capacity) knowledge to manage the system? Why or why not?	1) Yes 2)No 99)I do not know Comments:
A26	Do you believe your hospital staff have the knowledge (capacity) to train new staff on the management, maintenance, and operation of the system? Why or why not?	1) Yes 2)No 99)I do not know Comments:
A27	What is your role in relation to the water treatment system?	
A28	What are your goals for the water treatment system? Do you feel as though you are achieving those goals? Why or why not?	
A29	What do you do to promote the use of safe water use in the hospital?	
A30	In your opinion, what could be done to improve access to safe water in the community surrounding this hospital?	
A31	How can the hospital's water treatment system improve access to safe water in the community surrounding this hospital?	

A32	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		
A33 A33a A33b A33c A33d A33e A33f A33g A33h A33 a-h.a A33 a-h.b	Does your hospital keep records of the following activities related to water provision? Who is responsible for each? *A.* Availability of water *B.* Water treatment *C.* Cleaning water containers (polytanks, bucket tap, cisterns) *D.* Repairing taps and broken sinks *E.* Backwashing *F.* Chlorine residual testing *G.* System bypasses *H.* Other (on a scale from 1 -5, 1=not well maintained 5= maintained) **Observation:** Are the records up to date? **Observation:** Are the records well maintained? (Ask if there is record and where it is located. Find records later. Take a picture of the record)	A. 1) Yes 2) No 3) N/A ____________________ B. 1) Yes 2) No 3) N/A ____________________ C. 1) Yes 2) No 3) N/A ____________________ D. 1) Yes 2) No 3) N/A ____________________ E. 1) Yes 2) No 3) N/A ____________________ F. 1) Yes 2) No 3) N/A ____________________ G. 1) Yes 2) No 3) N/A ____________________ H. 1) Yes 2) No 3) N/A ____________________ 1 2 3 4 5 Comments: 1 2 3 4 5 Comments:
A34 A34a A34b A34c	Are there any organizations or institutions that are monitoring water quality within the hospital? [probe for specific names] How often do you have contact with x officials? What is the name of the x official? What is his/her title? Contact info:	1) Yes →SKIP to Ax 2) No →SKIP to Ax 99) I do not know →SKIP to Ax
A35 A35a	**If yes**, how frequently do they take samples? Do they share their findings with the hospital?	____ times a week/month/year/ever 1) Yes 2) No 99) I do not know Comments:

Hospital Director In-depth Interview Tool

A36	What is the closest city were water samples could be sent to for analysis? Where and what institution?	________________ 99) I do not know Comments:
A37 A37a A37b A33c	How often do you talk to GE Ambassadors/ Kwame Akorsa? What do you talk to them about? [Probe for specific examples] Are these meetings regularly scheduled? When you bring up issues, are they addressed?	____ times/week/ month/year 99) I do not know Comments: 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know
A38 A38a A38b A38c	Do you communicate with Assist International and Kwame Akorsa about the filtration system? How often? What do you discuss? [Probe for specific examples] Are these meetings regularly scheduled? When you bring up issues, are they addressed?	1) Yes 2) No 99) I do not know _____ times/week/month/year Comments: 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know
A39 A39a A39b	How frequently do you talk to maintenance staff about the filtration system? Are your meetings with the maintenance staff scheduled? What did you discuss the last time you spoke?	_____ times a day/week/month 1) Yes 2) No 99) I do not know Comments:
A41 A41a A41b	How frequently do you talk to laboratory staff about the filtration system? Are your meetings with the laboratory staff scheduled? What did you discuss the last time you spoke?	_____ times a day/week/month 1) Yes 2) No 99) I do not know Comments:
A42 A42a A42b	How frequently do you talk to the administrator (bookkeeper) about the filtration system? Are your meetings with the administrator scheduled? What did you discuss the last time you spoke?	_____ times a day/week/month 1) Yes 2) No 99) I do not know Comments:
A43	Have you ever spoken with the staff about the filtration system?	1) Yes 2) No 99) I do not know

A43a	What have you talked about?	
A44 A44a A44b	Does the hospital have a quality assurance committee? If yes, is safe water one of the themes they discuss? Have they taken any action with regard to improving the provision of safe water in the hospital? What actions? **Note**: may not be called biosafety committee in Ghana	1) Yes 2) No →SKIP to Ax 99) I do not know 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know Comments:
A55 A55a A55b A55c A55d	Do you communicate with the GHS about the water treatment system? How often? What do you discuss? [Probe for specific examples] Are these meetings regularly scheduled? When you bring up issues, are they addressed?	1) Yes 2) No 99) I do not know ____ times a week/month/year 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know
A85 A85a A85b A85c A85d	Do you communicate with the MOH about the water treatment system? How often? What do you discuss? [Probe for specific examples] Are these meetings regularly scheduled? When you bring up issues, are they addressed?	1) Yes 2) No 99) I do not know ____ times a week/month/year 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know
A 86 A86a A86b	How frequently do you talk to the bottling company about the filtration system? Are your meetings regularly scheduled? What did you discuss the last time you spoke? **N/A for Ghana	____ times a day/week/month 1) Yes 2) No 99) I do not know Comments:
Institutional Support (the MOH and GE)		
Training and Capacity Building		
A45	Who was trained (within the hospital) in maintaining the filtration system?	Name: ____________ Role: ____________ Name: ____________ Role: ____________ Name: ____________ Role: ____________ Name: ____________ Role: ____________ 99) I do not know

A46 A46a	Did hospital staff receive an information session about the water filtration system? (e.g. why the system was provided / water borne disease) What information sessions would be useful? (waterborne disease, water quality and treatment)	1) Yes 2) No 99) I do not know Comments:
A47 A47a	For how long do you expect GE to continue to offer their assistance? In what capacity? Why? If GE were to stop providing assistance, would you be able to continue to provide safe water? How?	Comments: 1) Yes 2) No 99) I do not know Comments:
Support for Operations and Maintenance, Repairs, and Replacements		
 A48a A48b A48c A48d A48e A49 A50 **Deleted**	Does GE or the MOH/GHS offer: ***A.*** Funds for the water bill ***B.*** Funds for water treatment ***C.*** Funds for infrastructure (tubing, sinks) ***D.*** Staff training ***E.*** Other (Specify): If yes, How much?	***A.*** 1) Yes 2) No 99) I do not know **Who:** 1) GE 2)MOH ***B.*** 1) Yes 2) No 99) I do not know **Who:** 1) GE 2)MOH ***C.*** 1) Yes 2) No 99) I do not know **Who:** 1) GE 2)MOH ***D.*** 1) Yes 2) No 99) I do not know **Who:** 1) GE 2)MOH E. Other ___________ Who: 1) GE 2) MOH A. _____GHc B. _____GHc C. _____GHc D. _____GHc E. _____GHc Comments:
 A51a A51b A51c	Does the hospital set aside funds for: A. Water treatment B. Infrastructure (tubing, sinks) C. Other (specify):	 A. 1) Yes 2) No 99) Don't know B. 1) Yes 2) No 99) Don't know C. Describe:
A52	Are there any outside organizations (apart from GE) that have financed infrastructure for the provision of water and sanitation within the hospital? (For example: wells, toilets, etc.)	1) Yes 2) No 99) I do not know Comments:
A53	What are other sources of external funding for the hospital? *Add question about communication with water bottling companies	

	(Honduras Only)	
A54	**DELETED QUESTION**	**DELETED QUESTION**
Finance Mechanisms		
A56 A56a	Who reviews expense reports? Where are they sent? How often?	___________ 99) I don't know Comments:
A57	How much does chlorine (bleach) cost on a monthly (or quarterly) basis for the filtration system? (probe for cost/unit time)	____ Ghc/monthly/quarterly/yearly 99) I do not know
A58	How often are repairs to the water treatment system completed? [please explain the system used to obtain consumables and parts]	____ Weekly ____ Monthly ____ Yearly 99) I do not know Comments:
A59	Who funds the cost of repairs associated with the system?	1)MOH 2)GE 3)No one 4) Hospital 99)I do not know Comments:
A60 A60a A60b	What process does the hospital have in place to track the expenses required for the water treatment system operating? (Ask to see expense tracking system) (on a scale from 1 -5, 1=not well maintained 5= maintained) **Observation:** Is the record up to date? **Observation:** Is the record well maintained?	Comments: 1 2 3 4 5 Comments: 1 2 3 4 5 Comments:
A61 A62	Has there been a time when chlorine was not purchased for the filtration system? Why? How frequently is chlorine not purchased for the system? Why?	1) Yes 2) No 99) I do not know Comments: _____ times a week/month/year/ N/A Comments:
A63	Is the hospital able to cover the recurring costs associated with the filtration system (i.e. chlorine, staff time, small repairs)?	1) Yes 2) No 99) I do not know Comments:
Satisfaction and Perceived Value		

Hospital Director In-depth Interview Tool

A64	In your opinion, what are the benefits of having a safe water source here in the hospital?	
A65	For who in the hospital is safe water most important? For what purpose? Can you give me an example?	
A66	What actions does the hospital take to promote the availability and awareness of safe water for staff, patients, and visitors?	
A67	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:
A68	In your opinion is the water from the tap safe to drink?	1) Yes 2) No 99) I do not know
A69	Do you drink from the tap?	1) Yes 2) No 99) I do not know
A70	On a scale of 1-5, 5=very satisfied 1=not satisfied: How would you rate your satisfaction with the taste of the water? [If no, why not?]	1 2 3 4 5 Comments:
A71	How would you rate your satisfaction with the color of the water? [If no, why not?]	1 2 3 4 5 Comments:
A72	How would you rate your satisfaction with the water pressure of the system? [If no, why not?]	1 2 3 4 5 Comments:
A73	How would you rate your satisfaction with the maintenance cost of the filtration system? [If no, why not?]	1 2 3 4 5 Comments:
A74	How would you rate your satisfaction with the filtration system to provide the need of safe water to the hospital? [explain]	1 2 3 4 5 Comments:
A75	Would you recommend this filtration system to other hospitals? Why or why not?	1) Yes 2) No 99) I do not know Comments:
A76	In your opinion, what distinguishes this hospital from other public hospitals?	
A77	Do you believe that there are benefits to safe water?	1) Yes 2) No 99) I do not know
Educational Messaging		

A78 A78a A78b	If an hour long information session or training regarding safe water was held in your hospital, would you attend? If yes, what would you like to learn about water? If yes, how would you like to learn about it? (role play, lecture, demonstration, poster)	1) Yes 2) No 99) I do not know Comments: Comments:
A79	If no, would you attend if you were given a certificate of completion?	1) Yes 2) No 99) I do not know
A80	If an hour long information session was given, when would be a good time during the day to have it? (i.e. During lunch or after work?)	
A81 A81a	What would be an effective way to tell others about water and the benefits of safe water? What Language should it be in?	
Personal Information (Observations)		
A82	Sex of the director:	1) Male 2) Female
A83	Age of the director:	1) ≤ 30 years 2) >30 years 3) ≥ 60 years
A84a A84b A84c A84d	**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:

Administrator Interview Tool

JH1	Date		JH4	Hospital Name	
JH2	Start Time		JH5	Name of Investigator(s)	
JH3	End Time				

J1	Role of Participant:	4) Administrator (bookkeeper) 88) Other, specify:
J2	Sex of Participant:	1) Male 2) Female
J3	Age of Participant:	1) ≤ 30 years 2) >30 years 3) ≥ 60 years
J4a J4b	What is the population of the municipality:	Area: Population:
J5	In your opinion, is the tap water safe to drink? Why or why not?	1) Yes 2) No 99) I do not know Comments:
J6	Do you drink from the tap?	1) Yes 2) No 99) I do not know Comments:
J7	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:
J8 J8a	Prior to being informed today, were you aware of the water treatment system at the hospital? How did you learn this information?	Treated: 1) Yes 2) No 99) I do not know Comments:
 J9a J9b J9c J9d	Who drinks the tap water? **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:___________
J10	What are the benefits of having safe water for your job?	
J11	Is contaminated water a problem for the communities living near this hospital? Why or why not?	1) Yes 2) No 99) I do not know Comments:
J12 J12a J12b J12c	What influences your decision to purchase (or not purchase) chlorine for the water treatment system? On a scale of 1-5, 5=influences 1= does not influence A. Cost B. Impact on water quality C. % of funds already spent on water	A. 1 2 3 4 5 B. 1 2 3 4 5 C. 1 2 3 4 5

J13	Approximately how much do you spend monthly to obtain consumables and parts needed to fix repairs for the water treatment system?	_________ Ghc
J14 J14a J14b J14c	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 or fittings on the water treatment system? On a scale of 1-5, 5=influences 1= does not influence A. Cost B. Impact on water quality C. % of funds already spent on water	A. 1 2 3 4 5 B. 1 2 3 4 5 C. 1 2 3 4 5
J15	Is there a specific budget for inputs and repairs for the water treatment system? [if not, please explain the system used to obtain consumables and parts]	1) Yes 2) No 99) I do not know Comments:
J16 J16a J16b J16c J16d J16e J16f J16g J16h J16a-h.a J16a-h.b	Does your hospital keep records of the following activities related to water provision? Who is responsible for each? A. Availability of water B. Water treatment C. Cleaning water containers (polytanks, bucket tap, cisterns) D. Repairing taps and broken sinks E. Backwashing F. Chlorine residual testing G. System bypasses H. Other (on a scale from 1 -5, 1=not well maintained 5= maintained) **Observation:** Are the records up to date? **Observation:** Are the records well maintained? (Ask if there is record and where it is located. Find records later. Take a picture of the record)	A. 1) Yes 2) No 0) N/A 99) I do not know ____________________ B. 1) Yes 2) No 0) N/A 99) I do not know ____________________ C. 1) Yes 2) No 0) N/A 99) I do not know ____________________ D. 1) Yes 2) No 0) N/A 99) I do not know ____________________ E. 1) Yes 2) No 0) N/A 99) I do not know ____________________ F. 1) Yes 2) No 0) N/A 99) I do not know ____________________ G. 1) Yes 2) No 0) N/A 99) I do not know ____________________ H. 1) Yes 2) No 0) N/A 99) I do not know ____________________ 1 2 3 4 5 Comments: 1 2 3 4 5 Comments:

J17 J17a J17b	What system does the hospital have in place to track the expenses required for the filtration system operating? (Ask to see expense tracking system) (on a scale from 1 -5, 1=not well maintained 5= Maintained) **Observation:** Is the record up to date? **Observation:** Is the record well maintained?	Comments: 1 2 3 4 5 Comments: 1 2 3 4 5 Comments:
J18 J18a J18b	Does the hospital have a quality assurance committee? If yes, is safe water one of the themes they discuss? Have they taken any action with regard to improving the provision of safe water in the hospital? What actions? **Note**: may not be called biosafety committee in Ghana	1) Yes 2) No →SKIP to Ax 99) I do not know 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know Comments:
J19 J19a	What is the closest city were water samples could be sent to for analysis? Where and what institution?	
J20 J20a J20b J20c	How often do you talk to GE Ambassadors/ Kwame Akorsa? What do you talk to them about? [Probe for specific examples] Are these meetings regularly scheduled? When you bring up issues, are they addressed?	___ times/week/ month/year 99) I do not know 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know
J21 J21a J21b J21c	Do you communicate with Assist International and \ about the filtration system? How often? What do you discuss? [Probe for specific examples] Are these meetings regularly scheduled? When you bring up issues, are they addressed?	1) Yes 2) No 99) I do not know ____ times/week/month/year 99)I do not know Comments: 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know

Administrator Interview Tool

J22 J22a J22b	How frequently do you talk to the director about the filtration system? Are your meetings with the director scheduled? What did you discuss the last time you spoke?	____ times a day/week/month 99)I do not know 1) Yes 2) No 99) I do not know Comments:
J23 J23a J23b J24	How frequently do you talk to maintenance staff about the filtration system? Are your meetings with the maintenance staff scheduled? What did you discuss the last time you spoke? Does the maintenance staff inform you when they shut off the filtration system?	_____ times a day/week/month 99)I do not know 1) Yes 2) No 99) I do not know Comments: 1) Yes 2) No 99) I do not know
J25 J25a J25b J25c	Are there any organizations or institutions that are monitoring water quality within the hospital? [probe for specific names] How often do you have contact with x officials? What is the name of the x official? What is his/her title? Contact info:	1) Yes 2) No 99) I do not know Comments:
J26 J26a	**If yes**, how frequently do these outside organizations take samples? Do they share their findings with the hospital?	_____ times a week/month/year/ever 99)I do not know 1) Yes 2) No 99) I do not know Comments:
J27	How much does chlorine (bleach) cost on a monthly (or quarterly) basis for the filtration system? (probe for cost/unit time)	_________ Ghc
J28 J28a	Has there been a time when chlorine was not purchased for the filtration system? Why? How frequently is chlorine not purchased for the system? Why?	1) Yes 2) No 99) I do not know Comments: _____ times a week/month/year/ N/A 99)I do not know Comments:

J29 J29a J29b	If an hour long information session or training regarding safe water was held in your hospital, would you attend? **If yes**, what would you like to learn about water? **If yes**, how would you like to learn about it? (role play, lecture, demonstration, poster)	1) Yes 2) No 99) I do not know Comments: Comments:
J30	**If no**, would you attend if you were given a certificate of completion?	1) Yes 2) No 99) I do not know
J31	If an hour long information session was given, when would be a good time during the day to have it? (i.e. During lunch or after work?)	
J32 J32a	What would be an effective way to tell others about water and the benefits of safe water? What Language should it be in?	
   J33a J33b J33c J33d	**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:

Laboratory Staff Interview Tool

KH1	Date		KH4	Hospital Name	
KH2	Start Time		KH5	Name of Investigator(s)	
KH3	End Time	Name: Daniel			

K1	Role of Participant:	2) Laboratory Technician 88) Other, specify:
K2	Sex of Participant:	1) Male 2) Female
K3	Age of Participant:	1) ≤ 30 years 2) >30 years 3) ≥ 60 years
K4	In your opinion, is the tap water safe to drink? Why or why not?	1) Yes 2) No 99) I do not know Comments: (See pilot data)
K5	Do you drink water from the tap?	1) Yes 2) No 99) I do not know Comments:
K6	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:
K7 K7a K7b	Where does the water in this hospital come from? (See pilot data) Is it treated before use? How? Where did you learn this information?	Source: Treated: 1) Yes 2) No 99) I do not know Method of treatment: Comments:
 K8a K8b K8c K8d	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:__________
K9	What are the benefits of having safe water for your job?	
K10	Is contaminated water a problem for the communities living near this hospital? **Why or why not?**	1) Yes 2) No 99) I do not know Comments:
K11	Who was trained in water sample collection and testing?	99) I do not know
K12	How many laboratory staff members have been trained to perform chlorine residual testing by another staff member?	____ Laboratory Staff 99) I do not know
K13 K13a	How often do you measure chlorine residual levels?	__ times/week/month/year

Laboratory Staff Interview Tool

K13b K13c	Where do you measure them? Do you document this information? Where and how often? (Follow up on testing records – last time were not present due to a move)	1) Yes 2) No 99) I do not know
K14 K14a	How often do you give advice (feedback) to the maintenance staff to adjust the chlorine levels in the water treatment system? How do they react? (probe for updates)	___ times/week/month/year Comments:
K15 K15a	When was the last time you discussed water chlorine levels with the director? (See pilot data) How often do you communicate with the administrator about the chlorine residual levels in the water treatment system?	Comments: ___ times/week/month/year
K16 K16a K16b	How often do you meet with the administrator about the water treatment system? (See pilot data) Are these meetings scheduled? What did you discuss the last time you talked?	____ times/day/week/month 1) Yes 2) No 99) I do not know Comments:
K17 K17a K17b	How often do you talk to the maintenance staff about the filtration system? How many times have the maintenance staff respond to your (the laboratory staff) advice? How many times did you (lab staff) retest the chlorine residual levels after, maintenance adjusted levels?	____ times a day/week/month Comments:
K18 K19	Does your laboratory have incubators? Are the laboratory technicians in this hospital trained on environmental microbiology? Culture methods? What did the training include?	1) Yes 2) No 99) I do not know Comments: 1) Yes 2) No 99) I do not know Comments:
K20 K20a K20b	If an hour long information session or training regarding safe water was held in your hospital, would you attend? If yes, what would you like to learn about water? If yes, how would you like to learn about it? (role play, lecture, demonstration, poster)	1) Yes 2) No 99) I do not know Comments: Comments:

K21	If no, would you attend if you were given a certificate of completion?	1) Yes 2) No 99) I do not know
K22	If an hour long information session was given, when would be a good time during the day to have it? (i.e. During lunch or after work?)	
K23 K23a	What would be an effective way to tell others about water and the benefits of safe water? What Language should it be in?	
   K24a K24b K24c K24d	**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:

Clinical Staff Interview Tool

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

B1	Role of Participant:	1) Doctor 2) Nurse 3) Pharmacist 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	In your opinion, is the water from the hospital tap safe to drink? Why or why not? [Probe for more information]	1) Yes 2) No 99) I do not know Comments:
B5	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:
B6 B6a	Prior to being informed today, were you aware of the water treatment system at the hospital? How did you learn this information?	Treated: 1) Yes 2) No 99) I do not know Comments:
B7	Is contaminated water a problem for the communities living near this hospital? Why or why not?	1) Yes 2) No 99) I do not know Comments:
 B8a B8b B8c B8d	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:__________
B9	Do patients comment about the water in the hospital? If yes, what do they say? (probe for water quality) [explain]	1) Yes 2) No 99) I do not know Comments:
B10	What are the benefits of having safe water for your job?	99) I do not know Comments:
B11	Do you recommend that your patients drink tap water in the hospital?	1) Yes 2) No If no, why ____________________
B12	Where do patients get water when the tap is not flowing?	
B13	If an hour long information session or training regarding safe water was held in your hospital, would you attend?	1) Yes 2) No 99) I do not know

B13a B13b	**If yes**, what would you like to learn about water? **If yes**, how would you like to learn about it? (role play, lecture, demonstration, poster)	Comments: Comments:
B14	**If no**, would you attend if you were given a certificate of completion/certification?	1) Yes 2) No 99) I do not know
B15	If an hour long information session was given, when would be a good time during the day to have it? (ie. During lunch or after work?)	
B16 B16a	What would be an effective way to tell others about water and the benefits of safe water? What Language should it be in?	
   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:

Staff Interview Tool

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

C1	Role of Participant:	1) Administrative Staff (Receptionist, finance, etc.) 3) Cook 5) Laundry 6) Sanitation/Janitorial 88) Other, specify: **Laboratory (2) and Administrator (4): see separate surveys**
C2	Sex of Participant:	1) Male 2) Female
C3	Age of Participant:	1) ≤ 30 years 2) >30 years 3) ≥ 60 years
C4	In your opinion, is the tap water safe to drink? Why or why not?	1) Yes 2) No 99) I do not know Comments:
C5	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:
C6 C6a	Prior to being informed today, were you aware of the water treatment system at the hospital? How did you learn this information?	1) Yes 2) No 99) I do not know Comments:
C7	What do you know about the water treatment system at the hospital?	
 C8a C8b C8c C8d	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:___________
C9	Do you drink from the tap?	1) Yes 2) No 99) I do not know Comments:
C10	What are the benefits of having safe water for your job?	
C11	Is contaminated water a problem for the communities living near this hospital? Why or why not?	1) Yes 2) No 99) I do not know Comments:
C12 C12a C12b	If an hour long information session or training regarding safe water was held in your hospital, would you attend? If yes, what would you like to learn about water? **If yes**, how would you like to learn about it?	1) Yes 2) No 99) I do not know Comments: Comments:

	(role play, lecture, demonstration, poster)	
C13	**If no**, would you attend if you were given a certificate of completion?	1) Yes 2) No 99) I do not know
C14	If an hour long information session was given, when would be a good time during the day to have it? (ie. During lunch or after work?)	
C15 C15a	What would be an effective way to tell others about water and the benefits of safe water? What Language should it be in?	
   C16a C16b C16c C16d	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:

Patients and Visitor Interview Tool

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 D5	How much time did it take you to get to the hospital from where you are coming from? How did you get to the hospital?	____hours ____minutes 1) Walk 2) Bus/public transport 3) Bike 4) Car 5) Motorcycle 88) Other:
D6	How long have you been here at the hospital since you arrived for this visit?	___hours ___minutes
D7	Did you drink water from the hospital tap today?	1) Yes 2) No 3) I do not know
D8	**If they did drink hospital tap water today**: How does the hospital tap water compare to the water you use in your house? Taste? Security?	1) Worse 2) Equal 3) Better 99) I do not know Comments:
D9	**If they did not drink hospital tap water**, why not?	
D10	**If they have children**, did your children drink the hospital tap water today?	1) Yes 2) No 99) I do not know
D11	Is the hospital tap water safe (good) to drink? Why or why not?	1) Yes 2) No 99) I do not know Comments:
D12	Did you know there is a water treatment system at this hospital? What do you know about the system?	1) Yes 2) No 99) I do not know Comments:
D13	Do you have a water tap in your house [or compound]?	1) Yes 2) No 99)I do not know
D14	Where do you collect your water from at home?	
D15 D15a	Do you treat your drinking water in your house [or compound]? **If yes**, How?	1) Yes 2) No →SKIP to D14 99) I do not know→SKIP to D14 Comments: Treatments [in the affirmative case] 1) Boil 2) Filter 3) Chlorine 88) Other

Patients and Visitor Interview Tool

D16	In your opinion, is contaminated water a problem in your community? Why or why not?	1) Yes 2) No 99) I do not know Comments:
D17 D17a	What would be a good way to share information about water and the benefits of safe water to the public? What language should it be in?	

Maintenance In-depth Interview Tool

HH1	Date		HH 4	Hospital Name	
HH2	Start Time		HH 5	Name of Investigator(s)	
HH3	End Time	**Name: Paul (Ask Benetton the electrician as well)**			

Demographic Information		
	Ask Maintenance person for a water map/ water treatment map for the hospital. (May be in the form of blue prints)	
H1	Role of Participant:	7)Maintenance 8)Plumber 11) Electrician 88) Other
H2	Sex of Participant:	1) Male 2) Female
H3	Age of Participant:	1) ≤ 30 years 2) >30 years 3) ≥ 60 years
H4	What is the highest education level you have completed?	
H5	How long have you been working here at this hospital?	______months/years
Electricity		
H6 H6a H6b H6c	In the last week, how many times has the electricity gone out? On average, how long does the electricity stay out when it does go out? Who is responsible for deciding to turn on the generator? When do you choose to turn the generator on? For what specific reasons?	______ time/day/week/month Comments:
Sanitation		
H7	What types of toilets are available in the hospital? (circle all that apply)	1) Tank flush toilet 2) Pressure flush toilet 3) Pour flush toilet 4) Tap flush toilet 5) Latrine 88) Other (specify):
H8	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:
On-Site Capacity		
Training		
H9	Who was trained by GE in the operations and maintenance of the filtration system? Do they all still work here?	Name _Paul ___ Role___________ 1) Yes 2) No Name _ Bentton__ Role___________ 1) Yes 2) No Name _________ Role___________ 1) Yes 2) No Name _________ Role___________ 1) Yes 2) No Name _________ Role___________ 1) Yes 2) No
H10 H10a H10b H10c	How often do you talk to GE Ambassadors/ Kwame Akorsa? What do you talk to them about? [Probe for specific examples] Are these meetings regularly scheduled? When you bring up issues, are they addressed?	___ times/week/ month/year 99) I do not know 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know

Maintenance In-depth Interview Tool

H11 H11a H11b H11c	Do you communicate with Assist International and Kwame Akorsa about the filtration system? How often? What do you discuss? [Probe for specific examples] Are these meetings regularly scheduled? When you bring up issues, are they addressed?	1) Yes 2) No 99) I do not know ____ times/week/month/year Comments: 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not
H12	How many visits did GE, Assist, and Kwame Akorsa make in the last year?	GE ___ Assist ___ Kwame Akorsa _____
H13	What are the issues you discussed during these visits?	
H14	Who is responsible for the GE water treatment system? (See pilot data)	
H15	Normally, how many people complete maintenance tasks associated with the filtration system? (See pilot data)	
H16	Has any staff member been trained to maintain the filtration system by another staff member?	1) Yes 2) No 99) I do not know
H17	How many days a week is there someone here that knows how to operate the filtration system?	___days/week
H18	How many days in the last month have you not used the filtration system? Why?	___days/month
H19 H19a H19b	If the system is not working, when was the last time it was used? Why are the filters not being used? Have there been any attempts to fix the filters? If no, why not?	
H20 H20a H20b H20c H20d	Do you communicate (on the phone/email) with Kwame Akorsa / GE Ambassadors about the water the filtration system? How often? What do you discuss? [Probe for specific examples] Are these meetings regularly scheduled? When you bring up issues, are they addressed?	1) Yes 2) No 99) I do not know ____ times a day/week/month 1)Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know
H21 H21a H21b	Do you communicate (on the phone/email) with Assist International about the filtration system? How often? What do you discuss? [Probe for specific	1) Yes 2) No 99) I do not know ____ times a week/month/year 1)Yes 2) No 99) I do not know

H21c H21d	examples] Are these meetings regularly scheduled? When you bring up issues, are they addressed?	1) Yes 2) No 99) I do not know
H22 H22a H22b	Do you communicate with the MoH/GHS about the filtration system? How often? What do you discuss? [Probe for specific examples]	1) Yes 2) No 99) I do not know ____ times a day/week/month Comments:
H23 H23a H23b	What system do you have in place to track the expenses required for the water treatment system operating? (Ask to see expense tracking system) **Observation:** Is the record up to date? **Observation:** Is the record well maintained?	1) Yes 2) No 99) I do not know Comments: 1 2 3 4 5 Comments: 1 2 3 4 5 Comments:
H24	What is your role in the provision of safe water within the hospital?	
H25 H25a H25b H25c	How often do you meet with the director about the filtration system? Are your meetings scheduled? What did you discuss the last time you met? Do you inform the director when you shut off the filtration system?	____ times a day/week/month 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know
H26 H26a H26b H26c H26d	How often do you meet with the laboratory staff about the filtration system? Are your meetings scheduled? What did you discuss the last time you met? Do you inform the laboratory when you shut off the filtration system? Do you inform the laboratory when you change to a new chlorine concentration?	____ times a day/week/month 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
H27 H27a H27b	How often do you talk to the administrator about the filtration system? Are these meetings scheduled? What did you discuss the last time you talked?	____ times a day/week/month 1)Yes 2) No 99) I do not know
H28 H28a	Have you ever spoken with the staff about the filtration system? (See pilot data – probe for more info) What have you talked about? (Probe for if he tells staff about raw water)	1) Yes 2) No 99) I do not know
H29 H29a H29b	How often do you have to buy chlorine for the water system? Where do you buy chlorine?	____ times a day/week/month __ Market __ Chemical shop (pharmacist) __ Other (describe)

Maintenance In-depth Interview Tool

H29c H29d H29e H29f	How much chlorine do you usually buy What type of chlorine do you use? (Liquid, powdered) Is it difficult to buy chlorine? Why? How many hours does it take you to buy chlorine? How much does chlorine (bleach) cost on a monthly (or quarterly) basis for the filtration system? (probe for cost/unit time)	_____liters __ Liquid chlorine __ Powdered chlorine __ Other (describe) 1) Yes 2) No Comment: _____Ghc
H30	Do you talk with other maintenance teams at other hospitals with GE filter systems? (See pilot data)	1) Yes 2) No 99) I do not know
H31 H31a H31b H31c H31d H31a-d.a	Does this hospital have a written record for any of the following activities? Who is responsible? A] when a by-pass is run B] measuring chlorine levels C] cleaning the water containers D] repairing taps and broken sink **Observation:** Are these records up to date? Are they well maintained?	A] 1) Yes 2) No 3) N/A __________________ B] 1) Yes 2) No 3) N/A __________________ C] 1) Yes 2) No 3) N/A __________________ D] 1) Yes 2) No 3) N/A __________________ 1 2 3 4 5 Comments:
H32 H32a	For how long do you expect GE to continue to offer their assistance? In what capacity? Why? If GE were to stop providing assistance, would you be able to continue to provide safe water? How?	Comments:
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?		
H33	**[For manual systems]** How often is a backwash performed?	_____times per day/week/month 0) Never
H34	**[For PLC systems]** How often are the filters checked to make sure the backwash is functioning?	_____times per day/week/month 0) Never
H35	How often is more chlorine added to the system?	_____times per day/week/month 0) Never
H36	Does the hospital always have enough chlorine for the system	1) Yes 2) No 99) I do not know
H37	How often is the pressure at the entrance and exit checked to see if there is a significant drop in pressure across the filters?	__ Weekly __ Monthly __ Yearly __ Never __ N/A

Maintenance In-depth Interview Tool

H38	Have you ever removed the tops of the filters and washed the filters in a chlorine bath? If yes, how often? (See pilot data – interesting responsibility deligation)	1) Yes 2) No 99) I do not know _____times per day/week/month 0) Never
H39	What do you do when there is a drop in pressure? [Probe about backwashing] **Only ask if pressure is a concern	
Repairs and Institutional Support		
H40	Is it one of your responsibilities to repair the water treatment system? Why or why not?	1) Yes 2) No Comment:
H41	Given the following scenarios, do you have the capacity to repair the water treatment system? Why or why not? A) What do you do (or would you do) when there is low flow or low pressure from the filters? Answer: Filters should be cleaned and flow and pressure inspected. Filters are cleaned by repeated backwashing. Flow can be measured using the flow meter in Ghana and pressure measured by the pressure gauges in Honduras. B) What do you do when a pump fails? Answer: The maintenance staff likely does not have the capacity to repair a pump. Therefore, the answer to this question should involve initiating a decision making process that involves assessing the situation and then seeking outside help to resolve the problem. C) What do you do if the laboratory tells you that the chlorine concentration is too low? Answer: The maintenance staff should either 1) increase the ratio of chlorine to water in the chlorine solution container 2) increase the size of the dose of chlorine injected into the water or 3) reduce chlorine storage time through better managing water supply.	A. 1) correct 2) incorrect Comment: B. 1) correct 2) incorrect Comment: C. 1) correct 2) incorrect Comment:
H42 H42a H42b H42c	Who do you call when there is a problem with the water treatment system? (See pilot data – probe for how often) How often do you complete repairs to the water treatment system? How accessible are replacement parts (tubing, connectors – elbows, fittings, reducers, glue) for the water treatment system? How far do you have to travel to find the replacement parts you need to repair the	Comments: Kwame __ Weekly __ Monthly __ Yearly __ Never 99) I do not know Comments: ___ Locally ___ Within the district ___ Within the region

Maintenance In-depth Interview Tool

H42d	water treatment system? Where have you been able to find the replacement parts needed to repair the water treatment system when they break down?	99) I do not know Comments:
H43	Have you ever sought external help for repairs? If so, why?[explain]	
H44 H44a H44b H44c H44d	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? (Ask to see repair log. Take a picture of log)	___/___/_____ Name: _______________ Role: _____________
H45 H45a	Which parts of the water system can you fix without help from an external support structure? Which parts of the water system cannot be fixed without help from an external support structure?	
H46	In your opinion, what specific aspects of maintenance would you want more training on?	
Satisfaction		
H47	What can GE do to improve the filtration system? (See pilot data – likes the idea of PLC manual controls)	
H48	Would you recommend the filtration system to other hospitals? Why or why not? (See pilot data)	1) Yes 2) No 99) I do not know
H49	What advice would you give others who operate the same water filtration system that you have here? (See pilot data)	
H50	Do you have other questions for GE about the filtration system? Kates note [no – ask Kate if she related that information]	
Educational Messaging		
H51 H51a H51b	If an hour long information session or training regarding safe water was held in your hospital, would you attend? If yes, what would you like to learn about water? If yes, how would you like to learn about it? (role play, lecture, demonstration, poster)	1) Yes 2) No 99) I do not know Comments: Comments:
H52	If no, would you attend if you were given a certificate of completion?	1) Yes 2) No 99) I do not know
H53	If an hour long information session was given, when would be a good time during the day to have it? (i.e. During lunch or after work?)	

H54 H54a	What would be an effective way to tell others about water and the benefits of safe water? What Language should it be in?	
Awareness/ Demand/ Attitudes		
H55	Why is it important to treat the water?	
H56	In your opinion is the water from the tank safe to drink?	
H57	Do you drink from the tap?	
H58	What are your (maintenance) goals for the water filtration system? Do you feel like you are achieving them? Why?	
Other (opinion of the investigator)		
  H59a H59b H59c H59d	**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:

Director Water-Use Survey Tool

Director/Clinical Staff

1) Doctor 2) Nurse 3) Pharmacist 4) Midwife 5) Dula 10) Director 88) Other, specify:

1. **What sources of water are available to you at the hospital for all of your daily activities (list them)?**

2. **Which other of your daily activities at the hospitals require you to use water (*list them*)?**

Which of these sources of water do you use for the following activities:

	Bottled	Tap untreated	Tap treated					N/A
Drinking								
Hand Washing								
Hand washing before surgery								
During surgery (surgical staff only)								
Water given to patients to consume with oral medications (probe for how decision is made to use which water source)								
Bathing newborn babies								
Sponge-bathing								
Cleaning wounds								
Cleaning Burns								
Teeth clean rinse (for dentists)								
Reconstitution of medications								

Comments & Observations:

Administrator Water-Use Survey Tool

Administrative Staff

1. What sources of water are available to you at the hospital for all of your daily activities (list them)?

2. Which other of your daily activities at the hospitals require you to use water (list them)?

Which of these sources of water do you use for the following activities:

	Bottled	Tap untreated	Tap treated					N/A
Drinking								
Drinking water provided for visitors								
Hand-Washing								

Comments & Observations:

Laboratory Water-Use Survey Tool

Laboratory Staff **1. What sources of water are available to you at the hospital for all of your daily activities (list them)?** **2. Which other of your daily activities at the hospitals require you to use water (list them)?**								
Which of these sources of water do you use for the following activities:								
	Bottled	**Tap untreated**	**Tap treated**	**DI water**	**Auto-claved water**			**N/A**
Drinking								
Hand washing								
Mixing Reagents								
Washing and cleaning laboratory supplies and equipment								
Sterilization of laboratory equipment								
Comments & Observations:								

Clinical Water-Use Survey Tool

Clinical Staff

1) Doctor 2) Nurse 3) Pharmacist 4) Midwife 5) Dula 88) Other, specify:

3. **What sources of water are available to you at the hospital for all of your daily activities (list them)?**

4. **Which other of your daily activities at the hospitals require you to use water (*list them*)?**

Which of these sources of water do you use for the following activities:

	Bottled	**Tap untreated**	**Tap treated**					**N/A**
Drinking								
Hand Washing								
Hand washing before surgery								
During surgery (surgical staff only)								
Water given to patients to consume with oral medications (probe for how decision is made to use which water source)								
Bathing newborn babies								
Sponge-bathing								
Cleaning wounds								
Cleaning Burns								
Teeth clean rinse (for dentists)								
Reconstitution of medications								

Comments & Observations:

Staff Water-Use Survey Tool

Various Hospital Staff

5). Laundry 3). Cook 6). Janitorial

88) Other, specify:

1. What sources of water are available to you at the hospital for all of your daily activities (list them)?

2. Which other of your daily activities at the hospitals require you to use water (list them)?

Which of these sources of water do you use for the following activities:

	Bottled	Tap untreated	Tap treated					N/A
Drinking								
Hand Washing								
Laundry (including hospital bedding) (Laundry)								
Washing floors and other surfaces (Janitorial/Sanitation)								
Flushing toilets (Janitorial/Sanitation)								
Watering plants and gardening (Janitorial/Sanitation)								
Washing hospital vehicles (ambulances, other) (Janitorial/Sanitation)								
Wash foods and vegetables (Kitchen)								
Preparing food (Kitchen)								
Washing dishes, utensils, glasses								

Comments & Observations:

Patients and Visitor Water-Use Survey Tool

Patient/Visitor/Caregiver
1) Patient
2) Visitor/Caregiver
88) Other, specify:

1. What sources of water are available to you at the hospital for all of your daily activities (list them)?

2. Which other of your daily activities at the hospitals require you to use water (list them)?

Which of these sources of water do you use for the following activities:

	Bottled	Tap untreated	Tap treated					N/A
Drinking while at hospital								
Hand washing while at hospital								
Washing raw foods, fruits or vegetable before eating								
Preparing food								
Bathing								
Taking oral medications								
Laundry								
Other?								

Comments & Observations:

Maintenance Info-Graphic Survey Tool

Maintenance Survey – Cisterns and Polytanks

NH1 # of cisterns: NH2 total volume of cistern:
NH3 # of polytanks: NH4 total volume of polytanks:
NH5 # of taps leaking: NH6 volume over 5 hours: (mL)
NH7 # of cisterns that are leaking at a wasteful rate (measure volume over 5 hours) ____ # ____ (mL)
NH8 Are the cisterns cleaned? Yes/No **If yes**, how often? _____time/week/month/year
NH9 Location of chlorination points:

Cistern #1 N1a Above ground/Below ground
N1b In use? Yes/No
N1c Divided in two sections? Yes/No
N1d Leak? Yes/No
N1e Screen present? Yes/No
N1f Tap? Yes/No N1g Tap functional? Yes/No
N1h Connected to piped water supply? Yes/No

Oth

N1m Cistern #1: If the water source ceased, how long would the water in cistern last?
1) < 1 day 2) 1-3 days 3) > 3 days

Cistern #2 N2a Above ground/Below ground
N2b In use? Yes/No
N2c Divided in two sections? Yes/No
N2d Leak? Yes/No
N2e Screen present? Yes/No
N2f Tap? Yes/No N2g Tap functional? Yes/No
N2h Connected to piped water supply? Yes/No

N2m Cistern #2: If the water source ceased, how long would the water in cistern last?
1) < 1 day 2) 1-3 days 3) > 3 days

Cistern #3 N3a Above ground/Below ground
N3b In use? Yes/No
N3c Divided in two sections? Yes/No
N3d Leak? Yes/No
N3e Screen present? Yes/No
N3f Tap? Yes/No N3g Tap functional? Yes/No
N3h Connected to piped water supply? Yes/No

N3m Cistern #3: If the water source ceased, how long would the water in cistern last?
1) < 1 day 2) 1-3 days 3) > 3 days

Cistern #4 N4a Above ground/Below ground
N4b In use? Yes/No
N4c Divided in two sections? Yes/No
N4d Leak? Yes/No
N4e Screen present? Yes/No
N4f Tap? Yes/No N4g Tap functional? Yes/No
N4h Connected to piped water supply? Yes/No

N4m Cistern #4: If the water source ceased, how long would the water in cistern last?
1) < 1 day 2) 1-3 days 3) > 3 days

Maintenance Info-Graphic Survey Tool

Polytanks

1 P1a **Connected to Cistern # ___**	P1b Leak? Yes/No P1c Lid present? Yes/No P1d Tap? Yes/No P1e Tap functional? Yes/No P1f Connected to piped water supply? Yes/No P1g Ever filled by tanker-truck? Yes/No P1h Filtered? Yes/N P1i Chlorinated? Yes/No P1j Chlorine residual level: ________
2 P2a **Connected to Cistern # ___**	P2b Leak? Yes/No P2c Lid present? Yes/No P2d Tap? Yes/No P2e Tap functional? Yes/No P2f Connected to piped water supply? Yes/No P2g Ever filled by tanker-truck? Yes/No P2h Filtered? Yes/N P2i Chlorinated? Yes/No P2j Chlorine residual level: ________
3 P3a **Connected to Cistern # ___**	P3b Leak? Yes/No P3c Lid present? Yes/No P3d Tap? Yes/No P3e Tap functional? Yes/No P3f Connected to piped water supply? Yes/No P3g Ever filled by tanker-truck? Yes/No P3h Filtered? Yes/No P3i Chlorinated? Yes/No P3j Chlorine residual level: ________
4 P4a **Connected to Cistern # ___**	P4b Leak? Yes/No P4c Lid present? Yes/No P4d Tap? Yes/No P4e Tap functional? Yes/No P4f Connected to piped water supply? Yes/No P4g Ever filled by tanker-truck? Yes/No P4h Filtered? Yes/No P4i Chlorinated? Yes/No P4j Chlorine residual level: ________
5 P5a **Connected to Cistern # ___**	P5b Leak? Yes/No P5c Lid present? Yes/No P5d Tap? Yes/No P5e Tap functional? Yes/No P5f Connected to piped water supply? Yes/No P5g Ever filled by tanker-truck? Yes/No P5h Filtered? Yes/No P5i Chlorinated? Yes/No P5j Chlorine residual level: ________
6 P6a **Connected to Cistern # ___**	P6b Leak? Yes/No P6c Lid present? Yes/No P6d Tap? Yes/No P6e Tap functional? Yes/No P6f Connected to piped water supply? Yes/No P6g Ever filled by tanker-truck? Yes/No P6h Filtered? Yes/No P6i Chlorinated? Yes/No P6j Chlorine residual level: ________
7 P7a **Connected to Cistern # ___**	P7b Leak? Yes/No P7c Lid present? Yes/No P7d Tap? Yes/No P7e Tap functional? Yes/No P7f Connected to piped water supply? Yes/No P7g Ever filled by tanker-truck? Yes/No P7h Filtered? Yes/No P7i Chlorinated? Yes/No P7j Chlorine residual level: ________
8 P8a **Connected to Cistern # ___**	P8b Leak? Yes/No P8c Lid present? Yes/No P8d Tap? Yes/No P8e Tap functional? Yes/No P8f Connected to piped water supply? Yes/No P8g Ever filled by tanker-truck? Yes/No P8h Filtered? Yes/No P8i Chlorinated? Yes/No P8j Chlorine residual level: ________
9 P9a **Connected to Cistern # ___**	P9b Leak? Yes/No P9c Lid present? Yes/No P9d Tap? Yes/No P9e Tap functional? Yes/No P9f Connected to piped water supply? Yes/No P9g Ever filled by tanker-truck? Yes/No P9h Filtered? Yes/No P9i Chlorinated? Yes/No P9j Chlorine residual level: ________

Maintenance Info-Graphic Survey Tool

Polytanks

10 P10a **Connected to Cistern # ___**	P10b Leak? Yes/No P10c Lid present? Yes/No P10d Tap? Yes/No P10e Tap functional? Yes/No P10f Connected to piped water supply? Yes/No P10g Ever filled by tanker-truck? Yes/No P10h Filtered? Yes/No P10i Chlorinated? Yes/No P10j Chlorine residual level: ________
11 P11a **Connected to Cistern # ___**	P11b Leak? Yes/No P11c Lid present? Yes/No P11d Tap? Yes/No P11e Tap functional? Yes/No P11f Connected to piped water supply? Yes/No P11g Ever filled by tanker-truck? Yes/No P11h Filtered? Yes/No P11i Chlorinated? Yes/No P11j Chlorine residual level: ________
12 P12a **Connected to Cistern # ___**	P12b Leak? Yes/No P12c Lid present? Yes/No P12d Tap? Yes/No P12e Tap functional? Yes/No P12f Connected to piped water supply? Yes/No P12g Ever filled by tanker-truck? Yes/No P12h Filtered? Yes/No P12i Chlorinated? Yes/No P12j Chlorine residual level: ________
13 P13a **Connected to Cistern # ___**	P13b Leak? Yes/No P13c Lid present? Yes/No P13d Tap? Yes/No P13e Tap functional? Yes/No P13f Connected to piped water supply? Yes/No P13g Ever filled by tanker-truck? Yes/No P13h Filtered? Yes/No P13i Chlorinated? Yes/No P13j Chlorine residual level: ________
14 P14a **Connected to Cistern # ___**	P14b Leak? Yes/No P14c Lid present? Yes/No P14d Tap? Yes/No P14e Tap functional? Yes/No P14f Connected to piped water supply? Yes/No P14g Ever filled by tanker-truck? Yes/No P14h Filtered? Yes/No P14i Chlorinated? Yes/No P14j Chlorine residual level: ________

Notes:

Facility Inspection

EH 1		Date		EH 4		Hospital Name	
EH 2		Start Time		EH 5		Name of Investigator(s)	
EH 3		End Time					

Sinks

Number	Functions	Leaks	Soap	Staff	Patients	Number	Functions	Leaks	Soap	Staff	Patients
1						43					
2						44					
3						45					
4						46					
5						47					
6						48					
7						49					
8						50					
9						51					
10						52					
11						53					
12						54					
13						55					
14						56					
15						57					
16						58					
17						59					
18						60					
19						61					
20						62					
21						63					
22						64					
23						65					
24						66					
25						67					
26						68					
27						69					
28						70					
29						71					
30						72					
31						73					
32						74					
33						75					
34						76					
35						77					
36						78					
37						79					
38						80					
39						81					
40						82					
41						83					
42						84					

FH 1	Date			FH	Hospital Name	

Facility Inspection

				4		
FH 2	Start Time			FH 5	Name of Investigator(s)	
FH 3	End Time					

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

Maintenance		
G1	How many liters of chlorine are in the chlorine tank?	3)N/A
G2	Is there chlorine stocked specifically for the water system? How much is there?	1) Yes 2) No 3) N/A 99) I do not know
G3	What is the pressure difference between the entry and the exit of the filter bank? (note: not all systems have pressure gauges)	1) Yes 2) No 3) N/A 99) I do not know
G4	Is the outside of the equipment (filters) clean?	1) Yes 2) No 99) I do not know
G5	Is the area around the filter system clean and clear of non-filter related items?	1) Yes 2) No 99) I do not know
G6	Are there any leaks in the system that has not been repaired?	1) Yes 2) No 99) I do not know

Educational Messages			
G7		Were any messages about safe water observed?	1) Yes 2) No →SKIP to G3 99) Don't Know → SKIP to G3
G8 G9 G10		Are the messages visible to staff? Are the messages visible to patients/visitors? Are the messages engaging/ catchy?	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
G11		Were any messages about hand-washing observed?	1) Yes 2) No →SKIP to G5

			99) Don't Know → SKIP to G5
G12 G13 G14		Are the messages visible to staff? Are the messages visible to patients/visitors? Are the messages engaging/ catchy?	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
G15		Were any messages about bathroom use observed?	1) Yes 2) No →SKIP to H1a 99) Don't Know → SKIP to H1a
G16 G17 G18		Are the messages visible to staff? Are the messages visible to patients/visitors? Are the messages engaging/ catchy?	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
G19		Which (organizations or projects) supported the hospital in developing the educational messages?	List Organizations/Projects

Water Sample Collection

MH 1	Date		MH 4	Hospital Name	
MH 2	Start Time		MH 5	Name of Investigator(s)	
MH 3	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	___ seconds 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	___ seconds 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	___ seconds 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):
Sample 4		
M4.	Is the water flowing today?	1) Yes

Water Sample Collection

1		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	____ seconds 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	____ seconds 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	____ seconds 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):
Sample 7		
M4. 1	Is the water flowing today?	1) Yes 2) No →SKIP
M4. 2 M4.	Collect two water samples	ID 1: _____ _____ _____ ID 2: _____ _____ _____

Water Sample Collection

3		
M4.4	Describe the location of the tap	
M4.5	Measure the flow	___ seconds 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 8		
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	___ seconds 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 9		
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	___ seconds 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):
Sample 10		
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	

Water Sample Collection

M4.5	Measure the flow	___ seconds 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 11		
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	___ seconds 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 12		
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	___ seconds 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):
Sample 13		
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	___ seconds 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 14		
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	___ seconds 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 15		
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	___ seconds 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):
Sample 16		
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	___ seconds 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 17		
M5.	Is the water flowing today?	1) Yes

Water Sample Collection

1		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	____ seconds 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 18		
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	____ seconds 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):
Sample 19		
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	____ seconds 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 20		
M5. 1	Is the water flowing today?	1) Yes 2) No →SKIP
M5. 2 M5.	Collect two water samples	ID 1: _____ _____ _____ ID 2: _____ _____ _____

Water Sample Collection

3		
M5. 4	Describe the location of the tap	
M5. 5	Measure the flow	___ seconds 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 21		
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	___ seconds 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):
Sample 22		
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	___ seconds 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 23		
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.	Describe the location of the tap	

Water Sample Collection

4		
M5.5	Measure the flow	___ seconds 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 24		
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	___ seconds 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):
Sample 25		
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	___ seconds 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 26		
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	___ seconds to fill 100 mL with the tap totally open
M5.6	Is the water filtered? Select all that apply.	1) Membrane 2) Amiad

Water Sample Collection

		3) No 88) Other (specify):
Sample 27		
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	____ seconds 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):
Sample 28		
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	____ seconds 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 29		
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	____ seconds 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):

Water Sample Collection

Sample 30		
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	____ seconds 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):

Accountability

Appendix B: Sustainability Metric Tool

Topic	Broad Questions	Code	Survey Questions and Metrics	0	1	2	3	4
Monitoring Performance	Does the hospital perform monitoring activities?	A33	Does this hospital have a record for any of the following activities? Who is responsible?	The hospital has no written records of activities regarding water infrastructure.	The hospital has some records but they are not well maintained and are out of date.	The hospital maintains some records of activities regarding water infrastructure but does not do so consistently or are missing key items.	The hospital maintains records of important activities regarding water infrastructure, 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 water infrastructure.
		A33a, J16a	Availability of water					
		A33b, J16b	Water treatment					
		A33g, H31a, J16g	By-passing the system					
		A33f, H31b, J16f	Measuring chlorine levels					
		A33c, H31c, J16c	Cleaning of water containers					
		A31d	Cleaning water cisterns					
		A33d, H31d, J16d	Repairing taps and broken sinks					
		A33e, J16e	backwashing					

Accountability

Oversight by another entity	Is there oversight by another entity?	A55a-d, A85 a-d A86 a-b A56-A56a A34-35, J25-26 A36, J19-a H22-b	Do you communicate with MoH, GHS, about the water treatment system? How often? What do you discuss? Are these meetings schedule? When you bring up issues, are they addressed? (Director)How frequently do you talk to the bottling company about the water treatment system? Are the meetings regularly schedule? What did you talk about last time you spoke? Who reviews expense reports? Where are they sent? How often? Are there any organizations or institutions that are monitoring water quality within the hospital? How often do you have contact when them? If yes, how frequently do they take samples? Do they share their findings with the hospital? What is the closest city where water samples could be taken for analysis? Do you (maintenance) communicate with the MoH/GHS about the filtration system? How often? What do	There are no outside organizations that monitor water quality in the hospital. The hospital does not have a biosafety committee/QA OR the biosafety/QA committee.	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/QA committee (if there is one) does not discuss water issues.	There are outside organizations that occasionally monitor water quality. The biosafety/QA committee has discussesed water quality.	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. The hospital communicates to the

			you discuss?					
		A44a-b, J18a-b	Does the hospital have a biosafety committee/quality assurance (QA) committee?If yes, is water one of the themes they discuss? Have they taken any action with regard to improving the provision of safe water? What actions?					
	Do the hospital and GE (or GE representatives through ambassadors, Assist, technicans) successfully communicate with each other?	H12-13	How many visits has Ge, Assist, and Kwame made in the past year? What are the issues you discuss during these visits?	The hospital does not communicate with GE representatives. GE representatives have made very few or no follow up visits. The hospital is not aware of GE's long-term level of involvement.	The director and the GE representatives communicate occasionally regarding the water system. The communication mostly involves planning the next visit by GE representatives. The hospital may have some sense of GE's long-term involvement but has many unanswered	The director and GE representatives communicate regarding the water filtration system semi-regularly, but key issues are not brought to the attention of GE representatives. If key issues are brought up, they may not be adequately addressed. The hospital has some sense of GE's long-term	The director and the GE representatives discuss the filtration system regularly; however, key issues may not adequately be addressed. The hospital is generally aware of GE's long-term involvement.	The hospital and GE representatives regularly communicate specifically about the water filtration system. The hospital feels that their concerns and issues are adequately addressed. The hospital is aware of and understands GE's long-term level of involvement.
		A38a-c, J21-c; H11-a-c, H21 a-d,	How often do you(director) talk to Assist International? What do you talk to them about? How often do you specifically talk to them about the water system? When you bring up issues are they addressed? (and same questions for maintenance)					

		A37a-c, J20-c; H10 a-c, H20a-d	How often do you (director) communicate with GE Ambassadors / Kwame Akorsa about the water system? How often? Are these meetings regularly scheduled? What do you discuss? When you bring up issues, are they addressed? (and same questions for maintenance)		questions.	involvement but has questions .		
		A46	Did hospital staff receive a training session regarding the water treatment system?					
		A47-a	Has GE communicated with the hospital regarding their long-term level of involvement regarding the water treatment system (see A47a) For how long to you expect GE to continue to offer their assistance? In what capacity? Why? If GE were to stop providing assistance, would you continue to be able to buy safe water?					
Financial Ownership	Does the hospital have the potential to fund the water system without GE support?	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	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 maybe not fixed costs. If GE stopped providing funding, the	The hospital has allocated funding for recurring and fixed costs; however, the funding may not be	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
		A48b	fund for water treatment (reoccurring costs)					
		A48c	funds for infrastructure (piping and sinks) (fixed					

			costs)	safe water. There is no evidence that the hospital has invested in the provision of safe water.		hospital would struggle to maintain the provision of safe water. There may be an outside organization/ foundation that can support fixed costs.	sufficient and is uncertain.	invested in the provision of safe water.
		A48d	Staff training					
		A48a	Water bill					
		A37e	Other					
		A49	If yes, how much?					
		A51	Does the hospital set aside funds for:					
		A51a	water treatment (reoccurring costs)					
		A51b	infrastructure (piping and sinks) (fixed costs)					
		A51c	Other					
		A52	Is there any part of the water system that was donated by a business, organization, or foreign government?					
		A52	Are there any outside organizations or institutions that finance infrastructure for the provision of water and sanitation in the hospital?					
		A53	What are other sources of external funding for the hospital?					

Accountability

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?	A57, H29f, J27	How much do chlorine (bleach) cost on a monthly or quarterly basis for the water system? (maintenance and director)	The hospital is consistently unable to pay recurring costs associated with the system and there are no records maintained for expenditures.	The hospital is sometimes able to pay the recurring costs but most of the time they are unable to. There may be records of expenditures but they are not easily traced to the water system.	The hospital is able to pay the recurring costs associated with the system most of the time but sometimes does not due to water quality being of low priority compared to other demands on hospital resources. There are records of expenditures but not easily traced specifically to the water system.	The hospital is able to pay recurring costs associated with the system the majority of the time. They maintain some records of expenditures easily traced to the water system.	The hospital is able to pay all recurring costs associated with the system and maintains a record of expenditures easily traced to the water system.
		A60, H23, J17	What process does the hospital have in place to track the expenses required for the water treatment system operation? (ask to see expense tracking system)					
		J15	Is there a specific budget for the water system? (if not, please explain the system used to obtain consumables and parts)					
		A59	Who funds the costs of repairs associated with the system?					
		J13	Approximately how much do you spend monthly to obtain consumables and parts needed to make repairs to the water system?					
		J12, J14	What influences your (the administrator's) decision to buy (or not buy) chlorine for the water system? To maintain infrastructure?					
		A63	Is the hospital able to cover the recurring cost associated with the water purification system (i.e. chlorine, staff time, small repairs)					

Accountability

		A61-62, J28-a	Has there been a time when chlorine was not bought for the system? How frequently is chlorine not bought for the system? Why?					

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?	A22	Is there a person responsible for: Who?	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 tasks are not accomplished.	There is a loose organizational structure in place but most key tasks are accounted for and most staff know their role.	There is basic organizational structure in place at the hospital, and all key tasks are accounted for and the majority of staff 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.
		A22a	Ensuring the filtration system is maintained					
		A22b	Repairing the filtration system					
		A22 c	Purchasing chlorine to treat the water					
		A22f	Ensuring that storage tanks and bucket taps are filled with water when the taps are not flowing					
		A22c	Ensuring that there is chlorine to treat the water					
		A22e	Testing the chlorine residual levels					
		A22g	Shutting off the filtration system when necessary					
		A23	Who assigns and ensures that the above responsibilities are completed?					
		A27	What is your (director's) role in to the water treatment system?					
		H24	What is your (maintenance staff) role in the provision of safe water in hospital?					
		H40	Is it one of your (maintenance staff) responsibilities to repair the water treatment system? Why or why not?					
		H42	Who do you call (maintenance) when there is a problem with the water treatment system?					
		A24a-b	When the treatment system is shut off or bypassed, is the director informed? Before or after? Who informs the director?					

		H14	(Maintenance) Who is responsible for the GE water system?					
	Is there effective and structured communication between the hospital director, the maintenance staff, and the laboratory staff?	A39a-A39b, A24, H25-a-c	**Maintenance and Director:** How frequently do you (the director) talk to the maintenance staff about the water system? Are these meetings scheduled? What did you discuss last time you spoke? Does the maintenance staff inform you (the director) when the system is shut down?......How often do you (the maintenance staff) meet with the director about the water system? Are the meeting scheduled? What did you discuss the last time you met? Did you inform the director when you shut off the filtration system?	There is very little to no communication between the director, maintenance staff, and laboratory staff about the water system.	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.
		A41a-b, K15-a	**Lab and Director:** How frequently do you (the director) talk to the laboratory staff about the water system? Are these meetings scheduled? What did you (the director and laboratory staff) talk about the last time you spoke about the water system?....When was the last time that you (the laboratory technician) spoke to the director about the chlorine levels?					

		A42a-b, J22-b	**Administrator and Director:** How often do you (the director) talk to the administrator about the water system? Are these meetings scheduled? What did you (the director and the administrator) talk about the last time you spoke about the water system? (and opposite questions for admin)					

		H26-a-d, K17, K14-a, K17a-b	**Maintenance and Lab:** How frequently do you (the maintenance) meet with the laboratory staff about the water system? Are these meetings scheduled? Did you inform the lab when you shut off the filtration system? Do you inform the lab when you change to a new chlorine concentration? .....What did you (the maintenance staff and laboratory staff) talk about the last time you spoke about the water system? .....How often do you give advice or feedback to the maintenance staff to adjust the chlorine levels? How do they react? ..... How many times have the maintenance staff responded to the lab staff advice? .....How many times did the lab staff re-measure the chlorine after the maintenance staff adjusted the levels? Do you (the maintenance staff) inform the laboratory when the water system is shut down?					

		K16-a-b, K15-a	**Lab and Administrator:** How often do you (lab) meet with the admin about the water system? Are these meetings regularly scheduled? What did you discuss last time you talked?.....How often do you (the laboratory staff) talk to the administrator about the chlorine residual levels in the water system?					
		H27-a-b, J23-24	**Maintenance and Administrator:** How often do you (the maintenance staff) talk to the administrator about the water system? Are these meetings scheduled? What did you discuss the last time you talked? (and opposite for admin re: maintenance)					
		A61-62	Has there been a time when chlorine was not bought for the system? How frequently is chlorine not bought for the system? Why?					
		H6b	Who is responsible for turning on the generator?					
Training and Capacity Strengthening	Are there sufficient trained personnel to manage, maintain,	A1	How long have you been working here as the director?	There are not enough trained personnel to	Some basic management and	Essential manageme nt and	There are a sufficient number of	There are a sufficient number of

	and operate the water system?	H16	Has any staff member been trained to maintain the filtration system by another staff member?	maintain the water system and there have not been any efforts made to increase the number of trained personnel. The hospital is not currently self-relient.	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.	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.	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.	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.
		A45	Who was trained within the hospital in maintaining the filtration system?					
		A25	Do you believe your hospital staff have the capacity/knowledge to maintain the system? Why or why not?					
		A26	Do you believe that your hospital staff have the knowledge/capacity to train new staff on the management, maintenance and operation of the system? Why or why not?					
		H5	How long have you (maintenance staff member) been working in this hospital?					
		H4	What is your (the maintenance staff member's) highest level of education?					
		A45, H9	Who was trained by GE in the operation and maintenance of the water treatment system? Do they all still work here?					

		K12	How many lab staff have been trained to perform the chlorine residual testing by another staff member?					
		H15	Normally, how many people do maintenance work on the water system?					
		H17	How many days a week is there someone present who knows how to manage the water system?					
		K19, K18	Does the hospital have the lab capacity to perform microbiological testing of water samples on-site? If not, are there other local options?					
		K11	Who was trained in water sample collection and testing? (lab)					
Maintenance	Are daily, weekly, and monthly recommended maintenance procedures followed?	H33	How often is a backwash performed? (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	The daily, weekly, and monthly recommended tasks are generally completed but not as	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.
		H34	How often are the filters checked to make sure the backwash is functioning?					
		G1	How many liters of chlorine are in the chlorine tank?					
		G3	Is there a significant drop in pressure at the entry and exit of the filter banks?					

		H37	How often do you check the pressure at the entry and exit to see if there is a significant pressure drop between the filters?		completed at least once a week, and weekly tasks at least once a month.	frequently as is recommended. Daily tasks often may not be completed during non-peak times (like on the weekends).		
		N (infographic) not in tool?	How often do you scrub and backwash the Amiad filters?					
		tap observations	How often do you add more chlorine to the system?					
		H36	Does the hospital always have enough chlorine for the system?					
		G4	**Observation:** Is the outside of the equipment clean?					
		G5	**Observation:** Is the area around the filter system clean and clear of non-filter related items?					
		G6	**Observation:** Are there any leaks in the system that have not been repaired?					
		NH8	Are the elevated tanks and cistern cleaned? If yes, how often? Are the polytanks cleaned? If yes, how often?					
		K13-c	How often do you measure chlorine residual levels? Do you document this information? Where do you measure them?					
		H38	Have you ever removed the tops of the filters and washed the filters in a chlorine bath? If yes, how often?					

On-site Capacity

	Is there limited downtime in the operation of the water system?	H19-a-b	How many days in the last month have you not used the water filtration system? If the system was not working when was the last time it was used? Why are the filters not being used? Have there been any attempts to fix the filters, if no, why not? (other WHY considerations: funds, leaks, pressure, communication failure, lack of demand for safe water, etc.	The water system has been bypassed or not used for at least 30 days within the past 2 months.	The water system has been bypassed or not used for at least a few hours multiple times a week OR maintenance or power issues make the system unreliable.	The water system is bypassed or not used at least every month but for no more than a couple hours at a time.	The only bypassing or disuse of the water system in the past 6 months has been due to repairs being made to the system and these have been minimal.	The water system has not been bypassed or not used within the past 6 months.
Repairs	Does the hospital maintain the capability to repair the water system when needed?	H42	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. External help is not called when needed.	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	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. When necessary, external help is brought in so that issues don't go
		H43	Has there been a time when you have sought external help for repairs? Explain.					
		A58, H42-a	How often are repairs to the water system completed?					
		H44 a-d (see maintenance supply sheet)	Have there been parts of the water system that have been successfully repaired or replaced?					
		H46	In your opinion, what specific aspects would you (maintenance) like more training on?					
		H39	What do you do if there is a drop in pressure?					

		H41	Give the following scenarios, do you have the capacity to repair the water treatment system? Why or why not?				system.	unresolved.
		H45a	Which parts of the filtration system cannot be fixed without help from an external support structure?					
		H39	What do you do when there is a pressure drop?					
		H45	Which parts of the filtration system could you (or your team) be capable of repairing without external help?					

Technical Feasibility

Topic	Broad Question	Code	Survey Questions & 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? Is the water managed in a way that provides the quantity and availability 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 rationed every day. Water is not available in more than two departments. The hospital frequently runs out of water and has to bring in water from another source (tanker truck) in at least one season. The hospital is not able to store sufficient water or manage their water supply in a way that meets demand.	The principle source of water is intermittent and it is necessary for water to be rationed. Stored water is relied upon during most weeks in at least one season. However, the hospital has sufficient stored water or manages their water in a way that most months, the hospital does not run out of water. Water is not available in more than two departments.	The principle source of water is intermittent. However, most days of the week, water is not rationed. The hospital rarely runs out of water. Water is not available in fewer than two departments.	The principle source of water is intermittent but for most of the month, it does not need to be rationed. Water is available in all departments. There is sufficient stored water available or water is managed in such a way that the intermittent water supply very rarely results in the hospital running out of water.	The principle source of water is dependable and while water may be stored, it is sufficient to meet demand. The hospital does not experience days without water supply (any interruptions are planned in advance and an alternative supply is pre-arranged). Water is available in every department within the hospital.
		A11	Are there any wards that do not have running water today [If not, why not?]					
		H6-a	In the last week, how many times has the electricity gone out? On average, how often does the electricity stay out when it goes out?					
		A12	Are there any wards that are not connected to the water purification system (exclusively)? Why not, which ones?					
		A16	What are other sources of drinking water in this hospital?					
		A13a-b	Typically how much unfiltered/untreated water do you store? Typically, how much filtered/treated water do you store?					
		Info graphic (N)	If the water source shut down, how long would the stored water last the hospital?					
		A15	Have you ever had to bring in water from a tanker truck due to lack of water? If yes, how often in the past year? Where is the water from the tanker truck usually stored (before or after filtration system).					
		A14a-d	How often is unfiltered/untreated water pumped into the elevated tank/cistern (Ghana only) How often is filtered water pumped to the clean side of the elevated tank? When the elevated tank/cistern is full of treated water, how long does it take to empty? When the polytanks are full of treated water, on average, how long do they take to empty?					
		A8	How often does water not flow from the taps in the hospital in the average week? (A9: What causes the water to stop flowing)					

Technical Feasibility

Local Access to Replacement Parts	Are replacement parts for foreseeable issues during the life of the filtration system available locally?	H42-d (see maintenance supply sheet)	Where have you been able to find replacement parts for the system when they break down?	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 (chlorine doser, homespring filters) can not be purchased within country.	All replacement parts for minor repairs can be purchased locally (tubes, glue, valves) and some parts for major repairs can be purchased within country (replacement parts for, pumps, chlorine doser.	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 pumps, chlorine doser.	All replacement parts for the water system can be purchased within the country, most of them locally.
		H42-c (see maintenance supply sheet)	How far do you need to travel to find replacement parts?					
		H42-b (see maintenance supply sheet)	How accessible are replacement parts (tubing, etc.) for water treatment system?					
Current Infrastructure	Is the hospital committed to maintenance and management of infrastructure and resources for water, sanitation, and hygiene?	E, F, G	Tap Observations	Hospital infrastructure relating to water, sanitation, and hygiene is not maintained. The majority of the sinks observed were non-functional. Water storage containers are never cleaned and most polytanks (if applicable and	Hospital infrastructure is not consistently maintained. At least 50% of sinks observed were functional. Fewer than	Hospital infrastructure relating to water, sanitation, and hygiene is moderately maintained. At least 75% of all sinks observed were functional. At least 75% of all	Hospital infrastructure relating to water, sanitation, and hygiene is mostly maintained. At least 85% of all sinks observed were	Hospital infrastructure relating to water, sanitation, and hygiene is well maintained. At least 95% of all sinks observed were functional. Water storage containers are cleaned according to
		NH1-N4K (P1A-P14A..etc)	TBD (Cistern and Polytanks) Number of polytanks without lids, cleaning schedule for polytanks and cisterns					
		H7	What types of toilets are available?					
		H8	What are the common maintenance problems associated with the toilets? (not part of metric)					

				commonly used) do not have lids.	75% of all polytanks (if applicable and commonly used) have lids. Most storage containers are never cleaned but some may be.	polytanks (if applicable and commonly used) have lids. Most storage containers are occasionally cleaned.	functional. At least 90% of all polytanks (if applicable and commonly used) have lids. Most storage containers are cleaned on a semi-regular basis.	a schedule and all polytanks (if applicable) have lids.
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.

Institutional Engagement

Sub-Domain	Broad Question	Code	Survey Questions and Metrics	0	1	2	3	4
Demand	Is treated water accessible and utilized by the population within the hospital for drinking, hygiene and medical purposes?	A17a, B8a, C8a, J9a, K8a	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. In patient care, treated water is not used any differently than untreated water.	Few people drink water from the treatment plant. Bottled water is purchased or provided but is not always available. Treated water is sometimes but rarely used hygiene and medical purposes when it is appropriate.	While some people drink water filtered in the plant, they are not the majority. Bottled water is purchased. Treated water is used for the majority of hygiene and medical purposes when it is appropriate.	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 does not purchase bottled water. Treated water is used for the vast majority of hygiene and medical purposes when it is appropriate.	Staff, patients, and visitors alike drink filtered water from the plant (either from the tap or bottles of water filled from the treatment plant). Treated water is used when appropriate for all hygiene and medical purposes.
		A17b, B8b, C8b, J9b, K8b	Do patients drink water from the tap?					
		A17c, B8c, C8c, J9c, K8c	Do visitors/caretakers drink water from the tap?					
		A17d, B8d, C8d, J9d, K8d	Do others drink water from the tap?					
		A10f	Does the hospital buy bottled water for staff? For patients? (look at water use surveys)					
		water use survey	Is treated water used for critical hygiene purposes? Is treated water used for critical medical purposes?					
Satisfaction and Perceived Value	Is the director of the hospital satisfied with the water system?	A67	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.(1)	The hospital director is mostly unsatisfied with the water filtration system. S/He would probably not recommend the system to other hospitals. (2)	The hospital director is somewhat satisfied with the water filtration system. S/He knows it has its problems but he would probably recommend the system to	The hospital director is mostly satisfied with the water filtration system. S/He would recommend the system to other hospitals. (4)	The hospital director is completely satisfied with water filtration system and would definitely recommend the system to other hospitals. (5)
		A70	How would you rate your satisfaction with the taste of the water?					
		A71	How would you rate your satisfaction with the color of the water?					

		A72	How would you rate your satisfaction with the water pressure of the system?			other hospitals. (3)		
		A73	How would you rate your satisfaction with the maintenance cost of the system?					
		A74	How would you rate your satisfaction with the ability of the filtration system satisfy your hospital's needs?					
		A68	In your opinion (director) is the water from the tap safe to drink?					
		A69	Do you (the director) drink from the tap?					
		A75	Would you recommend this water system to other hospitals? Why or why not?					
	Is the maintenance staff satisfied with the water system? Is the maintenance staff committed to the water treatment system?	H48	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 does not understand the	The maintenance staff is mostly unsatisfied with the water filtration system. They would probably not recommend the system to other hospitals. They are marginally committed to	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	The maintenance staff is mostly satisfied with the water filtration system. They would recommend the system to other hospitals. They are committed to	The maintenance staff is completely satisfied with water filtration system and would definitely recommend the system to other hospitals. The maintenance staff understands the importance of safe water and
		H50	Do you have other questions for GE about the water filtration system?					

Institutional Engagement

		H30	Do you (maintenance staff) talk to other maintenance teams with GE water filtration systems?	importance of safe water, does not have goals for the system and is not committed. (1)	maintaining the system. (2)	other hospitals. They are committed to maintaining the water system, as long as it is not too much work above and beyond their normal duties. (3)	the water system and will go above and beyond their responsibilities to ensure it's success. However, there are also examples of the maintenance man not being fully committed.(4)	has set goals for the water treatment system. He is committed to maintaining the system, even when there are challenges. (5)
		H32-a	For long do you expect GE to continue to offer their assistance? In what capacity and why? If GE were to stop providing assistance, would you be able to continue to provide safe water? How?					
		H49	What advice would you give others who operate the same water filtration system?					
		H57	Do you drink from the tap?					
		H56	In your opinion (maintenance) is the water from the tap safe to drink?					
		H55	Why is it important to treat the water?					
		H58	What are you (maintenance) goals for the water filtration system? Do you feel like you are achieving them? Why?					

			Maintenance commitment scores					
		H47	What can GE do to improve the filtration system?					
		A28	What are your (director's) goals for the water treatment 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. If GE were to stop providing support, water filtration would not continue.	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. It is likely that water filtration would not continue if GE stopped providing support.	The hospital director has goals for the water filtration system and has set plans in motion for some of them. If GE stopped providing support, the hospital may be able to sustain water filtration for a time.	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 is preparing for the day when they can manage the system on their own. If	The hospital director is committed to maximizing the water filtration system's full potential. They are preparing for the day when GE will no longer provide support and by that point, should be able to withstand challenges to continued provision of filtered water.

Institutional Engagement

	Is the hospital director committed to the sustainability of the water system?	A47-a	For how long do you expect GE to continue to offer their assistance? In what capacity and why? If GE were to stop providing assistance, would be able to continue to provide safe water? How?				GE stopped providing support they would do their best to continue to provide filtered water. However, it is likely that large challenges would not be surmountable.	
Engagement of Hospital Director and Staff	Are the hospital director and staff committed to the provision of clean water?	A57, B17, C17, H59	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?					

Institutional Engagement

		A66	What actions does the hospital take to promote the availability and awareness of safe water for staff patients and visitors?					
		A29	What do you do to promote safe water use in the hospital?					
		A64	In your opinion (director) what are the benefits of having a safe water source here in the hospital?					
Educational Messaging and Awareness	Does the hospital provide educational materials/trainings/PSAs regarding safe water, sanitation, and hygiene practices? What does the hospital do to promote safe water use in the hospital?	G7	Did you observe any messages regarding safe water?	No educational messaging regarding safe water, sanitation, or hygiene practices were visible during the hospital visit. There are not hospital workshops regarding safe water and the director and maintenance staff do not educate the staff about the water system.	Educational messaging regarding safe water, sanitation, or hygiene practices were observed infrequently and not in both staff and patient areas. There may be some hospital workshops that involve topics surrounding safe water and the director and maintenance staff have educated the staff about the water system at some point but it was not consistent.	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. There may be hospital workshops regarding safe water and the director and maintenance staff have educated the staff about the	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. There may be hospital workshops regarding safe water and the director and maintenance staff do educate the	Compelling educational messaging regarding safe water, sanitation, and hygiene practices were very visible in places where both patients and staff can see them. There may be hospital workshops regarding safe water and the director and maintenance staff educate the staff about the water system in a manner that reaches all staff on a consistent basis.
		G8-10	Are the messages visible to staff? Are the messages visible to patients/ visitors? Are the messages engaging/catchy?					
		G11	Did you observe any messages regarding hand washing?					
		G12-14	Are the messages visible to staff? Are the messages visible to patients/ visitors? Are the messages engaging/ catchy?					
		G15	Did you observe any messages regarding bathroom usage?					
		G16-18	Are the messages visible to staff? Are the messages visible to patients/ visitors? Are the messages engaging/ catchy?					
		A43a , H28-a	Have you even spoken with the staff about the filtration system? What have you talked about? (Director and Maintenance Staff)					

Institutional Engagement

		G19	Messages observed/organizations:			water system on several occasion s but it was informal and only to specific staff.	staff about the water system; however, more consistent and widespread education would be an improvement.	
	Are staff and patients aware of the water system and the water quality?	B6-a, C6-a, D12, J8-a, K7-b	Prior to being informed today, were you aware of the water treatment system at the hospital? How did you learn this information?	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/use 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/use water from the system because they believe it to be safe.	The majority of staff are aware of the water system and some are knowledgeabl e about the process. Over half the participants believe the water from the system is safe to drink/use.	Staff are knowledgeable about the water treatment plant. Everyone knows water from the system is safe to drink/use.
		C7	What do you know about the water treatment system at the hospital?					
		D7, D9, D10	Have you (the patient) drunk from the tap in the hospital? If not, why not? Did your children drink from the hospital tap?					
		B4, C4, D11, J5, K4	Do you believe that the tap water is safe to drink? Why or why not?					
		B11	Do you recommend that your patients drink the tap water?					
		BW, C9, J6, K5	Do you drink from the tap?					
		A 17a-d, B8	Who drinks the water?					
		B10, C10, J10, K9	What are the benefits of having safe water for your job?					

Appendix C: Institutional Review Board Documentation

EMORY UNIVERSITY

View: IRB Study - AM2_IRB00057332

<< Back | Exit | Hide/Show Errors | Print... | Jump To: - IRB Study Identification | Continue >>

Study Identification Information

1.0 * **Enter the Full title of the study (include any version dates from the sponsor)**

Impact Evaluation of Hospital Water Purification Systems in Honduras, Ghana, Kenya, and Rwanda & Assessment of Global Field Sites for Water Purification Systems

2.0 * **Enter a SHORT identifying title for tracking purposes:**

Impact Evaluation of Hospital Water Purification Systems in Honduras, Ghana, Kenya and Rwanda

3.0 **What is the estimated start date of this study:**

01-Apr-12

4.0 **What is the estimated completion date of this study:**

01-Jan-13

5.0 * **Name of Principal Investigator. Limit is one person; Emory affiliation is required. If name does not appear in menu, the person probably does not yet have an eIRB account.** **For more information about obtaining an eIRB account, click here.**

Christine Moe **Dept**:Global Health

6.0 **Names of Emory Co-Investigators. May include Emory personnel and non-Emory persons with sponsored eIRB accounts. If name does not appear in menu, the person probably does not yet have an eIRB account.** **For more information about obtaining an eIRB account, click here.**

Last	First	Dept
There are no items to display		

7.0 **Names of Emory Study Coordinators. May include Emory personnel and non-Emory persons with sponsored eIRB accounts. If name does not appear in menu, the person probably does not yet have an eIRB account.** **For more information about obtaining an eIRB account, click here.**

Last	First	Dept
Gallegos	Marisa	Global Health
Huttinger	Alexandra	Global Health
Robb	Katharine	Financial Aid - Cdc
Roguski	Katherine	Public Health

8.0 **Names of other Emory Study Staff not listed above. If name does appear in menu, the person probably does not yet have an eIRB account.** **For more information about obtaining an eIRB account, click here.**

	Last	First	Dept	Type
View	Igboh	Ledor	Public Health	Research Fellow
View	Lie-Tjauw	Samantha	Public Health	Research Fellow
View	Swearing	Erin	Emory College - Main	Research Fellow

	Last	First	Dept	Type
View	Turner	Sarah	Public Health	Research Fellow

9.0 **Enter information on Non-Emory Study Staff:** (this is for non-Emory personnel who will not be logging into eIRB)

Name	Affiliation	Type
There are no items to display		

<< Back

Exit | Hide/Show Errors | Print... | Jump To: - IRB Study Identification

Continue >>

EMORY UNIVERSITY | Institutional Review Board

May 25, 2012

Christine Moe, PhD
Principal Investigator
Global Health

RE: **Exemption of Human Subjects Research**
IRB00057332
Impact Evaluation of Hospital Water Purification Systems in Honduras & Assessment of Global Field Sites for Water Purification Systems

Dear Principal Investigator:

Thank you for submitting an application to the Emory IRB for the above-referenced project. Based on the information you have provided, we have determined on **05/25/2012** that although it is human subjects research, it is exempt from further IRB review and approval.

This determination is good indefinitely unless substantive revisions to the study design (e.g., population or type of data to be obtained) occur which alter our analysis. Please consult the Emory IRB for clarification in case of such a change. Exempt projects do not require continuing renewal applications.

This project meets the criteria for exemption under 45 CFR 46.101(b)(2). Specifically, the project aims to improve strategies for increasing access to small-scale, safe drinking water systems around the world and ensure their sustainability. The project will evaluate safe water practices in hospitals in Honduras where water purification systems have been implemented by the General Electric Foundation (GEF); compare these hospitals to matched control hospitals without purification systems. Evaluation will address water distribution patterns and uses, and knowledge and attitudes about treatment and use of safe water. This evaluation will engage hospital staff, patients, and other water users.
Other project activities that do not include human subjects research involve water quality data collection, facility inspections, and in-depth evaluations at each hospital in Honduras. The data collected throughout this project will be analyzed and then used to make recommendations to the stakeholders regarding improvements to sustainability of these water filtration systems in Honduras and in other areas of the world where these safe drinking water systems have been implemented.

Documents reviewed with this application:

- Protocol_v2_Version Date: 05/18/2012

- Consent_GE Honduras_v2_Version Date: 03/28/2012

Please note that the Belmont Report principles apply to this research: respect for persons, beneficence, and justice. You should use the informed consent materials reviewed by the IRB unless a waiver of consent was granted. Similarly, if HIPAA applies to this project, you should use the HIPAA patient authorization and revocation materials reviewed by the IRB unless a waiver was granted. CITI certification is required of all personnel conducting this research.

Unanticipated problems involving risk to subjects or others or violations of the HIPAA Privacy Rule must be reported promptly to the Emory IRB and the sponsoring agency (if any).

In future correspondence about this matter, please refer to the study ID shown above.
Thank you.

Sincerely,

Carol Corkran, MPH, CIP
Senior Research Protocol Analyst
This letter has been digitally signed

	Huttinger	Alexandra	Global Health
CC:	Robb	Katharine	Financial Aid - Cdc
	Roguski	Katherine	Public Health

Emory University
1599 Clifton Road, 5th Floor - Atlanta, Georgia 30322
Tel: 404.712.0720 - Fax: 404.727.1358 - Email: irb@emory.edu - Web: http://www.irb.emory.edu/
An equal opportunity, affirmative action university