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Erin Swearing Date

Assessing the Sustainability of Decentralized Water Treatment Systems in Six Ghanaian Hospitals between 2013 and 2014

By

Erin Swearing
Master of Public Health

Global Environmental Health

Christine L. Moe, PhD
Committee Chair

Paige Tolbert, PhD
Committee Member

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By

Erin Swearing

B.A.
Emory University
2013

Thesis Committee Chair: Christine L. Moe, Ph.D.

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Abstract

Assessing the Sustainability of Decentralized Water Treatment Systems in Six Ghanaian Hospitals between 2013 and 2014
By Erin Swearing

Background: There has been insufficient attention given to water access and quality in health care facilities in low-income countries. The lack of safe water in health care settings can compromise the quality of care and lead to health care-associated infections. Decentralized water treatment technology is a potential solution for facilities that rely on intermittent or unimproved water sources. In 2005, the General Electric Foundation donated decentralized water treatment systems to six hospitals in Ghana. A baseline sustainability assessment was conducted in 2013 and a follow-up assessment was performed in 2014 to identify factors contributing to gaps in sustainability of the water system.

Objective: To compare baseline data collected in 2013 to follow-up data collected in 2014 in six Ghanaian hospitals and identify areas for improvement in sustainability of decentralized water treatment systems through the assessment of internal factors within each study hospital.

Methods: A mixed-methods approach was utilized. Water samples were tested for total coliforms, *Escherichia coli*, *Pseudomonas aeruginosa*, and residual chlorine. KAP surveys and in-depth interviews assessing hospital practices and perceptions of water quality were administered to hospital staff and patients. A sustainability metric was used to systematically measure four domains of sustainability: Accountability, Technical Feasibility, On-site Capacity, and Institutional Engagement and Support. Baseline data collected in 2013 was compared to follow-up data collected in 2014.

Results: Four of the six study hospitals experienced an increase in the overall sustainability score from 2013 to 2014, and the scores for three hospitals met the sustainability cutoff. Among hospitals that met the cutoff in 2014, scores in the On-site Capacity domain increased the most between 2013 and 2014. From 2013 to 2014, the percentage of tap samples without detectable organisms in study hospitals decreased from 55.0% to 42.3% for total coliforms, increased from 58.3% to 69.2% for *E. coli*, and decreased from 54.4% to 36.8% for *P. aeruginosa*. There was a statically significant increase (p-value: 0.0385) in the percentage of staff that drank water from hospital taps between 2013 and 2014.

Conclusion: There is a need to better engage stakeholders to provide oversight and technical support for improved water in health care facilities. Facilities with strong internal communication and financial management were more likely to sustainably operate and maintain on-site water treatment systems.

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INTRODUCTION AND BACKGROUND

Since the institution of the Millennium Development Goals in 1990, efforts have been devoted to improve sustainable access to drinking water through target 7.C. In 2010, the goal was met, and as of 2012, 748 million people continued to lack access to an improved water source [1]. Between 1990 and 2012, Ghana saw an increase of 32.8 percentage points in the proportion of the population with access to an improved water source [2]. Despite these successes, there has been little focus on water access and quality in health care facilities. Poor water quality in health care facilities can compromise the quality of care causing facilities to become primary sources of disease outbreaks [3]. The prevalence of health care-associated infections (HCAI) can be as high as 19.1% in low- and middle- income countries, damaging trust among patients and staff in health care facilities and adding a greater burden to already strained health care systems [4] [5].

A groundbreaking report from the World Health Organization (WHO) on the provision of WASH in health care facilities in low- and middle-income countries indicates that 38% of health care facilities lack access to an improved water source [6]. Access to improved water sources is slightly higher in the Africa region at 42%, and access in Ghana exceeds this at 68% [6]. Proposed Post-2015 goals for health care facilities include the provision of basic drinking water supply for all users in all health care facilities by 2030. Currently, Ghana has a partial policy for water in health care facilities that remains to be fully specified, implemented, and monitored. Along with national governments, development organizations, like the General Electric Foundation, have begun to take interest in the provision of water and sanitation in health care facilities.

General Electric Foundation

The General Electric Foundation (GEF) is General Electric's philanthropic organization. For decades, the organization has supported grantees and created programs for collegiate education and emergency response. GEF has since created the Developing Health Globally™ (DHG) Initiative, designed to "improve healthcare delivery for some of the world's most vulnerable populations" [7]. The Initiative works to improve health care access by focusing on four core pillars: clinical practice, capacity-building, social determinants, and infrastructure and technology. GEF employs ambassadors to promote accountability and technical leadership [8]. In collaboration with General Electric Water, Dahlberg Consulting, Assist

International, and The Center for Global Safe Water (CGSW) at Emory University, GEF works to improve the quality and quantity of water available in hospitals through the installation and monitoring of decentralized water treatment systems in 20 hospitals and health care facilities in Honduras, Ghana, and Rwanda [8]. The beneficiary hospitals are often rural and located in areas that lack access to a safe municipal water supply. With the assistance of these partners, GEF is able to foster technical capacity, institutional engagement and awareness, and good practices for small-scale improved water source management.

The General Electric Homespring water filters remove 99.99% of bacteria and viruses through small membrane filtration, and activated carbons improve taste and odor. At each site, water from the purification system is piped to taps within the hospital. The systems require upkeep for their functionality, and their management affects water quality and access within the hospitals. Chlorine must be added to a doser to treat the filtered water, and the membrane filters must be backwashed to remove particles and maintain their integrity to ensure rapid filtration. These processes require proper operation and routine maintenance, and maintenance staff at each hospital are expected to perform these tasks.

GEF History in Ghana and 2013 Baseline Study

In 2005, The General Electric Foundation collaborated with Assist International and The Ghana Ministry of Health to install decentralized, institutional-level water purification systems, including one sand filter system and five membrane filtration systems, in six hospitals located in Apam, Axim, Bole, Kete Krachi, Kintempo, and Mampong, Ghana. In June and July of 2013, a baseline sustainability assessment was conducted at each of the six hospitals utilizing a revised sustainability metric, developed using relevant sustainability literature and previous pilot tests. The sustainability metric was used in Honduras and had been refined to fit the Ghanaian context.

At the conclusion of each hospital visit, a meeting was held with the director and other key hospital staff where the water quality results were presented. Recommendations were given based on observed practices and knowledge gained during the visit. After the sustainability scores were calculated, each hospital received a report with their scores and recommendations, based on all data collected, to improve the provision of improved water within the facility.

Study Sites

The six hospitals sites were located throughout the country, each in a different region: Apam Catholic Hospital in the Central region, Axim Government Hospital in the Western region, Bole District Hospital in the Northern region, Kete Krachi District Hospital in the Volta region, Kintampo Municipal Hospital in the Brong-Ahafo region, and Mampong District Hospital in the Ashanti region. Hospitals varied by catchment area, and some were in more densely populated areas than others. All of the hospitals received a GE Homespring® membrane filter system from the General Electric Foundation except Kintampo Municipal Hospital, which received a sand filter.

Figure 1. Map of hospital sites in Ghana with General Electric Foundation water treatment technology.

Problem Statement

Recommendations for water quality in health care facilities in low- and middle-income countries have been outlined in the WHO's *Essential Environmental Health Standards in Health Care*, but in-depth information regarding the types of treatment and maintenance required to ensure the provision of safe water is not addressed. In addition, the quality and consistency of water sources available in health care facilities can vary depending on the water source that services the facility. Decentralized systems that are maintained at the facility level can be challenging to maintain due to lack of funding, maintenance capacity, and access to sustainable safe water sources. Currently, there is minimal research on decentralized water treatment systems in health care facilities in low- and middle- income country settings.

Purpose

The purpose of this study is to conduct a follow-up evaluation of the sustainability of the six water treatment systems donated by the General Electric Foundation in Ghana. This follow-up evaluation hopes to inform the General Electric Foundation and partners of challenges and successes. These experiences will be used to influence strategies to ensure system sustainability for current and future donations.

Research Objectives

1. Identify knowledge, attitudes, and practices (KAP) surrounding safe water provision and use among hospital staff and patients.
2. Assess water quality by testing for chlorine residual, *Escherichia coli*, total coliforms, and *Pseudomonas aeruginosa.*
3. Measure four sustainability domains for safe water provision and use: Accountability, Technical Feasibility, On-site Capacity, and Institutional Engagement and Support.

Research Questions

1. What domains and subdomains saw the biggest differences in sustainability scores from baseline in 2013 and follow up in 2014?
    a. Is there a statistically significant difference in sustainability scores from each hospital in each domain from baseline in 2013 and follow up in 2014?

   b. What are the trends in subdomain scores among hospitals that meet the cutoff for sustainability compared to hospitals that failed to meet the cutoff for sustainability in 2014?

2. Based on the comparison of water quality results from raw, filtered, tap, and stored water samples in the hospitals from baseline in 2013 to follow up in 2014, what are areas for improvements in sustainability of the treatment system?
   a. Is there a statistically significant difference in the proportion of water samples collected in the hospitals that were <1 MPN / 100 mL for total coliform, *Escherichia coli,* and *Pseudomonas aeruginosa* from baseline in 2013 and follow up in 2014?
   b. Are there differences in the distribution of total coliform, *E. coli*, and *P. aeruginosa* concentrations in water in each hospital from baseline in 2013 and follow up in 2014?
   c. Is there an association between the location of a point-of-use (POU) water sample and no detectable levels (<1 MPN / 100 mL) of microbial contamination in the sample?
3. Are there changes in staff perceptions and practices within the hospital from 2013 to 2014?
   a. Is there a statistically significant difference in percentages of staff that believe that water in the hospital is safe to drink from baseline in 2013 to follow up in 2014?
   b. Is there a statistically significant difference in percentages of staff that consume hospital water from baseline in 2013 to follow up in 2014?
   c. Is there an association between hospital water consumption and perceptions of hospital water quality among staff in each hospital in 2013 and 2014?

Significance

Poor water quality in health care facilities can lead to the presence of health care associated infections. In low- and middle-income countries, health care facilities may be forced to utilize one water source for a variety of tasks, including medical and personal uses. It is necessary to ensure that water sources within the hospital are of pristine quality to ensure the health of patients and staff. The utilization of decentralized water treatment systems is a potential solution to facilitate the provision of safe water in infrastructure- and resource-poor settings.

LITERATURE REVIEW

Global Water Access

Currently, over 748 million people worldwide lack access to safe water [9]. In 2010, the Millennium Development Goal 7 target C, to halve the "proportion of the population without sustainable access to safe drinking water and sanitation", was met [10, 11]. Over 2.3 billion people, an increase of 13 percentage points, gained access to improved drinking water from 1990 to 2012 [11]. Sub-Saharan Africa experienced an increase of 16 percentage points in the proportion of the population that has gained access to improved drinking water since 1990 [11]. Access to improved drinking water sources in Ghana has risen from 54.4% in 1990 to 87.2% in 2012 [2].

The Drinking Water Ladder

Of the 2.3 billion people that gained access to improved water between 1990 and 2012, 1.6 billion gained access to a piped drinking water source. Piped drinking water on the premises is the highest level of the drinking-water ladder, a scale used to represent perceived water quality based on the water source. Piped water is followed by "other improved sources", "unimproved sources", and "surface water" [12]. Other improved sources include public taps, standpipes, tube wells, boreholes, protected dug wells, protected springs, and rain water. Unimproved sources include unprotected dug wells, unprotected springs, carts with small tank drums, surface water, and boiled water. Surface water sources are from dams, ponds, rivers, lakes, streams, canals, irrigation or channels [13]. A meta-analysis of studies assessing the quality of water used for drinking showed that improved sources, as defined by the Joint Monitoring Programme (JMP), were less likely to be contaminated than unimproved sources. It is important to note that improved sources are not always safe sources, as water quality is not an indicator measured by the JMP [14].

The Diarrheal Disease Burden

Deaths attributed to diarrheal diseases have declined from 1.5 million in 1990 to near 600,000 in 2012 [9]. Despite this, it was estimated that diarrheal diseases accounted for 1.5% of the global daily burden of disease in 2012. Around 502,000 of these diarrheal deaths were associated with inadequate water in 2012, with 229, 316 occurring in Sub-Saharan Africa [15]. In 2008 alone, it was estimated that 5,193 children in Ghana under the age of five died as a result of diarrheal disease [16].

Guidelines for Drinking Water Quality

The WHO has developed *Guidelines for Drinking Water Quality* (GDWQ). The guidelines are to assist in managing "the risk from hazards that many compromise the safety of drinking water" [17]. The WHO recommendations are intended to only serve as guidelines, as it is up to national governments to develop their own standards [17]. According to the WHO, a safe water system ensures the quality of the water from "catchment to consumer" using multiple measures to maintain water quality. This includes the selection and protection of source water, treatment, and management [17]. Obtrusions or disruptions in this process can leave water sources vulnerable to pathogen contamination. According to the WHO GDWQ, no total coliforms or *E. coli* should be detected in any 100 mL sample of drinking water [17].

Measurements of fecal indicator bacteria (FIB) are used to assess the microbiological quality of drinking water. Infections from enteric pathogens are primarily transmitted through the fecal-oral route. The ingestion of water that has been contaminated with fecal pathogens can lead to diarrheal disease. *Escherichia coli (E. coli)* is a standard fecal indicator, commonly used to monitor drinking water quality [17]. The measurement of *E. coli* is used to indicate the presence of fecal contamination [17]. Total coliforms and *E. coli* are naturally present in humans and animals and occur in greater numbers than fecal pathogens, making them reliable indicators for enteric bacterial pathogens [17]. However, many types of bacteria, protozoa and viruses are more resistant to treatment methods than *E. coli*, and can be present in water samples that do not test positive for *E. coli*.

Water Quality and Water Usage in Health Care Settings

According to the WHO, health care facilities should have access to safe and sufficient quantities of water that present a low risk of microbial contamination and should also have clean tools and surfaces to limit unacceptable risk of infections. The WHO recommends that drinking water meet WHO GDWQ recommendations and is treated with residual disinfectants to ensure safety. The WHO also advises that water not be turbid, discolored, or of an unusual odor that would discourage consumption. The WHO does not require that water for non-medical uses, like laundry and floor cleaning, is of pristine quality, but water used for medical purposes should adhere to guidelines for chemical and microbial contaminants. Sufficient

amounts of water should be available for all hospital uses, including personal hygiene and food preparation [3].

Poor water quality can serve as a reservoir for opportunistic pathogens at various points in a hospital's piped network [18]. The WHO suggests that health care settings with poor environmental health could become epicenters of diarrheal disease outbreaks [3]. Health care-associated infections (HCAI), also known as hospital-acquired infections or nosocomial infections, occur after patients have been admitted to or have received care at a health care facility. HCAI due to poor water quality and quantity, put a strain on already limited health care resources in low-income countries [3]. In addition, health care facilities that lack improved water sources and sanitation and hygiene facilities can discourage patient admittance and lead to absenteeism of health care staff [19]. Research to assess water quality in hospital water systems is limited, and there is a lack of data on the risks of infection that hospital piped networks may pose to patients and staff [18]. Proposed "Post-2015 WASH Targets and Indicators" seek to improve hospital water access through improvements to water, sanitation, and hygiene (WASH) infrastructure that will provide handwashing stations and basic drinking water, but water quality is not addressed [20].

WASH and Health-Care Associated Infections in Low-Income Countries

Poor water, sanitation, and hygiene practices in health care facilities can lead to a higher prevalence of HCAI. Patients in low-income countries are likely to be immune-compromised, as they often experience higher rates of malnutrition and disease. Poor health care facility infrastructure and high patient to health care worker (HCW) ratios can exacerbate these issues [5] [21]. Health care facilities plagued with intermittent water supplies can face disruptions in disinfection procedures that affect handwashing compliance and the sterility of hospital equipment [22]. Water sources that contain pathogens can also contaminate sinks and drains in health care facilities, creating opportunities for direct exposure among patients and HCWs [23].

A systematic review of literature from 1995 to 2011 indicates that the total global burden of HCAI is unknown, as only 66% of low-income countries were represented in information gathered from "multicenter or published national studies" [24]. Reported prevalence of HCAI was higher in low- and middle-income countries compared to high-income countries. Prevalence of HCAI in low- and middle-income countries

ranges from 5.4% to 19.1% from 1995 – 2010 [24]. The burden of HCAI is greatest in Africa and the Western Pacific. Specifically, Ghana reported a 6.7% prevalence of HCAI during this time period [24]. It is important to note, that reported prevalence of HCAI is likely a gross underestimate, as many hospitals may lack microbiological lab capacities to diagnose these infections and formal surveillance systems for monitoring them.

A study conducted in a rural hospital in Ghana found pathogenic bacteria on fomites in multiple wards of the hospital. Desks, taps, door handles, and lavatories were among the most contaminated areas, and the hospital's surgical theatre contained the most pathogenic isolates [25]. Baseline data from a teaching hospital in Accra, Ghana indicated that wards in the hospital lacked soap, hand sanitizer, drying towels, and/or clean and accessible handwashing facilities [26].

HCAI: *Pseudomonas aeruginosa*

Pseudomonas infections, one of the most prevalent HCAI, typically occur in immune-compromised individuals in health care settings [17] [24]. *Pseudomonas aeruginosa (P. aeruginosa)* is one of the most common causes of ventilator-associated pneumonia (VAP) [27]. A review of 11,471 blood samples indicated that *Pseudomonas* isolates were responsible for 3.3% of HCAI in Africa [28]. To prevent infection, it is advised that only sterile water is used to wash the face, open wounds, burn areas, and reusable parts of ventilators and catheters [27] [17]. *P. aeruginosa* grows in wet, airy environments, and older piped water networks often found in low-income countries can be primary breeding sites [27]. Several studies have implicated hospital tap water in transmission of to *P. aeruginosa* infections [29] [30] [31]. However, there is not enough evidence to suggest that the ingestion of *P. aeruginosa* in drinking water causes infection [17]. The United Kingdom Department of Health advises that concentrations of *P. aeruginosa* in augmented care units within 1- 10 CFU / 100 mL be resampled to confirm the detection of the organism. If the organism is still present during resampling, then the water network should be flushed. Concentrations greater than 10 CFU / 100 mL should be flushed immediately after detection [32].

Source Water Quality and Availability in Ghana

Compared to other countries in Sub-Saharan Africa, Ghana has a higher percentage of household access to improved water sources. In 2012, 92.5% of people in urban areas and 81.3% of people in rural areas in Ghana had access to an improved water source [2].

Piped Water

In 2008, only 30% of Ghana's population had access to piped water sources [33]. Service delivery faces difficulties, and in 2005, only 25% of residents in Accra had 24-hour service from the national piped water source, and 35% of residents only had piped water service two days per week [34]. In the metropolitan Accra area, water demand has outpaced supply, and water companies resort to water rationing [35]. Piped water access can also be limited due to pipe breakages, illegal connections, and low pressure [36]. Illegal connections, cross connections, and pipe breakage can affect water quality by potentially introducing microbial contamination [37].

Water Access and Quality in Health Care Facilities in Ghana

In Ghana, it is common for hospitals to have piped water networks, but in the event that the national water supply is unavailable, hospitals rely on boreholes and deep wells that may not be safe water sources, as they carry a higher risk of microbial contamination [38] [36].

Intermittent water supply from municipal sources in developing countries also contributes to microbial contamination of piped water, as stagnant water in piped networks creates opportunities for recontamination or pathogen growth [37]. Due to water scarcity concerns resulting from water rationing or shortages, water is often stored in large plastic cisterns called poly tanks or smaller plastic buckets called Veronica buckets [36]. Stored water quality is affected by length of time in storage containers, frequency of disinfection, and the presence of sediment [37]. A study of water quality in poly tanks located on hospital grounds in Ghana detected indicator bacteria in all samples. Concentrations of total coliforms ranged from 2.3 to 3.2 $\log_{10}$ CFU / 100 mL, and concentrations of *E. coli* ranged from 2.1 to 2.6 $\log_{10}$ CFU / 100 mL [39].

Decentralized Water Treatment

Centralized water systems can be expensive, limiting access. Large scale piped water systems in low-income countries are often of poor water quality [40]. Outside of the metro Accra area, decentralized bodies are responsible for the provision of water. Decentralized water systems can foster community engagement and autonomy as power is transferred from a larger, government entity to private, local sectors [41]. Decentralized systems also disperse the risk of malfunction, as obstructions and intrusions in piped networks will only affect smaller populations [42]. Decentralized treatment systems can improve water quality in areas that are not connected to a centralized water supply, as many rural areas would otherwise resort to using unimproved water sources in the absence of piped connections. Decentralized water systems can also create a sense of ownership and encourage responsibility among those in charge of their management [43]. Unfortunately, limited capacity and organizational structure in rural areas has affected progress in maintaining decentralized water supply, as local workers may lack oversight from government ministries [44]. Despite the benefits of decentralized systems, they are hindered due to poor installation, insufficient upkeep, and limited ability to acquire spare parts [45].

Membrane Filtration

Decentralized water treatment systems often utilize membrane filtration. Membrane filtration involves using a permeable film and pressure to filter water [40]. Pores in the membrane can be of varying sizes to ensure filtering of specific microbial contaminants [46]. Membrane filtration is chemical-free and does not have high energy costs [40]. Membrane treatment technologies require constant upkeep, as they need to be frequently backwashed and cleaned to maintain integrity [40].

Chlorine Disinfection

Chlorine disinfection is effective in killing bacteria and inactivating some protozoa and viruses and providing precautionary protection after initial water treatment. Disinfection using chlorine is most effective when combined with coagulation and flocculation [47]. The Centers for Disease Control (CDC) Safe Water Storage Program recommends that chlorine-treated water contain no more than 2.0 mg/L of chlorine residual [48]. The WHO GDWQ recommend that water be dosed with chlorine at 2.0 mg/L and 4.0 mg/L

for turbid water [17]. The WHO and CDC recommend a 30-minute lapse in time between disinfection and consumption [3] [48]. Residual chlorine should be between 0.2 – 0.5 mg/L at the point of delivery and 0.5 mg/L at any point in water systems [17].

Sustainability

Monitoring and evaluation of programs have become increasingly more routine in development efforts. After years of only focusing on short-term impacts, consideration has been given to including indicators for sustainability. The United States Agency for International Development (USAID) defines sustainability as, "the capacity of a host country entity to achieve long-term success and stability and to serve its clients and consumers without interruption and without reducing the quality of services after external assistance ends" [49]. Researchers and academics have suggested that sustainability of programs, or more generally, the persistence or continuation of desired results, can be impacted by several measurable indicators, including financials, policies, management, supply, demand, and access. Also included in determinants of sustainability is the integration of clearly-defined cultural, socioeconomic, geographical, and political factors [50] [51]. When assessing the sustainability of water projects, the WHO considers system functionality, access, prolonged use, management of service, operation, and effects on the environment [52]. The sustainability of decentralized water treatment systems is influenced by several factors including Accountability, Technical Feasibility, On-site Capacity, and Institutional Engagement and Support.

Accountability

Decentralized systems shift power into the hands of community members and local stakeholders [43]. Local water operations have shorter lines of communication to beneficiaries, and decision-making can occur rapidly, allowing for increased oversight and responsibility [53]. Oversight and community responsibility can foster accountability for water system maintenance and operation. Ownership has been shown to promote responsibility to maintain systems. In rural settings in Ghana, a sense of ownership was related to better management of decentralized water systems [54]. This is crucial, as upsets in management can dismantle years of satisfaction with service delivery, discouraging future utilization of the service or technology [50]. External oversight can prove to be useful in managing decentralized operations. Influential

government bodies can advocate for provision of water in areas where access is limited due to financial constraints [55]. Lack of political will can serve as a barrier to the improvement and expansion of existing water sources. National water quality standards to facilitate monitoring are also necessary to ensure consistent quality of decentralized sources [41]. Institutions in supervisory positions should provide monitoring of water provision and quality, thus resulting in enhanced institutional motivation to maintain decentralized water systems. Local parties are responsible for selecting water systems they can afford, rather than subscribing to services that are too costly and fail to fit their needs [56]. System maintenance may be hindered by a lack of finances. Some communities and institutions may find it difficult to manage complex decentralized systems that require specialized training and high costs for system consumables and repairs [57] [43].

Technical Feasibility

Large development institutions indicate that attention must be given to technical capacity when considering appropriate operation and management of water systems [58] [59] [52]. Water systems can be complex, requiring various parts for operation and upkeep, and access to replacement parts and parts for regular maintenance must be ensured. Often, systems are installed with little consideration given to the capacity of management personnel to obtain spare parts [52]. The World Bank suggests that technical tools management should focus on the support of demand- and supply-side management. Parts may also be too expensive to obtain or not available in-country, particularly in the case of donated technologies. The time it takes to locate replacement parts can result in system downtime, affecting consumer satisfaction [43]. New sources of supply for system consumables and replacement parts should be developed by seeking out opportunities for improvements of water quality through technological innovation [58]. Limited capacity to acquire spare parts can lead to system neglect, and consumers may resort to unsafe water sources [60].

On-site Capacity

Water systems require maintenance and repair, and on-site personnel with technical training will enhance community involvement and provide opportunities for training of additional personnel [61]. Institutions must ensure that they are equipped with the local capacity to carry out rigorous tasks related to

operation and management of the water system [52]. Personnel that are employed to specifically maintain water systems are likely to have higher levels of technical expertise that supports system functionality. The WHO recommends that on-site staff focus on the routine operation and maintenance of the water systems, as repairs can be conducted by external entities [52]. In one area of Ghana, 86% of all rural water systems in 44 communities were functional, and it was likely due to a local NGO that provided technical system maintenance expertise through quarterly visits [60].

Institutional Engagement and Support

Stakeholder engagement is an integral part of water systems. In efforts to sustain the provision of water, collaboration is key among decentralized institutions, government agencies, and beneficiaries that may adhere to specific social and cultural structures [62]. Decentralization of water systems also allows for greater involvement of local entities, and the shift to local operation is accompanied by increased responsibilities. To ensure sustainable operations and management of water systems, consumers must also demand water access. Systems desired by the public ensure the consistent provision of water, thus holding providers accountable [56].

Significance

Donated water systems in low-income settings have failed largely due to a lack of integration of several factors that affect system sustainability. The donation of water systems is well-intentioned, but often there is little consideration given to cost, necessary technical support, system integrity, and prolonged use [45]. Despite the presence of technological interventions to increase water access, many people in low-income countries still do not have access to a consistent source of improved water. Current literature fails to provide success stories for the sustainability of water systems [18]. Current literature also fails to address access and availability of water in health care facilities in low-income countries. The need for further research on solutions to address issues related to water access and quality in health care facilities is crucial. Decentralized water systems that place responsibility for water provision in the hands of local entities may be a potential solution for health care facilities that lack access to an improved water source. Local entities, like large hospitals, may lack experience operating and managing water systems. Research to identify indicators of

sustainability will aid in determining the ideal treatment technologies and water management strategies necessary for health care facilities of different financial statuses, sizes, and services to address water access and quality concerns. Despite poor health outcomes in low-income countries, many may fail to seek care due to fear of facing death in health care facilities [4]. Ensuring health care facility water quality and quantity will aid in the prevention of HCAI as well. Limited water access and quality pose a threat to ensuring that health care facilities in low-income countries are places where quality care is received in the absence of unacceptable risks of infection. Through the targeting of indicators of successful provision of improved water sources, we can aid in eliminating this threat to health care services in low-income settings around the world.

METHODS

Research Design

During July and August 2014, a mixed methods study was conducted to assess the sustainability of water treatment systems that were donated to six hospitals in Ghana. Methods included water quality testing, KAP surveys, in-depth interviews, and site observations. This assessment was a follow-up to a baseline study conducted at each hospital in June and July 2013. Results of the follow-up study conducted in 2014 were compared to the results of the 2013 baseline study.

Research Tools

The research tools developed to conduct the sustainability assessment were based on studies conducted in Honduras to assess the sustainability of decentralized water treatment systems in hospitals also donated by the General Electric Foundation. The research tools were amended to be applicable to study sites in Ghana and were then pilot tested in Ghana in April 2013.

Knowledge, Attitudes, and Practice (KAP) Surveys

KAP surveys were administered to assess perceptions of water quality within the hospital and awareness of the water treatment system. KAP surveys were administered to the following: patients and visitors, general staff, and clinical staff. General staff was considered to be any member of staff that did not perform medical duties and did not hold any of the aforementioned titles. At each site, there was an attempt to survey a member of general staff from laundry services, food preparation, and cleaning. A different survey was administered to each group, and there were 17-18 questions per survey. Participants were not recruited using formal sampling methods, but there was an attempt to survey staff in multiple areas of the hospital. Interviews took place in hospital wards, waiting areas, kitchens, laundry rooms and other work areas. Most surveys were conducted in English, and, when necessary, an interpreter would translate for patients and visitors that lacked the level of English proficiency necessary to complete the survey. All responses were recorded in English.

In-depth Interviews

Structured in-depth interviews were administered to garner general hospital information, as well as specifics that were related to the management, operation and value of and satisfaction with the water treatment system.

Interviews were conducted with laboratory staff, administrators, directors, maintenance staff, and procurement officers, and there were 33-59 questions per survey. All interviews were conducted with one individual at a time, except interviews with maintenance staff, which were conducted as group interviews when there was more than one maintenance personnel at the hospital. Maintenance interviews took place in open areas, while interviews with administrative staff took place in office settings. The interviews included a mix of open-ended and closed-ended questions. Questions about the date of system installation, educational attainment, and access to replacement parts were omitted if they were known not to have changed between baseline to follow-up. In-depth interviews were administered and recorded in English.

Water Use Survey

Water use surveys were used to determine water use practices in and outside of the hospital. Questions were asked to determine the types of water that were used for typical medical and non-medical activities. Water use surveys were administered at the conclusion of all KAP surveys and in-depth interviews.

Water Sampling

Water samples were collected from the treatment system, areas within the hospital, and other areas connected to the treatment system that were not in the hospital. The latter was done to: (1) assess the quality of the treated water as it moved from the treatment system farther down the piped network, and (2) include other water sources that patients and staff may use for their daily activities. At each hospital, raw water was collected before treatment, at the system after filtration, at the POU at a hospital tap or standpipe, and from water storage containers, such as Veronica Buckets. Water samples were collected from the same areas that were tested in the 2013 baseline study. Consideration was also given to piped connections, which determined which hospital taps were sampled.

Samples were tested for total coliforms, *Escherichia coli*, *Pseudomonas aeruginosa*, chlorine residual and turbidity. Water samples were collected in 100 mL Whirl-Pak® bags and the Thio-Bag®. The Thio-Bag®, bag containing sodium thiosulfate, was used to dechlorinate water samples before microbiological analyses. Whirl-Pak® bags without sodium thiosulfate were used to collect water to be tested for chlorine residual and turbidity. For every sampling location, two 100 mL samples were collected in the Thio-Bag®, and one 100 mL sample was

collected in a Whirl-Pak® bag that did not contain sodium thiosulfate. Water samples were placed in a cooler until the conclusion of sample collection. All sampling locations were recorded during the collection process, and unique codes were assigned to each water sample.

Water Quality Testing

Water samples were tested for total coliforms, *E. coli*, and *P. aeruginosa*, chlorine residual and turbidity. All samples were processed within a maximum of 3 hours after collection. The IDEXX Quanti-Tray® 2000 method was utilized to determine most probable numbers (MPN) of the indicator bacteria.

For each set of water samples collected from a specific location: samples collected in the Thio-Bag® were mixed with Colilert-18 and Pseudalert® reagents in the bags in which they were collected until dissolve. Antifoam was added to samples mixed with Pseudalert® reagent to minimize foam buildup. When samples were dissolved, they were transferred to Quanti-Trays® and sealed with the Quanti-Tray® Sealer 2X. Samples were then placed in an incubator at 38° C. Samples tested for total coliforms and *E. coli* were incubated for 18 hours, and samples tested for *P. aeruginosa* were incubated for 24 hours. A negative control (deionized (DI) water that was autoclaved in the United States) was included in each assay. Consideration was given to contamination that may result from unsterile measures, and hands were disinfected with hand sanitizer before contact with different samples.

Following incubation, Quanti-Trays® were examined under ultraviolet light to determine the presence of *E. coli* and *P. aeruginosa*. Cells that fluoresced indicated growth. Quanti-Trays® being assessed for total coliforms were examined under natural light. Cells that turned yellow indicated growth. The number of cells that indicated growth were counted and MPNs were calculated. Lower limit of detection was 1.00 MPN / 100 mL, and the upper limit of detection was 2419.60 MPN / 100 mL.

Water samples collected in Whirl-Pak® bags were tested for chlorine residual and turbidity. Chlorine residual was tested using a LaMotte Single Test Colorimeter® (model 1200). Free and total chlorine residuals were measured. Turbidity was measured using a Hach 2100P Portable Turbidimeter. Vials containing sample water were wiped of fingerprints before being placed in the turbidimeter. Vials were also rinsed with DI water that was autoclaved in the U.S., or with Voltic Natural Mineral Water certified by the Ghana Standards Board,

after every use. The vials were placed upside down to dry before sample water was transferred inside for testing.

Site Observations

Tap observations were conducted at each hospital to assess tap functionality, leaks, and the presence of soap. All taps in all parts of the hospital were turned on to see if water flowed from the tap. If water did not flow, the tap was marked as non-functional. Water was left on long enough to determine if any leakages occurred. Taps included theater scrub stations and showers, and taps were in public and private areas. Tap observations would only occur when water was flowing in the hospital, as to not incorrectly assess tap functionality. The presence of soap at each tap was recorded.

Observations of poly tanks and cisterns were also conducted. Poly tanks were assessed for functionality in the treatment network. The presence of safe water messaging was also observed. If members of the research team witnessed signs about safe water or handwashing in the hospital, it was recorded, and a picture was taken.

Sustainability Metric

A sustainability metric was utilized to assess the sustainability of the water treatment systems donated by the General Electric Foundation. The sustainability metric utilized a five-point scoring system with scores ranging from 0-4, with a score of 2 defined as the cutoff for sustainability. A score of 0 indicated no evidence of an environment that would support system sustainability, while a score of 4 indicated evidence of a strong environment that would support system sustainability. Four key domains were addressed: Accountability, Technical Feasibility, On-site Capacity, and Institutional Engagement and Support. Each domain consisted of four equally-weighted subdomains that were averaged to obtain the score for each domain (Figure 2). Subdomains were informed by broad questions. Answers to broad questions were obtained through a series of individual questions pulled from surveys, in-depth interviews, water quality tests, and observations. A hospital's overall sustainability score was the average of all four domains (See Appendix for metric).

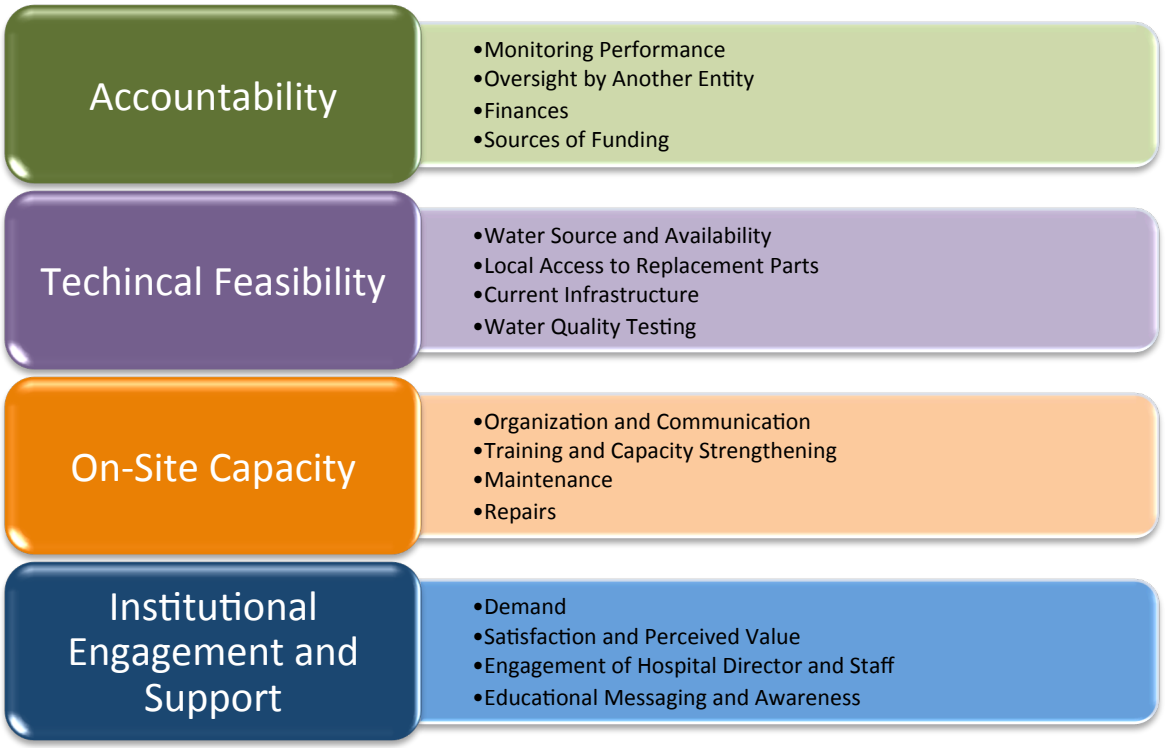


Figure 2. Sustainability metric domains and subdomains.

Analysis

Data was coded and entered into a database created in Microsoft Excel while in the field. Statistical analysis was performed using SAS 9.4, and Microsoft Excel was used to create tables and figures.

Sustainability Score Assessment

Differences in the overall sustainability scores were calculated by subtracting scores assigned in the 2013 study from scores assigned in the 2014 study. Differences in domain and subdomain scores were also calculated for each hospital using this method. Using a paired t-test with a significance level of 0.05, statistically significant differences were determined for the differences between domain scores in 2013 to 2014. Trends among the hospitals that met the sustainability cutoff of two were compared to hospitals that failed to meet the cutoff. Radar plots, representing the sustainability scores assigned for each domain and subdomain were generated utilizing Microsoft Excel.

Water Quality Assessment

Water quality results were classified by the location of sample collection. Samples included: Raw Water, Filtered Water, Tap Water, and Stored Water. Raw water was classified as water that had not yet been filtered or treated by the system. Raw water was collected from a tap at the treatment system for each of the five hospitals with membrane filter technology. Kintampo Municipal Hospital has a sand filter, and raw water was collected at the base of a water pipe that was constructed for this purpose (Figure 3). Filtered water was classified as water that had been filtered but not yet chlorinated by the system and not yet piped to hospital grounds. Filtered water was collected from a tap located at the system (Figure 4). This water was not yet chlorinated. The water treatment system chlorinates water just before it enters the hospital plumping network, and there was not an opportunity to sample the chlorinated water before it reached hospital taps. Tap water was classified as water that came from any tap in or around the hospital containing water from the treatment system. This included outdoor standpipes that received water from the system. Stored water is tap water, given the previous classification, that has been stored in containers on hospital grounds. Stored water was considered to be a POU water sample. MPNs from water samples were excluded if duplicates were collected from the same source on the same day. Due to issues with the incubation of samples from Mampong District Hospital in 2014, only some of the samples collected were included in the analysis.

Figure 3: Raw water sample site at Kintampo Municipal Hospital.

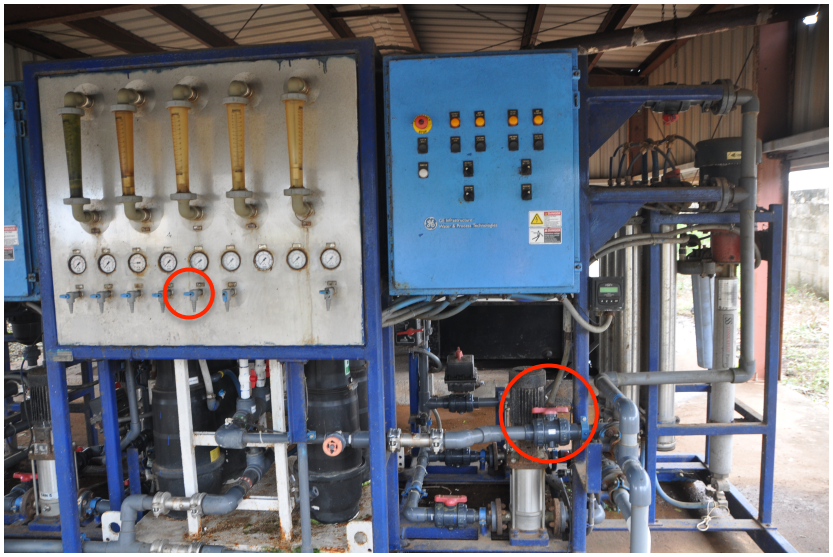


Figure 4: Raw water and filtered water sample sites for hospitals with membrane filters.

Trend Assessment

Using categorical variable coding, individual water samples that presented the following characteristics: within the range of 0.2 - 2.0 mg/L for chlorine residual and <1 MPN / 100 mL for total coliforms, *E. coli* or *P. aeruginosa* were coded as "Yes", and "No" was the code given to water samples not meeting these characteristics. To assess the water quality at POU, only tap and stored samples were included in the analysis. Data was disaggregated to compare tap water samples and stored water samples. Using Chi-square tests of independent proportions with a significance level of 0.05 to determine statistically significant differences between percentages in 2013 and 2014, the percentages of water samples that met WHO recommendations (<1 MPN / 100 mL) for total coliforms and *E. coli* in 2013 were compared to percentages in 2014. The percentages of samples that had <1 MPN / 100 mL for *P. aeruginosa* in 2013 were compared to percentages in 2014. The percentages of samples that met CDC recommendations (0.2 – 2.0 mg/L) for chlorine residual in 2013 were compared to percentages in 2014. All Chi-square tests of independent proportions were conducted for overall hospital data and then were disaggregated by hospital. In cases where the expected cell count assumption was violated, Fisher's Exact test was utilized. The differences in concentration distributions from 2013 to 2014 were also analyzed. The following categories were utilized.

- <1 MPN / 100 mL
- 1 MPN / 100 mL – 50 MPN / 100 mL

- 50 MPN / 100 mL – 1000 MPN / 100 mL
- >1000 MPN / 100 mL

Differences in percentages of samples within the categories from 2013 and 2014 were graphed using Microsoft Excel. Distributions of total coliforms in tap samples were graphed separately using boxplots to determine changes in the concentration of this treatment process indicator between 2013 and 2014. A Chi-square test of association with a significance level of 0.05 was performed to determine the presence of a statistically significant relationship between samples that met WHO recommendations for total coliforms, *E. coli*, or <1 MPN / 100 mL of *P. aeruginosa* and the location the sample was collected. Tap samples and stored water samples were compared.

Staff Perceptions and Practices Assessment

Data about perceptions of safe water and drinking water practices were analyzed from the following hospital personnel: general staff, clinical staff, and laboratory staff. Personnel directly involved with the maintenance and oversight of the treatment system, like maintenance staff and administrative staff, were excluded from the analysis due to potential bias. A Chi-square test of independent proportions, with a significance level of 0.05, was conducted to examine the association between the percentage of staff members that reported they believed that the water at the hospital was safe and the percentage of staff members that (1) did not believe water at the hospital was safe to drink or (2) were unsure in 2013 compared to 2014. A Chi-square test of association, with a significance level of 0.05, was also performed to examine the relationship between the proportion of staff that thought hospital water was safe to drink and the proportion that reported that they drank from water from the hospital taps in 2013. In cases where the expected cell count assumption was violated, Fisher's Exact test was utilized. Differences in percentages from 2013 and 2014 were graphed using Microsoft Excel.

RESULTS

A total of 46 in-depth interviews, 268 surveys, and 485 tap observations were collected from six hospitals in Ghana. Two hundred and ninety (290) water samples were collected and analyzed. Eleven (11) in-depth interviews and 118 surveys were analyzed. Hospitals included in this study were all located in different regions of the country, and catchment populations ranged from 100,000 – 140,000 (Table 1).

Table 1. Hospital Information

Hospital	City	Region	District	Catchment Population
Apam Catholic Hospital	Apam	Central	Gomoa West	~200,000
Axim Government Hospital	Axim	Western	Nzema East Municipal	~100,000
Bole District Hospital	Bole	Northern	Bole	~140,000
Kete Krachi District Hospital	Kete Krachi	Volta	Krachi West	~100,000
Kintampo Municipal Hospital	Kintampo	Brong-Ahafo	Kintampo North Municipal	~130,000
Mampong District Hospital	Mampong	Ashanti	Mampong Municipal Region	~100,000

Sustainability Measurements

The overall sustainability scores for each hospital experienced a change ranging from -0.2 to 1.8 points (Table 2) between the assessments in June and July 2013 and July and August in 2014.

Table 2. Overall Sustainability Scores

Hospital Location	2013 Score[a]	2014 Score[a]	Δ Score
Apam	1.5	1.6	0.1
Axim	**2.4**	**2.8**	0.4
Bole	1.0	**2.8**	1.8
Kete Krachi	1.6	**2.6**	1.0
Kintampo	1.0	0.8	-0.2
Mampong	1.5	1.3	-0.2

[a] Bolded values represent scores that met and / or exceeded the sustainability cutoff of 2.

Four of the six hospitals, Apam, Axim, Bole, and Kete Krachi, had an increase in the overall sustainability score, ranging from 0.1– 1.8 between 2013 to 2014 (Table 2). Two hospitals, Kintampo and Mampong, had a decrease of 0.2 in their overall sustainability scores from 2013 to 2014. Of the six hospitals, only Axim, Bole and Kete Krachi received overall sustainability scores that met or exceeded the cutoff of 2 for sustainability.

Apam, Kintampo and Mampong hospitals did not reach the cutoff of 2 for sustainability. Overall sustainability scores failed to reach a score of 3 in any of the six hospitals.

Table 3. Sustainability Scores by Domain

Hospital Location	Domain	2013 Score[a]	2014 Score[a]
Apam	Accountability	0.9	1.1
	Technical Feasibility	0.8	1.5
	On-site Capacity	1.8	1.8
	Institutional Engagement and Support	**2.5**	**2.1**
Axim	Accountability	1.9	**2.3**
	Technical Feasibility	**3.0**	**2.6**
	On-site Capacity	**2.6**	**3.5**
	Institutional Engagement and Support	**2.1**	**2.9**
Bole	Accountability	1.4	**2.8**
	Technical Feasibility	0.8	**2.6**
	On-site Capacity	0.5	**3.0**
	Institutional Engagement and Support	1.5	**2.8**
Kete Krachi	Accountability	1.3	**2.0**
	Technical Feasibility	1.5	**2.3**
	On-site Capacity	1.4	**3.3**
	Institutional Engagement and Support	**2.4**	**3.0**
Kintampo	Accountability	0.3	0.1
	Technical Feasibility	1.0	0.8
	On-site Capacity	1.4	0.9
	Institutional Engagement and Support	1.4	1.4
Mampong	Accountability	1.5	1.4
	Technical Feasibility	1.5	1.5
	On-site Capacity	1.0	0.8
	Institutional Engagement and Support	**2.0**	1.5

[a] Bolded values represent scores that met and / or exceeded the cutoff of 2 for sustainability.

Scores failed to reach the highest possible score of 4 in any of the four domains for all hospitals (Table 3). There was a statistically significant difference between domain scores in 2013 and domain scores in 2014 (p-value: 0.0095).

Tables 4-6 show subdomain scores from all of the four domains in 2013 and 2014 and the differences between 2013 and 2014. Figures 6-9 display radar plots showing scores by domain (See Tables and Figures).

Trends Among Hospitals Meeting the Sustainability Cutoff

The three hospitals, Axim, Bole, and Kete Krachi, that met the sustainability cutoff of 2 in 2014, had increases scores in all domains, with the exception of Axim, which received a lower score in the Technical Feasibility domain (Figure 5). Axim, Bole and Kete Krachi met the cutoff of 2 for sustainability in all domains. Scores among these hospitals were highest in the On-site Capacity domain. Scores were lowest in the Accountability domain for Axim and Kete Krachi hospitals and the Technical Feasibly domain for Bole hospital. All three hospitals had greatest increase in scores from 2013 to 2014 in the On-site Capacity domain.

Accountability

In the Accountability domain, scores collectively were lowest and below 2 in the *oversight by another entity* subdomain in all hospitals, with each hospital receiving a score of 1. Scores were collectively highest in the *finances* subdomain for all hospitals. The highest collective increase in scores from 2013 to 2014 was in the *sources of funding* subdomain.

Technical Feasibility

In the Technical Feasibility domain, scores were collectively lowest in the *water quality testing* subdomain with Axim hospital receiving a score below 2. Scores were not collectively highest in any of the subdomains, and scores did not increase collectively in any subdomain. The highest increases in scores from 2013 to 2014 were in the *source water and availability* subdomain in Bole and Kete Krachi hospitals and in the *current infrastructure* and *water quality testing* subdomains at Kete Krachi hospital.

On-site Capacity

In the On-site Capacity domain, scores were not collectively lowest or highest in any subdomain. There were also not any collective increases in subdomain scores from 2013 to 2014.

Institutional Engagement and Support

In the Institutional Engagement and Support domain, scores were collectively lowest in the *educational messaging and awareness* subdomain. Scores were collectively highest in the *satisfaction and perceived value* subdomain. The highest collective increase in scores from 2013 to 2014 was in the *demand* subdomain.

Trends Among Hospitals Failing to Meet Sustainability Cutoff

The three hospitals, Apam, Kintampo, and Mampong, that did not meet the cutoff of 2 in the overall sustainability score in 2014 failed to meet the cutoff of 2 in the Accountability, Technical Feasibility, and On-site Capacity domains (Figure 5). Apam hospital met the cutoff of 2 in the Institutional Engagement and Support domain. Scores at Apam and Kintampo hospitals were lowest in the Accountability domain. Scores were collectively highest in the in the Institutional Engagement and Support domain.

Accountability

In the Accountability domain, scores collectively were lowest and below 2 in the *sources of funding* and *monitoring performance* subdomains in all hospitals. Scores were not collectively highest in any subdomain. Subdomain scores did not reflect a collective increase or decrease from 2013 to 2014.

Technical Feasibility

In the Technical Feasibility domain, scores were collectively lowest in the *water quality testing* subdomain with all hospitals receiving a score below 2. Kintampo and Mampong hospitals also received their lowest scores in the *source water and availability* subdomain, with both scores below 2. Scores were not collectively highest in any of the subdomains. Subdomain scores did not reflect a collective increase or decrease from 2013 to 2014.

On-site Capacity

In the On-site Capacity domain, scores were not collectively lowest in any subdomain. Kintampo and Mampong hospitals received their lowest scores in the *communication and organization* subdomain. Scores were also not collectively highest in any subdomain. Subdomain scores did not reflect a collective increase or decrease from 2013 to 2014. Apam and Mampong hospitals received their highest decreases in scores from 2013 to 2014 in the *communication and organization* subdomain.

Institutional Engagement and Support

In the Institutional Engagement and Support domain, scores were not collectively lowest in any subdomain. Scores were also not collectively highest in any of the subdomains. The highest collective decrease in scores from 2013 to 2014 was in the *engagement of hospital director and staff* subdomain, with all hospitals receiving a score of 2 after previously receiving a score of 3.

Table 4. Sustainability Score Matrix 2013							
Domain	**Subdomain**	**Apam**	**Axim**	**Bole**	**Kete Krachi**	**Kintampo**	**Mampong**
Accountability	Monitoring Performance	1	3	1	0	0	1
	Oversight by another entity	0.5	0.5	0.5	0	1	1
	Sources of Funding	1	2	2	2	0	2
	Finances	1	2	2	2	0	2
Average Score		0.9	1.9	1.4	1.3	0.3	1.5
Technical Feasibility	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	0	2	1	1
	Water Quality Testing	0	3	0	1	0	2
Average Score		0.8	3.0	0.8	1.5	1.0	1.5
On-site Capacity	Organization and Communication	2.5	2.5	0.5	1	1	1
	Training and Capacity Strengthening	2	3	0	1	1	1
	Maintenance	1.5	3	0.5	2.5	2.5	1
	Repairs	1	2	1	1	1	1
Average Score		1.8	2.6	0.5	1.4	1.4	1.0
Institutional Engagement and Support	Demand	2	2	1	2	0	2
	Satisfaction and Perceived Value	2.6	3	2	3	1	2
	Engagement of Hospital Director and Staff	3	2	2	3	3	3
	Educational Messaging and Awareness	2.5	1.5	1	1.5	1.5	1
Average Score		2.5	2.1	1.5	2.4	1.4	2.0

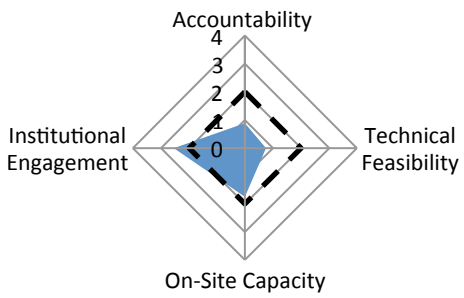
Table 5. Sustainability Score Matrix 2014							
Domain	**Subdomain**	**Apam**	**Axim**	**Bole**	**Kete Krachi**	**Kintampo**	**Mampong**
Accountability	Monitoring Performance	1	2	3	1	0	1
	Oversight by another entity	1.5	1	1	1	0.5	1.5
	Sources of Funding	1	3	3	3	0	1
	Finances	1	3	4	3	0	2
Average Score		1.1	2.3	2.8	2.0	0.1	1.4
Technical Feasibility	Water Source and Availability	3	4	4	2	0	1
	Local Access to Replacement Parts	2	2	2	2	2	2
	Current Infrastructure	1	3	2	3	1	2
	Water Quality Testing	0	1.5	2.5	2	0	1
Average Score		1.5	2.6	2.6	2.3	0.8	1.5
On-site Capacity	Organization and Communication	1.5	3	4	2.5	0.5	0
	Training and Capacity Strengthening	1	3	2	4	1	1
	Maintenance	2.5	4	3	3.5	1	1
	Repairs	2	4	3	3	1	1
Average Score		1.8	3.5	3.0	3.3	0.9	0.8
Institutional Engagement and Support	Demand	2	3	3	3	1	2
	Satisfaction and Perceived Value	2.3	3	3.3	3.3	0.7	1
	Engagement of Hospital Director and Staff	2	3	3	3	2	2
	Educational Messaging and Awareness	2	2.5	2	2.5	2	1
Average Score		2.1	2.9	2.8	3.0	1.4	1.5

Table 6. Matrix of Differences[b] in Sustainability Scores							
Domain	**Subdomain**	**Apam**	**Axim**	**Bole**	**Kete Krachi**	**Kintampo**	**Mampong**
Accountability	Monitoring Performance	0	-1	2	0	0	0
	Oversight by another entity	1	0.5	0.5	1	-0.5	0.5
	Sources of funding	0	1	1	1	0	-1
	Finances	0	1	2	1	0	0
Average Difference		0.3	0.4	1.4	0.8	-0.1	-0.1
Technical Feasibility	Water source and availability	2	0	3	1	-1	0
	Local Access to replacement parts	0	0	0	0	0	0
	Current infrastructure	1	0	2	1	0	1
	Water quality testing	0	-1.5	2.5	1	0	-1
Average Difference		0.8	-0.4	1.9	0.8	-0.3	0
On-site Capacity	Organization and communication	-1	0.5	3.5	1.5	-0.5	-1
	Training and capacity strengthening	-1	0	2	3	0	0
	Maintenance	1	1	2.5	1	-1.5	0
	Repairs	1	2	2	2	0	0
Average Difference		0	0.9	2.5	1.9	-0.5	-0.3
Institutional Engagement and Support	Demand	0	1	2	1	1	0
	Satisfaction and perceived Value	-0.3	0	1.3	0.3	-0.3	-1
	Engagement of hospital Director and staff	-1	1	1	0	-1	-1
	Educational Messaging and Awareness	-0.5	1	1	1	0.5	0
Average Difference		-0.4	0.8	1.3	0.6	0.0	-0.5

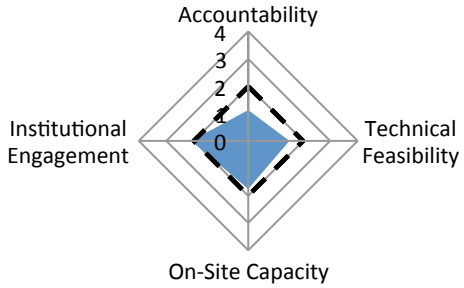
[b] Values presented represent 2013 scores subtracted from 2014 scores.

Figure 5. Sustainability Score Radar Plots by domain.

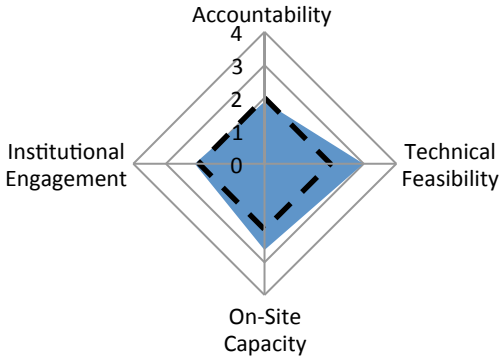
Apam 2013



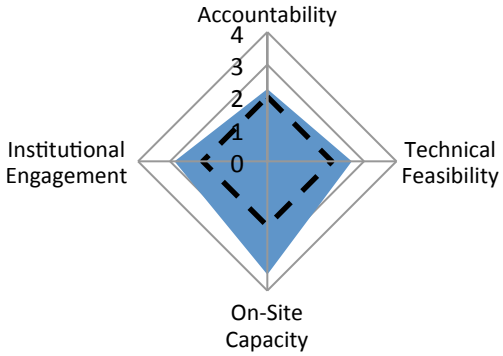
Apam 2014



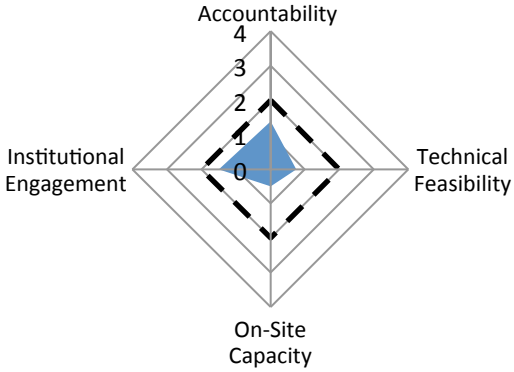
Axim 2013



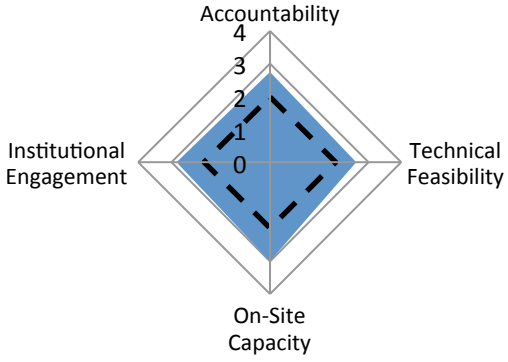
Axim 2014



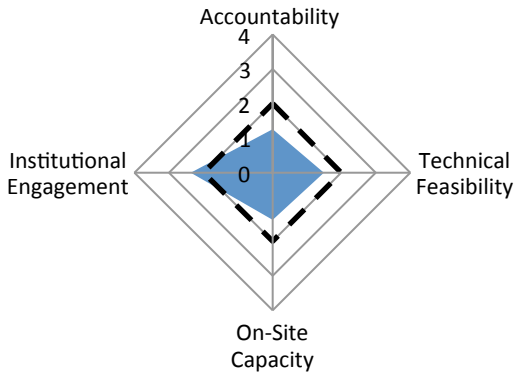
Bole 2013



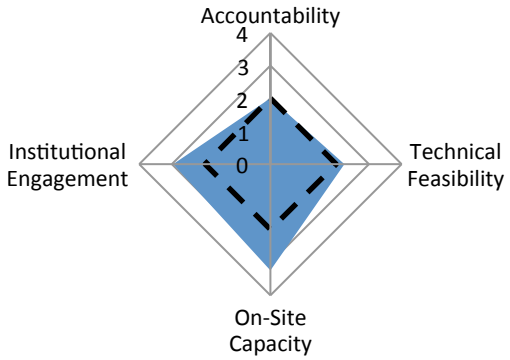
Bole 2014



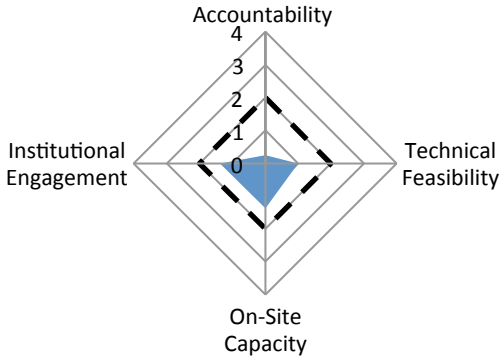
Kete Krachi 2013



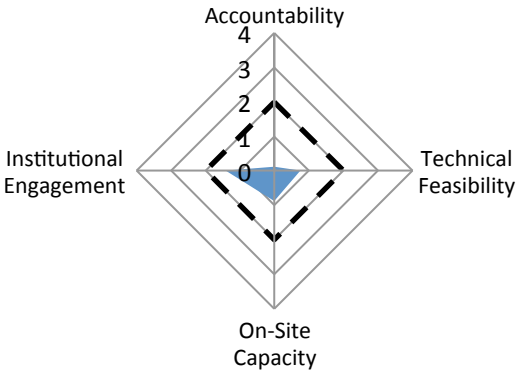
Kete Krachi 2014



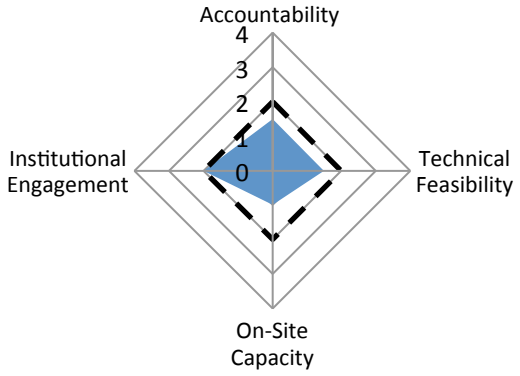
Kintampo 2013



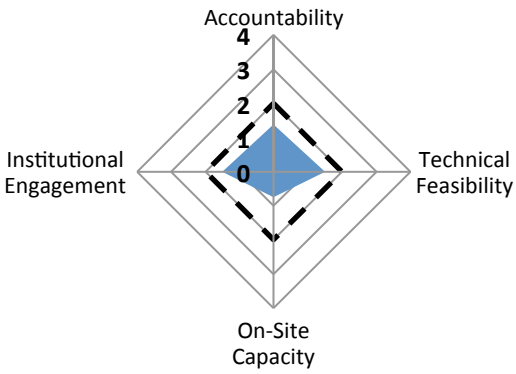
Kintampo 2014



Mampong 2013



Mampong 2014



Water Quality

Raw and Filtered Water Concentrations

Concentrations of total coliforms, *E. coli*, and *P. aeruginosa* in raw, untreated water samples were compared to concentrations in filtered water samples to quantify indicator concentrations in the water: (1) before water was treated and (2) after treatment before water was piped to the hospital. There were only 1-2 samples of raw or filtered water from each hospital. Filtered water samples usually had lower concentrations of indicator organisms than raw water. Indicator bacteria in raw water and filtered water samples both ranged from <1 - >2419.6 MPN / 100 mL. Apam and Kete Krachi hospitals had higher concentrations of total coliforms in filtered samples in 2014 than in 2013 (Table 7). Apam hospital had higher concentrations of *E. coli* in the filtered sample in 2014 than in 2013 (Table 8). *P. aeruginosa* was detected in 2013 and 2014 in filtered samples (Table 9). In 2013, Axim and Kete Krachi hospitals had higher concentrations of *P. aeruginosa* in filtered samples than in raw water samples. This was also the case in 2014 in Apam, Bole, and Kete Krachi hospitals. Axim hospital also had detectable *P. aeruginosa* in the raw samples that was not seen in 2013.

Table 7. Mean MPN / 100 mL for Total Coliforms in Raw and Filtered Water Samples 2013 and 2014

		Raw Water (Before Filtration)		Filtered Water (Pre-Chlorination)	
Year	**Hospital Location**	**N**	**MPN / 100 mL (SD)**	**N**	**MPN / 100 mL (SD)**
2013	Apam	1	>2419.6	1	<1
	Axim	2	<1	1	<1
	Bole	2	55.55 (56.64)	-	-
	Kete Krachi	-	-	1	<1
	Kintampo	1	95.5	-	-
	Mampong	-	-	-	-
2014	Apam	1	1011.2	1	14.5
	Axim	1	12.1	1	<1
	Bole	1	20.9	1	<1
	Kete Krachi	2	115.95 (153.80)	2	89 (125.87)
	Kintampo	1	>2419.6	-	-
	Mampong	2	1769.75 (919.03)	2	<1

- No Data

Table 8. Mean MPN / 100 mL for *E. coli* in Raw and Filtered Water Samples 2013 and 2014					
		Raw Water (Before Filtration)		Filtered Water (Pre-Chlorination)	
Year	**Hospital Location**	**N**	**MPN / 100 mL (SD)**	**N**	**MPN / 100 mL (SD)**
2013	Apam	1	>2419.6	1	<1
	Axim	2	<1	1	<1
	Bole	2	5.9 (6.93)	-	-
	Kete Krachi	-	-	1	<1
	Kintampo	1	2	-	-
	Mampong	-	-	-	-
2014	Apam	1	187.3	1	11
	Axim	1	<1	1	<1
	Bole	1	<1	1	<1
	Kete Krachi	2	16.42 (17.47)	2	<1
	Kintampo	1	28.1	-	-
	Mampong	2	3.55 (0.78)	2	<1

- No Data

Table 9. Mean MPN / 100 mL for *P. aeruginosa* in Raw and Filtered Water Samples 2013 and 2014					
		Raw Water (Before Filtration)		Filtered Water (Pre-Chlorination)	
Year	**Hospital Location**	**N**	**MPN / 100 mL (SD)**	**N**	**MPN / 100 mL (SD)**
2013	Apam	1	>2419.6	1	>2419.6
	Axim	2	<1	1	>2419.6
	Bole	2	39.3 (54.16)	-	-
	Kete Krachi	1	67.6	1	1732.9
	Kintampo	1	261.3	-	-
	Mampong	-	-	-	-
2014	Apam	1	43.6	1	>2419.6
	Axim	1	16.6	1	4
	Bole	1	1	1	66.8
	Kete Krachi	1	<1	1	30.1
	Kintampo	1	36.8	-	-
	Mampong	2	84 (44.26)	2	0

- No Data

Chlorine Residual in POU Samples

Figure 10 indicates the percentage of tap samples within in the CDC-recommended chlorine residual range of 0.2 – 2.0 mg/L in 2013 and 2014 by hospital. The percentage of tap samples within the CDC recommendations ranged from 0 – 77.7% in 2013 and 0 - 53.9% in 2014. In 2014, Apam and Kete Krachi hospitals had an increase in the percentage of tap samples that were within the CDC-recommended range for

chlorine residual compared to 2013. The percentage of tap samples that were within the CDC-recommended range for chlorine residual decreased in Axim and Mampong hospitals in 2014. There was a statistically significant difference in the percentage of samples in Kete Krachi within chlorine residual range from 2013 to 2014 (p-value: 0.0206). Figure 11 indicates the presence of chlorine residual in stored water samples within the CDC-recommended range of 0.2 – 2.0 mg/L in 2013 and 2014 by hospital. The percentage of stored samples within CDC recommendations ranged from 0 – 33.3% in 2013 and 0 – 50.0% in 2014. Only Bole and Kete Krachi hospitals had stored water samples within the CDC-recommended range for chlorine residual in 2014, compared to only Mampong hospital in 2013. Sufficient data was not available for stored samples to conduct statistical analyses between 2013 and 2014 results. Among all hospitals, there were no statistically significant differences in the percentage of tap samples or stored water samples that were in the CDC-recommended range for chlorine residual from 2013 to 2014.

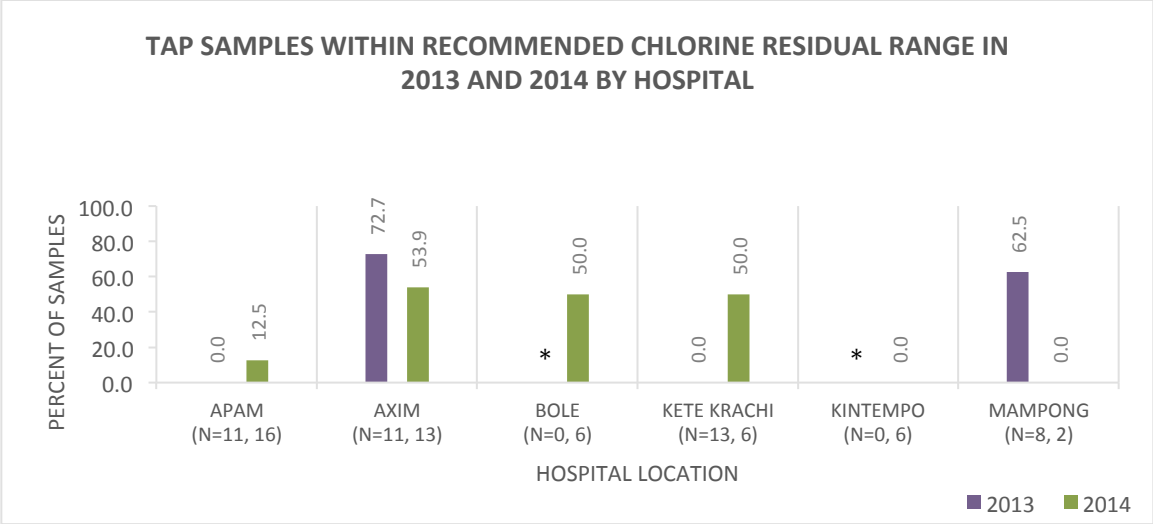


Figure 10. Percentage of tap samples meeting CDC recommendations for chlorine residual (0.2 – 2.0 mg/L) by hospital. *No data. The x-axis denotes the hospital where samples were collected and the sample sizes from 2013 followed by sample sizes from 2014. The y-axis denotes the percent of samples within the WHO-recommended range.

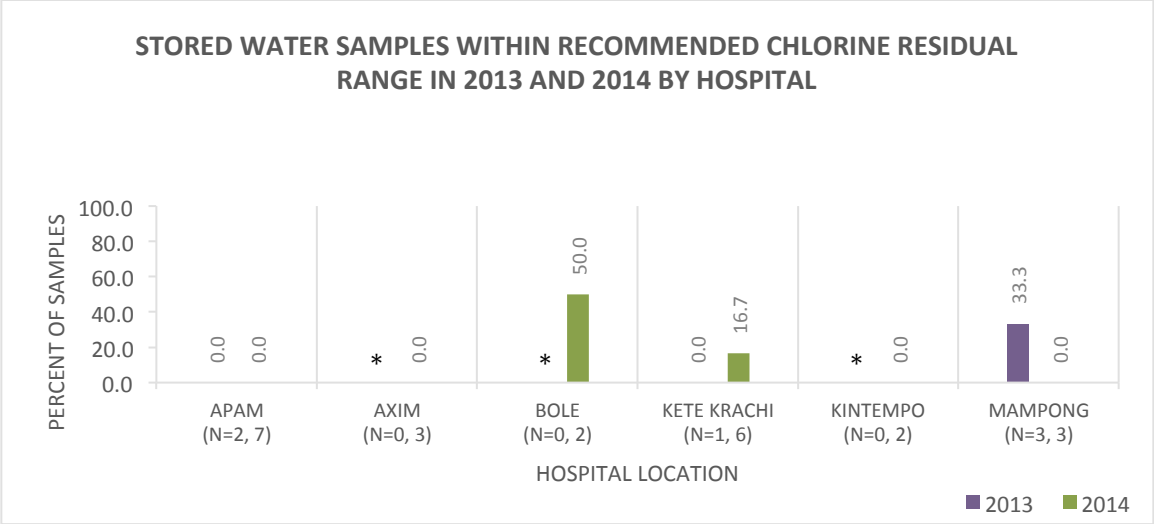


Figure 11. Percentage of stored water samples meeting CDC recommendations for chlorine residual (0.2 – 2.0 mg/L) by hospital. *No data

Concentrations of Organisms in POU Samples

Concentrations of total coliforms, *E. coli*, and *P. aeruginosa* were analyzed in point-of-use samples in 2013 and were compared to concentrations in 2014 to assess changes in water quality throughout the hospital (Figures 12 - 17).

Figures 12 and 13 indicate the percentage of tap and stored water samples that met WHO drinking water quality guidelines (<1 MPN / 100 mL) for total coliforms in 2013 and 2014. The percentage of tap samples within WHO guidelines ranged from 0 – 100% in 2013 and 0 - 100% in 2014. Between 2013 and 2014, there was a decrease in the proportion of tap water samples that met WHO drinking water guidelines in Axim and Mampong hospitals. In Apam, Bole, and Kete Krachi hospitals, there were increases in the proportion of tap water samples that met WHO guidelines. Kintampo hospital failed to have any samples meet WHO guidelines in 2013 and 2014. Kete Krachi was the only hospital to have 100% (n=9) of tap samples meet WHO guidelines. Bole hospital had a statistically significant (p-value: 0.0047) positive difference in the percentage of tap samples meeting WHO guidelines for total coliforms between 2013 and 2014. Axim hospital had a statistically significant (p-value: <0.0001) negative difference in the percentage of tap samples meeting WHO guidelines for total coliforms between 2013 and 2014. The percentage of stored samples within WHO guidelines ranged from 0 – 66.7% in 2013 and 0 - 100% in 2014. Four hospitals had an increase in the percentage of stored water samples meeting WHO guidelines. Mampong hospital was the only hospital

to show a decrease. Sufficient data was not available for stored samples to conduct statistical analyses between the 2013 and 2014 results.

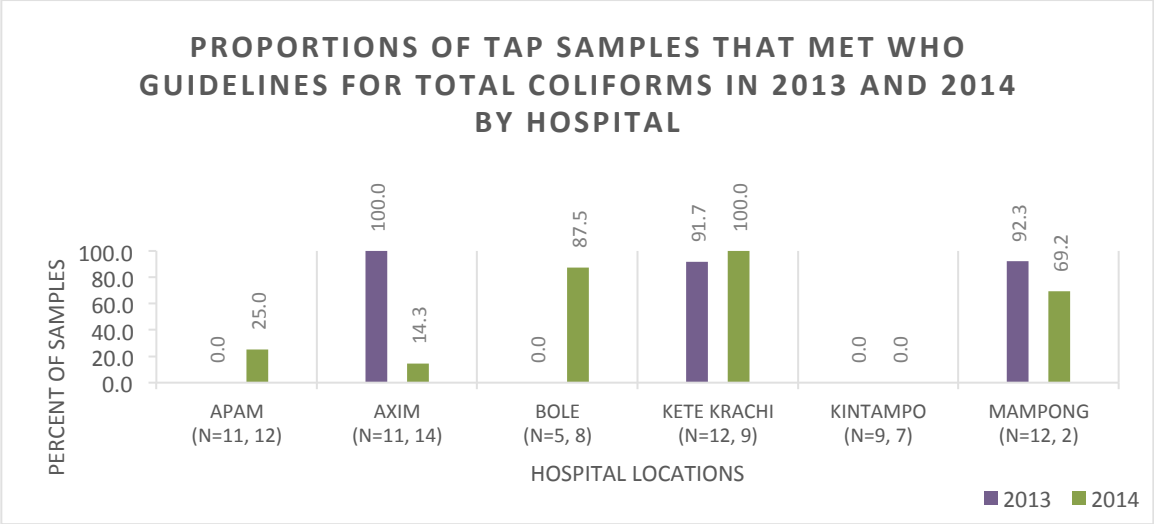


Figure 12. Percentage of tap water samples meeting WHO guidelines for total coliforms (<1 MPN / 100 mL) by hospital. The x-axis denotes the hospital where samples were collected. The y-axis denotes the percent of samples meeting <1 MPN / 100 mL of indicator organisms detected.

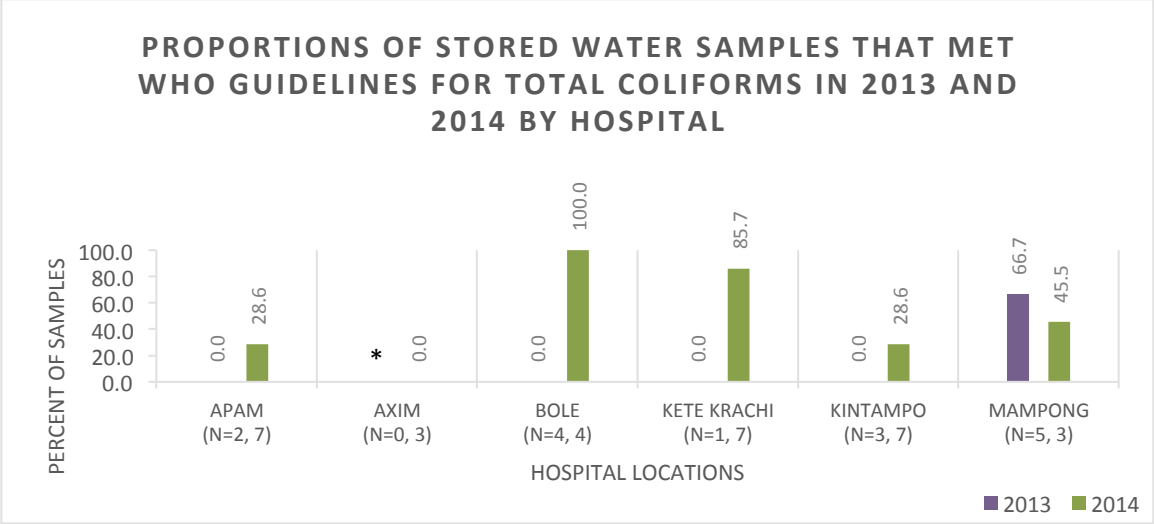


Figure 13. Percentage of stored water samples meeting WHO guidelines for total coliforms (<1 MPN / 100 mL) by hospital. *No data

Figures 14 and 15 indicate the percentage of tap and stored water samples that met WHO water quality guidelines (<1 MPN / 100 mL) for *E. coli* in 2013 and 2014. The percentage of tap samples within WHO guidelines ranged from 0 – 100% in 2013 and 14.3 - 100% in 2014. All hospitals except Axim had an increase in the percentage of tap samples meeting WHO guidelines for *E. coli*. Bole, Kete Krachi, and Mampong

hospitals had 100% of tap samples meeting WHO guidelines in 2014. Axim hospital was the only hospital to have a decrease in the percentage of samples with non-detectable levels of *E. coli*, moving from 100% (n=11) in 2013 to 78.6% (n=14) in 2014. Bole hospital had a statistically significant (p-value: 0.0008) positive difference in the percentage of tap samples meeting WHO guidelines for *E. coli* between 2013 and 2014. Axim hospital had a statistically significant (p-value: 0.0373) negative difference in the percentage of tap samples meeting WHO guidelines for *E. coli* between 2013 and 2014. The percentage of stored samples within WHO guidelines ranged from 0 – 66.7% in 2013 and 28.6 - 100% in 2014. All hospitals sampled in 2013 and 2014 had a substantial increase in the percentage of stored water samples that met WHO guidelines for *E. coli*. In Bole hospital 100% (n=4) of samples met WHO guidelines for *E. coli*. Sufficient data was not available for stored samples to conduct statistical analyses between 2013 and 2014 results.

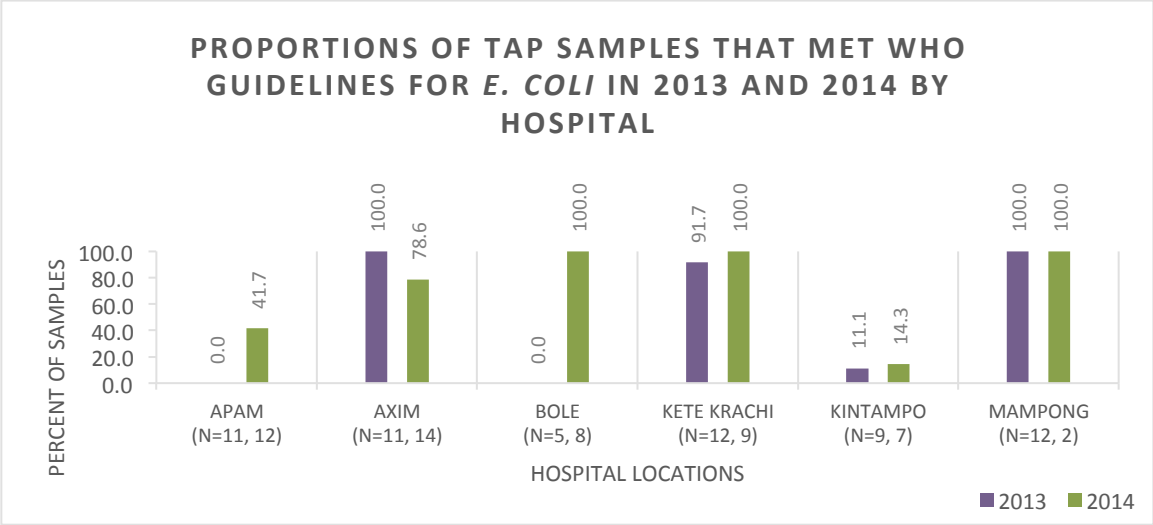


Figure 14. Percentage of tap water samples meeting WHO guidelines for *E. coli* (<1 MPN / 100 mL) by hospital.

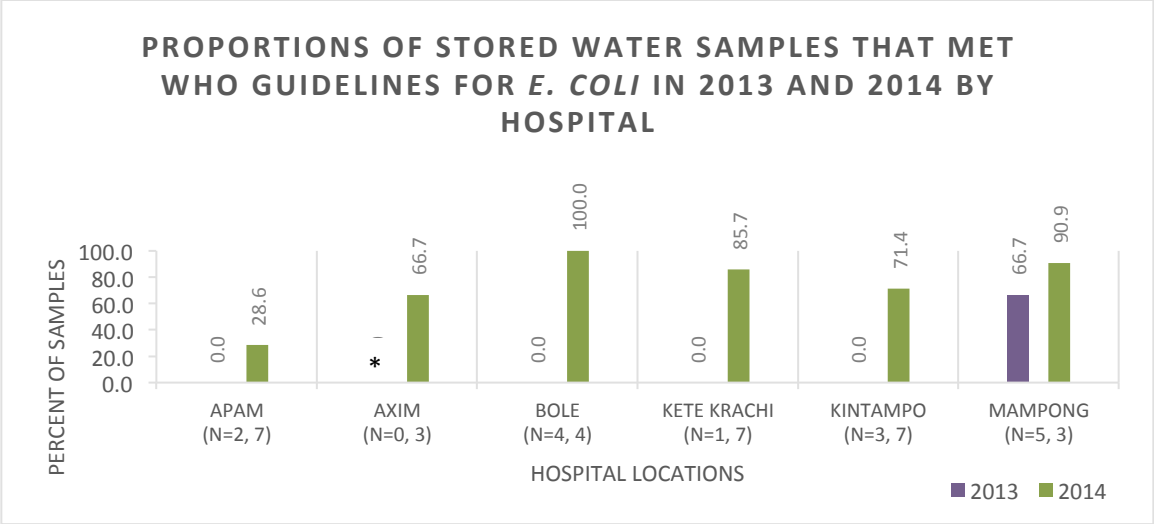


Figure 15. Percentage of stored water samples meeting WHO guidelines for *E. coli* (<1 MPN / 100 mL) by hospital.
* No data

Figures 16 and 17 indicate the percentage of tap and stored water samples that were <1 MPN / 100 mL for *P. aeruginosa* in 2013 and 2014. The percentage of tap samples containing <1 MPN / 100 mL of *P. aeruginosa* ranged from 0 – 100% in 2013 and 14.3 – 88.9% in 2014. Bole, Kete Krachi, and Kintampo hospitals had an increase in the percentage of tap samples with no detectable *P. aeruginosa*. All hospitals had detectable *P. aeruginosa* concentrations in tap samples in 2014. Bole hospital had a statistically significant (p-value: 0.0101) positive difference in the percentage of tap samples containing <1 MPN / 100 mL of *P. aeruginosa* between 2013 and 2014. Axim hospital had a statistically significant (p-value: 0.0010) negative difference in the percentage of tap samples meeting containing <1 MPN / 100 mL of *P. aeruginosa* between 2013 and 2014. The percentage of stored samples containing <1 MPN / 100 mL of *P. aeruginosa* ranged from 0 – 6.3% in 2013 and 0 – 100% in 2014. All hospitals sampled in 2013 and 2014, except Kintampo, had an increase in the percentage of stored water samples containing no detectable levels of *P. aeruginosa*. Bole hospital had 100% (n=4) of samples containing no detectable levels of *P. aeruginosa*. Sufficient data was not available for stored samples to conduct statistical analyses between 2013 and 2014 results.

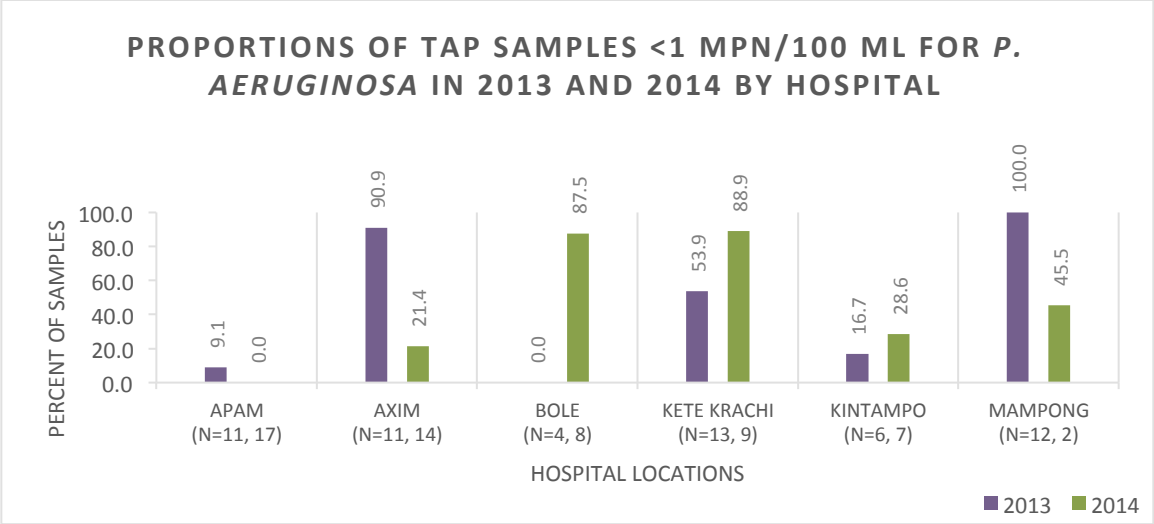


Figure 16. Percentage of tap water samples with <1 MPN / 100 mL for *P. aeruginosa* by hospital.

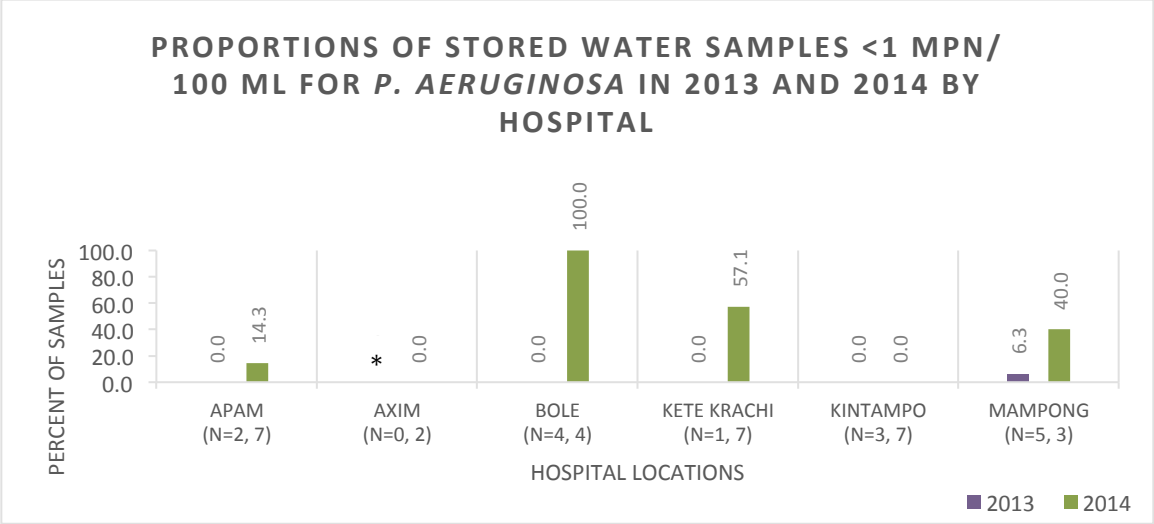


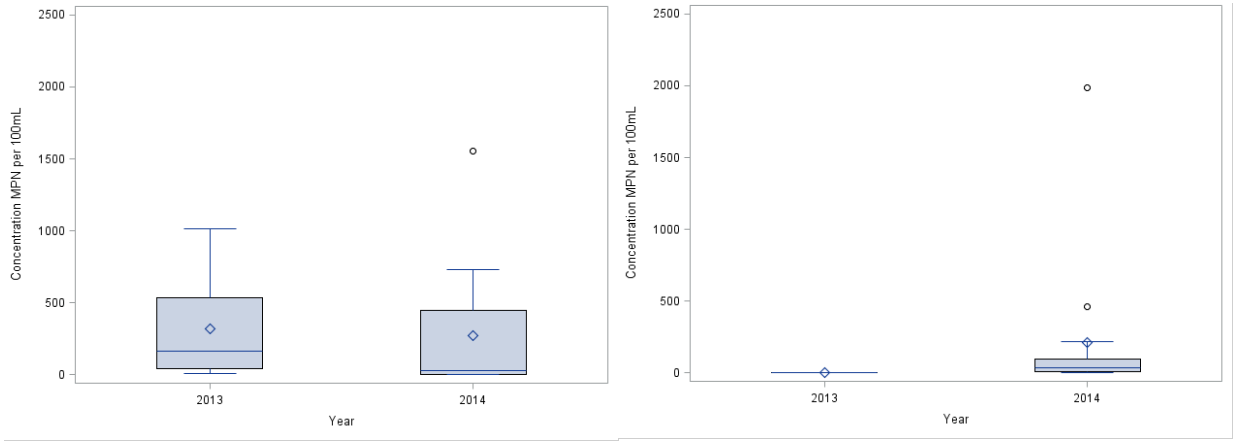
Figure 17. Percentage of stored water samples with <1 MPN / 100 mL for *P. aeruginosa* by hospital. *No data

Distribution of Indicator Bacteria Concentrations in POU Samples

Figure 18 indicates the distribution of concentrations of total coliforms in tap samples in each hospital in 2013 and 2014. In all study hospitals except Axim, Kintampo, and Mampong, the mean of total coliforms in tap samples were lower in 2014 than in 2013.

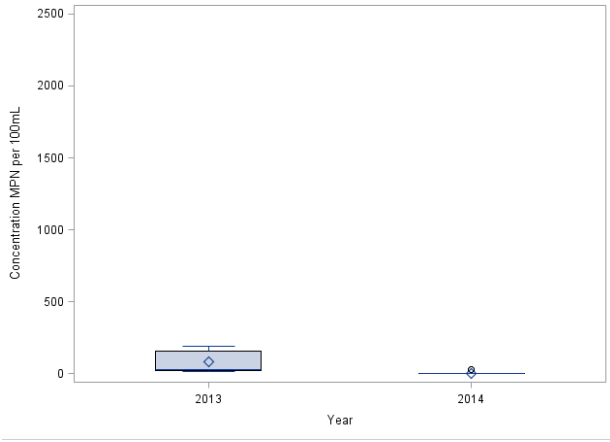
Figures 19 - 36 (See Tables and Figures) indicate the distributions of total coliforms, *E. coli*, and *P. aeruginosa* concentrations in tap and stored water samples in 2013 and 2014 for each hospital.

Distributions of total coliforms, *E. coli*, and *P. aeruginosa* in tap samples in Kintampo remained similar from 2013 to 2014. Distributions of total coliforms, *E. coli*, and *P. aeruginosa* in tap and stored samples in Mampong remained similar from 2013 to 2014. Mampong hospitals remained relatively the same from 2013 to 2014. Changes occurred in the remaining four hospitals. Apam, Bole, and Kete Krachi hospitals had higher percentages of POU samples with no detectable total coliforms, *E. coli*, and *P. aeruginosa* concentration in 2014 than in 2013. In Bole and Kete Krachi hospitals, higher percentages of indicator bacteria concentrations >1 MPN / 100 mL present in 2014 were concentrated in lower ranges than indicator bacteria concentrations present in 2013. The distribution of indicator bacteria concentration >1 MPN / 100 mL present in Axim hospital in 2014 was more evenly distributed among the ranges, including higher concentrations of indicator organisms than present in 2013.

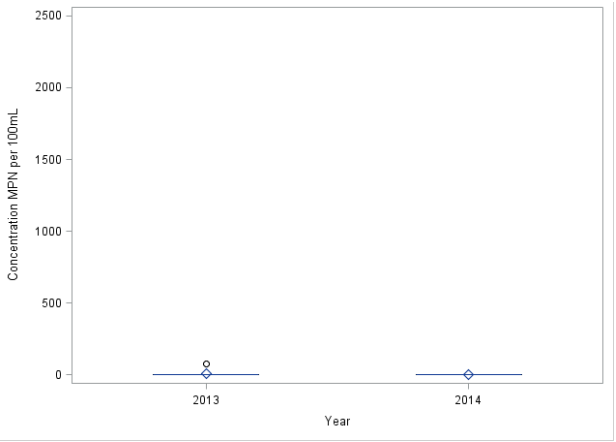


Apam

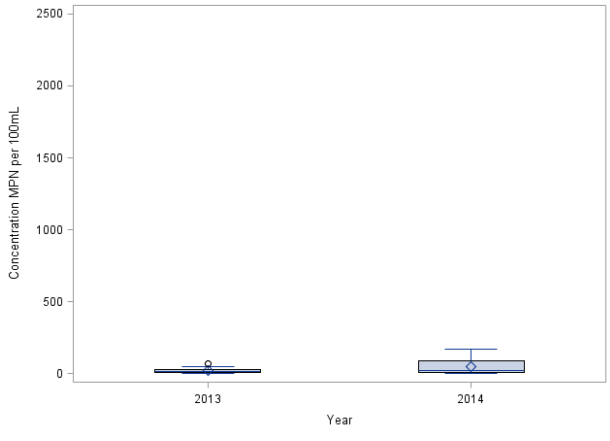
Axim



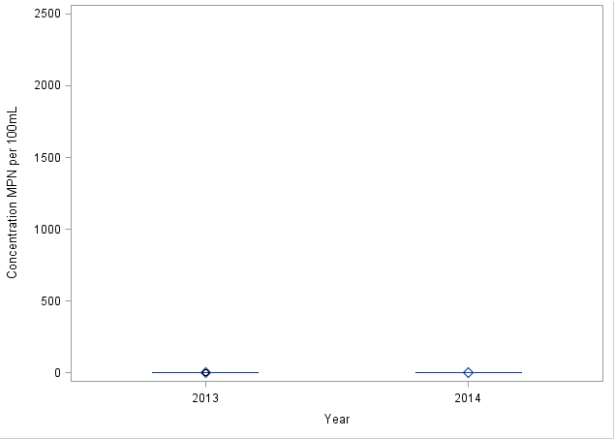
Bole



Kete Krachi



Kintampo



Mampong

Figure 18. Distribution of total coliforms in tap samples in 2013 and 2014 (Concentration MPN / 100 mL).

Association with Water Quality and Location of Sample Collection

Differences were observed in the percentage of samples that had no detectable levels of indicator organisms based on the location of sample collection.

Figure 25 indicates the overall percentage of POU samples that met WHO guidelines of <1 MPN / 100 mL for total coliforms in 2013 compared to 2014. There was a decrease in the percentage of tap samples that met WHO guidelines in 2014, but there was an increase in the percentage of stored water samples that met WHO guidelines in 2014. There was not a significant difference between the percentage of tap samples that met WHO guidelines in 2013 and 2014. There was also not a significant difference in the proportion of stored water samples that met WHO guidelines in 2013 and 2014. There was a statistically significant difference between the percentage of tap samples and stored water samples that met WHO guidelines for total coliforms in 2013 (p-value: 0.0496). In 2013, tap samples were 2.06 times more likely to meet WHO guidelines for total coliforms than stored water samples (CI: 0.86 – 4.92). There was not a statistically significant difference in the percentages of tap samples and stored water samples that met WHO guidelines for total coliforms in 2014.

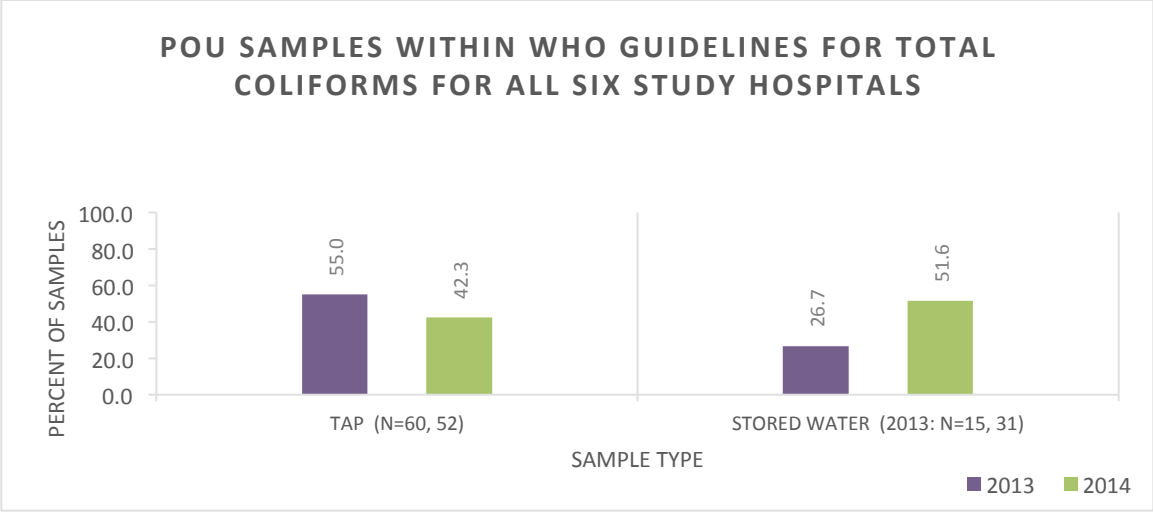


Figure 25. Percentage of tap water and stored water samples that met WHO guidelines (<1 MPN / 100 mL) for total coliforms among all hospitals in 2013 and 2014.

Figure 26 indicates the overall percentage of POU samples that met WHO guidelines of <1 MPN / 100 mL for *E. coli*. There was an increase in the percentages of tap samples and stored water samples that met WHO guidelines for *E. coli* in 2014. There was not a significant difference between the percentage of tap samples

that met WHO guidelines from 2013 to 2014, but there was significant difference in the proportion of stored water samples that met WHO guidelines in 2013 and 2014 (p-value: 0.0087). There was a statistically significant difference between the percentage of tap samples and stored water samples that met WHO guidelines for *E. coli* in 2013 (p-value: 0.0281). In 2013, tap samples were 2.19 times more likely to meet WHO guidelines for *E. coli* than stored water samples (CI 0.92 – 5.20). There was not a statistically significant difference in the percentages of tap samples and stored water samples that met WHO guidelines for *E. coli* in 2014, as there were improvements in water quality in stored water samples.

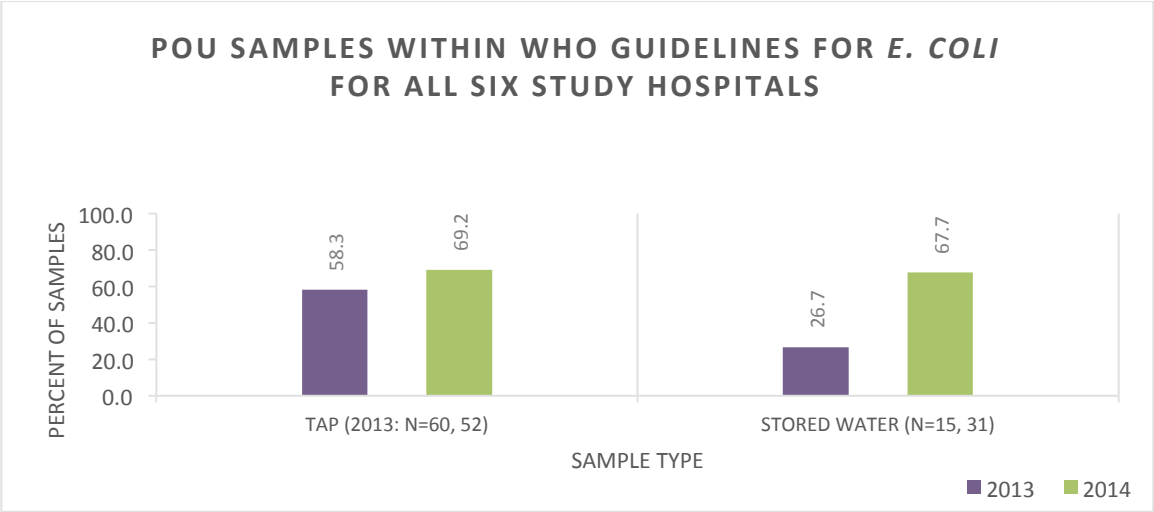


Figure 26. Percentage of tap water and stored water samples that met WHO guidelines (<1 MPN / 100 mL) for *E. coli* among all hospitals in 2013 and 2014.

Figure 27 indicates the overall percentage of POU samples that had less than <1 MPN / 100 mL of *P. aeruginosa*. There was a decrease in the percentage of tap samples and an increase in the percentage of stored water samples that had no detectable levels of *P. aeruginosa* in 2014. There was not a significant difference between the percentage of tap samples that had no detectable levels of *P. aeruginosa* in 2013 and 2014, but there was significant difference in the proportion of stored water samples that had no detectable levels of *P. aeruginosa* from 2013 to 2014 (p-value: 0.0497). There was a statistically significant difference between the percentage of tap samples and stored water samples that did not contain detectable levels of *P. aeruginosa* in 2013 (p-value: 0.0009). In 2013, tap samples were 8.16 times more likely to not contain any detectable *P. aeruginosa* concentration than stored water samples (CI 1.21 – 55.00). There was not a statistically significant

difference in the percentages of tap samples and stored water samples that did not contain any detectable *P. aeruginosa* concentration in 2014.

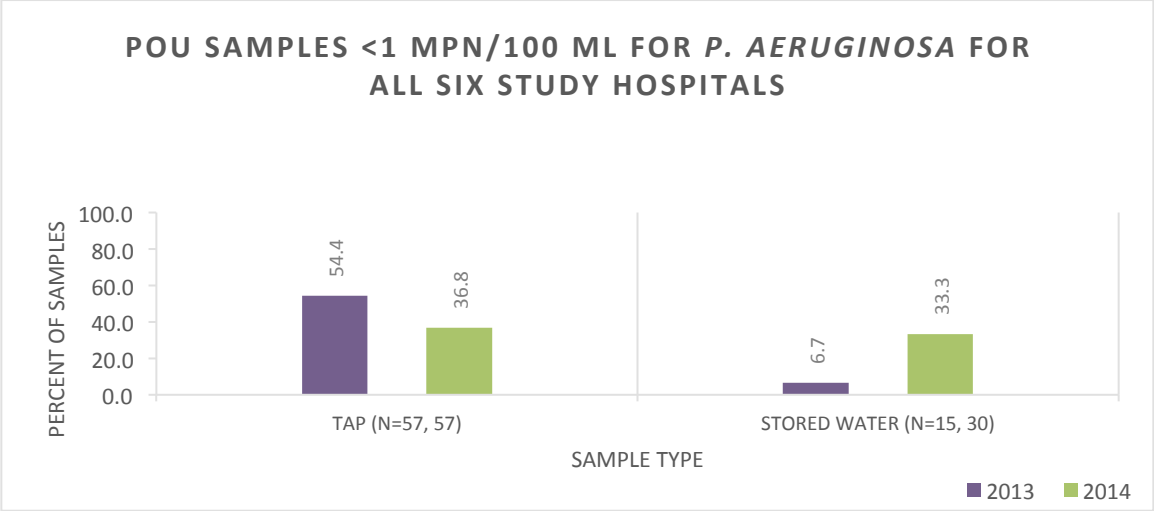


Figure 27. Percentage of tap water and stored water samples with no detectable *P. aeruginosa* (<1 MPN / 100 mL) among all hospitals in 2013 and 2014.

Improvements were seen the in overall quality of stored water in 2014, as higher proportions of samples did not contain detectable levels of indicator bacteria. However, the percentage of tap samples with detectable levels of total coliforms and *P. aeruginosa* increased in 2014.

Perceptions and Practices

Figure 28 indicates the percentage of staff from all hospitals that thought the water in the hospital was safe to drink and the percentage that drank water from taps in the hospital in 2013 and 2014. Figure 29 indicates the percentage of staff members at each hospital that believed the water from hospital taps was safe to drink by hospital, and the percentage of staff members that drank water from taps in the hospital by hospital. Overall, there was an increase in the percentage of staff sampled that reported drinking water from taps within the hospital in 2014. There was a slight increase in the percentage of staff that believed hospital water was safe to drink. In 2014, a little more than 25% of staff sampled reported drinking from the hospital taps and less than 50% of all staff members sampled believed that the water in the hospital was safe to drink. Three hospitals had increases in the percentages of staff that believed that the water was safe to drink, and

five hospitals saw increases in the number of staff sampled that reported drinking from the hospital taps. No statistically significant differences were present between percentages of staff awareness and practices between 2013 and 2014 by hospital. Overall, there was statistically significant positive difference in the proportion of people that reported drinking water from hospital taps from 2013 to 2014 (p-value: 0.0385). There was a statistically significant difference in the proportion of staff that thought hospital water was safe and those that (1) did not think hospital water was safe or (2) were unsure who reported drinking from water from hospital taps in 2013 (p-value: 0.0437) and 2014 (p-value: <0.0001). In 2014, staff that thought hospital water was safe were 5.85 (CI 2.34 – 14.60) times more likely to consume water from hospital taps than those that did not.

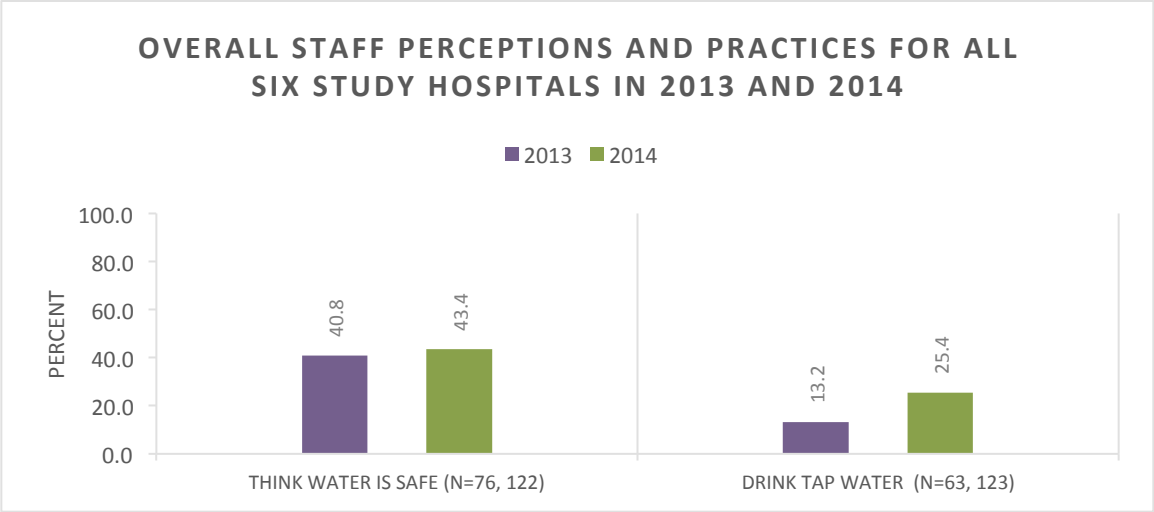
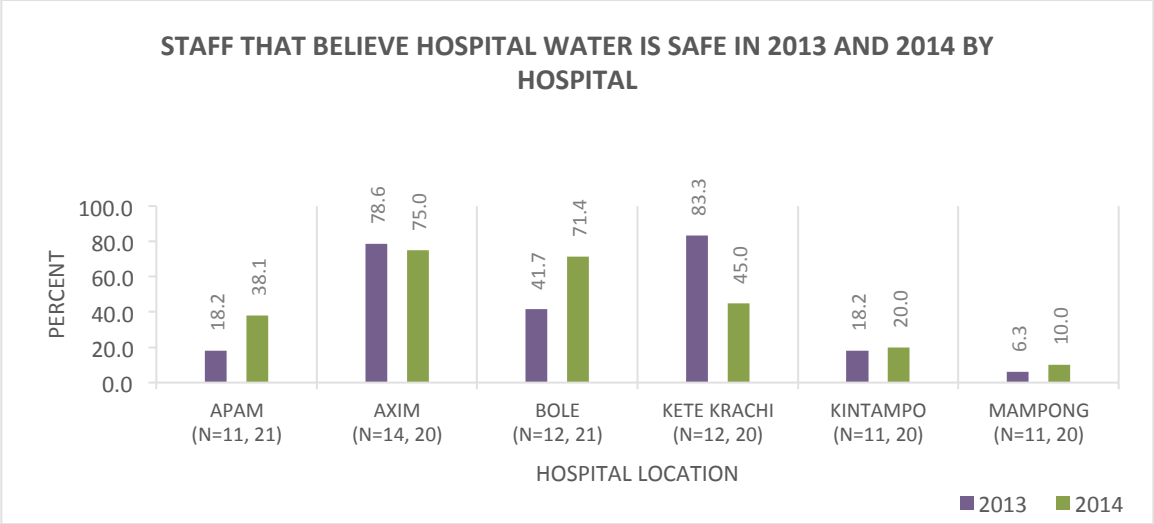


Figure 28. Percentage of staff members that think hospital water is safe to drink and percentage of staff members reporting drinking from hospital taps in all hospitals in 2013 and 2014. The x-axis denotes the hospital where data was collected and the sample sizes from 2013 followed by sample sizes from 2014. The y-axis denotes the percent of staff.



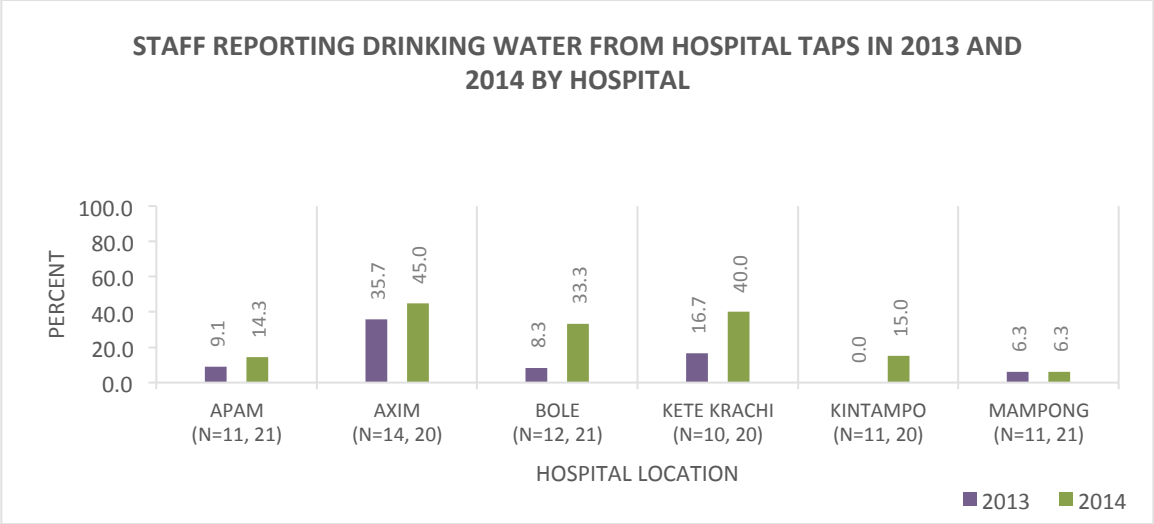


Figure 29. Percentage of staff members that think hospital water is safe to drink and percentage of staff members reporting drinking water from hospital taps by hospital in 2013 and 2014.

DISCUSSION

Overall sustainability scores differed in all hospitals from baseline in 2013 to follow-up in 2014, with two more hospitals meeting the sustainability cutoff of 2 in 2014. Sustainability scores by domain in 2014 were significantly different from scores in 2013. The largest collective increases were seen in the On-site Capacity domain for hospitals meeting the cutoff of 2 for sustainability. Lowest scores were seen in the Accountability domain among a majority of hospitals. In-depth analysis of water quality data showed trends among hospitals that met the cutoff for sustainability in 2014. These hospitals had the highest percentages of samples of tap and stored water samples that met CDC recommendations for chlorine residual. Despite this, Axim hospital had a decrease in the percentage of samples with no detectable levels of total coliforms, *E. coli*, and *P. aeruginosa* compared to 2013. However, Bole and Kete Krachi hospitals had higher percentages of tap and stored water samples with no detectable levels of total coliforms, *E. coli*, and *P. aeruginosa*. The percentage of staff members who believed that the water in the hospital was safe to drink did not significantly increase between 2013 and 2014, but there was a statistically significant increase in the percentage of hospital staff who reported that they drank water from hospital taps. Staff that believed water in the hospital was safe to drink were more likely to drink water from hospital taps in 2013 than in 2014.

Sustainability

On-site Capacity

Four of the six hospital sites (Apam, Axim, Bole, and Kete Krachi) had higher overall sustainability scores in 2014. Three of these hospitals (Axim, Bole, and Kete Krachi) met the cutoff of 2 for sustainability. The biggest differences between 2013 and 2014 in the three hospitals that met the sustainability cutoff were in the On-site Capacity domain. Each hospital received a score of at least 3 in the domain in 2014. The subdomains in this domain include: *organization and communication, training and capacity strengthening, maintenance,* and *repairs*.

Communication and organization: Structured organization and communication in the hospitals between key staff members ensured that all tasks were performed. Communication from maintenance staff to the hospital director helped ensure that problems were communicated to the highest level in the hospital.

According to WHO tools used to assess operation and management of water systems, a clear structure should be present to determine the role and responsibilities of stakeholders [63]. Often a hierarchy existed in many of the hospitals, and concerns of staff members would not always be communicated to the hospital director. Communication among laboratory staff, maintenance staff, and the hospital director aids in the exchange of information related to chlorine residual levels and general system concerns. Communication among the hospital administrator, maintenance staff, and laboratory staff ensured that tasks were performed, as the administrator often supervised the hospital staff. Hospitals that met the sustainability cutoff benefitted from organization, as roles and responsibilities were structured and delegated to ensure system operation. Scores were above 2 in this subdomain, as communication among key staff members was frequent, and most were aware of the current status of the treatment system. Bole hospital received the highest score in this subdomain, as maintenance personnel had little problem communicating with the hospital director because he was often accessible. The hospital director, administrative staff, and laboratory personnel all performed their duties thoroughly. The hospital director also included nurses and cleaning staff into the organizational structure by tasking them with ensuring that Veronica buckets were cleaned.

Training and Capacity Strengthening: Training of hospital staff is likely to ensure that tasks are performed to maintain the treatment system. Increasing capacity by training multiple people to manage and operate the system ensure that processes will be continued in the absence of key personnel. In this subdomain, Kete Krachi hospital received a score of 4, as the maintenance person had certificates in plumbing, was trained to maintain the system, and an apprentice was trained to operate the system in his absence. Axim hospital received a score of 3, as the maintenance person gained a lot of skills in his previous position with Ghana Water Company, Limited, the national municipal water supply company in Ghana. There was not an additional person available to monitor the system, and the staff person was overworked and considering leaving the hospital. Bole hospital received a score of 2, as the maintenance person was also an accountant in the hospital. He was the only person trained to maintain the system, and he had no prior training in this area. The WHO recommends that training should also be provided to owners and managers of building facilities as well in order to improve understanding of technology and increase capacity [37].

Maintenance: Regular maintenance contributes to the ongoing operation of the water treatment system. Daily, weekly, and monthly tasks were regularly completed among hospitals that met the sustainability cutoff. In these hospitals, chlorine was regularly added to the chlorine doser in the system, backwashing was performed, and the system was used regularly with no lags on weekends. Kete Krachi hospital received a score of 3.5 because all these tasks were performed, but cisterns and poly tanks were not regularly cleaned. Bole hospital received a score of 3 despite all tasks being performed because regular cleaning and operation only began a few months prior to our evaluation.

Repairs: The ability to repair the system is indicative of the long-term life of the treatment facility. Hospitals meeting the cutoff for overall sustainability were confident that they would not have trouble repairing the treatment system. Hospitals demonstrated that they were aware of how to troubleshoot the system, and with support from the GE Ambassador, many problems could be resolved. Axim hospital received a score of 4 in this subdomain, as the maintenance person indicated that any problems with the system could be fixed. He indicated that he would use his connections at Ghana Water Company, Limited to ensure that the system was functional. Kete Krachi hospital received a score of 3, as an issue with the functionality of water pump was left unresolved. The maintenance person in the hospital intended to fix the problem, which was limiting the flow of water to the treatment system, but allowed the problem to persist and did not consult other sources in a timely manner. Bole hospital received a score of 3, as they utilized a staff member from a nearby institution to assist with repairs. The hospital also frequently consulted with the GE Ambassador, and an outside source was employed to connect a borehole to the treatment system. These actions demonstrated willingness to repair the system when necessary. Research on decentralized water systems in the Philippines has shown that communities were more motivated to maintain and conduct repairs on systems over which they felt they had ownership [43]. The WHO also mentions that the frequency of repairs to treatment technology is dependent on the amount of regular corrective and preventative maintenance performed [52].

Accountability

Four of the hospital sites (Apam, Axim, Kete Krachi, and Kintampo) all had their lowest domain scores in the Accountability domain in 2014. The subdomains in this domain include: *monitoring performance, oversight by another entity, sources of funding,* and *finances*.

Monitoring and performance: Efforts to record the status of the treatment system's functionality, chlorine treatment, and other areas requiring maintenance indicates the ability of the hospital to determine if the treatment processes are working and being maintained as intended. Records of chlorine residual, cleaning of cisterns and poly tanks, bypasses of the system, broken sinks and taps, and availability of water would aid in self-audits of performance related to the provision of safe water. Kintampo hospital received a score of 0, as they had no written records used to monitor the system since 2008. Apam, Kete Krachi, and Mampong hospitals all received a score of 1 in this subdomain because they only had records of chlorine residual. Axim received a score of 2 because they also only had records for chlorine residual, but the records were duplicated and maintained by maintenance staff and the laboratory technician. Bole received a score of 3, as they had records of chlorine residual, poly tank and veronica bucket cleaning, and broken sinks and taps. Record keeping began only a few months prior to our evaluation.

Oversight by another entity: Involvement from another party engaged in the provision of safe water within hospitals would provide supervision and accountability. Communication with the GE Ambassador or Assist International indicates that the status of the treatment system was regularly shared with organizations that can provide technical support. Kintampo received the lowest score of 0.5, as there was no external oversight or biosafety committee in the hospital. However, there was a relationship with the GE Ambassador, and he made visits to Kintampo during the past year. The hospital is also dependent on support from GEF. Axim, Bole, and Kete Krachi all received a score of 1 because there is no external oversight. All three hospitals have biosafety committees, but the committee in Kete Krachi is the only one that discusses safe water. These hospitals also receive visits from the GE ambassador, and they indicated that they are dependent on his support. Apam and Mampong hospitals received scores of 1.5. Both hospitals received the most frequent visits from the GE Ambassador, but the hospitals lack oversight from an external source. Both

hospitals had a biosafety committee, but safe water was only discussed in Mampong. National accountability is limited, as hospitals in Ghana lack government oversight in the provision of safe water within the facilities. In contrast, Sierra Leone has a monitoring system that uses "facility improvement investment teams". These teams travel to all health centers quarterly or every six months to assess the status of seven criteria, and scores on these criteria are used to determine necessary improvements [6].

Source of funding: Funding sources that can be used to maintain the system indicate the ability of the hospital to fund system expenses without assistance from external sources. Kintampo hospital received a score of 0 because the hospital is in severe debt from high water expenses from the local municipal source. The hospital is not able to fund any system expenses. Apam and Mampong received a score of 1, as both of the hospitals had difficulty purchasing chlorine for the system. Both hospitals can fund small system expenses, but they have difficulty funding large expenses. Bole and Kete Krachi hospitals both received a score of 3 in this subdomain, as they demonstrated that they were able to fund all system expenses with money from hospital resources. Specifically, Kete Krachi hospital has a pharmacy on site that was able to fund most system expenses. Government hospitals receive financial allocations at the beginning of the fiscal year, but it may be difficult to incorporate additional line items related to operation and management. Money is often spent without conducting effective budgeting [63].

Finances: Records of finances related to upkeep of the system indicate the ability to fund recurring or emergency expenses. Kintampo hospital received a score of 0 because there were no records of expenses related to the system. The hospital would also not be able to pay recurring system expenses. Apam hospital received a score of 1, as the financial records were not up-to-date, and expenses associated with the system were not budgeted. The hospital could fund some system expenses, but funds were not available for all expenses. Mampong hospital received a score of 2, as the current budget included expenses for the system. Expenses that were not specifically budgeted for were not always funded. Axim and Kete Krachi hospitals received a score of 3, as the financial records were up to date, and while they were not included in the budget, invoices were provided for expenses associated with the system, demonstrating that the hospital was able to pay for recurring expenses in most cases. Bole received a score of 4, as the financial records were up to date

and recurring expenses for the system were included. The hospital demonstrated that funds were sufficient to pay for all system expenses by purchasing chlorine for the system and paying an independent contractor to connect a borehole to the treatment system. Independently financing system expenses due to proper budgeting and generation of internal funds indicate that the hospitals have the means to support system sustainability without the GEF. Without the means to independently finance system expenses, a loss of funding from external sources could eventually result in the end of system operation [64].

Engagement of the Hospital Director

The largest collective decrease in subdomains occurred in *engagement of hospital director and staff*. Hospitals that did not meet the sustainability cutoff had a decrease of 1 point in this subdomain. In 2013, Apam, Kintampo, and Mampong hospitals all scored a 3 in the subdomain, but these scores decreased to 2 in 2014. Overall, there was a decrease in commitment from hospital directors to ensure the provision of safe water using the hospital's treatment system. Other key staff, like administrators, estate managers, and maintenance staff, demonstrated their commitment in each hospital, but their efforts were limited by director disengagement. Director engagement at Kintampo hospital was low, as the director was preparing to be transferred to another hospital. His involvement declined as a result. The director at Mampong hospital stated his preference for municipal supply over the treatment system, indicating that he would like the hospital to be connected to a municipal source in the future. Maintaining the treatment facility appeared burdensome for the director, and almost all oversight of operation and maintenance was performed by the hospital administrator and a committed nurse.

Water Quality

Water quality results varied by hospital, but areas of opportunity for improvements to the water piped network were identified based on the type of microbial contamination present and the location of sample collection. Comparisons between 2013 and 2014 data also help to identify changes that may have occurred in the water network between the two years.

Total coliform contamination was detected in raw water in both years for all hospitals sampled, except Axim in 2013. Filtered samples in 2014 had more total coliforms than filtered samples in 2013. While

all hospitals, except Kete Krachi, had total coliforms in tap samples in 2014, higher percentages of tap samples in 2014 had no detectable levels of total coliforms. Tests for total coliforms are used to assess the effectiveness of the water treatment process [17]. Total coliforms were detected in raw water sources, but the concentrations should decrease after treatment. The detection of total coliforms in filtered water samples in Apam and Kete Krachi hospitals in 2014 may indicate a potential issue with integrity of the membrane filters. Total coliforms were not detected in filtered samples in these hospitals in 2013, and this many indicate that the functionality of the membrane filters had declined. The detection of total coliforms in water from hospital taps, sometimes at high concentrations, may indicate problems with the post-treatment water storage in poly tanks, the piped network, or chlorination process. All hospitals, except Kintampo and Mampong, had tap samples within the recommended chlorine residual range of 0.2 and 2.0 mg/L, but the highest percentage of tap samples within this range was 53.9% (Axim hospital). Total coliforms may be present in biofilm in hospital pipes and poly tanks. Biofilm is dead organic or inorganic material that accumulates on a surface. Biofilms in piped water systems can cause a reduction of chlorine residual in water at the POU [65]. Hospitals with intermittent water flow are more likely to have total coliforms in POU samples, as water is not flowing consistently through the pipes. When water is released from poly tanks, the initial water flow could cause biofilm to dislodge. Studies have shown that this can occur even when chlorine residual levels were between an average of 2.0 and 2.5 mg/L [65]. This may explain the higher percentage of samples with detectable total coliforms in Axim hospital in 2014.

E. coli contamination was detected in raw water in many of the study hospitals in 2013 and 2014. Axim hospital was the only hospital that had no *E. coli* detected in the raw water in both years. No *E. coli* contamination was detected in any samples of filtered water in 2013. Apam hospital was the only hospital to have *E. coli* contamination in filtered samples in 2014, indicating potential issues with integrity of the membrane filters. Apam, Axim, and Kintampo hospitals had tap samples with *E. coli* in 2014, and four of the hospitals had higher percentages of tap samples with no detectable *E. coli*

The presence of *E. coli* indicates fecal contamination and can be an indicator of pathogens in the water. *E. coli* in raw water may indicate fecal contamination of the source water [17]. The detection of *E. coli*

in tap water samples could also be due to biofilm in pipes or post-treatment storage in poly tanks before being piped to the hospital [17]. Sewage near the hospital's piped network could also be a potential issue, as intrusions in the pipes could lead to contamination. Residual chlorine can kill *E. coli* within one minute if recommended concentrations are maintained [66]. Among the hospitals with detectable levels of *E. coli* in tap samples, hospitals with the highest percentages of tap samples within the chlorine residual range of 0.2 and 2.0 mg/L presented the lowest percentage of samples with *E. coli* contamination.

P. aeruginosa contamination was detected in all raw water samples in 2013 and 2014 with the exception of Axim hospital in 2013. *P. aeruginosa* contamination was found in all filtered samples except Mampong hospital in 2014. *P. aeruginosa* was also detected in all tap samples in 2013 and 2014. *P. aeruginosa* is an opportunistic pathogen [17]. Detection of higher levels of *P. aeruginosa* in filtered water samples could be due to poor integrity of the membrane filters. Water is piped from each filter to the sampling site via a small hose, and the hose may also have biofilm containing *P. aeruginosa*. Because *P. aeruginosa* can also be found in biofilm, hospital pipes are another possible reason for its detection in tap water samples. *P. aeruginosa* is relatively resistant to chlorine disinfection, which may explain the detection of *P. aeruginosa* in tap water samples in every hospital [67]. High concentrations of *P. aeruginosa* found in stored and tap water samples in study hospitals could pose a risk to immune-compromised patients [17].

Stored water samples

Water classified as "stored water" in this study was the furthest removed from the water treatment process. All hospitals had water storage containers with detectable levels of total coliforms, *E. coli*, and *P. aeruginosa* except Bole. More samples tested in 2014 contained no detectable levels of microbial contamination, as all of the samples collected in 2013 contained at least some level of microbial contamination except for samples collected in Mampong hospital. In 2013, tap samples were more likely to have undetectable levels of contamination compared to stored water samples. In 2014, there was no statistical difference between the percentage of samples of tap water and stored water with no detectable microbial contamination.

Stored water was covered with a lid, and a spout was located at the bottom of the bucket to prevent recontamination, but the detection of different organisms in stored water can indicate different exposure pathways. Hands can contaminate stored water if there is contact with the water or the inside of the container. Biofilm can also accumulate in water storage containers that contain water that has not been changed. This can also occur if the buckets have not been cleaned [68]. A study conducted in Accra, Ghana detected total coliforms in 30% of water samples from poly tanks on hospital grounds. Samples from poly tanks that were recently cleaned contained lower concentrations of total coliforms and *E. coli* compared to samples from other poly tanks [39]. Total coliforms and *E. coli* can be introduced into stored water by contaminated hands. When *E. coli* is detected in samples of stored water but not in samples of tap water, as in the cases of Kete Krachi and Mampong hospitals, it may indicate poor handwashing behavior after bathroom use. Fomites could contaminate hands with total coliforms and *P. aeruginosa*. According to a study conducted in an intensive care unit in Germany, *P. aeruginosa* was found to contaminate hands after handwashing at hospital taps [69]. Without careful distribution of water into storage containers and scrubbing to remove biofilm, microbial contamination could persist.

In Bole District Hospital, measures were put in place to ensure weekly cleaning of stored water containers. After containers were cleaned using powdered laundry soap, the date of cleaning and the date of the next cleaning were placed on the container. None of the samples from any of the containers sampled in Bole in 2014 contained detectable levels of total coliforms, *E. coli*, or *P. aeruginosa* contamination.

Perceptions and Practices

The percentage of staff members who reported that they thought the hospital water was safe to drink remained relatively unchanged between 2013 and 2014, while the percent of staff members who reported that they drank the hospital water increased. Hospitals that met the cutoff for sustainability in 2014 had higher percentages of: (1) staff that thought water in the hospital was safe to drink, and (2) staff that drank water from hospital taps. Staff that believed the hospital water was safe to drink were more likely to report that they consumed water from hospital taps. Staff in these hospitals may have perceived a difference in water quality in 2013 from 2014 prompting them to drink the water, although the percentage of staff that reported that

they believed the hospital water was safe to drink decreased in Axim and Kete Krachi hospitals. Smell and taste may have influenced water consumption habits, as the hospitals that met the sustainability cutoff also had the highest percentages of samples with chlorine residual within the recommended range of 0.2 and 2.0 mg/L.

Perceptions of safety of hospital water may have been affected by perceptions of safety of all tap water sources in Ghana. A majority of participants reported that they utilized bottled and / or sachet water as their primary drinking water source. In a few instances, study participants reported that tap water would only be consumed when money was not available or when one was far away from their preferred water source. Some patients who believed that the hospital water was safe to drink indicated that they believed this because "It is a hospital." This suggests that there is an expectation for a health care facility to have better water quality than other places.

According to a study on health worker retention in Pacific and Asian countries, poor working conditions and weak support and supervision are factors contributing to the shortage of health care professionals [70]. A study in Ghana indicated that health workers would be motivated if their superiors listened to their concerns and allowed them to participate in decision-making [71]. Hospitals may be more motivated to ensure the provision of safe water if they are aware that the staff are consuming water within the hospital. Awareness of this practice may increase the value of safe water within the hospital. As a result, commitment of hospital administration to improve conditions within the hospital may contribute to staff retention.

Strengths and Weaknesses of the Sustainability Tool

The sustainability tool utilized in this study was pilot tested and revised to fit the context of hospitals in Ghana. The development of the tool was well supported by relevant research on water treatment system sustainability. The tool collected a wide range of data on various sustainability determinants. Methods used to inform sustainability scores were systematic, and included KAP surveys, in-depth interviews, water quality testing, and observations to present a well-rounded picture of the current status at each hospital. The

sustainability metric was well-defined, as criteria for each subdomain were provided to aid in the selection of the correct score.

While the sustainability tool considers a variety of factors related to the provision of safe water in the hospital, it may not fully capture the multitude of scenarios and circumstances that may occur at a hospital. The sustainability tool measures many of the important factors in typical scenarios in hospital facilities. However, the tool may failed to capture other relevant factors that affect sustainability within hospitals. In practice, the tool collects data from relatively small numbers of health care staff and patients per hospital to inform sustainability scores. It would be preferable for KAP data to be collected from a larger sample of the staff, patient and visitor populations in the hospitals. It would also be useful to collect information on water preferences and practices outside of the hospital from hospital staff and patients to compare to their preferences and practices when they are at the hospital. Responses may have been influenced by perceptions and practices not specific to hospital settings.

Strengths of the Study

In addition to the utilization of a systematic evaluation tool, there were several study strengths. The study utilized mixed methods, allowing for diversity in the data collected. Water quality testing was performed in the study, allowing for assessments of microbiological water quality. The study also was able to obtain information from stakeholders and beneficiaries within the hospitals. Using surveys and in-depth interviews, we were able to learn the concerns and motivations of hospital directors, maintenance staff, and patients order to gain an array of perspectives on sustainability determinants. In addition, the data was collected at two different time points, allowing for comparisons between assessments.

Limitations

Water samples collected in the hospital were only collected during a few days during the summer months of June-August for the 2013 and 2014 studies, and do not capture possible seasonal variations in water quality that may be observed if sampling occurred throughout the year. Maintenance staff and hospital administration were also made aware of our visits, as they were always planned. This may have affected the status of the treatment system upon our arrival. Study participants were not selected in a random manner, and

sample sizes were small among staff, patients and visitors. Surveys were always administered in the daytime, and night shift personnel and patients and visitors arriving at night were not represented in our samples. In addition, participants were only surveyed once during summer months, and perceptions of water safety and drinking practices could change depending on seasonality. A more representative sample of staff members, patients and visitors surveyed at several points throughout the year would be required to truly assess perceptions about water safety and awareness of the water treatment system within the hospital. Water quality results were only limited to a few samples of raw and filtered water, and therefore do not represent the variability that may occur in the water source during the year or throughout the hospital.

Areas of Consideration for Future Studies

- Currently, no national regulatory authority is in place to monitor water quality within hospitals in Ghana [6]. Data on water quality within health care facilities will become critical with the adoption of the Post-2015 water and sanitation goals. Currently, the drinking water ladder is used as a proxy to determine water quality, but this is a weak proxy for certain types of contamination and may not be appropriate for the many different uses of water in health care facilities. The impact of water quality on HCAI should be assessed in low- and middle-income settings.
- In-depth research on perceptions of water quality in health care facilities compared to perceptions of home water quality should be conducted. This may aid in better understanding health-seeking behaviors that are related to perceived water safety in health care facilities.
- Many of the hospitals included in our study had difficulty financing the water treatment system expenses. A resource planning analysis conducted in The Democratic Republic of Congo examined the cost of essential surgical services relative to overall budget costs. The study results showed that surgical needs alone (including water) could comprise up to 24% of the total hospital budget [72]. Similar studies should be conducted in Ghanaian hospitals to better understand competing cost priorities that may hinder infrastructure funding.

RECOMMENDATIONS

The following recommendations are provided for the benefit of the national government of Ghana and Ghanaian hospitals included in this study to improve the provision of safe water.

Recommendations for the National Government of Ghana to Improve the Provision of Safe Water in Health Care Facilities

- Currently, Veronica buckets are a requirement in Ghanaian hospitals as an indicator of preparedness during times of water shortages. This requirement must be accompanied by standards for maintenance of Veronica buckets. Standards should include: (1) how often water in buckets should be changed, (2) how often buckets should be cleaned, (3) what materials should be used to clean buckets, (4) methods for refilling buckets to limit recontamination, and (5) water treatment options if water is too scarce to change frequently.
- The development of standards for water quality within health care facilities at a national level and a monitoring and enforcement program would provide a regulatory framework for facilities that are responsible for providing safe water to patients. Municipal water utilities should undergo an approval process for use within hospitals, as there are variations in treatment and quality among different water companies. Multiple government organizations, including the Ministry of Health, Ministry of Water Resources, Works, and Housing, and Ghana Health Service, should be engaged in this effort.
- Monitoring of water quality should be conducted at a regional level, with hospitals periodically reporting results to regulatory boards.

Recommendations for Study Hospitals to Improve Provision of Safe Water

- Future treatment systems should be equipped with a sampling port to monitor filtered and chlorinated water as it leaves the system. This will assist in diagnosing potential problems with the water treatment system and targeting specific interventions to improve water quality within hospital structures.
- Chlorine residual levels measured in 2014 should be utilized to determine the amount of chlorine necessary to treat the water before it enters hospital pipes. Enough chlorine residual should be

present to offset a decrease in levels due to chlorine demand from organic matter in biofilm that may exist in hospital pipes. Chlorine testing in the first and last taps in the piped network should be performed to ensure that chlorine levels are not too high or too low at both points, respectively.

- Chlorine should be used to clean water storage containers. Chlorine will eliminate total coliforms and *E. coli* present. Cleaning with ethanol should also be considered. A concentration of 30 – 100% kills *P. aeruginosa* within 10 seconds [73]. Testing should be conducted to determine how plastic containers would withstand constant cleaning with the chemical. Ethanol may also be costly for the hospitals in our study. Bole District Hospital's weekly cleaning schedule should be adopted by all hospitals since this seemed to be successful in maintaining good water quality in the storage containers.
- Staff members should be included in decision-making regarding water system updates and improvements. Advise staff members of chlorine shortages and bypasses of the system. This will aid in increasing morale among the staff members by including them in hospital affairs, and staff can inform patients of the current water quality in the hospital.

CONCLUSIONS

This study was conducted to assess the sustainability of decentralized water treatment systems donated by the General Electric Foundation to six Ghanaian hospitals from baseline data collection in 2013 to follow-up in 2014. Results showed that the water treatment systems in only three of the six hospitals were deemed as being sustainable in 2014. Several factors, as systematically evaluated by a sustainability metric, hinder the provision of safe water in the hospitals studied. Results showed gaps in accountability and oversight in nearly all the facilities in both 2013 and 2014. Communication among stakeholders is crucial for ensuring that optimal resources, support, and engagement are in place to improve the provision of safe water in health care facilities in Ghana.

As national governments move to address the water availability and quality in health care facilities in low- and middle-income countries, decentralized water filtration systems may be an option to consider because they can provide treatment to alternative water sources and make them microbiologically safe. There is a need for government capacity to evaluate internal and external factors that may affect system sustainability over time, and specialized assessment tools, like the sustainability metric utilized in this study, can assist with these evaluations. Results from 2013 and 2014 have shown that there is a need for updates to water infrastructure. New investments must be made to existing systems to ensure better water quality, and a review of current water storages practices must be performed.

The recommendations provided by this study will aid in improving stakeholder communication and oversight through the development of monitoring efforts. This will give government organizations the opportunity to become familiar with unique challenges at hospital sites across the county. Many of the hospitals in this study were government or district facilities, and they require additional technical and financial support for the sustainable provision of safe water. The challenges appear vast, as there has been limited focus on the provision of safe water in health care settings, but the importance of safe water for health care delivery is paramount. Drinking water access has increased in households since the introduction of the Millennium Development Goals in 1990. Knowledge gained from ongoing efforts to improve water access for households, and for other institutions like schools, can be harnessed to ensure that health care facilities are able to improve water availability and quality and minimize risks posed by limited water provision.

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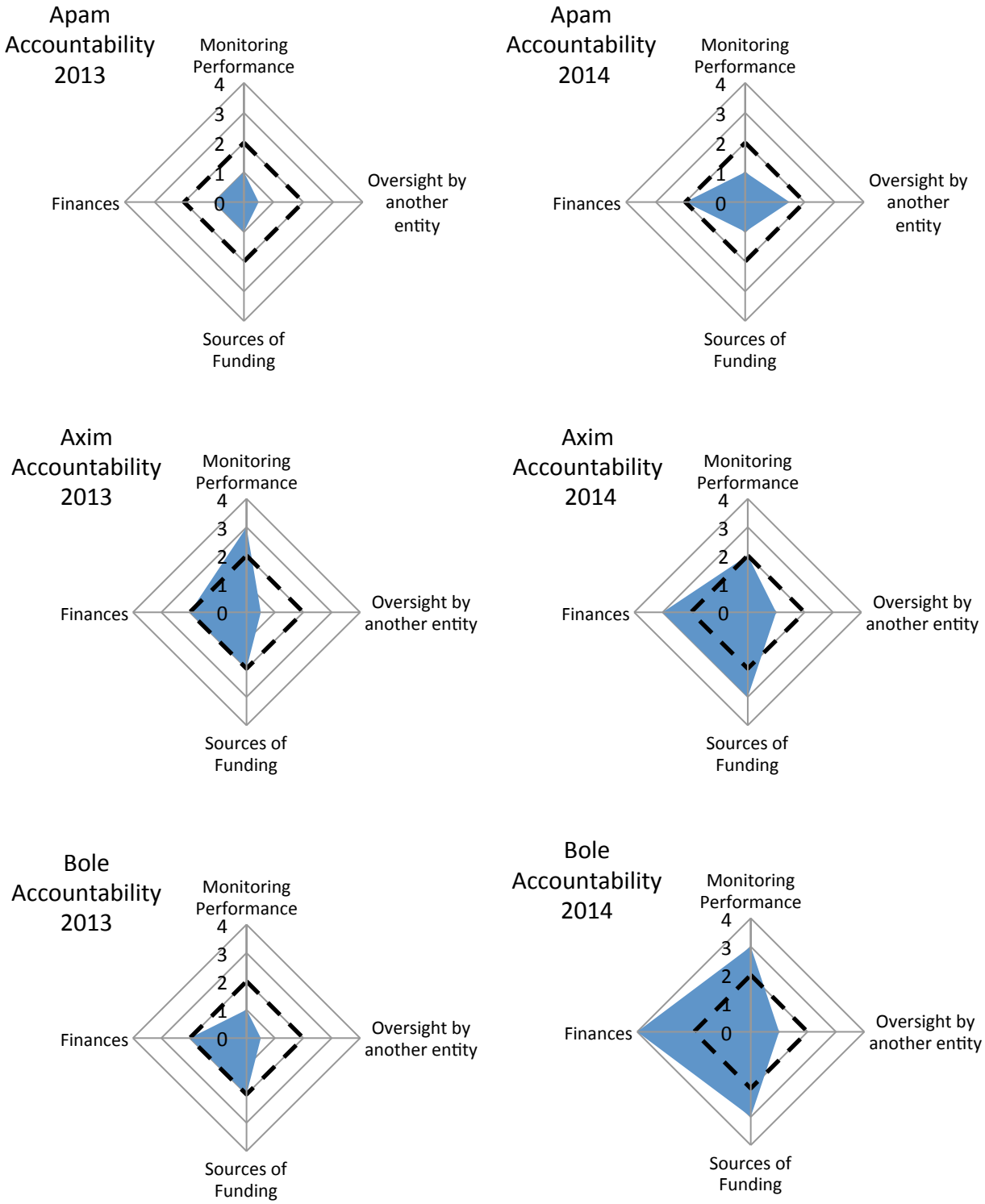
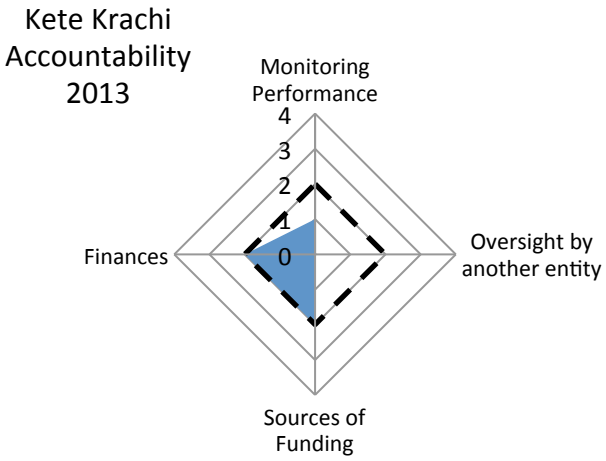
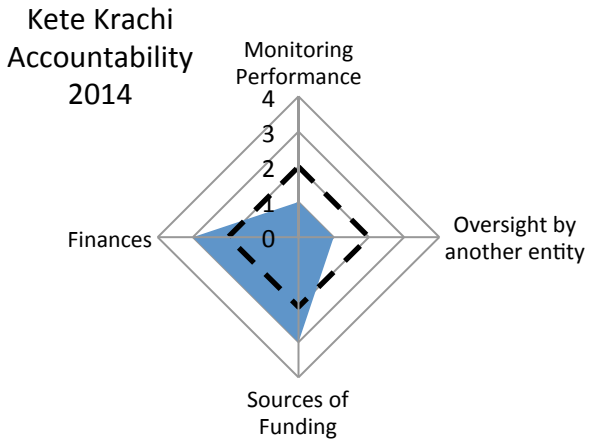
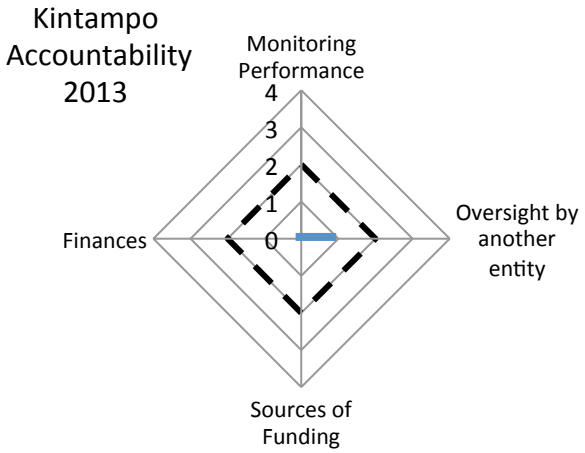
ADDITIONAL FIGURES

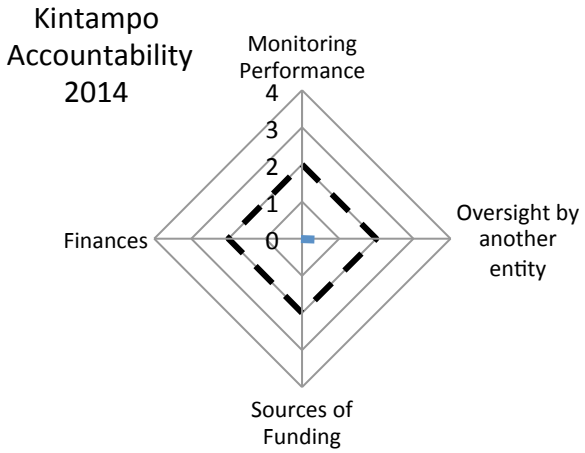
Figure 6. Sustainability Score Radar Plots for Accountability domain.

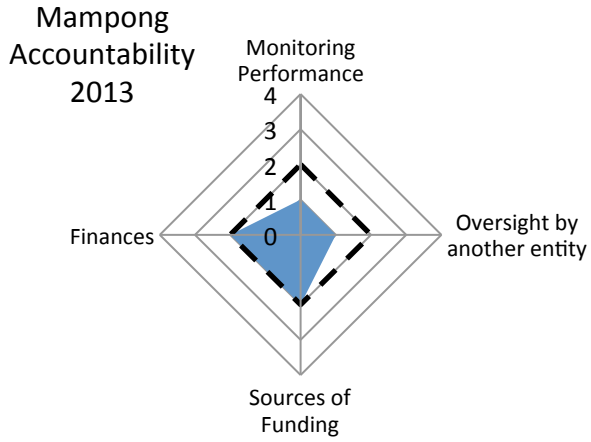



Kete Krachi Accountability 2013
Monitoring Performance
Oversight by another entity
Sources of Funding
Finances
4
3
2
1
0


Kete Krachi Accountability 2014
Monitoring Performance
Oversight by another entity
Sources of Funding
Finances
4
3
2
1
0


Kintampo Accountability 2013
Monitoring Performance
Oversight by another entity
Sources of Funding
Finances
4
3
2
1
0


Kintampo Accountability 2014
Monitoring Performance
Oversight by another entity
Sources of Funding
Finances
4
3
2
1
0


Mampong Accountability 2013
Monitoring Performance
Oversight by another entity
Sources of Funding
Finances
4
3
2
1
0

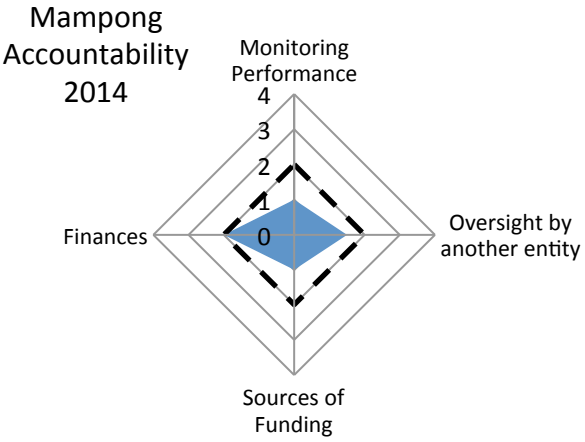
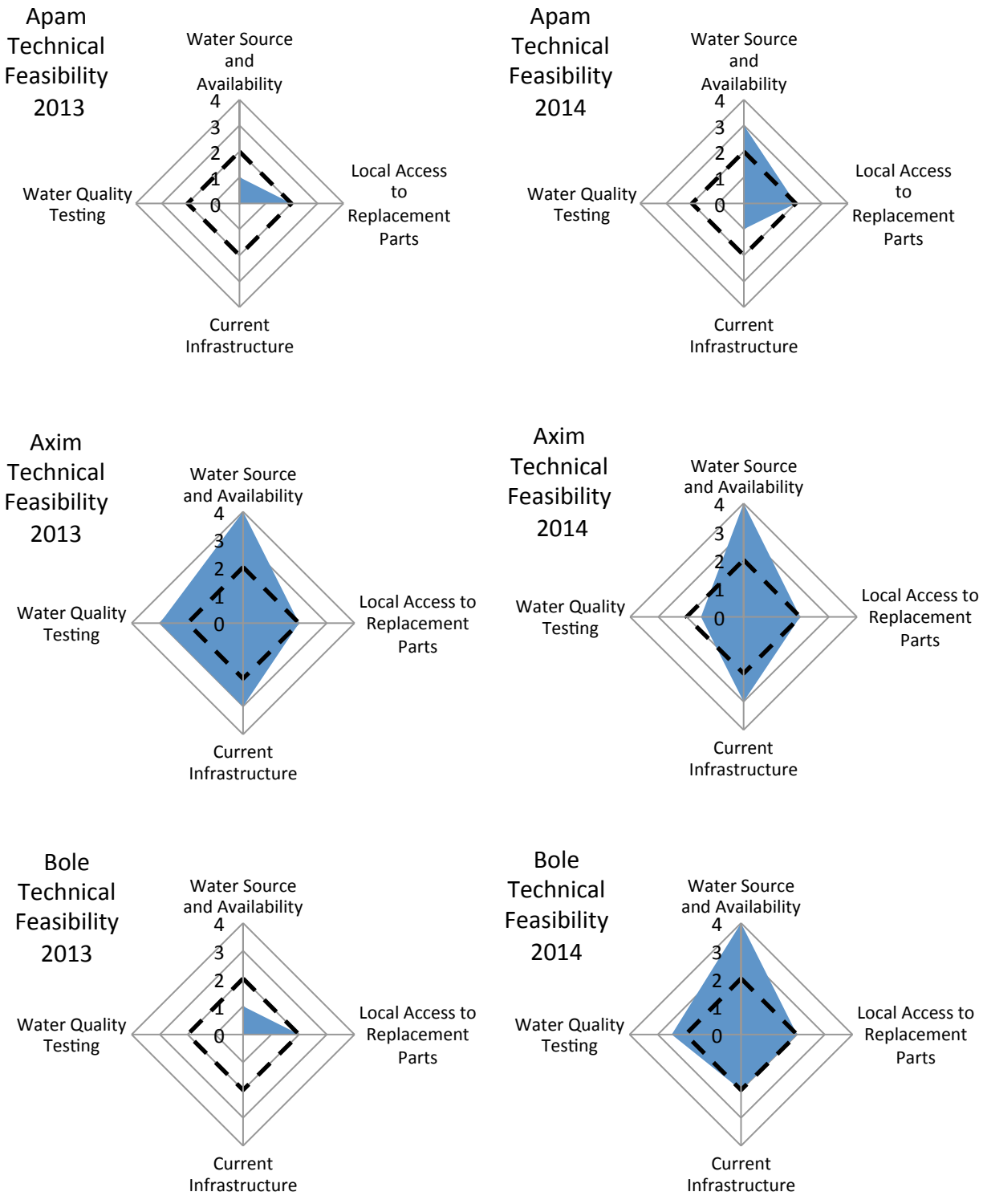

Mampong Accountability 2014
Monitoring Performance
Oversight by another entity
Sources of Funding
Finances
4
3
2
1
0

Figure 7. Sustainability Score Radar Plots for Technical Feasibility domain.



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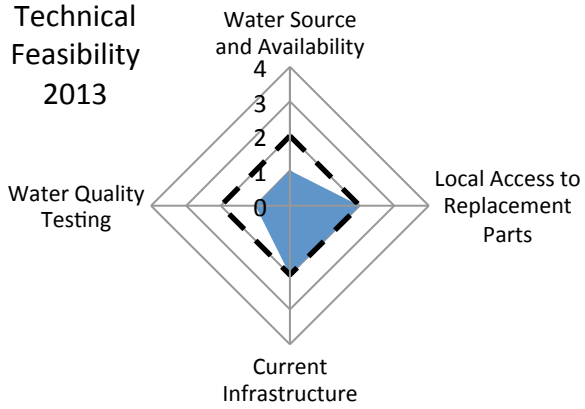

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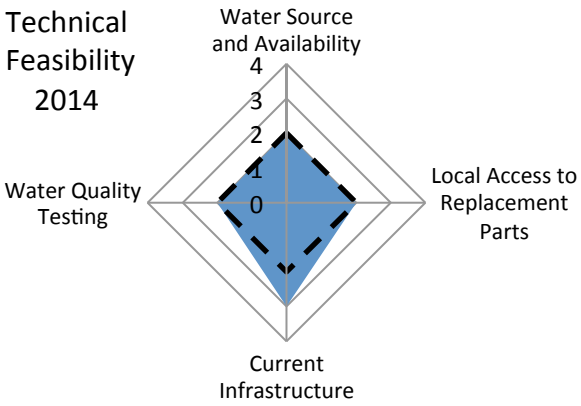

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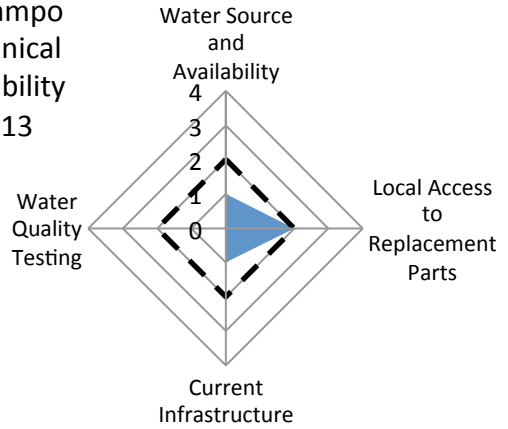

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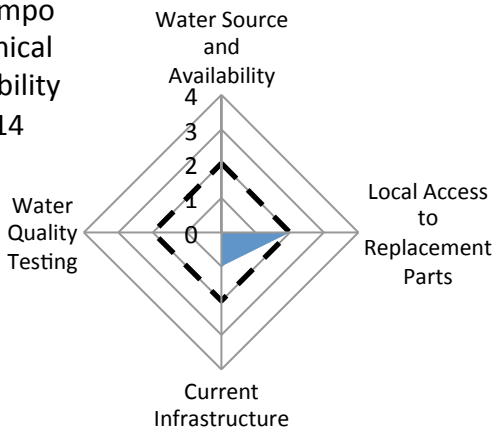

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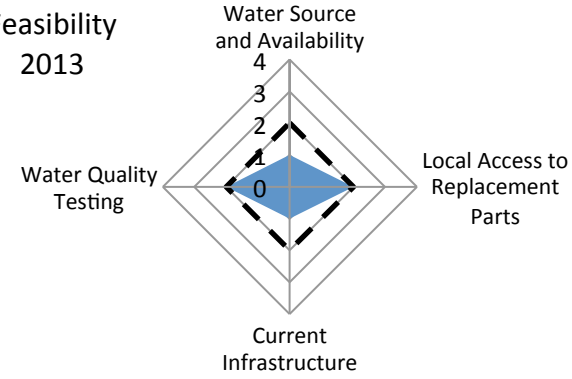


Mampong Technical Feasibility 2014

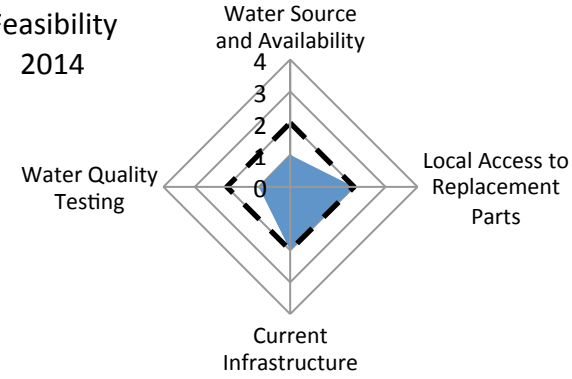
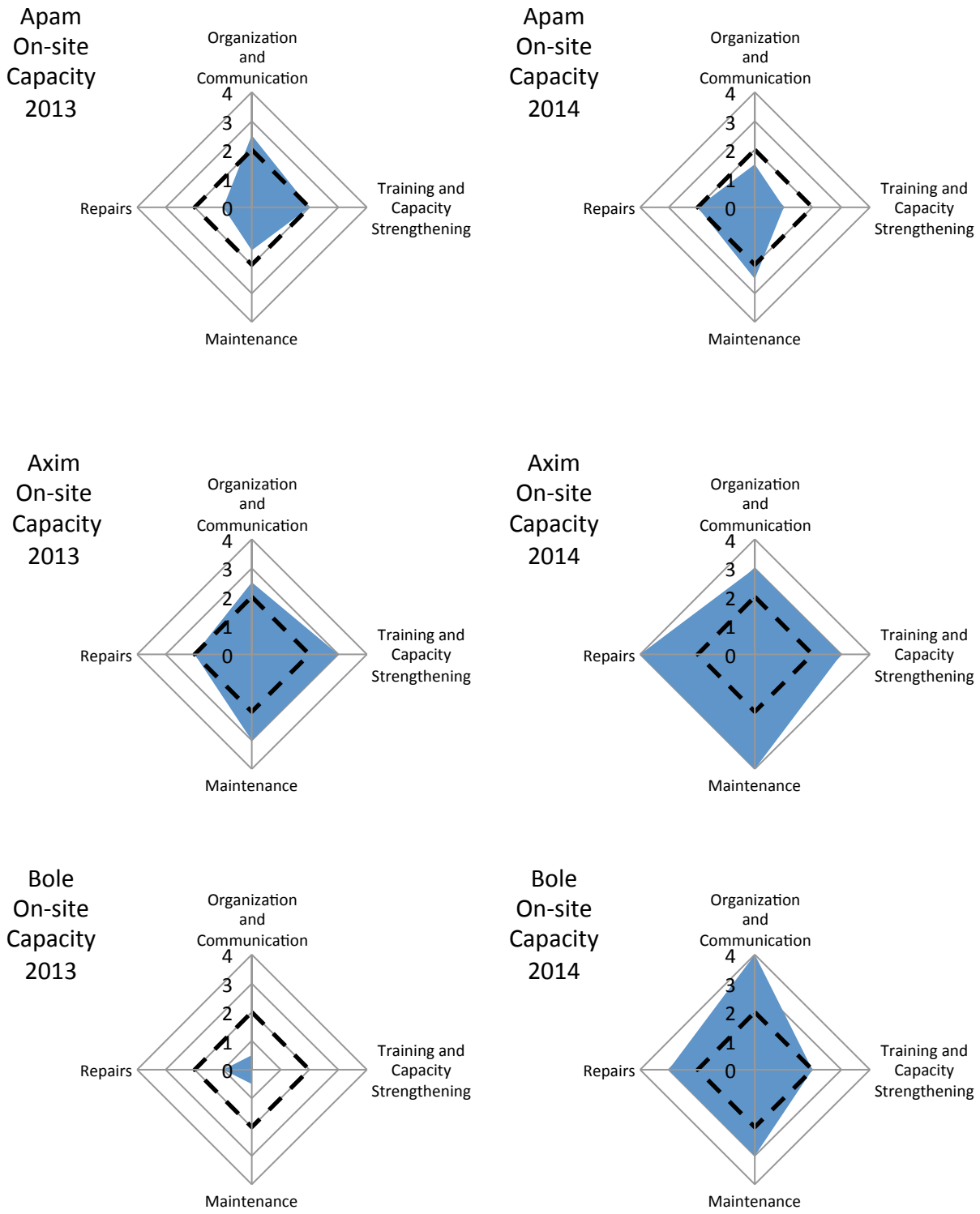
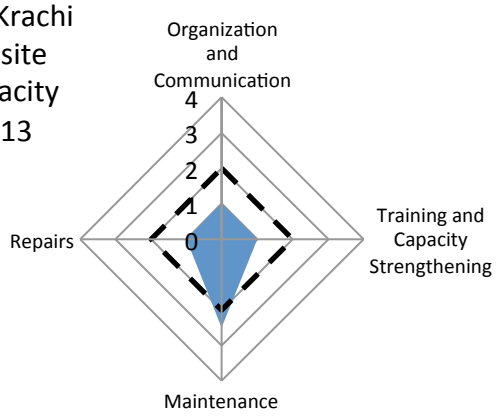


Figure 8. Sustainability Score Radar Plots for On-site Capacity domain.



Kete Krachi On-site Capacity 2013



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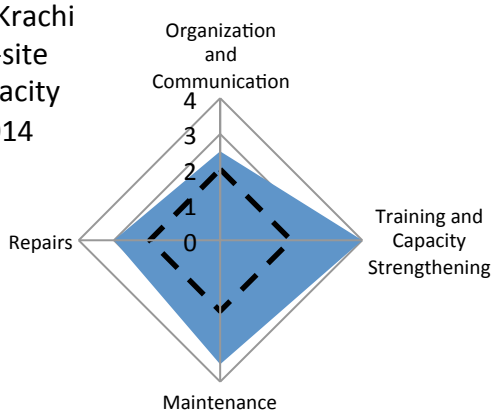

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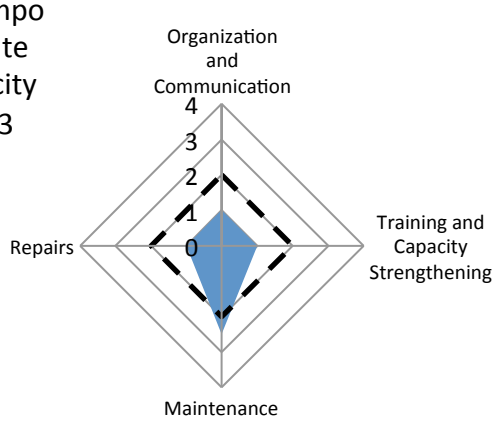

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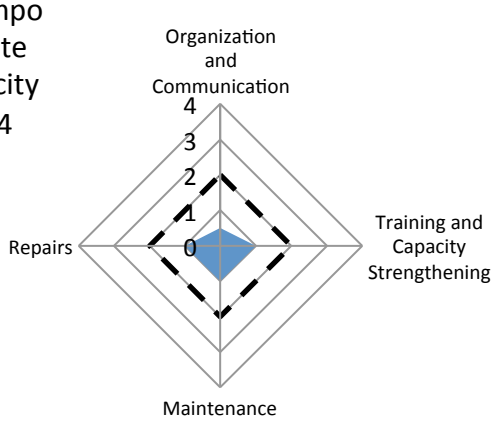

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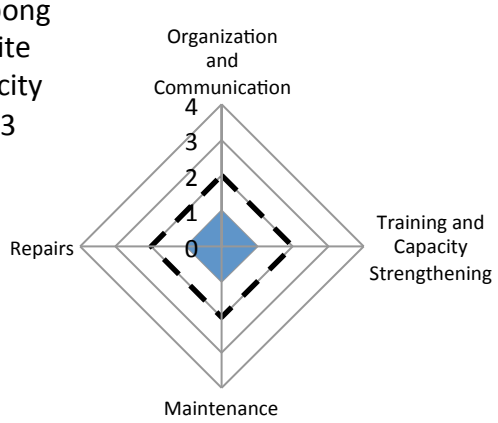


Mampong On-site Capacity 2014

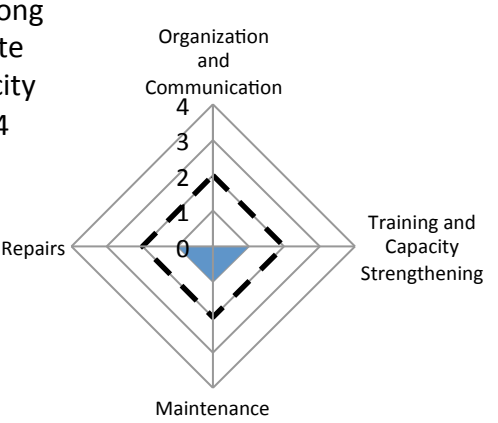
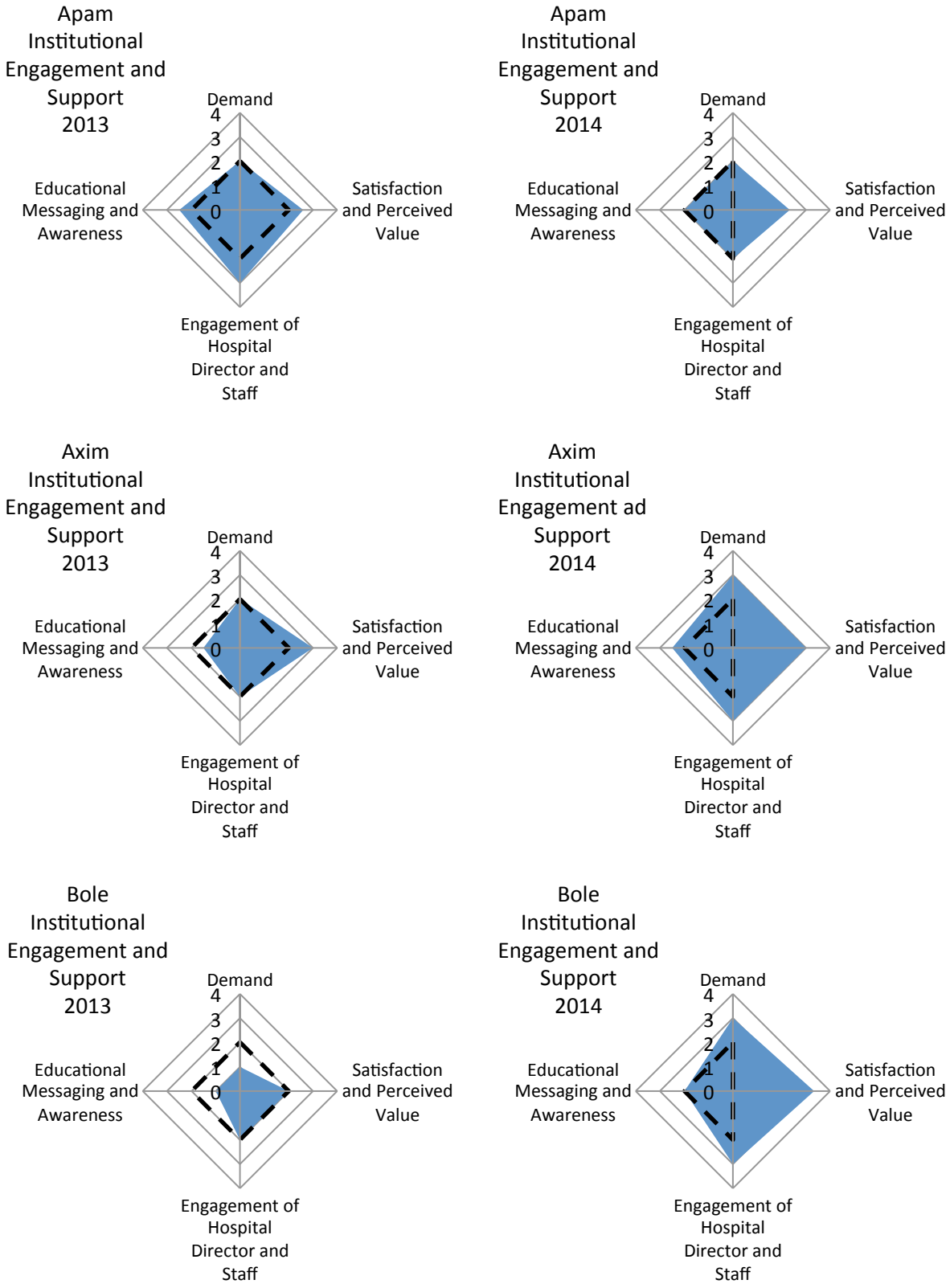
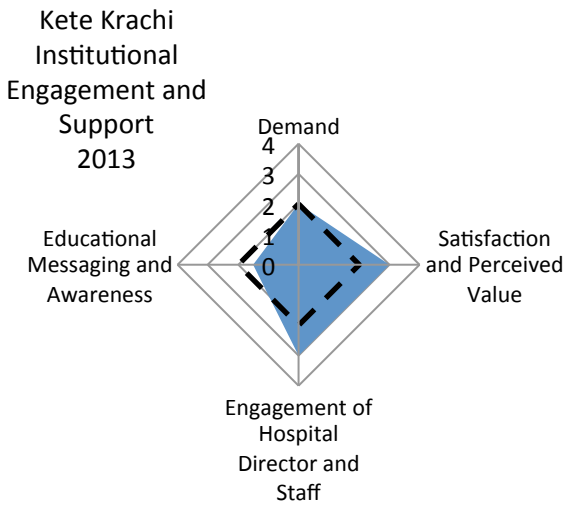
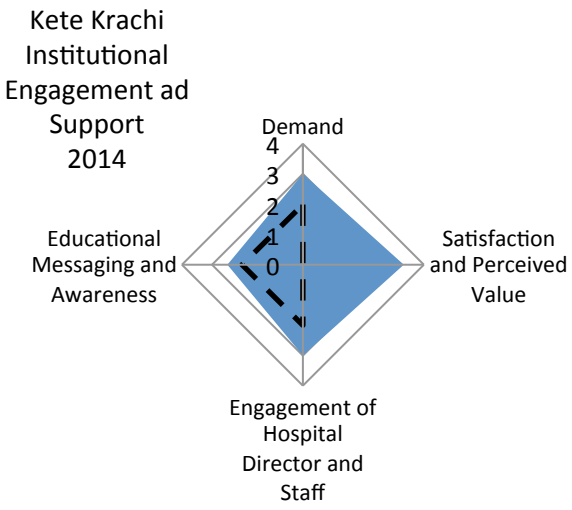
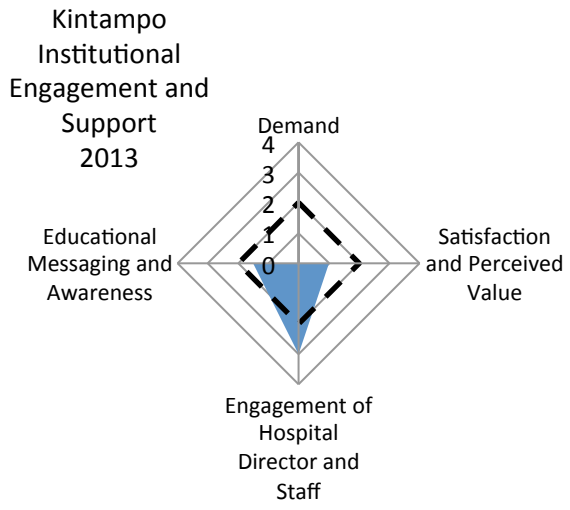


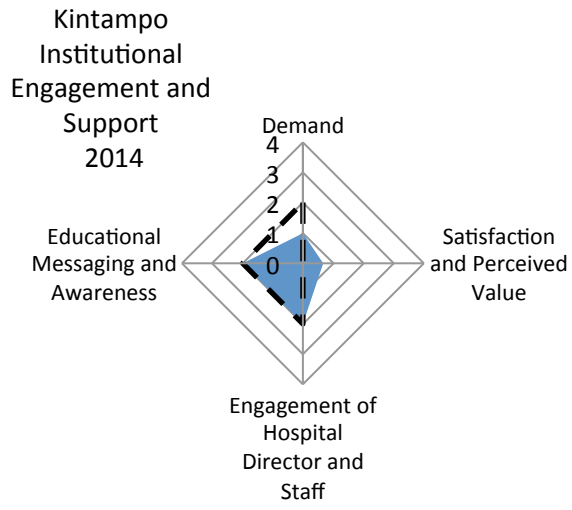
Figure 9. Sustainability Score Radar Plots for Institutional Engagement and Support domain.

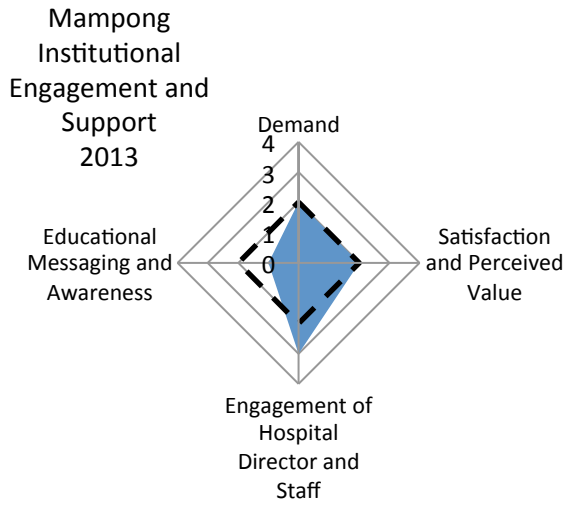



Kete Krachi Institutional Engagement and Support 2013
Demand
4
3
2
1
0
Satisfaction and Perceived Value
Engagement of Hospital Director and Staff
Educational Messaging and Awareness


Kete Krachi Institutional Engagement ad Support 2014
Demand
4
3
2
1
0
Satisfaction and Perceived Value
Engagement of Hospital Director and Staff
Educational Messaging and Awareness


Kintampo Institutional Engagement and Support 2013
Demand
4
3
2
1
0
Satisfaction and Perceived Value
Engagement of Hospital Director and Staff
Educational Messaging and Awareness


Kintampo Institutional Engagement and Support 2014
Demand
4
3
2
1
0
Satisfaction and Perceived Value
Engagement of Hospital Director and Staff
Educational Messaging and Awareness


Mampong Institutional Engagement and Support 2013
Demand
4
3
2
1
0
Satisfaction and Perceived Value
Engagement of Hospital Director and Staff
Educational Messaging and Awareness

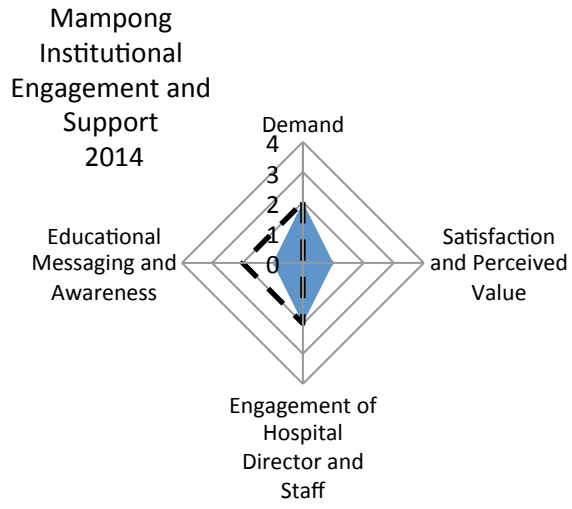
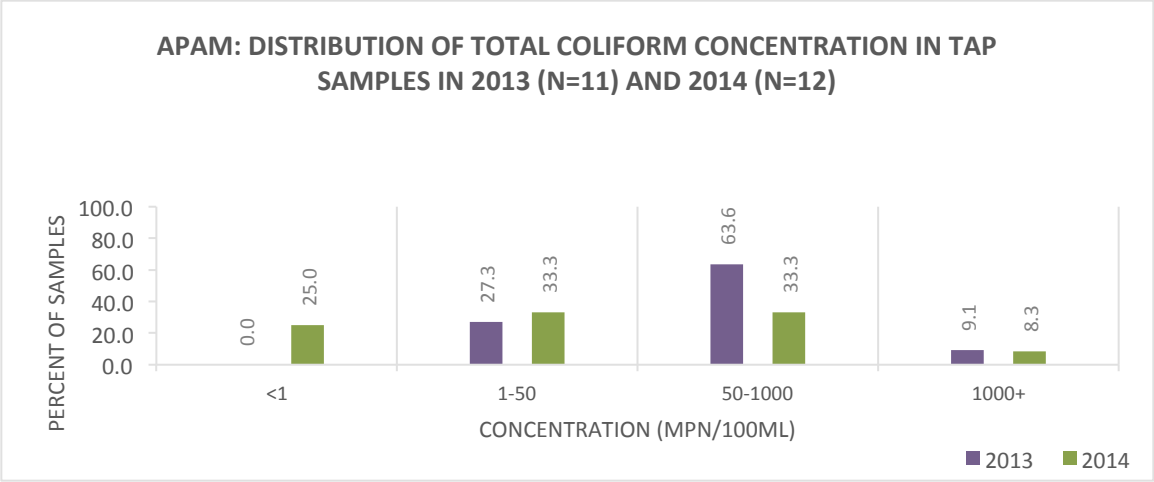
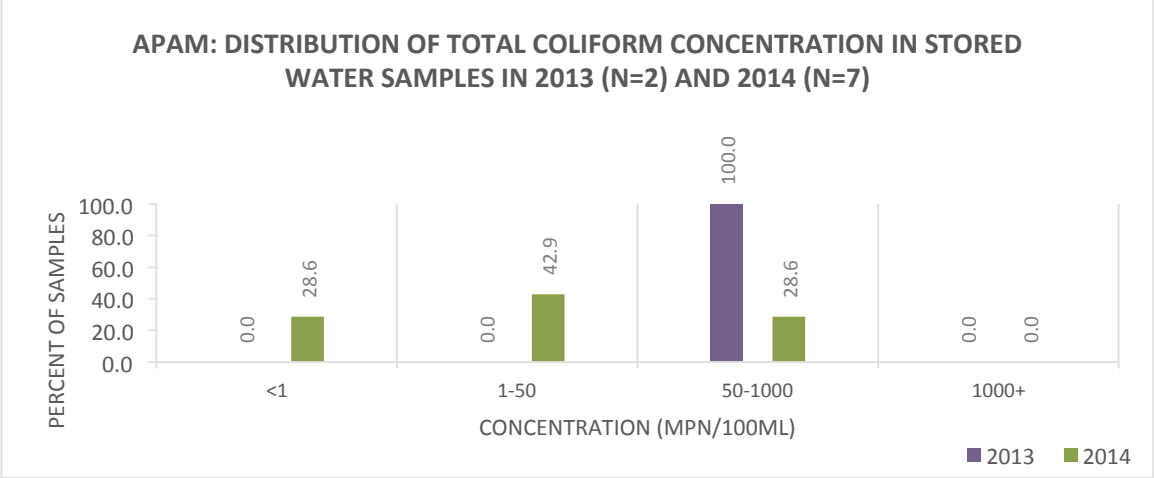
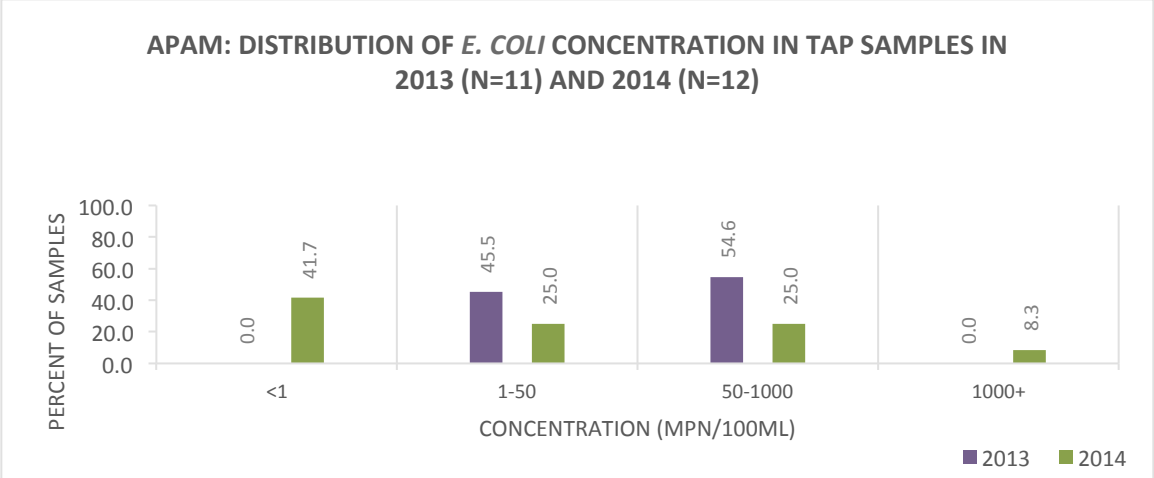
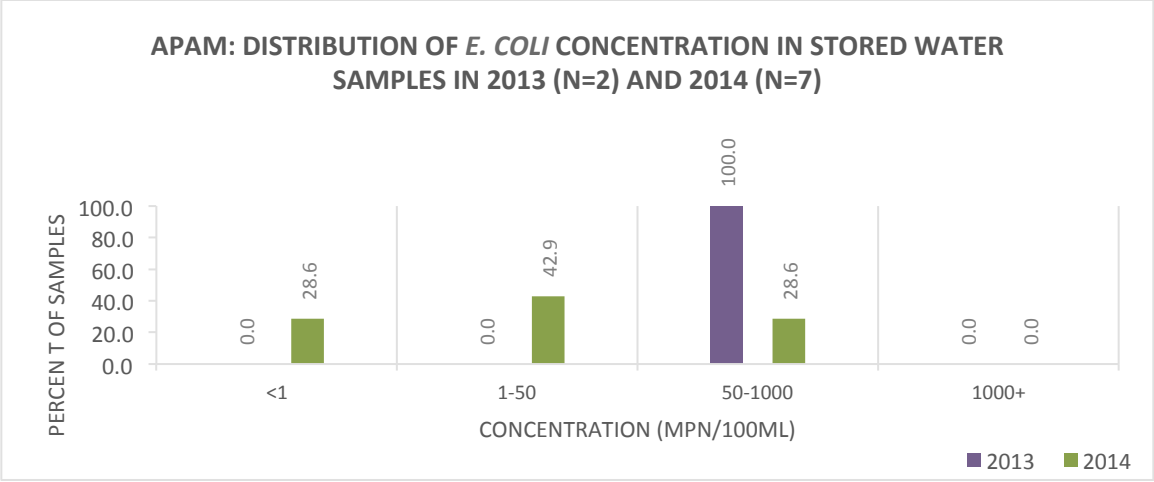

Mampong Institutional Engagement and Support 2014
Demand
4
3
2
1
0
Satisfaction and Perceived Value
Engagement of Hospital Director and Staff
Educational Messaging and Awareness

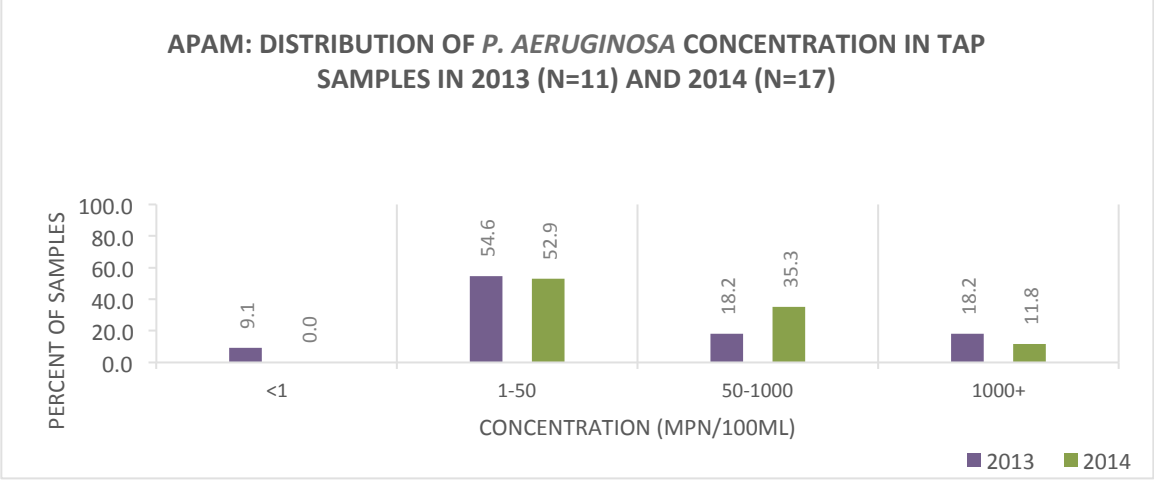
Figure 19. Distributions of tap water and stored water sample concentrations of total coliforms, *E. coli*, and *P. aeruginosa* in Apam Catholic Hospital in 2013 and 2014. The x-axis indicates the concentrations of indicator organisms represented by a range, and the y-axis indicates the percent of samples in each range.








APAM: DISTRIBUTION OF E. COLI CONCENTRATION IN STORED WATER SAMPLES IN 2013 (N=2) AND 2014 (N=7)
PERCEN T OF SAMPLES
100.0
80.0
60.0
40.0
20.0
0.0
0.0
28.6
0.0
42.9
100.0
28.6
0.0
0.0
<1
1-50
50-1000
1000+
CONCENTRATION (MPN/100ML)
2013
2014


APAM: DISTRIBUTION OF P. AERUGINOSA CONCENTRATION IN TAP SAMPLES IN 2013 (N=11) AND 2014 (N=17)
PERCENT OF SAMPLES
100.0
80.0
60.0
40.0
20.0
0.0
9.1
0.0
54.6
52.9
18.2
35.3
18.2
11.8
<1
1-50
50-1000
1000+
CONCENTRATION (MPN/100ML)
2013
2014

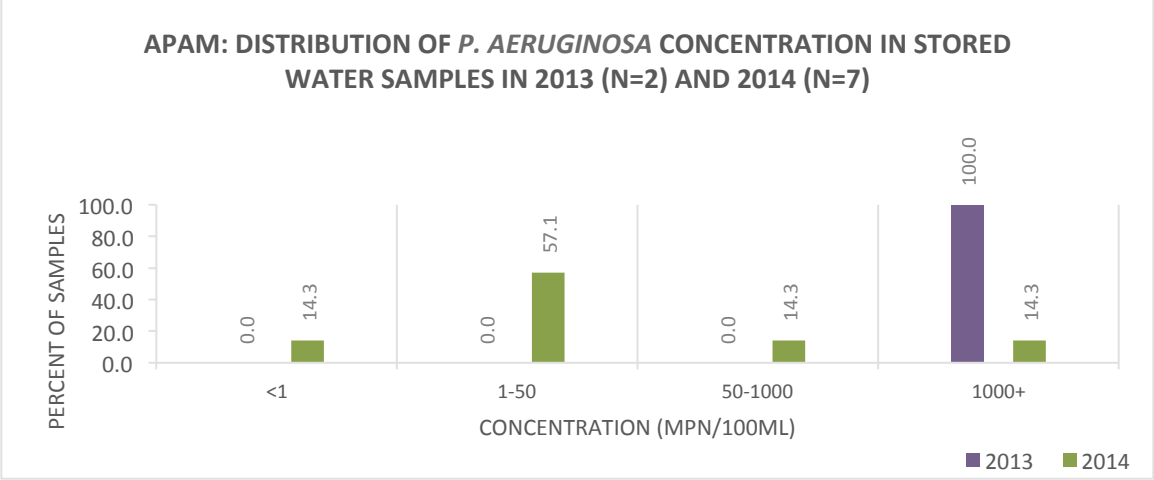
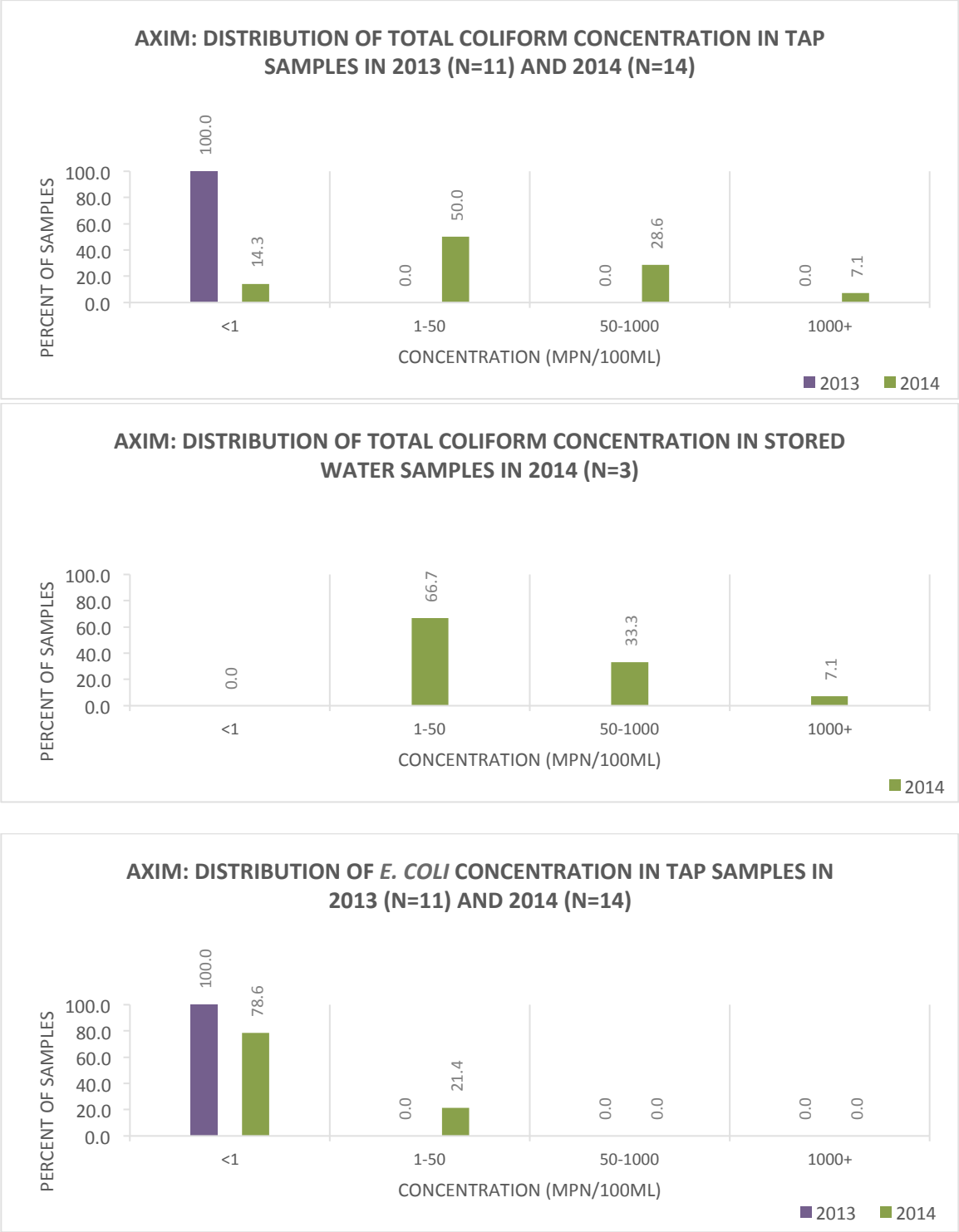
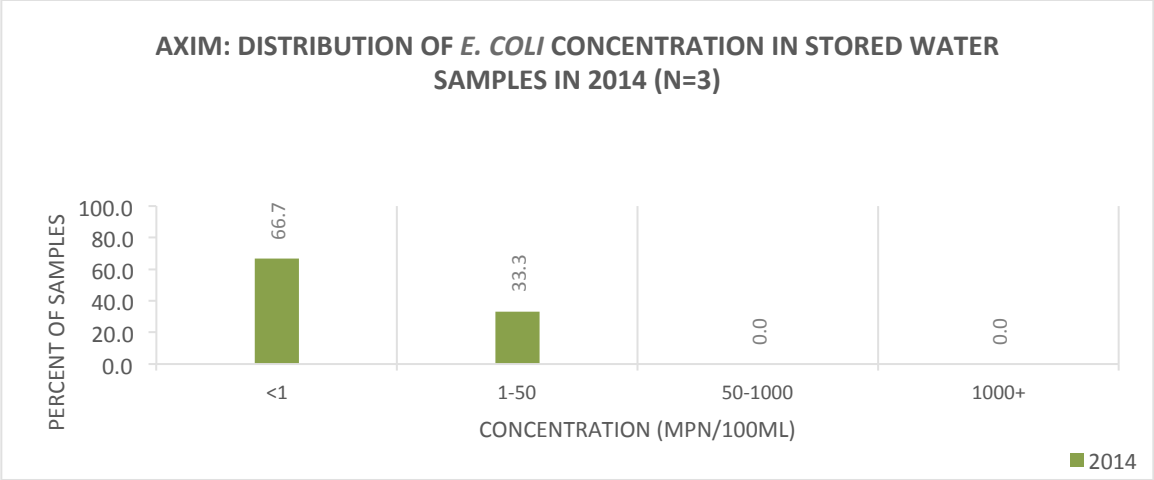
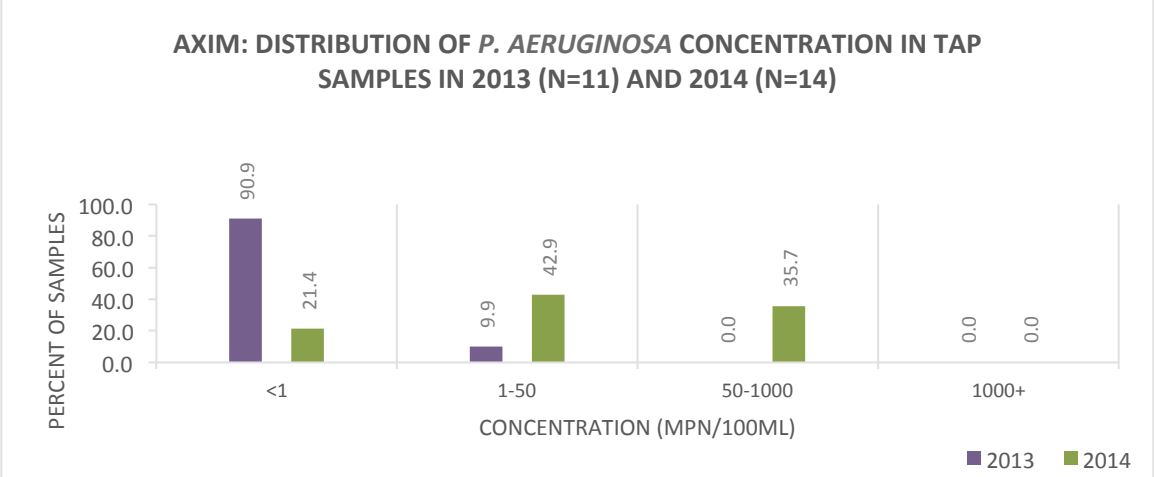

APAM: DISTRIBUTION OF P. AERUGINOSA CONCENTRATION IN STORED WATER SAMPLES IN 2013 (N=2) AND 2014 (N=7)
PERCENT OF SAMPLES
100.0
80.0
60.0
40.0
20.0
0.0
0.0
14.3
0.0
57.1
0.0
14.3
100.0
14.3
<1
1-50
50-1000
1000+
CONCENTRATION (MPN/100ML)
2013
2014

Figure 20. Distributions of tap water and stored water sample concentrations of total coliforms, *E. coli*, and *P. aeruginosa* in Axim Government Hospital in 2013 and 2014.




AXIM: DISTRIBUTION OF E. COLI CONCENTRATION IN STORED WATER SAMPLES IN 2014 (N=3)
PERCENT OF SAMPLES
100.0
80.0
60.0
40.0
20.0
0.0
66.7
33.3
0.0
0.0
<1
1-50
50-1000
1000+
CONCENTRATION (MPN/100ML)
2014


AXIM: DISTRIBUTION OF P. AERUGINOSA CONCENTRATION IN TAP SAMPLES IN 2013 (N=11) AND 2014 (N=14)
PERCENT OF SAMPLES
100.0
80.0
60.0
40.0
20.0
0.0
90.9
21.4
9.9
42.9
0.0
35.7
0.0
0.0
<1
1-50
50-1000
1000+
CONCENTRATION (MPN/100ML)
2013
2014

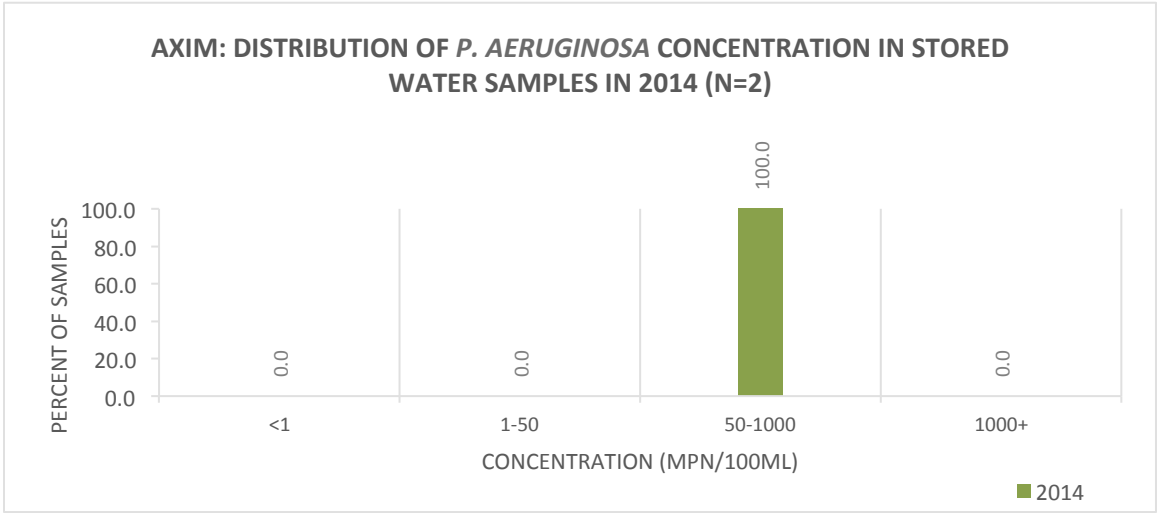
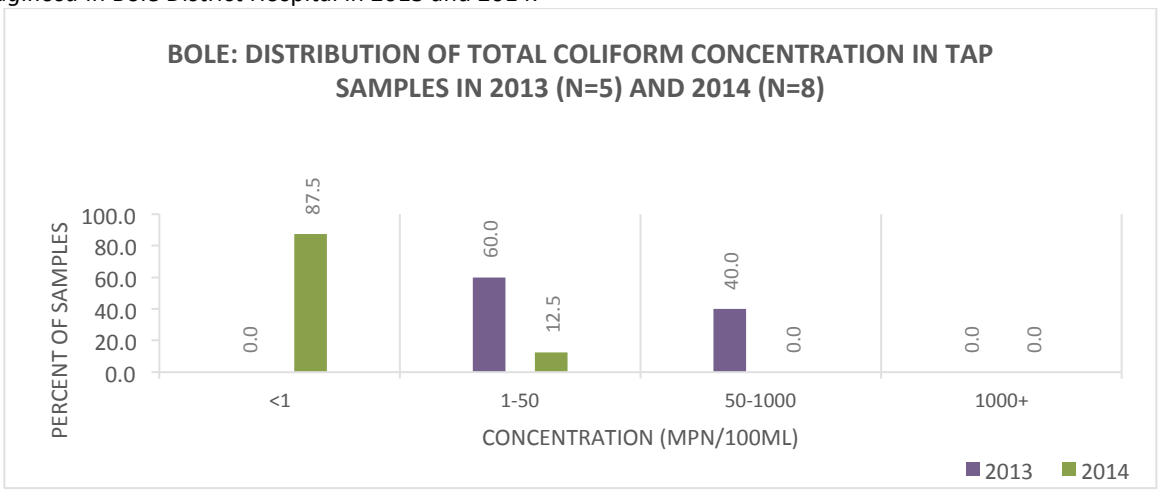
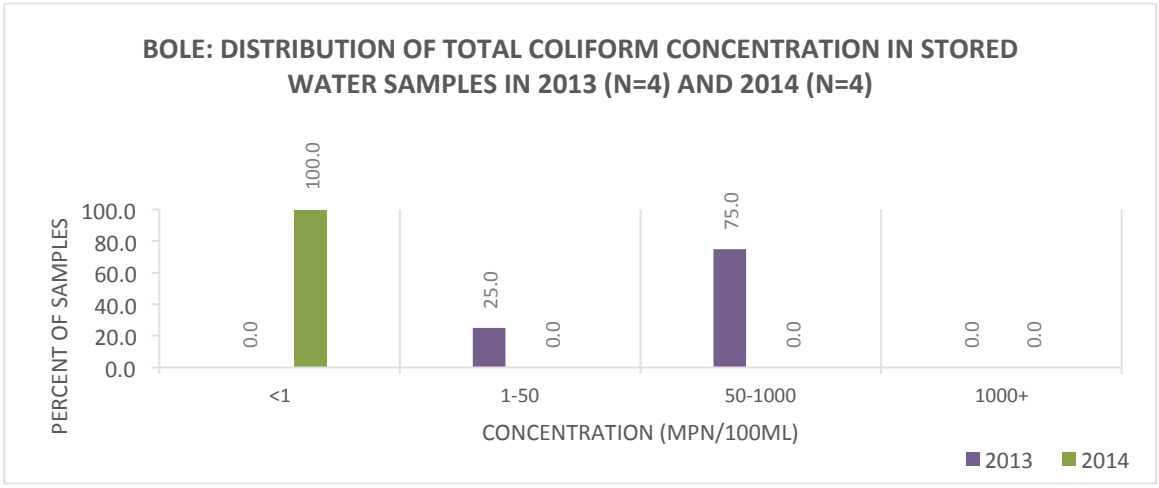
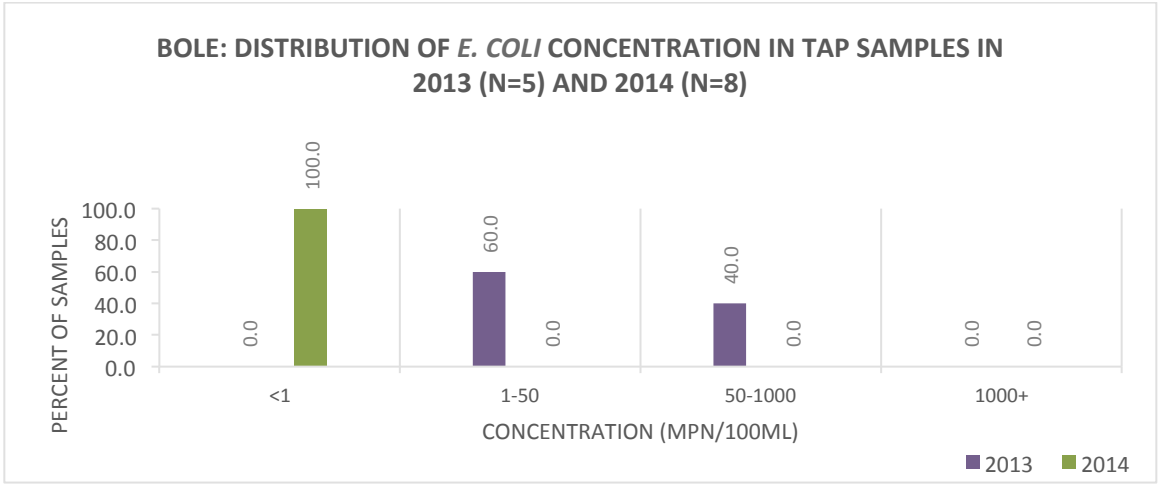
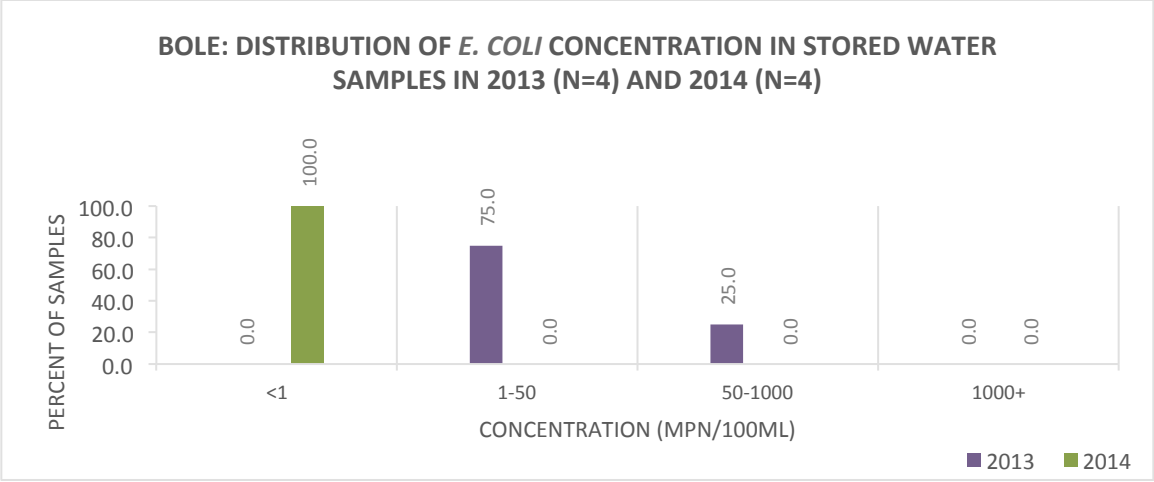

AXIM: DISTRIBUTION OF P. AERUGINOSA CONCENTRATION IN STORED WATER SAMPLES IN 2014 (N=2)
PERCENT OF SAMPLES
100.0
80.0
60.0
40.0
20.0
0.0
0.0
0.0
100.0
0.0
<1
1-50
50-1000
1000+
CONCENTRATION (MPN/100ML)
2014

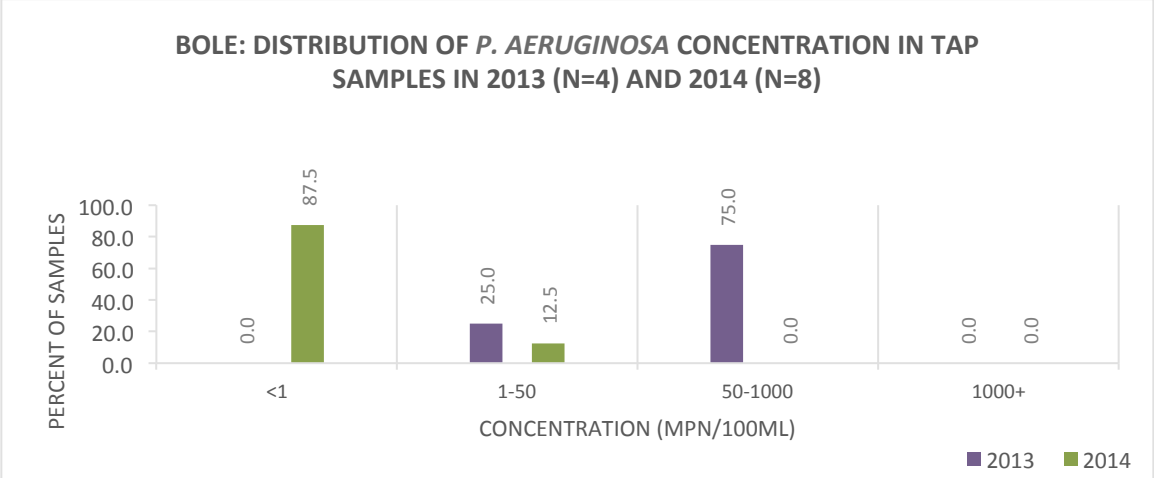
Figure 21. Distributions of tap water and stored water sample concentrations of total coliforms, *E. coli*, and *P. aeruginosa* in Bole District Hospital in 2013 and 2014.








BOLE: DISTRIBUTION OF E. COLI CONCENTRATION IN STORED WATER SAMPLES IN 2013 (N=4) AND 2014 (N=4)
PERCENT OF SAMPLES
100.0
80.0
60.0
40.0
20.0
0.0
0.0
100.0
75.0
0.0
25.0
0.0
0.0
0.0
<1
1-50
50-1000
1000+
CONCENTRATION (MPN/100ML)
2013
2014


BOLE: DISTRIBUTION OF P. AERUGINOSA CONCENTRATION IN TAP SAMPLES IN 2013 (N=4) AND 2014 (N=8)
PERCENT OF SAMPLES
100.0
80.0
60.0
40.0
20.0
0.0
0.0
87.5
25.0
12.5
75.0
0.0
0.0
0.0
<1
1-50
50-1000
1000+
CONCENTRATION (MPN/100ML)
2013
2014

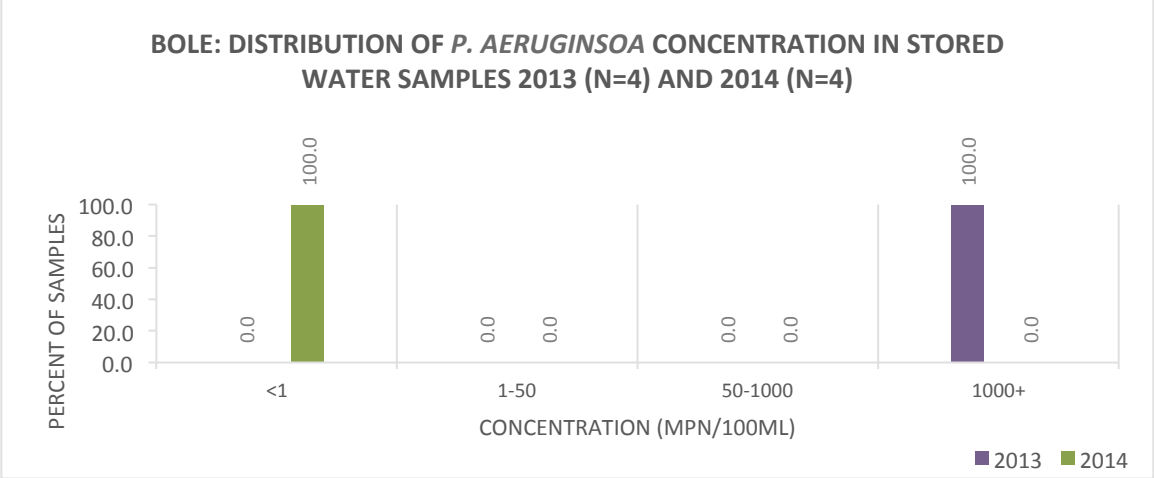
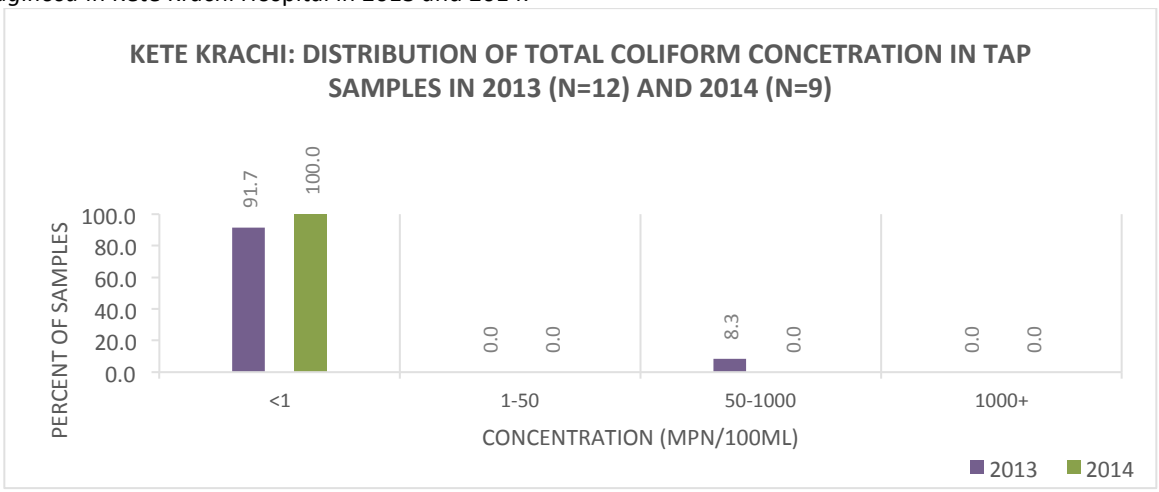
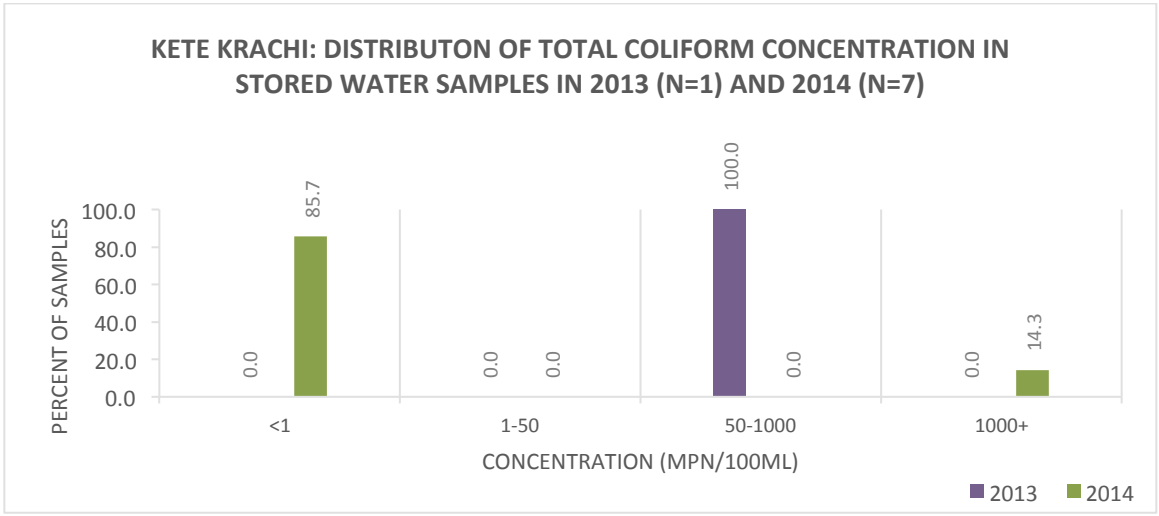
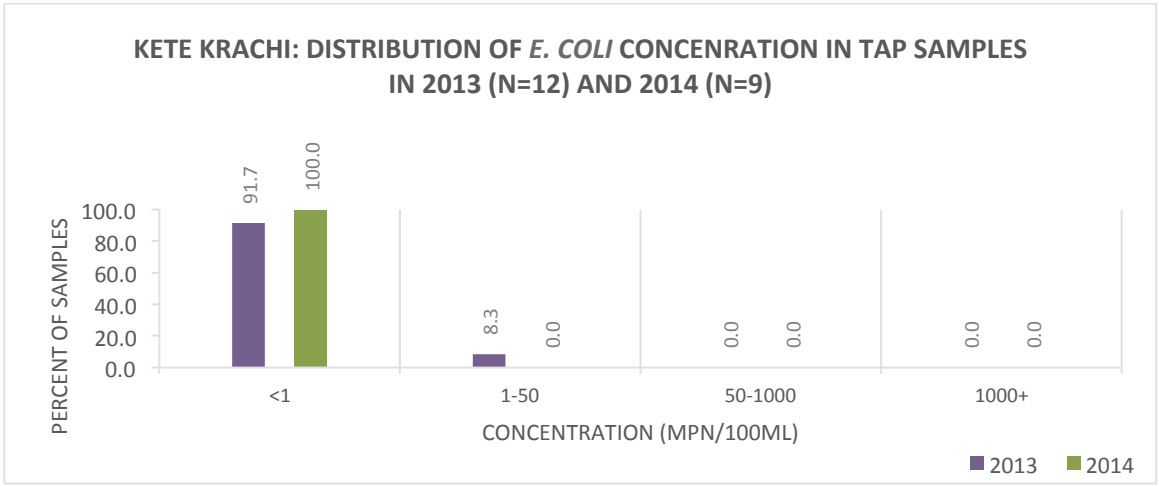
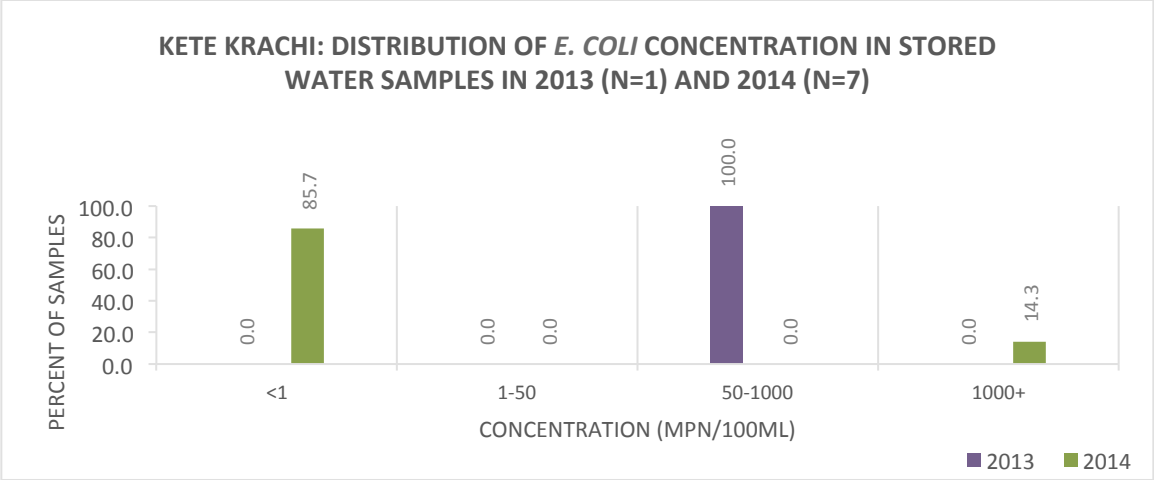

BOLE: DISTRIBUTION OF P. AERUGINSOA CONCENTRATION IN STORED WATER SAMPLES 2013 (N=4) AND 2014 (N=4)
PERCENT OF SAMPLES
100.0
80.0
60.0
40.0
20.0
0.0
0.0
100.0
0.0
0.0
0.0
0.0
100.0
0.0
<1
1-50
50-1000
1000+
CONCENTRATION (MPN/100ML)
2013
2014

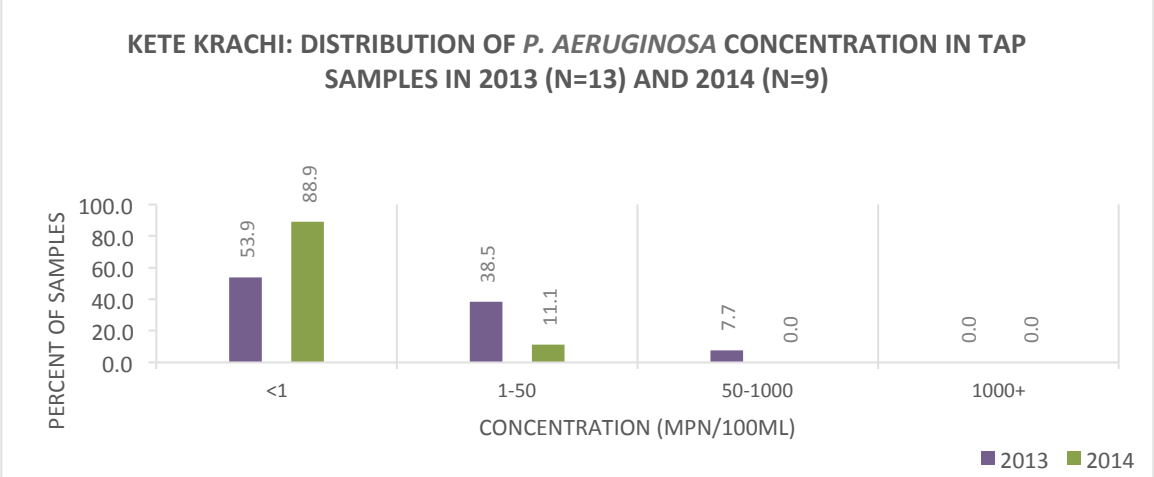
Figure 22. Distributions of tap water and stored water sample concentrations of total coliforms, *E. coli*, and *P. aeruginosa* in Kete Krachi Hospital in 2013 and 2014.








KETE KRACHI: DISTRIBUTION OF E. COLI CONCENTRATION IN STORED WATER SAMPLES IN 2013 (N=1) AND 2014 (N=7)
PERCENT OF SAMPLES
100.0
80.0
60.0
40.0
20.0
0.0
0.0
85.7
0.0
0.0
100.0
0.0
0.0
14.3
<1
1-50
50-1000
1000+
CONCENTRATION (MPN/100ML)
2013
2014


KETE KRACHI: DISTRIBUTION OF P. AERUGINOSA CONCENTRATION IN TAP SAMPLES IN 2013 (N=13) AND 2014 (N=9)
PERCENT OF SAMPLES
100.0
80.0
60.0
40.0
20.0
0.0
53.9
88.9
38.5
11.1
7.7
0.0
0.0
0.0
<1
1-50
50-1000
1000+
CONCENTRATION (MPN/100ML)
2013
2014

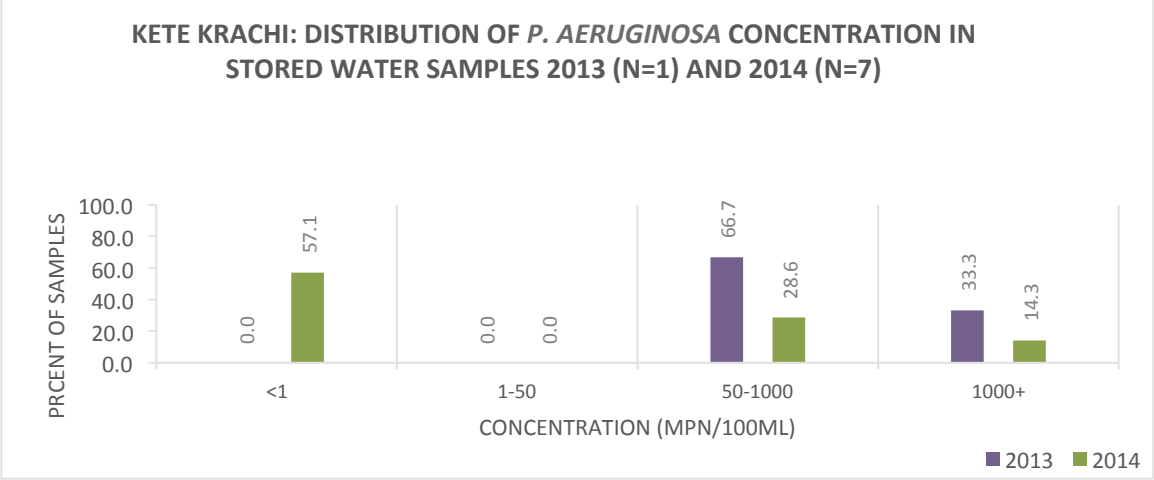
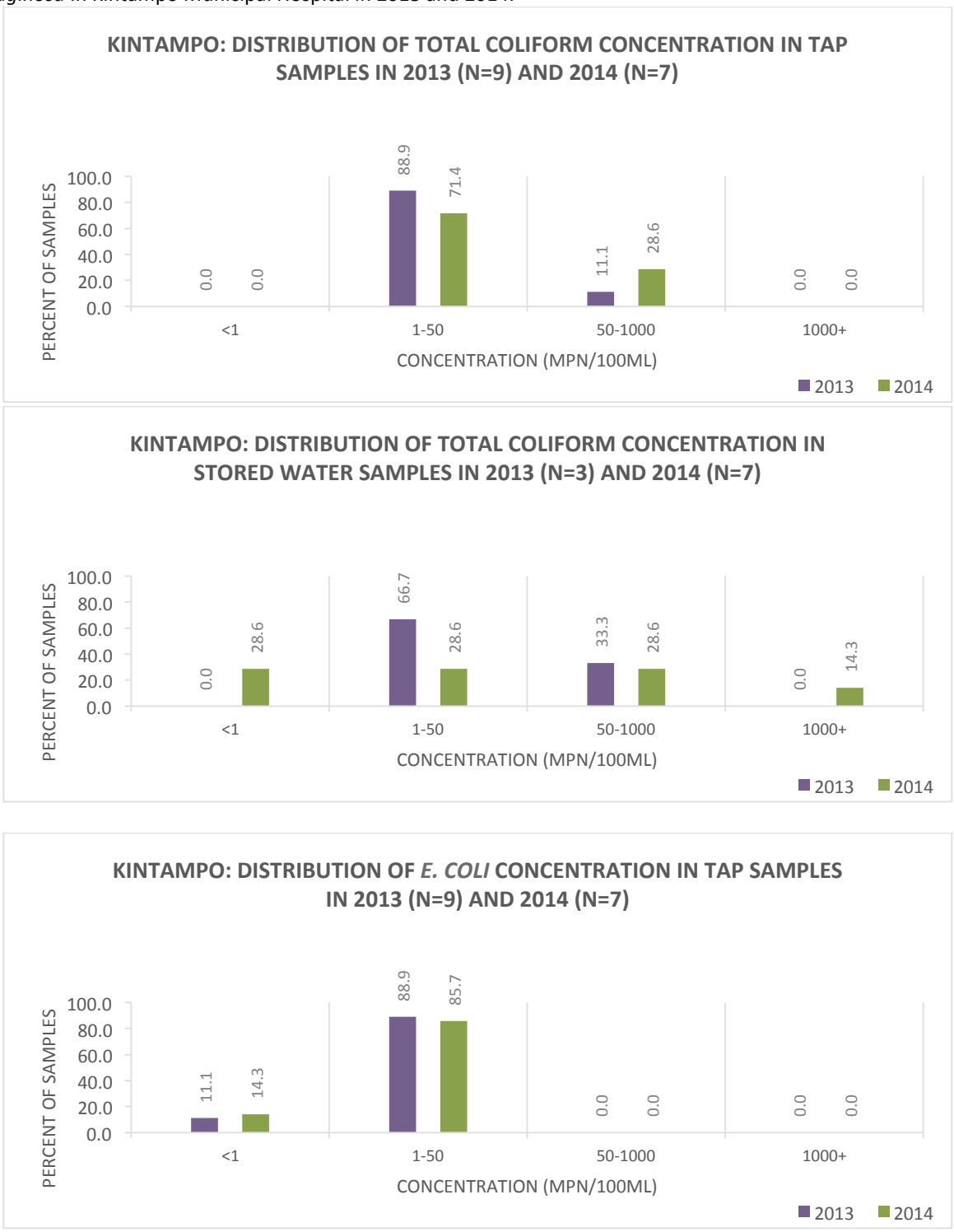
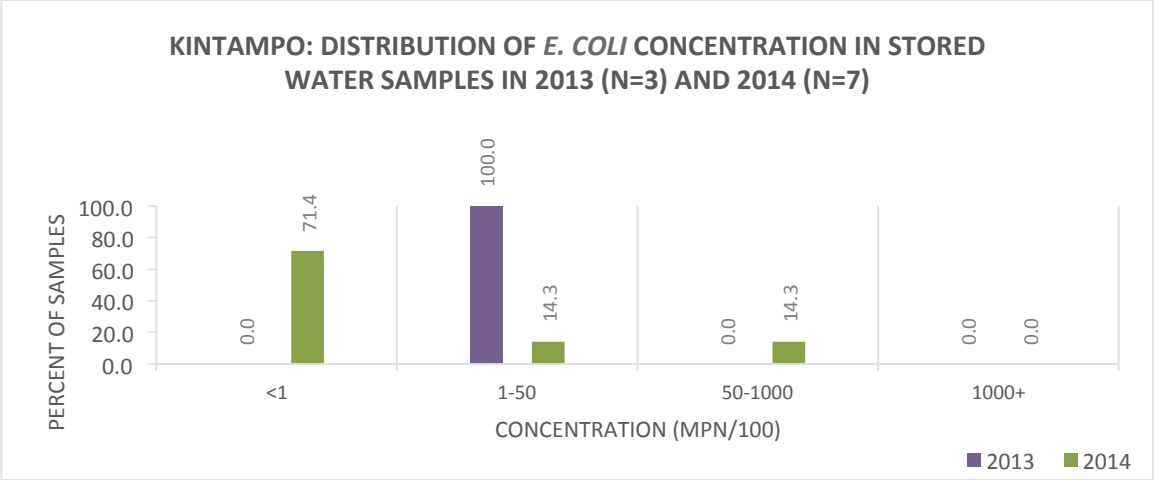
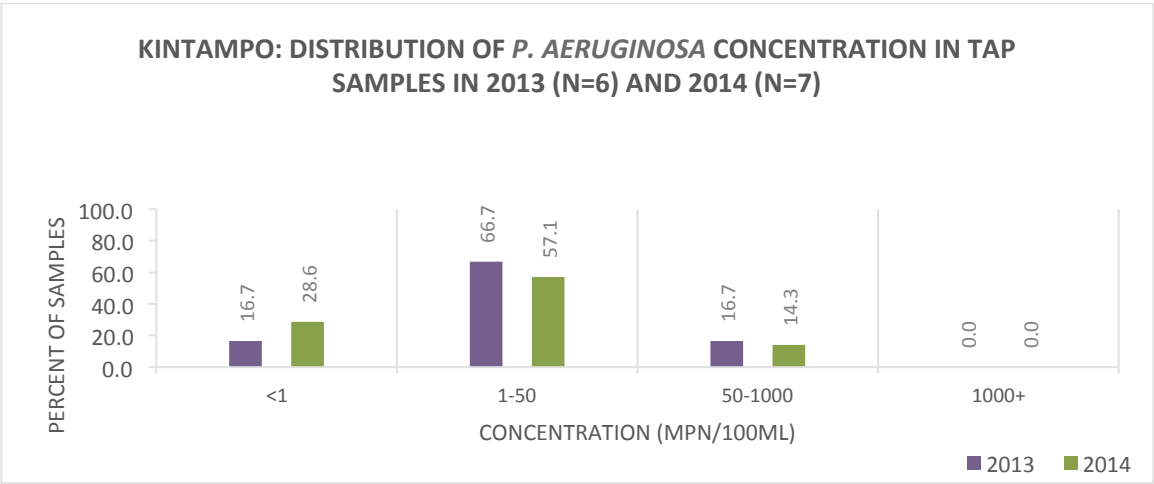

KETE KRACHI: DISTRIBUTION OF P. AERUGINOSA CONCENTRATION IN STORED WATER SAMPLES 2013 (N=1) AND 2014 (N=7)
PRCENT OF SAMPLES
100.0
80.0
60.0
40.0
20.0
0.0
0.0
57.1
0.0
0.0
66.7
28.6
33.3
14.3
<1
1-50
50-1000
1000+
CONCENTRATION (MPN/100ML)
2013
2014

Figure 23. Distributions of tap water and stored water sample concentrations of total coliforms, *E. coli*, and *P. aeruginosa* in Kintampo Municipal Hospital in 2013 and 2014.




KINTAMPO: DISTRIBUTION OF E. COLI CONCENTRATION IN STORED WATER SAMPLES IN 2013 (N=3) AND 2014 (N=7)
PERCENT OF SAMPLES
100.0
80.0
60.0
40.0
20.0
0.0
0.0
71.4
100.0
14.3
0.0
14.3
0.0
0.0
<1
1-50
50-1000
1000+
CONCENTRATION (MPN/100)
2013
2014


KINTAMPO: DISTRIBUTION OF P. AERUGINOSA CONCENTRATION IN TAP SAMPLES IN 2013 (N=6) AND 2014 (N=7)
PERCENT OF SAMPLES
100.0
80.0
60.0
40.0
20.0
0.0
16.7
28.6
66.7
57.1
16.7
14.3
0.0
0.0
<1
1-50
50-1000
1000+
CONCENTRATION (MPN/100ML)
2013
2014

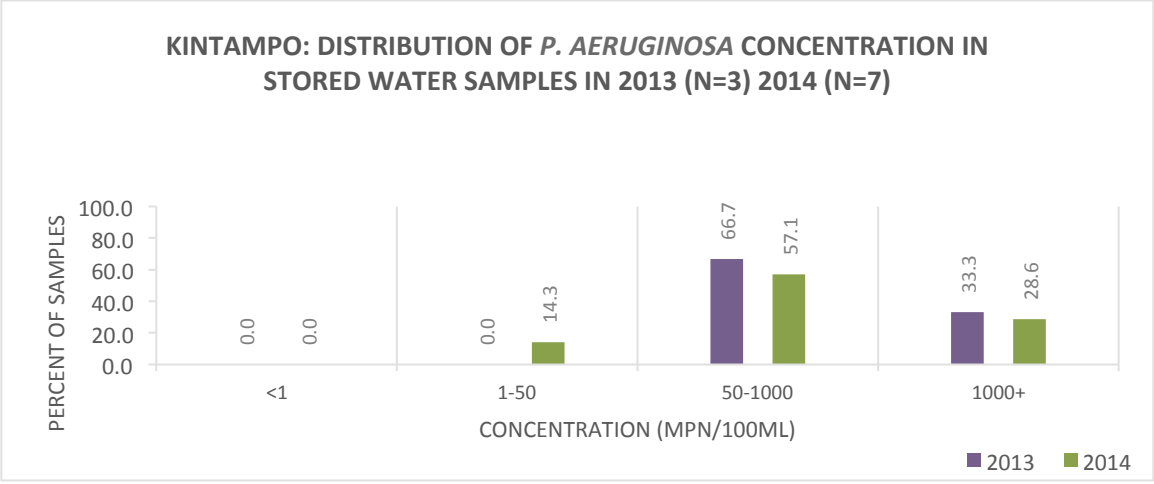
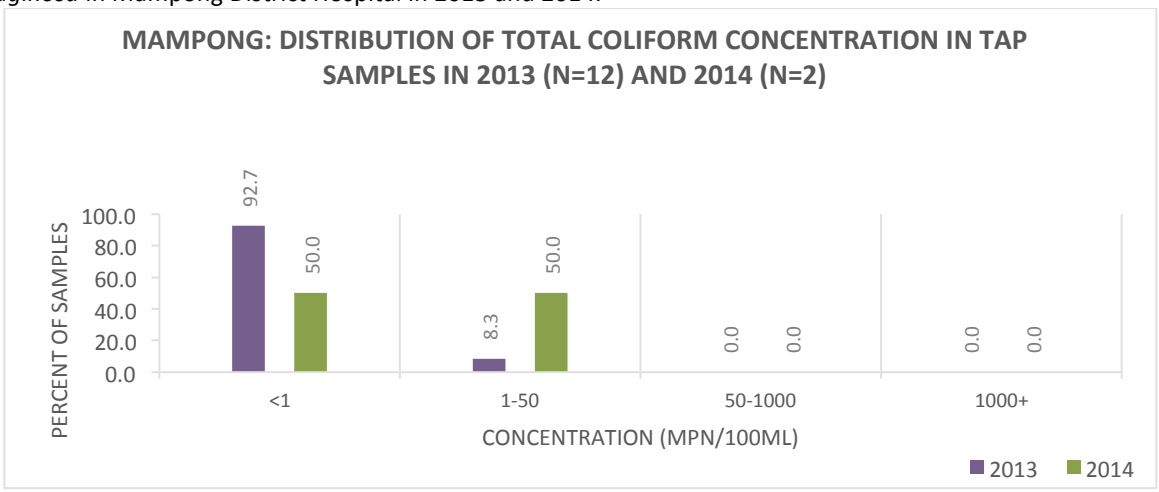
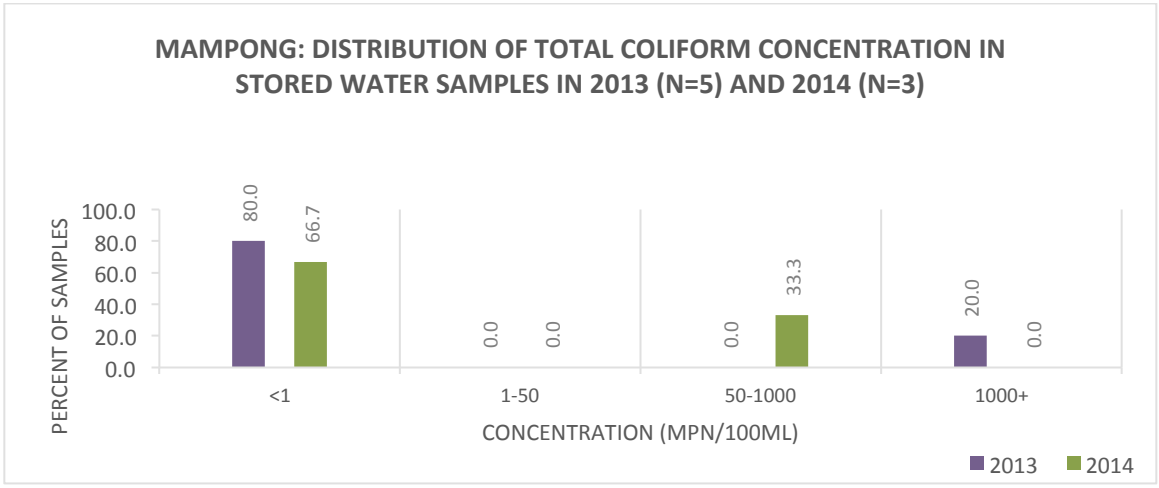
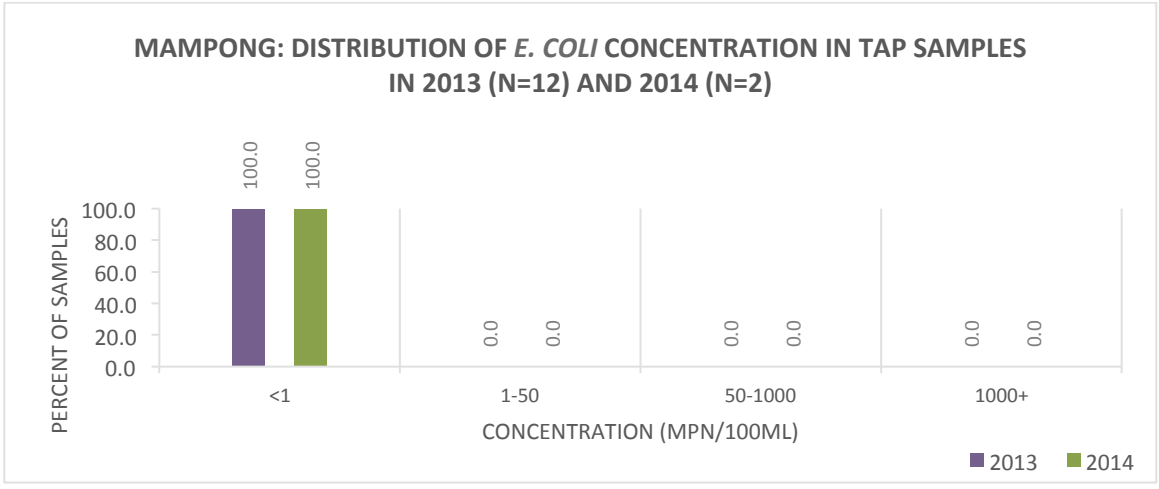
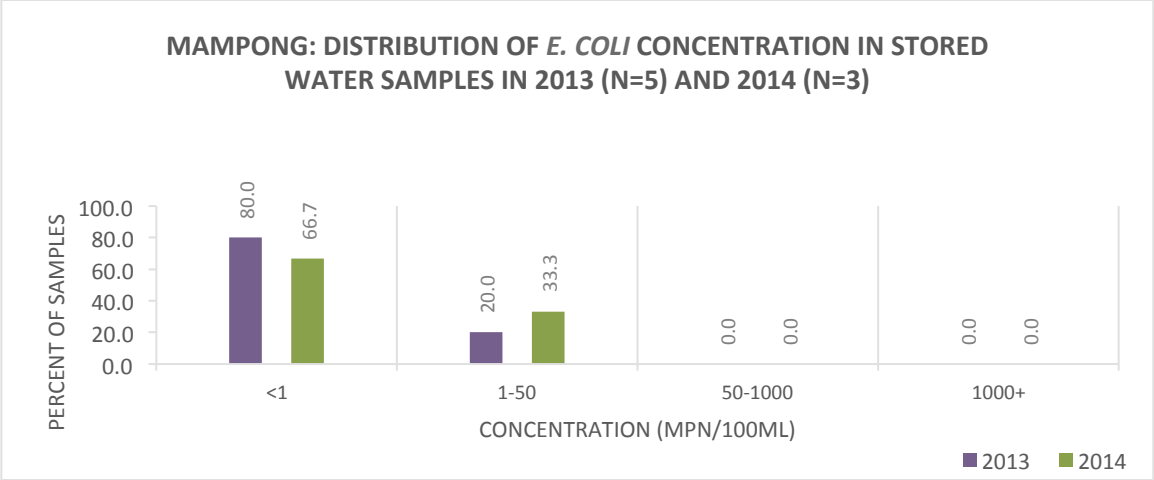

KINTAMPO: DISTRIBUTION OF P. AERUGINOSA CONCENTRATION IN STORED WATER SAMPLES IN 2013 (N=3) 2014 (N=7)
PERCENT OF SAMPLES
100.0
80.0
60.0
40.0
20.0
0.0
0.0
0.0
0.0
14.3
66.7
57.1
33.3
28.6
<1
1-50
50-1000
1000+
CONCENTRATION (MPN/100ML)
2013
2014

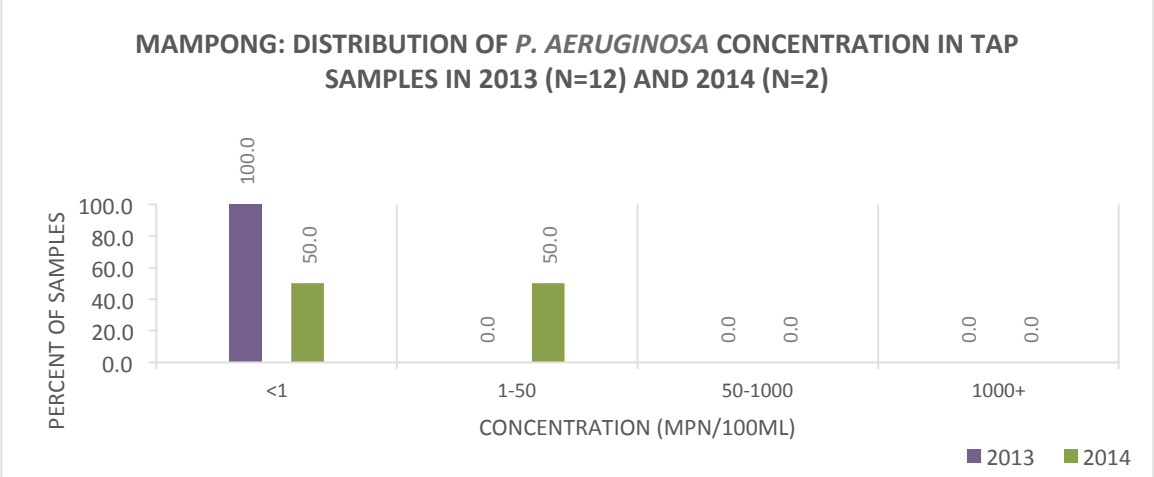
Figure 24. Distributions of tap water and stored water sample concentrations of total coliforms, *E. coli*, and *P. aeruginosa* in Mampong District Hospital in 2013 and 2014.

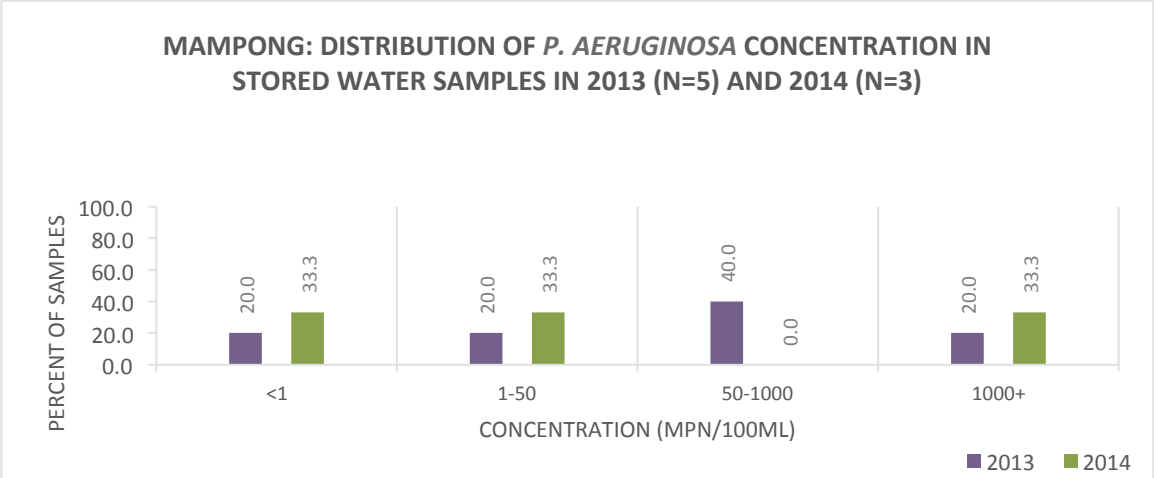







MAMPONG: DISTRIBUTION OF E. COLI CONCENTRATION IN STORED WATER SAMPLES IN 2013 (N=5) AND 2014 (N=3)
PERCENT OF SAMPLES
100.0
80.0
60.0
40.0
20.0
0.0
80.0
66.7
20.0
33.3
0.0
0.0
0.0
0.0
<1
1-50
50-1000
1000+
CONCENTRATION (MPN/100ML)
2013
2014


MAMPONG: DISTRIBUTION OF P. AERUGINOSA CONCENTRATION IN TAP SAMPLES IN 2013 (N=12) AND 2014 (N=2)
PERCENT OF SAMPLES
100.0
80.0
60.0
40.0
20.0
0.0
100.0
50.0
0.0
50.0
0.0
0.0
0.0
0.0
<1
1-50
50-1000
1000+
CONCENTRATION (MPN/100ML)
2013
2014


MAMPONG: DISTRIBUTION OF P. AERUGINOSA CONCENTRATION IN STORED WATER SAMPLES IN 2013 (N=5) AND 2014 (N=3)
PERCENT OF SAMPLES
100.0
80.0
60.0
40.0
20.0
0.0
20.0
33.3
20.0
33.3
40.0
0.0
20.0
33.3
<1
1-50
50-1000
1000+
CONCENTRATION (MPN/100ML)
2013
2014

Appendix A. 2014 Sustainability Tool

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?	
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 A10e A10f A10g	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 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:

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? (specify location, check if location is before or after filtration system)	1) Yes 2) No 99) I do not know Comments: Location: _____ 1) Before filtration 2) After filtration 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	Are there times when people collect water from the hospital to take home with them?	1) Yes 2) No →SKIP to Ax
A18a	**If yes**, approximately how many people each day?	99) I do not know →SKIP to Ax _____ people/day Comments:
A18b	Are they staff or patients/visitors?	1) Staff 2)Patients/Visitors 3) Both 99) I do not know
A19	When people do take water home with them, from which collection points within the hospital do people collect the water?	
A20	Does the hospital support or discourage people collecting water from the hospital taps?	1) Support 2) Discourage 99) I do not know Comments:
A21	How much do people pay (per liter) when they purchase water from vendors for household purposes?	_____ 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	1) Yes 2)No 99)I do not know

	the (capacity) knowledge to manage the system? Why or why not?	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:
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?	
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:
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 A43a	Have you ever spoken with the staff about the filtration system? What have you talked about?	1) Yes 2) No 99) I do not know
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
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	Did hospital staff receive an information session about the water filtration system? (e.g. why the system was provided / water borne disease)	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	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
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)	
Finance Mechanisms		
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 A59a	Who funds the cost of repairs associated with the system? Who funds the cost of replacing broken sinks and taps?	1)MOH 2)GE 3)No one 4) Hospital 99)I do not know Comments: 1)MOH 2)GE 3)No one 4) Hospital 99)I do not know 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	1) Yes 2) No 99) I do not know Comments:

	time, small repairs)?	
Satisfaction and Perceived Value		
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?	
A68	In your opinion is the water from the tap safe to drink?	1) Yes 2) No 99) I do not know
A69 A69a	Do you drink from the tap? If yes, how often per day?	1) Yes 2) No 99) I do not know 1) 1-2 times per day 2) 3-4 times per day 3) 5-6 4)7+
   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:
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:

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	Sachet	Tap	Other			Not Asked
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:

CLINICAL STAFF

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

B1	Role of Participant:	1) Doctor 2) Nurse 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:
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:
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	Are there benefits of having safe water for your job?	1) Yes 2) No 99) I do not know Comments:
B10a	How does water quality impact your job? Has there ever been a time when there wasn't enough water to do your job? If so, how often does that happen?	1) Never 2) Sometimes 3) Frequently 4) Always
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?	
   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	 A. 1 2 3 4 5 B. 1 2 3 4 5 C. 1 2 3 4 5 D. 1 2 3 4 5

	information? D. What was the participant's level of commitment to the provision of clean water?	Comments and observations:

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	Sachet	Tap	Other			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:

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:
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?	
C9 C9a	Do you drink from the tap? How Often?	1) Yes 2) No 99) I do not know
C10	Are there benefits of having safe water for your job?	1) Yes 2) No 99) I do not know Comments:
C10a	How does water quality impact your job? Has there ever been a time when there wasn't enough water to do your job? If so, how often does that happen?	5) Never 6) Sometimes 7) Frequently 8) Always
   C16a C16b C16c	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	 A. 1 2 3 4 5 B. 1 2 3 4 5 C. 1 2 3 4 5

C16d	examples and additional information? D. What was the participant's level of commitment to the provision of clean water?	D. 1 2 3 4 5 Comments and observations:

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	Sachet	Tap	Other			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:							

ADMINISTRATOR

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
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:
J10	Are there benefits of having safe water for your job?	1) Yes 2) No 99) I do not know Comments:
J13	Approximately how much do you spend monthly to obtain consumables and parts needed to fix repairs for the water treatment system?	_____ Ghc
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	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)	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

J16a-h.a	**Observation:** Are the records up to date?	_____ 1 2 3 4 5 Comments:
J16a-h.b	**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)	1 2 3 4 5 Comments:
J17	Is there an operating budget for the treatment system? If so can we see it? (on a scale from 1 -5, 1=not well maintained 5= Maintained)	1) Yes 2) No 0) N/A 99) I do not know
J17a	**Observation:** Is the record up to date?	1 2 3 4 5 Comments:
J17b	**Observation:** Is the record well maintained?	1 2 3 4 5 Comments:
J18	Does the hospital have a quality assurance committee?	1) Yes 2) No →SKIP to Ax 99) I do not know
J18a	If yes, is safe water one of the themes they discuss?	1) Yes 2) No 99) I do not know
J18b	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 99) I do not know Comments:
J19	What is the closest city were water samples could be sent to for analysis?	
J19a	Where and what institution?	
J20	How often do you talk to GE Ambassadors/ Kwame Akorsa?	___ times/week/ month/year 99) I do not know
J20a	What do you talk to them about? [Probe for specific examples]	
J20b	Are these meetings regularly scheduled?	1) Yes 2) No 99) I do not know
J20c	When you bring up issues, are they addressed?	1) Yes 2) No 99) I do not know
J21	Do you communicate with Assist International and \ about the filtration system? How often?	1) Yes 2) No 99) I do not know ____ times/week/month/year 99)I do not know

J21a J21b J21c	What do you discuss? [Probe for specific examples] Are these meetings regularly scheduled? When you bring up issues, are they addressed?	Comments: 1) Yes 2) No 99) I do not know 1) Yes 2) No 99) I do not know
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?	1) Yes 2) No 99) I do not know Comments:

	How frequently is chlorine not purchased for the system? Why?	_____ times a week/month/year/ N/A 99)I do not know Comments:
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:

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	Sachet	Tap	Other			N/A
Drinking							
Drinking water provided for visitors							
Hand-Washing							

Comments & Observations:

LABORATORY STAFF

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:
K5	Do you drink water from the tap?	1) Yes 2) No 99) I do not know Comments:
K7 K7a K7b	Where does the water in this hospital come from? 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:
K10	Are there benefits of having safe water for your job?	1) Yes 2) No 99) I do not know Comments:
K10a	How does water quality impact your job? Has there ever been a time when there wasn't enough water to do your job? If so, how often does that happen?	9) Never 10) Sometimes 11) Frequently Always
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 K13b K13c	How often do you measure chlorine residual levels? Where do you measure them? Do you document this information? Where and how often?	___ times/week/month/year 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? 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? 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:
   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:

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)?

3. Is your distilling machine working? For how long?

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

	Bottled	Sachet	Tap	DI water	Auto-claved water	Other	N/A
Drinking							
Hand washing							
Mixing Reagents							
Washing and cleaning laboratory supplies and equipment							
Sterilization of laboratory equipment							

Comments & Observations:

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:
D13b	Do you have pipe born water in your home?	1) Yes 2) No 99) I do not know Comments:
D14b	*** For Maternity Patients/ Visitors*** Did you have to bring water with you to drink or to use during your visit? If so why?	1) Yes 2) No 99) I do not know Comments:

D16	In your option is contaminated water a problem in your community? Why or Why not?	1) Yes 2) No 99) I do not know Comments:

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	**Sachet**	**Tap**	**Location that water was collected**	**Pipe**	**River/ Stream**	**Lake**	**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								
For labor and delivery								
Other?								

Comments & Observations:

OBSERVATIONS

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

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					

OBSERVATIONS

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

		catchy?	
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
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

MAINTENANCE OFFICER

HH1	Date		HH4	Hospital Name	
HH2	Start Time		HH5	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	Did you receive technical training prior to starting this job?	
H5	How long have you been working here at this hospital?	_____months/years
Electricity		
H6	In the last week, how many times has the electricity gone out?	_____ time/day/week/month
H6a	On average, how long does the electricity stay out when it does go out?	_____ time/day/week/month
H6b	Who decides to turn on the generator?	Comments:
H6c	When do you choose to turn the generator on? For what specific reasons?	Comments:
H6d	Is the generator automatic?	Comments:
	Why does the generator decision maker decide not to turn it on or to turn off the automatic switch?	1) Yes 2) No 99) I do not know

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 _____Role_____ 1) Yes 2) No Name _____Role_____ 1) Yes 2) No Name _____ Role_____ 1) Yes 2) No Name _____ Role_____ 1) Yes 2) No Name _____ Role_____ 1) Yes 2) No

H10	How often do you talk to GE Ambassadors/ Kwame Akorsa?	___ times/week/ month/year 99) I do not know
H10a	What do you talk to them about? [Probe for specific examples]	1) Yes 2) No 99) I do not know
H10b	Are these meetings regularly scheduled?	1) Yes 2) No 99) I do not know
H10c	When you bring up issues, are they addressed?	
H11	Do you communicate with Assist International and Kwame Akorsa about the filtration system?	1) Yes 2) No 99) I do not know
	How often?	____ times/week/month/year
H11a	What do you discuss? [Probe for specific examples]	Comments: 1) Yes 2) No 99) I do not know
H11b	Are these meetings regularly scheduled?	1) Yes 2) No 99) I do not
H11c	When you bring up issues, are they addressed?	
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?	
H15	Normally, how many people complete maintenance tasks associated with the filtration system?	
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?	____days/month
	Why?	
H19	If the system is not working, when was the last time it was used?	
H19a	Why are the filters not being used?	
H19b	Have there been any attempts to fix the filters?	
	If no, why not?	
H20	Do you communicate (on the phone/email) with Kwame Akorsa / GE Ambassadors about the water the filtration system?	1) Yes 2) No 99) I do not know
	How often?	_____ times a day/week/month
H20a	What do you discuss?	
H20b	[Probe for specific examples]	
H20c	Are these meetings regularly scheduled?	
H20d		1)Yes 2) No 99) I do not know

	When you bring up issues, are they addressed?	1) Yes 2) No 99) I do not know
H21	Do you communicate (on the phone/email) with Assist International about the filtration system?	1) Yes 2) No 99) I do not know
H21a	How often?	_____ times a week/month/year
H21b	What do you discuss? [Probe for specific examples]	1)Yes 2) No 99) I do not know
H21c	Are these meetings regularly scheduled?	1) Yes 2) No 99) I do not know
H21d	When you bring up issues, are they addressed?	
H22	Do you communicate with the MoH/GHS about the filtration system?	1) Yes 2) No 99) I do not know
H22a	How often?	_____ times a day/week/month
H22b	What do you discuss? [Probe for specific examples]	Comments:
H23	What system do you have in place to track the expenses required for the water treatment system operating? (Ask to see expense tracking system)	1) Yes 2) No 99) I do not know Comments:
H23a	**Observation:** Is the record up to date?	1 2 3 4 5 Comments:
H23b	**Observation:** Is the record well maintained?	1 2 3 4 5 Comments:
H24	What is your role in the provision of safe water within the hospital?	
H25	How often do you meet with the director about the filtration system?	_____ times a day/week/month
H25a	Are your meetings scheduled?	1) Yes 2) No 99) I do not know
H25b	What did you discuss the last time you met?	
H25c	Do you inform the director when you shut off the filtration system?	1) Yes 2) No 99) I do not know
H26	How often do you meet with the laboratory staff about the filtration system?	_____ times a day/week/month
H26a	Are your meetings scheduled?	1) Yes 2) No 99) I do not know
H26b	What did you discuss the last time you met?	
H26c	Do you inform the laboratory when you shut off the filtration system?	1) Yes 2) No 99) I do not know
H26d	Do you inform the laboratory when you change	1) Yes 2) No 99) I do not know

	to a new chlorine concentration?	
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? 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 H29c H29d H29e H29f	How often do you have to buy chlorine for the water system? Where do you buy chlorine? 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)	_____ times a day/week/month __ Market __ Chemical shop (pharmacist) __ Other (describe) _____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?	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
H38	Have you ever removed the tops of the filters and washed the filters in a chlorine bath? If yes, how often?	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	 A. 1) correct 2) incorrect Comment:

	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.	B. 1) correct 2) incorrect Comment: C. 1) correct 2) incorrect Comment:
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		
H48	Would you recommend the filtration system to other hospitals? Why or why not?	1) Yes 2) No 99) I do not know
Awareness/ Demand/ Attitudes		
H55	Why is it important to treat the water?	
H56	In your opinion is the water from the tap safe to drink?	1) Yes 2) No 99) I do not know

H57 H57a H57b	Do you drink from the tap? How often? Which tap do you fetch water to drink from?	1) Yes 2) No 99) I do not know __ Weekly __ Monthly __ Yearly __ Never __ N/A Comments
H58	What are your (maintenance) goals for the water filtration system? Do you feel like you are achieving them? Why?	
H58a	What motivates you to work on the water Treatment system?	
H58b	Have you ever gotten sick from unsafe water?	1) Yes 2) No 99) I do not know
H58c	How much time per week do you spend doing tasks for the Water Treatment System?	__ Weekly
H58d	Considering all of your other tasks how high of a priority are doing tasks for the Water Treatment System?	1) High 2) Somewhat high 3) not at all a priority
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:

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
N1i Filtered? Yes/No N1j Chlorinated?

N1l
Cement
Plastic
Metal
Other
_____

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

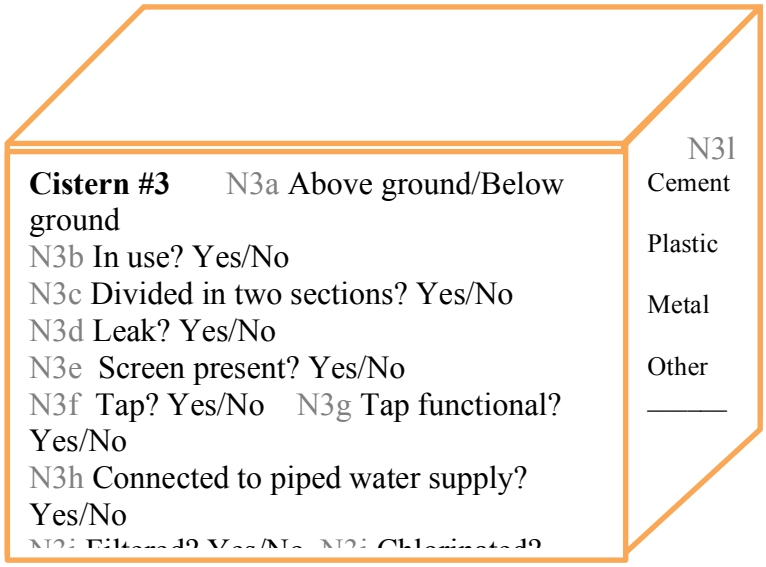
Notes on Cistern #1:

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
N2i Filtered? Yes/No N2j Chlorinated?

N2l
Cement
Plastic
Metal
Other
_____

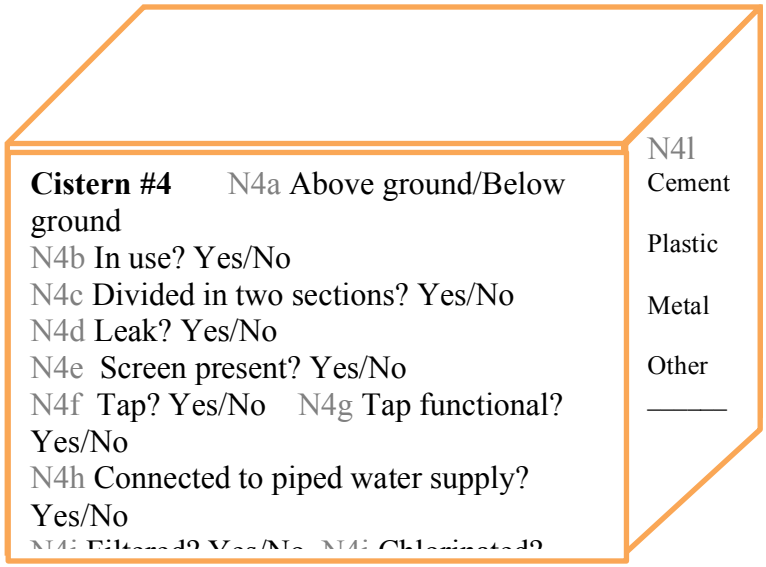
N2m Cistern #2: If the water source ceased, how long would the water in cistern last?
1) < 1 day 2) 1-3 days 3) > 3 days

Notes on Cistern #2



Notes on Cistern #3

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



Notes on Cistern #4

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

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/No P1i Chlorinated? Yes/No P1j Chlorine residual level: _____ P1k What is the volume of the polytank?
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/No P2i Chlorinated? Yes/No P2j Chlorine residual level: _____ P2k What is the volume of the polytank?
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: _____ P3k What is the volume of the polytank?
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: _____ P4k What is the volume of the polytank?
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: _____ P5k What is the volume of the polytank?
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: _____ P6k What is the volume of the polytank?
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: _____ P7k What is the volume of the polytank?

Notes:

Polytanks

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: _____ P8k What is the volume of the polytank?
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: _____ P9k What is the volume of the polytank?
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:

Maintenance 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	Sachet	Tap	Other			N/A
Drinking							
Hand washing							
Chlorine Filter Solution							
Washing water storage containers (cisterns, bottles, etc)							
Other?							

Comments & Observations:

WATER SAMPLES

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

Sample 1		
M1.1	Is the water flowing today?	1) Yes 2) No →SKIP
M1.2 M1.3	Collect two water samples	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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		
M4.1	Is the water flowing today?	1) Yes 2) No →SKIP
M4.2 M4.3	Collect two water samples	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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 M4.3	Collect two water samples	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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	Collect two water samples	

M4.3		TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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 11		
M5.1	Is the water flowing today?	1) Yes 2) No →SKIP
M5.2 M5.3	Collect two water samples	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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		
M5.1	Is the water flowing today?	1) Yes 2) No →SKIP
M5.2 M5.3	Collect two water samples	TC 1: _____ _____ _____ Turb: _____

		EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____

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 M5.3	Collect two water samples	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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 24		
M6.1	Is the water flowing today?	1) Yes 2) No →SKIP
M6.2 M6.3	Collect two water samples	TC 1: _____ _____ _____ Turb: _____

		EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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 27		
M6.1	Is the water flowing today?	1) Yes 2) No →SKIP
M6.2 M6.3	Collect two water samples	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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 30		
M6.1	Is the water flowing today?	1) Yes 2) No →SKIP
M6.2 M6.3	Collect two water samples	TC 1: _____ _____ _____ Turb: _____ EC 2: _____ _____ _____ Free: _____ PS 2: _____ _____ _____ Total: _____
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):

P6 P6a	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:
P7	Are there benefits of having safe water for your job?	1) Yes 2) No 99) I do not know Comments:
P8	Approximately how much do you spend monthly to obtain consumables (chlorine, fixing broken taps, pumps, etc) and parts needed to fix repairs for the water treatment system?	_____ Ghc
P8a	Why are repairs not made for certain items?	
P9	In what quantity is chlorine purchased?	
P10	How much does chlorine (bleach) cost on a monthly (or quarterly) basis for the filtration system? (probe for cost/unit time)	_____ Ghc
P11 P12	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:
P13	Where do you buy the chlorine?	
P14	How often do you purchase chlorine?	
P15	What are the challenges in procuring chlorine?	
P16	Do you know how much chlorine is used for the water treatment system vs. for cleaning purposes in the hospital?	
P17	Do you buy a different kind of chlorine for the water treatment system vs. for cleaning in the hospital?	
P18 P18a P18b	Is there an operating budget for the water treatment system? If so can we see it? (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?	1) Yes 2) No 0) N/A 99) I do not know 1 2 3 4 5 Comments: 1 2 3 4 5 Comments:
P19	**Opinion of the investigator:** On a scale of 1-5, 5=very committed 1=not	

	committed: How committed was the participant to respond to the questions asked? What was the participant's level of knowledge about the practices at this hospital? How willing was the participant to give examples and additional information? 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:

Procurement Officer

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	Sachet	Tap	Other			N/A
Drinking							
Drinking water provided for visitors							
Hand-Washing							

Comments & Observations:

APPENDIX B. 2014 Sustainability Metric

Accountability

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					
		A33 b, J16b	Water treatment					
		A33g, H31 a, J16g	By-passing the system					
		A33f, H31 b, J16f	Measuring chlorine levels					
		A33c, H31c, J16c	Cleaning of water containers					
		A31 d	Cleaning water cisterns					
		A33 d, H31 d, J16d	Repairing taps and broken sinks					
		A33e, J16e	backwashing					

Oversight by another entity	Is there oversight by another entity?	A55a-d, A85 a-d	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?	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 discussed 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
		A86 a-b	(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?					
		A56-A56a	Who reviews expense reports? Where are they sent? How often?					
		A34-35, J25-26	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?					
		A36, J19-a	What is the closest city where water samples could be taken for analysis?					

		H22-b	Do you (maintenance) communicate with the MoH/GHS about the filtration system? How often? What do 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	The director and the 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	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
		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, H20 a-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)		has many unanswered questions.	hospital has some sense of GE's long-term involvement but has questions .		GE's long-term level of involvement.
		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 hospital is able to cover some of the costs associated with the system	The hospital has allocated funding toward the recurring costs but maybe	The hospital has allocated funding for recurring and fixed costs;	The hospital has allocated funding to both the recurring costs and fixed
		A48 b	fund for water treatment (reoccurring costs)					

		A48c	funds for infrastructure (piping and sinks) (fixed costs)	the fixed costs associated with the provision of safe water. There is no evidence that the hospital has invested in the provision of safe water.	but relies on GE for the majority.	not fixed costs. If GE stopped providing funding, the hospital would struggle to maintain the provision of safe water. There may be an outside organization/ foundation that can support fixed costs.	however, the funding may not be sufficient and is uncertain.	costs associated with the provision of safe water. There is evidence that the hospital has invested in the provision of safe water.
		A48 d	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)					
		A51 b	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?					
Finances	Is the hospital able to pay reoccurring costs for the system and does it maintain a record of their finances regarding	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	The hospital is sometimes able to pay the recurring costs but most of the time they are	The hospital is able to pay the recurring costs associated with the system most of the time but	The hospital is able to pay recurring costs associated with the system the majority of the	The hospital is able to pay all recurring costs associated with the system and maintains a

	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)	there are no records maintained for expenditures.	unable to. There may be records of expenditures but they are not easily traced to the water system.	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.	time. They maintain some records of expenditures easily traced to the water system.	record of expenditures easily traced to the water 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)					

		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?					

Technical Feasibility

Topic	Broad Question	Code	Survey Questions and Metrics	0	1	2	3	4
Water Source and Availability	Is there a reliable water source that provides the quantity and availability of water needed to meet demand? 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	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?	in a way that meets demand.				
		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)					
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 commonly used) do not have lids.	Hospital infrastructure is not consistently maintained. At least 50% of sinks observed were functional. Fewer than 75% of all polytanks (if applicable and commonly used) have lids. Most storage containers are never cleaned but some may be.	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 polytanks (if applicable and commonly used) have lids. Most storage containers are occasionally cleaned.	Hospital infrastructure relating to water, sanitation, and hygiene is mostly maintained. At least 85% of all sinks observed were functional. At least 90% of all polytanks (if applicable and commonly used) have lids. Most storage containers are cleaned on a semi-regular basis.	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 a schedule and all polytanks (if applicable) have lids.
		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)					

Water Quality Testing	Does the tap water throughout the hospital meet WHO standards for microbial water quality?	M		Fewer than 40% of all samples met WHO standards for microbial water quality.	Between 40-59% of all samples met WHO standards for microbial water quality.	Between 60-79% of all samples met WHO standards for microbial water quality.	Between 80-99% of all samples met WHO standards for microbial water quality.	100% of all samples met WHO standards for microbial water quality.
	Does the tap water throughout the hospital meet standards for chlorine residual?	M		Fewer than 20% of samples met standards for chlorine residual.	Between 20-39% of samples met standards for chlorine residual.	Between 40-59% of samples met standards for chlorine residual.	Between 60-79% of samples met standards for chlorine residual.	More than 80% of samples met standards for chlorine residual.

On-site Capacity

Topic	Broad Question	Code	Survey Questions and Metrics	0	1	2	3	4
Organization and Communication	Is there a clearly defined organizational structure? Are all key tasks accounted for?	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	Are there sufficient	A1	How long have you been working here as the director?	There are not enough trained	Some basic management	Essential management	There are a sufficient	There are a sufficient

Strengthening	trained personnel to manage, maintain, and operate the water system?	H16	Has any staff member been trained to maintain the filtration system by another staff member?	personnel to 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.	and operations are accomplished. However, additional capacity building is needed in at least two of the following areas: lab, management, maintenance. The hospital is self-reliant for some operation and maintenance; however, they depend on GE for the majority of it.	and operations are accomplished. However, additional capacity building is needed in one of the following areas: lab, management, maintenance. The hospital is self reliant for many operation and maintenance issues; however, they do not have any plans to be self-reliant in the next 5 years.	number of trained personnel to manage, maintain, and operate the water system. However, additional capacity building would be beneficial to sustainably manage and operate the system. The hospital is on the road to being able to maintain and operate the water system without support from GE within the next 5 years.	number of trained personnel to manage, maintain, and operate the water system. The hospital is capable of holding their own follow-up trainings. The hospital can operate and maintain the water system without support from GE.
		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 completed at least once a week, and weekly tasks at least once a month.	The daily, weekly, and monthly recommended tasks are generally completed but not as frequently as is recommended. Daily tasks often may not be completed during non-peak times (like on the	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?					

		N (info graphic) not in tool?	How often do you scrub and backwash the Amiad filters?			weekends).		
		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?					

	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	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
		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?				inner workings of the filtration system.	don't go 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?					

Institutional Engagement and Support

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	The hospital director is completely unsatisfied with water filtration	The hospital director is mostly unsatisfied with the water	The hospital director is somewhat satisfied with the water filtration	The hospital director is mostly satisfied with the water filtration system.	The hospital director is completely satisfied with water filtration

			house?	system and would not recommend to another hospital.(1)	filtration system. S/He would probably not recommend the system to other hospitals. (2)	system. S/He knows it has its problems but he would probably recommend the system to other hospitals. (3)	S/He would recommend the system to other hospitals. (4)	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?					
		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 importance of safe water, does not have goals for the system and is not committed. (1)	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 maintaining the system. (2)	The maintenance staff is somewhat satisfied with the water filtration system. They know it has its problems but they would probably recommend the system to other hospitals. 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 maintenance staff is mostly satisfied with the water filtration system. They would recommend the system to other hospitals. They are committed to 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)	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 has set goals for the water treatment system. He is committed to maintaining the system, even when there are challenges. (5)
		H50	Do you have other questions for GE about the water filtration system?					
		H30	Do you (maintenance staff) talk to other maintenance teams with GE water filtration systems?					
		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?					
	Is the hospital director committed to the sustainability of the water 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	The hospital director is unsure of the future of the water filtration system in the	The hospital director has goals for the water filtration system and has set plans in	The hospital director has both short-term and long-term goals for the water filtration system	The hospital director is committed to maximizing the water filtration system's full

		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 were to stop providing support, water filtration would not continue.	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.	motion for some of them. If GE stopped providing support, the hospital may be able to sustain water filtration for a time.	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 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.	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.
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?					
		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	Educational messaging regarding safe water, sanitation, or hygiene practices were observed infrequently and not in both staff and patient areas. There may	Educational messaging regarding safe water, sanitation, or hygiene practices were observed in several locations and were visible to both patients and staff.	Educational messaging regarding safe water, sanitation, or hygiene practices were observed in several locations and were visible to both patients and staff. Some	Compelling educational messaging regarding safe water, sanitation, and hygiene practices were very visible in places where both patients and staff can see
		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?	regarding safe water and the director and maintenance staff do not educate the staff about the water system.	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.	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 water system on several occasions but it was informal and only to specific staff.	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 staff about the water system; however, more consistent and widespread education would be an improvement.	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.
		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)					
		G19	Messages observed/organizations:					
	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	There is some awareness of the water system among staff, though the knowledge is limited or vague. Some participants drink/use water	The majority of staff are aware of the water system and some are knowledgeable about the process. Over half the participants	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?		because they know it is safe.	from the system because they believe it to be safe.	believe the water from the system is safe to drink/use.	
		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?					