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EVALUATION OF WATER SAFETY PLANS IN RURAL GHANA:
BASELINE ASSESSMENT

September 2023

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ABOUT USAID/REAL-WATER:

USAID Rural Evidence and Learning for Water (REAL-Water) is a five-year partnership that develops and evaluates strategies for expanding access to safe, equitable, and sustainable rural water services. REAL-Water supports policymakers, development partners, and service providers to make strategic decisions and implement best practices for water management through implementation research. It also ensures coordination with USAID programs contributing to the water, sanitation, and hygiene (WASH) and water resources management (WRM) knowledge base, in alignment with the USAID Water for the World Implementation Research Agenda. For further information about this and other aspects of the project, as well as to access our knowledge products, please visit globalwaters.org/real-water.

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STUDY RATIONALE

Much of the global population is exposed to contaminated drinking water. In piped systems, contamination can be mitigated at the water supplier or household levels, but it is often easier to mitigate at the water supplier level where it can be centrally managed. A water safety plan (WSP) is a holistic tool for proactively ensuring the safety of drinking water supplies from source to tap. The World Health Organization (WHO) recommends this systematic risk assessment and preventive management approach for water supplies of all sizes to ensure drinking water safety and avoid exposure to contamination.

While application of WSPs have spread, systematic evidence for their implementation and effectiveness in improving water quality and health is limited, particularly in low-resource settings. Randomized controlled trials with staggered implementation (i.e., implementing in the control group at the end of data collection) have been recommended to overcome these issues. WSPs are also at the early stages of implementation in Ghana, and an evaluation of their implementation approaches and impact would help guide nationwide adoption and provide evidence useful to water service providers.

STUDY DESIGN

This Rural Evidence and Learning for Water (REAL-Water) study includes 92 piped water supply systems operated by a non-profit, private water supplier in Ghana. The water systems are located across nine regions in southern Ghana, primarily in rural towns ranging in size from approximately 1,000 to over 10,000 people. Most systems (85%) rely on groundwater from a borehole that is chlorinated, pumped to a tank, and distributed by gravity to shared public taps and/or household connections. The remaining systems have surface water sources followed by filtration and disinfection. Consumers pay a volume-based fee to collect water from the systems.

We designed a randomized controlled trial to test the implementation effectiveness and outcomes of WSPs, with half of included water systems randomly assigned to the intervention group to develop and implement WSPs immediately, while the other half will wait to develop WSPs after endline data collection is complete. This staged implementation will ensure all of the studied water systems have an opportunity to use the risk management approach.

This report presents the results of baseline data collection to understand the existing conditions of the water systems and communities prior to implementing WSPs. It discusses preliminary implications for water safety planning in rural, low-income settings.

DATA COLLECTION METHODS

We collected baseline data from March to June 2023 from 92 water systems, 1,840 households, and 77 healthcare facilities. At the water systems, we collected information on system functionality and management, measured water quality at public standpipes, and conducted sanitary inspections of infrastructure. At the households (20 per water system), we captured water consumption practices and perspectives, socioeconomic information, water-related illnesses, and water quality in stored household water. In addition to surveys, we explored consumer perceptions in more depth using focus group discussions with community members in 45 communities. At healthcare facilities, we assessed water access and requested records of the number of visits potentially related to waterborne diseases from administrators. Most healthcare facilities served multiple communities and had larger coverage areas than the water systems, so we will further evaluate the usefulness of this health data for determining potential changes in waterborne disease due to water system improvements prior to endline.

SUMMARY OF BASELINE FINDINGS AND IMPLICATIONS

Baseline data revealed several areas of improvement that WSP implementation could address:

- **SYSTEM FUNCTIONALITY AND RELIABILITY:** While the majority of consumers (73%) felt the frequency of water supply was generally sufficient to meet their needs, almost two-thirds (63%) reported interruptions in the past month, typically due to a technical problem or power failure. Operators also reported interruptions (though to a lesser degree), some due to weather events such as droughts, storms, wind, or floods. Improved management of risks could reduce breakdowns, improve reliability, and improve climate resilience of systems.

- **WATER QUALITY:** Microbial water quality was typically good at the point of collection, but deteriorated before use. Most standpipes (84%) had no *E. coli* in 100-ml water samples, but this proportion reduced to 41% in household stored water. Free chlorine residual levels at the point of collection were often below recommended levels of at least 0.2 mg/L (67% of water samples), providing insufficient protection against recontamination during transport and storage. Improving chlorination and addressing sanitary risks related to infrastructure would likely improve water quality.

- **CONSUMER PERCEPTIONS:** Among customers of the piped water systems under investigation, only 61% used it as their main source of drinking water, while others primarily drank sachet water. A majority of respondents (56%) reported some water quality issues related to taste, odor, and/or appearance of the water. While some customers opted not to drink piped water due to the chlorine taste and smell, focus group discussions suggested that community sensitization about chlorine and the associated smell may improve user perceptions.

- **DOCUMENTATION:** Most water systems did not have detailed documentation of water system operation and management protocols. For example, only 17% of water systems had a detailed manual documenting the system's standard operating procedures and 12% a detailed emergency response plan. Development of system documents and plans covering the entire WSP process should improve institutional memory and consistency in the operation and management of systems. It can also facilitate periodic reflection and strategic planning that promotes performance improvements over time.

NEXT STEPS

WSP implementation began in water systems in July 2023 and is ongoing. We are concurrently conducting a process evaluation of the implementation quality. Endline data collection is planned for 2024-2025, following 12-18 months of implementation in the intervention group, after which the intervention will be applied in the control group.

INTRODUCTION

BACKGROUND

In rural areas of Western Africa, more than half of the population is exposed to contaminated drinking water (UNICEF/WHO, 2022). In Ghana, piped water services are slowly expanding into rural areas, where community members have traditionally operated water supplies under the oversight of local government. Consolidation is an emerging trend for rural water service provision, wherein a central entity may instead operate around one hundred or more water systems dispersed across the country (REAL-Water, 2023a). One rationale is that consolidation provides opportunities for greater professionalization, cost sharing, and centralized monitoring of rural water supply services.

Contaminants can enter water supplies at the source (e.g., lakes or groundwater wells), in the distribution network (in the case of piped water), during collection and transport (when collecting from public standpipes or handpumps), and during household storage. All of these potential sources of contamination are important to address. Correspondingly, water contamination can be mitigated within water supplies (e.g., source protection, treatment of piped water) or at the household level (e.g., point-of-use treatment, promotion of safe storage practices). Mitigating contamination at the water supply level is often easier, since it can be centrally managed by the water supplier, whereas household-level mitigation strategies require all individual water users to carry out specified safety practices consistently.

A water safety plan (WSP) is a holistic tool for proactively ensuring the safety of drinking water supplies from source to tap. The World Health Organization (WHO) recommends this systematic risk assessment and preventive management approach for water supplies of all sizes (WHO, 2022b) to ensure drinking water safety and avoid exposure to contamination (IWA, 2004; WHO, 2022b). WSPs have become widely used and are incorporated into legal requirements for water utilities in several countries (Ferrero et al., 2019; Gunnarsdottir et al., 2012; Macleod et al., 2020; WHO/IWA, 2017). The purview of WSPs has also expanded to ensure consideration of climate resilience along all steps of the water supply chain (WHO, 2017).

While application of WSPs and related policies and regulations have spread, systematic evidence for their implementation and effectiveness in improving water quality and health is limited, particularly in low-resource settings (Gunnarsdottir et al., 2012; Setty et al., 2017). Previous studies of WSP impacts (Kayser et al., 2019; Kumpel et al., 2018; String & Lantagne, 2016) have limited abilities to discern causal relationships between implementation and outcomes due to their observational study designs and poor retrospective data accessibility. Randomized controlled trials with staggered implementation (i.e., implementing within the control group at the end of data collection) have been recommended to overcome these issues (Kumpel et al., 2018).

In Ghana, WSPs are being implemented by utilities and private water suppliers in both rural and urban areas (REAL-Water, 2023b). For example, the Community Water and Sanitation Agency (CWSA) is implementing WSPs for rural piped water systems under its management. The urban water utility, Ghana Water Company Limited (GWCL), has also started a WSP at one of its systems in the Central region with plans to scale up nationwide (REAL-Water, 2023b). WSPs are also gaining interest among private, non-profit water suppliers—often referred to as safe water enterprises. An evaluation of WSP implementation approaches and impact would help guide nationwide adoption and provide evidence useful to water service providers in Ghana. Greater evidence on the effectiveness of WSP implementation would also be valuable to the larger water sector.

OBJECTIVES

This report examines the baseline status of water systems managed by a private, non-profit water supplier in Ghana, prior to implementing WSPs. It discusses preliminary implications for water safety planning in rural, low-income settings. The overall evaluation proceeds through 2025, with the following research objectives:

1. Evaluate the impact of WSPs on water supply system infrastructure, water availability and reliability, water quality, consumer perceptions, water service provider management and financial sustainability, climate resilience, equity, and consumer health.
2. Examine WSP implementation processes and challenges in rural communities and small towns in Ghana, and explore specific aspects of water system management and intervention delivery that lead to better outcomes and impacts.

WHO guidance (WHO, 2012, 2022a) will be the basis for WSP implementation as well as past guidance developed for Ghana water systems in rural communities and small towns by UNICEF, WHO, CWSA, and other government stakeholders.

We will use an evaluation framework consistent with frameworks previously developed and described by the Centers for Disease Control and Prevention (CDC), WHO, Aquaya, and others (Gelting et al., 2012; Kumpel et al., 2018; Lockhart et al., 2014; WHO, 2019) (Figure 1). This framework considers both shorter- and longer-term potential outcomes and impacts.

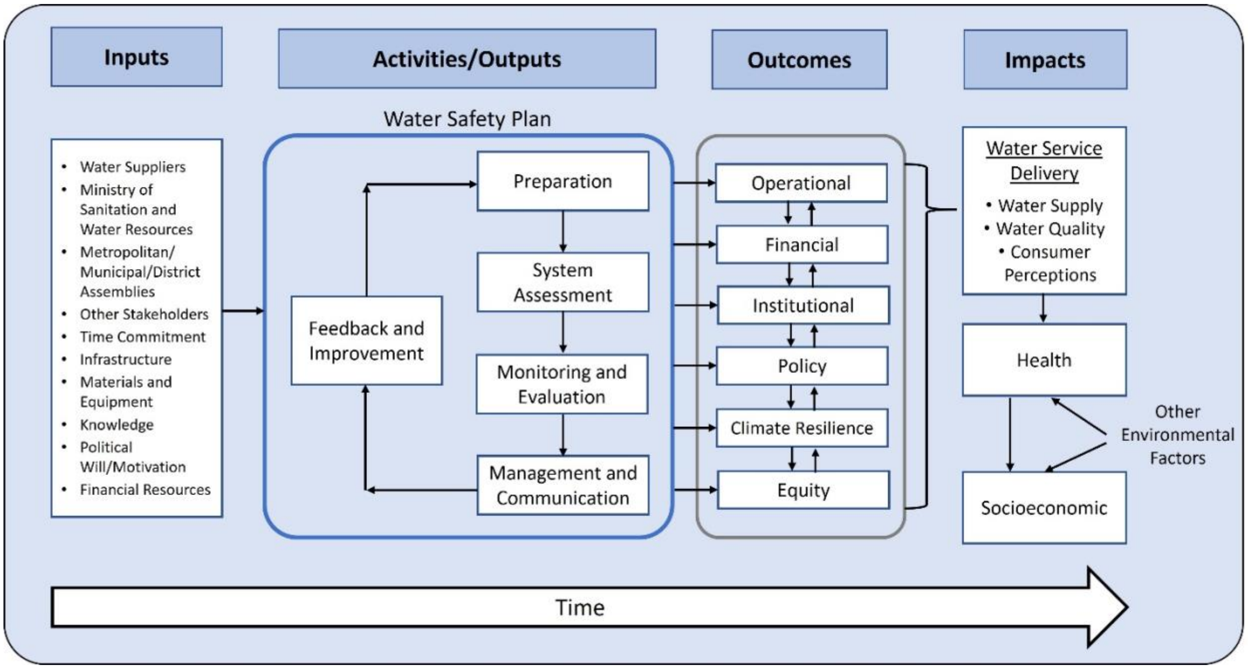

Figure 1. Evaluation framework for WSPs in Ghana, adapted from Gelting et al. 2012.

METHODS

STUDY DESIGN

A randomized controlled trial will test WSP implementation effectiveness and outcomes using the gold-standard approach for understanding causal effects, while staged implementation will ensure all of the studied water systems have an opportunity to use the risk management approach. Half of included water supply systems, randomly assigned to the intervention group, will develop and implement WSPs immediately, while the other half in the control group will wait to develop WSPs after endline data collection is complete (Figure 2). We will conduct a comprehensive process evaluation throughout the implementation period to measure implementation quality. All water systems operated by a partnering private, non-profit water supplier were eligible for inclusion, except for three systems that were included in another ongoing research trial with similar expected outcomes, one that had a WSP implemented as part of a pilot, and two that were non-functional throughout baseline data collection. This left a total of 92 water supply systems included in the study.

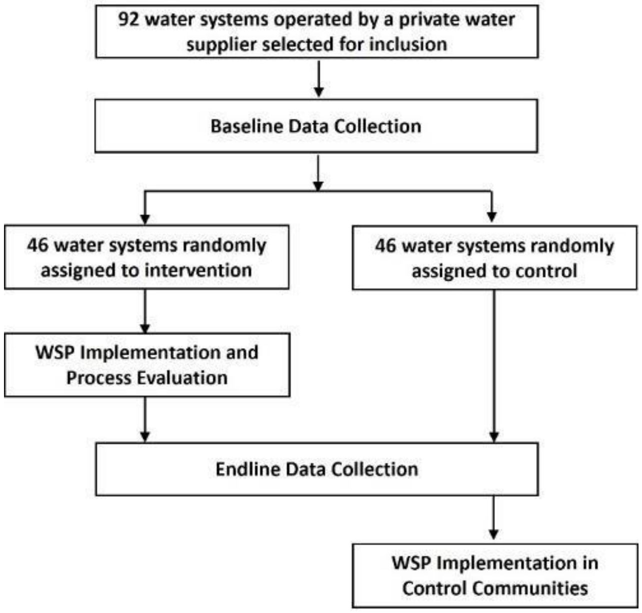

Figure 2. Study flow diagram for WSP evaluation study in Ghana.

This report presents the results of baseline data collection to understand the existing conditions of the water systems and communities prior to randomization and implementation of the WSP intervention.

DESCRIPTION OF WATER SYSTEMS

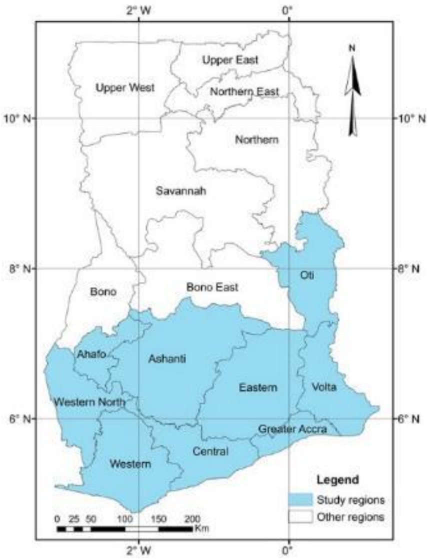

Figure 3. Map of study regions in Ghana (highlighted in blue).

The piped water systems included in this study are located across nine regions in southern Ghana (Figure 3), primarily in small towns ranging in size from approximately 1,000 to over 10,000 people. Each water system has a full-time local operator responsible for day-to-day operations. Additionally, a regional manager oversees the operations of approximately nine water systems within one geographic cluster, while a management team in Accra manages finances and operations centrally. This supplier is a non-profit organization that receives external donor support to supplement system revenue from consumer tariffs. Two-thirds of systems had higher annual operating expenses than revenue.

The water systems are typically sized to produce one million liters per month and were reported to supply a median of about 14,000 liters per day. Customers pay an upfront fee to collect water, either in cash or with a prepaid card. The fee was typically 20 pesewas per 20 liters (the equivalent of about 0.02 USD) at the time of baseline data collection, but was since increased to 25 pesewas per 20 liters. Most communities with these water systems also have other water sources available, and therefore not everyone in the communities uses the same water supplier.

The systems vary in source water and treatment employed. Most (74 systems, 85%) rely on groundwater from a borehole that is chlorinated, pumped to a tank, and distributed by gravity to shared public taps and/or household connections. Only one of these water systems reported not chlorinating due to complaints about the chlorine taste and smell. The remaining 14 systems have surface water sources and use either slow sand filtration, ultrafiltration, or rapid sand filtration treatment followed by chlorination. Some systems also employ UV disinfection in addition to chlorination or use an additional treatment step for iron or hardness removal. All water systems had storage tanks to serve as reservoirs for water before it enters the distribution system.

BASELINE DATA COLLECTION

We collected baseline data from March to June 2023 from 92 water systems, 1,840 households, and 77 healthcare facilities (Table 1). At the water systems, we collected information on system functionality and management, measured water quality at public standpipes, and conducted sanitary inspections of infrastructure. For water quality measurements, we used digital instruments to measure free and total chlorine, turbidity, pH, conductivity, total dissolved solids, and salinity in the field, and Aquagenx Compartment Bag Tests to measure the *E. coli* most probable number (MPN) in 100-ml samples. We also conducted interviews with regional managers and a focus group discussion with central management staff to supplement and validate data collected from water systems.

At the households (20 per water system), we preferably surveyed a female head of household, because women generally collect water in these settings. We conducted the survey with another adult household member if the target respondent was not available. The survey captured water consumption practices and perspectives, socioeconomic information, water-related illnesses, and water quality in stored household water. We primarily targeted customers of the piped water system, but also surveyed up to four households per community that did not use the water system to better understand perceptions of non-customers. In addition to surveys, we explored consumer perceptions in more depth using focus group discussions with community members in 45 communities. At the healthcare facilities, we assessed water access and requested records of the number of visits potentially related to waterborne diseases from administrators. We collected this information from the main healthcare facility located within or nearby the community that would serve patients with waterborne illness. Most healthcare facilities served multiple communities and had larger coverage areas than the water systems.

The Council for Scientific and Industrial Research (CSIR) ethical review board in Ghana approved our research protocol. We introduced the study and obtained informed consent from all participants before surveying or interviewing them. We only provided aggregated results to water supplier management staff to protect the identity of respondents.

TABLE 1. SUMMARY OF BASELINE DATA COLLECTED

	SOURCE	**DATA COLLECTED**
Water systems (N = 92)	System operator Regional manager Central management	System characteristics Management practices Revenue and financials
	System infrastructure	Sanitary inspection of borehole, surface water intake, water tank, distribution system, and standpipe infrastructure
	5 standpipes/taps per system*	Water quality (free and total chlorine residual, *E. coli*, pH, conductivity, total dissolved solids, salinity, turbidity)
Households (N = 1,840)	20 households per water system†	Consumer practices and perceptions Chlorine residual and *E. coli* in stored water Self-reported water-related diseases
Focus group discussion (N = 45)	At least 3 per geographic cluster	Consumer perceptions
Healthcare facilities (N = 77)	Administrator or head	Water access Number of patient visits for water-related diseases

[*] When a system had less than five functional standpipes, we sampled outdoor household taps connected to the water system to supplement (if available). If there were less than five functional standpipes and no available household taps, we sampled all functional standpipes. When there were more than five functional standpipes per system, we divided standpipes into two groups of approximately equal size: (1) those close to a storage tank, and (2) those far from all storage tanks. We then randomly selected two standpipes from the first group and three standpipes from the second group.

[†] We systematically selected households to participate from each sampled standpipe at various distances and directions in relation to the standpipe to ensure good spatial coverage of respondents.

Image 1. Enumerators measure chlorine residual in a water sample (left) and conduct a focus group discussion (right).

RESULTS

RESPONDENT CHARACTERISTICS

At the household level, most respondents were female (85%) and about half (57%) had completed junior high school or higher levels of education. Their main occupation was mixed between agriculture (26%), sales of produce or goods (34%), work in the informal sector (15%), stay at home care (14%), or other employment (e.g., formal work in the private sector or government; 11%). Most households had a mobile phone (98%) and electricity (93%), but fewer had a bicycle (16%), motorcycle (17%), or car (7%). Most (94%) respondents used the piped water system under investigation and 15% of households had a private tap in their house or compound. Only one household survey was recorded incompletely, which we excluded from the dataset.

In contrast, water system operators were mostly male (90%) and had higher levels of education than household respondents with almost all (95%) reporting to have completed junior high school or higher levels of education. Worker retention was good: just 10% had been in their current position for less than a year, 26% for one to two years, and the remaining 63% for more than two years.

Healthcare facilities interviewed were predominately health centers (56%) and Community Health Planning and Services (CHPS) facilities (32%), with a few hospitals (9%) or clinics (3%). Most were government facilities (88%), and the remainder were faith based. Respondents mostly had roles of doctor or nurse (42%), facility head (26%), or administrator (12%), with a few other various roles (e.g., head nurse, health officer). About one-third (35%) of these facilities were connected to the piped water system of interest, either inside their building or on their plot. The remaining healthcare facilities were connected to other piped water suppliers such as CWSA (8%), relied on boreholes (52%), or had rainwater or other tanks (4%). Only one healthcare facility reported having no water source (1%). Most healthcare facilities (83%) served wider areas than the piped water systems and did not disaggregate records by community, so the health data we collected may not be representative of water system customers. We will further evaluate the usefulness of this type of health data for determining potential changes in waterborne disease due to water system improvements prior to endline.

KEY FINDING 1: WATER SYSTEM FUNCTIONALITY WAS GENERALLY SUFFICIENT TO MEET CONSUMER NEEDS, BUT RELIABILITY COULD BE IMPROVED.

Only half of households (48%) reported that water was available from the piped water system every day. Almost two-thirds (63%) indicated interruptions or stoppage of the water supply within the month before the survey, typically for one to four days. Household respondents reported that a technical problem or power failure typically caused these interruptions. Only half of respondents reported that they were satisfied or very satisfied with the water supplier's response to system breakdown and emergency repairs. However, 73% indicated that the frequency of water supply was generally sufficient to meet their needs.

Water operators reported higher functionality and reliability of water systems, and less frequent water service interruptions, when compared to household perceptions. Water operators reported interruptions for 45% of the water systems within the past three months due to technical problems, in comparison to household reports that 63% had been interrupted in the past month alone. Operators reported interruptions were typically for three days or less, which is similar to the interruption length reported by households. Some of the difference in reported interruptions by households and water system operators may be due to households being unable to collect water when a standpipe vendor is unavailable to open the standpipe, which households may consider an interruption of service but the operator may not. For households with private connections, some interruptions reported due to technical problems may also be related to problems with adding funds to prepaid meters that would only interrupt supply to their household. It is also possible that operators may not be aware of all interruptions experienced by consumers, as water may be flowing out of the storage tank but not reaching all sections of the distribution network (e.g., if demand exceeds supply, households at the far end of the distribution network may not get water). About one-third (34%) of system operators reported interruptions to the water supply within the past 12 months due to weather events such as droughts, storms, wind, or floods. However, this frequency is greater than the frequency reported in records kept by the central management team and requires further investigation into this discrepancy.

KEY FINDING 2: MICROBIAL WATER QUALITY WAS TYPICALLY GOOD AT THE POINT OF COLLECTION BUT DETERIORATED BEFORE USE.

Free chlorine residual levels at standpipes and taps were often below recommended levels of 0.2 mg/L, with only 33% of water samples meeting this standard. Similarly, only 43% of standpipe samples had free chlorine at 0.1 mg/L or above, which is often considered the lower limit for detection for chlorine. However, a greater proportion (60%) of standpipe samples had free chlorine at 0.05 mg/L or above, which is sometimes used as a less conservative lower limit for detectable chlorine.[1] The source water quality and chlorination levels often sufficed to eliminate *E. coli* at the point of collection, but not to protect against recontamination. Most standpipes (84%) had no *E. coli* in 100-ml water samples, but only 41% of household stored water samples were free from *E. coli* contamination (Figures 4 and 5). As

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[1] The manufacturers of the Hach DR300 Pocket Colorimeter instrument used to measure free chlorine levels specify a minimum lower limit of detection of 0.02 mg/L, but we raised the detection limit to account for possible false positives caused by manganese interference.

chlorine residual levels naturally decreased over time during household storage, microbial contamination levels dramatically increased. About two-thirds (63%) of water sampled had been stored for at least one or more days after collection. Households also reported moderate levels of diarrhea[2], with 8% reporting any household member had diarrhea within the past two weeks and 18% of households with children reporting that a child under five years had diarrhea within the past two weeks. A few (5%) households reported that a member of the household had visited a clinic or healthcare center due to diarrhea-related sickness in the past year. However, these cases may be attributed to several difference sources of exposure, with drinking water being only one potential source.

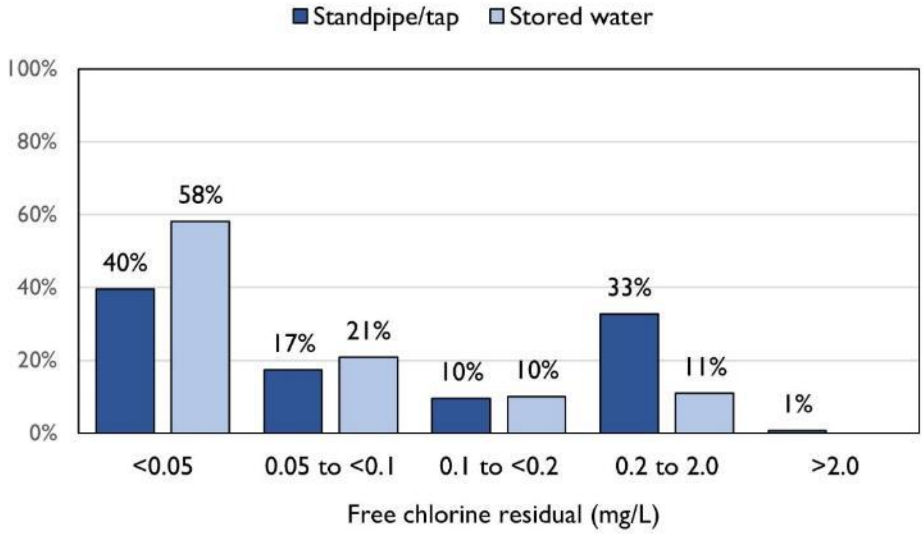

Figure 4. Free chlorine residual in standpipe/tap (N = 437) and household stored (N = 1,071) water samples. The majority of standpipe samples did not meet the minimum recommended level of 0.2 mg/L free chlorine. Chlorine levels also degraded from point of collection (i.e., standpipes) to point of use (i.e., stored household water).

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[2] Diarrhea was defined as three or more loose or watery stools within 24 hours.

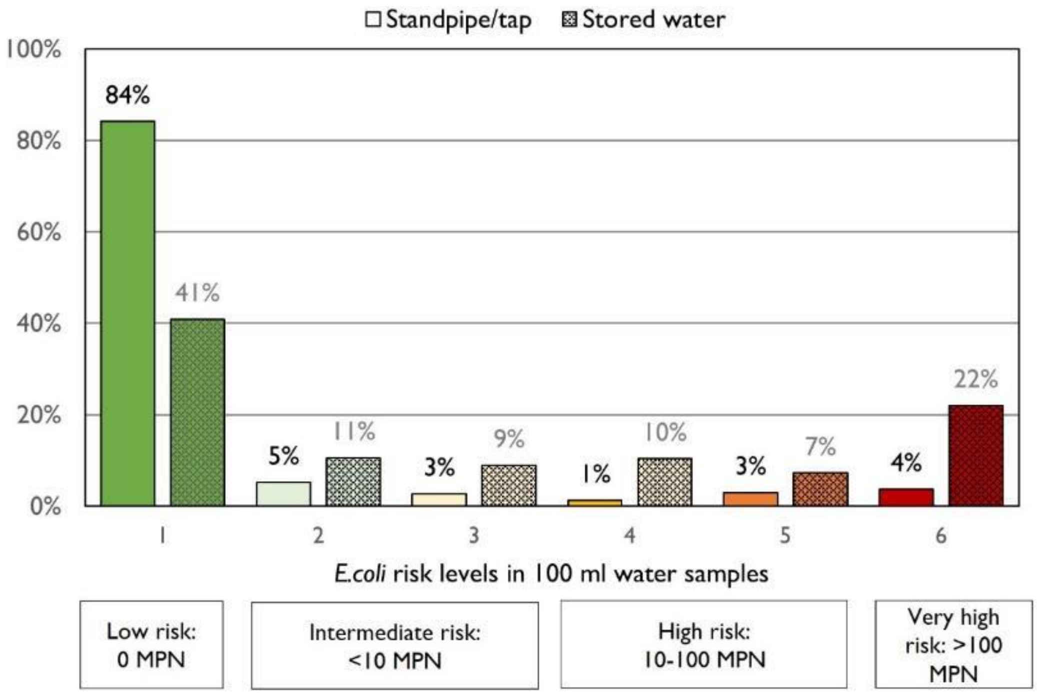

Figure 5. *E. coli* contamination in standpipe/tap (N = 404) and household (N = 472) stored water samples. Most water was free from contamination at standpipes, but contaminated within household stored water samples before use. Risk levels of 1 to 6 were defined based on the most probable number (MPN) and the related upper 95% confidence interval, and each was assigned to WHO risk levels of low, intermediate, high, and very high based on the MPN. Risk levels of 3 and 5 have an upper 95% confidence interval that overlaps with the next risk level.

Chlorine levels often varied across standpipes/taps within the same water system. Only 28% of systems had reliably detectable chlorine (0.1 mg/L or above) at all sampled standpipes. Over a third (36%) of systems had no detectable chlorine at any system standpipes, and the remaining 36% had detectable chlorine for at least one but not all standpipes.

KEY FINDING 3: MANY RESPONDENTS COMPLAINED ABOUT WATER QUALITY AND DID NOT USE THE PIPED WATER SOURCE FOR DRINKING.

ALTERNATIVE DRINKING WATER SOURCES

Among customers of the piped water systems under investigation, only 61% used it as their main source of drinking water. The rest of customers primarily drank sachet water (27%), water fetched from a handpump or mechanized borehole (6%), or water from other sources (e.g., water from a standpipe operated by someone else, rainwater, surface water; each used by 2% or less of respondents). Respondents provided several reasons for not using the piped water system as their primary source of drinking water, both related and unrelated to water quality, mainly that they:

- Did not like the smell or taste of the water;
- Preferred the cold temperature of sachet water, which is stored in plastic bags in coolers or on ice;
- Believed the piped water supply was not safe or that sachet water was safer;
- Thought the water tariffs were too expensive;

- Did not like the color of the water; or
- Thought the nearest standpipe was too far from their house.

PERCEIVED WATER QUALITY

Although not necessarily indicative of actual water safety, a majority of respondents (56%) reported some water quality issues related to taste, odor, and/or appearance of the water. A few (5%) reported other issues with the water quality, typically mentioning that the water did not lather with soap (likely due to hardness) or that black debris settled on the bottom of their water container. Less than half (43%) reported no water quality issues. Still, when asked to rate the water quality, just 2% said it was poor and 12% fair. Most (70%) said it was good, and 15% excellent.

TASTE. About a third of respondents (31%) reported an issue with taste, mostly related to a chlorine taste (53% of those reporting a taste issue) or salty taste (44% of taste issues). However, there was no difference in measured chlorine levels in stored water among households who reported an issue with chlorine taste and those who did not.

ODOR. Just under a quarter of respondents (24%) reported an issue with odor, mostly related to a chlorine smell (96% of those reporting an odor issue). Enumerators also noted a chlorine smell at 17% of sampled standpipes. Similar to taste, there was no difference in measured chlorine levels in stored water among households who reported an issue with chlorine odor and those who did not, suggesting odor and taste perceptions varied among consumers.

Focus group discussions suggested that increased engagement with community members about chlorine and the associated smell may improve user perceptions. For example, while some complained of the smell and one respondent thought that chlorine was being added to reduce the salty taste, some of those who understood the purpose explained that they were satisfied with the water, despite the smell:

> *Female focus group respondent: I also think it is because of the medicine [chlorine] they put in the water and you can even perceive its odor.*
>
> *Interviewer: So, you are not satisfied with it?*
>
> *Female focus group respondent: I am satisfied because that's what is used to treat the water.*

APPEARANCE. About one-fifth of respondents (21%) reported issues with water appearance, noting concerns about water appearing a brown/yellow color (48% of those reporting an appearance issue), dirty (25%), cloudy (20%), or other concerns (e.g., green/black color, particles; 7%). Enumerator observations of water retrieved from standpipes noted 11% of water samples were cloudy, 7% were colored, and 3% had particles. Almost all samples (94%) had low turbidity levels below the Ghana standard of 5 turbidimetric turbidity units (NTU), and 92% below the visibility threshold of 4 NTU. Most (83%) were also below the WHO guideline of 1 NTU for optimal disinfection.

OFFICIAL COMPLAINTS. Despite the water quality issues reported by households during our survey, only one-fifth of respondents (18%) reported that they had contacted the water service provider with a complaint regarding the service or quality of water in the past six months. Of these, 54% reported that the water service provider had responded to their complaint within one week or less, 18% reported the water service provider had responded in a few weeks or more, and 28% reported they received no response. Those who had received a quick response within one week or less were more likely to be satisfied with the water service provider and satisfied with the water quality.

KEY FINDING 4: WATER SYSTEM INFRASTRUCTURE AND MANAGEMENT PRACTICES REVEALED OPPORTUNITIES FOR IMPROVED RISK MANAGEMENT.

Sanitary inspections of water system infrastructure identified many hazards where contamination could enter the drinking water supply. The inspections identified potential risks for 94% of boreholes, 100% of surface water catchments and intakes, 76% of distribution systems, 64% of storage tanks, and 87% of standpipes. At boreholes, risks identified were often potential sources of contamination within 10 or 50 meters of the borehole, such as latrines, animals, or cultivated land. Similarly, we often observed human habitation, farm animals, or crop production upstream of the intake for surface water sources. We often observed risks from pipes exposed above ground for distribution systems. Storage tanks were commonly uncovered, partially open, or missing a screen on air vents. Standpipes were commonly unfenced, creating a risk by allowing animals access to the area, and the area around many standpipes or taps sometimes appeared unsanitary (e.g., trash or feces on the ground).

Image 2. Hazards observed during sanitary inspections related to exposed pipe in the distribution system (left) and animal feces at a standpipe (right).

Most water systems did not have detailed documentation of water system operation and management protocols (Figure 6). Only 17% of water systems had a detailed manual documenting the system's standard operating procedures (SOPs) of how to operate the water system, and 5% of water systems had a detailed troubleshooting manual with steps for fixing any issues that arise with system operation. Similarly, only 19% of systems had a detailed operational monitoring plan of using visual inspections or water quality monitoring to inform operational decisions, 11% had a detailed maintenance schedule, and 12% had a detailed emergency response plan for major supply interruptions, contamination events, or other emergencies affecting the water system. The majority of water system operators reported having access to training programs through the water supplier, with 42% reporting informal training and 43% reporting detailed formal training. Only 14% of operators were unaware of training programs.

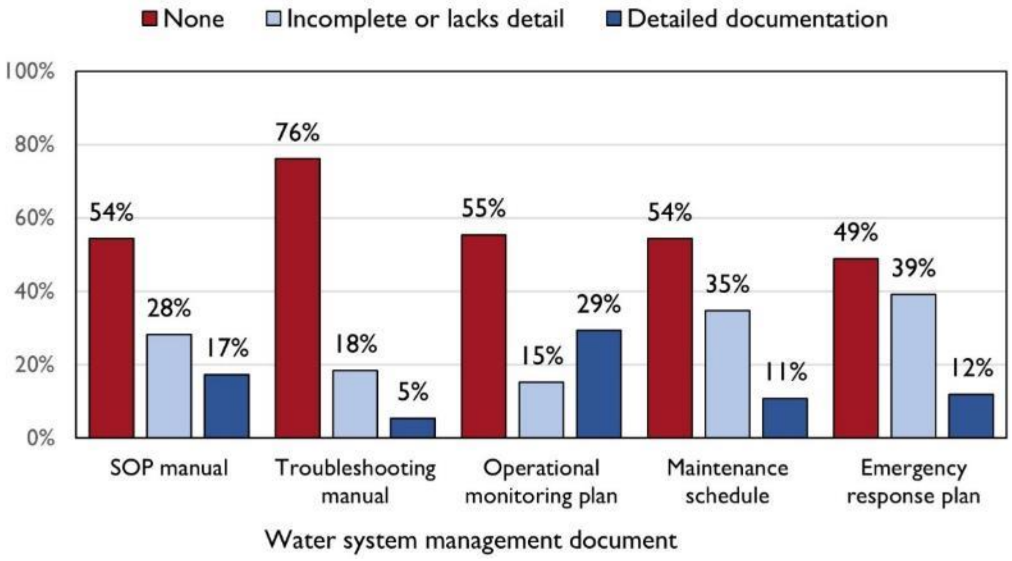

Figure 6. Availability of system management-related documents at individual water systems. A minority of water systems had detailed documentation of operation protocols.

Climate resilience planning for climatic events and shocks was also rare among water systems. Almost all (98%) system operators reported that climate-related risks, hazardous events, or climate variability had not been identified and planned for. Interviews with regional managers corroborated these findings, noting only a few instances where climate-related risks such as flooding or droughts and related impacts on a few specific water systems had been identified.

IMPLICATIONS

Baseline data revealed several areas of improvement that could be addressed by WSP implementation:

- **SYSTEM FUNCTIONALITY AND RELIABILITY**: Improved management of risks could reduce system breakdowns and improve reliability of water supply. This could also improve climate resilience of systems.

- **WATER QUALITY**: Improved chlorination and chlorine measurement could provide a greater chlorine residual to protect against recontamination during storage. Addressing identified potential infrastructure-related risks could also reduce contamination entering the system and improve water quality.

- **CONSUMER PERCEPTIONS**: Increased engagement about water treatment could increase satisfaction, increase use of safe water sources, and potentially decrease complaints related to taste or odor.

- **DOCUMENTATION:** Development of system documents and plans covering the entire WSP process should improve institutional memory and consistency in the operation and management of systems. It can also facilitate periodic reflection and strategic planning that promotes performance improvements over time.

This baseline assessment also identified some areas that may require further investigations. For example, many people were drinking sachet water and we observed that piped water collected by households was likely to be re-contaminated during storage before use. We did not measure the water quality of sachet water in this study, and therefore could not establish whether it is indeed a safer alternative to stored piped water. While some recent studies have found no fecal contamination (i.e., culturable *E. coli*) in sachet water in Ghana (Addo et al., 2020; Aslan et al., 2020; Dzodzomenyo et al., 2018), others have sometimes measured fecal contamination (Addo et al., 2019), so contamination may be brand or location dependent. Additionally, further evidence is needed to understand the best way to balance supplying chlorine levels in systems to provide an adequate chlorine residual without driving consumers away due to the taste or smell of chlorine.

We shared aggregate baseline information related to water availability, consumer practices and perceptions, water quality, and hazard identification with water system managers undertaking the WSPs as a source of information about potential contamination risks that might need to be addressed.

NEXT STEPS

Baseline data collection informed stratification decisions for randomization, and we decided to stratify randomization by regional manager so that half of the systems in a similar geographic setting would receive the WSP invention initially and half would serve as control. WSP implementation began in water systems in July 2023 and is currently ongoing. We are concurrently conducting a process evaluation of the implementation quality. Endline data collection is planned for 2024-2025, following 12-18 months of implementation in the intervention group, after which we will apply the intervention in the control group.

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