IMPROVING WATER QUALITY MANAGEMENT, WATER EQUITY, AND NON-REVENUE WATER IN GHANA

Component 1 Report: Improving Water Quality Management

March 2024

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ACRONYMS AND ABBREVIATIONS

CFU	Colony-forming Units
GHS	Ghanaian Cedis
GPS	Geographic Positioning System
GSA	Ghana Standards Authority
GWCL	Ghana Water Company Limited
ICP	Inductively Coupled Plasma
NRW	Non-revenue Water
NTU	Nephelometric Turbidity Units
PURC	Public Utility Regulatory Commission
UNICEF	United Nations Children's Fund
URBAN WASH	Urban Resilience by Building and Applying New Evidence in Water, Sanitation, and Hygiene
USAID	United States Agency for International Development
WaterCaRD	Water Capacity Rating Diagnostic
WHO	World Health Organization
WSP	Water Safety Plan

EXECUTIVE SUMMARY

Rapid urbanization has strained Ghana's urban water systems, with approximately 40 percent of the urban population lacking access to safely managed water. Challenges with watershed protection, climate change, water quantity, intermittent power, water contamination, and wealth disparities all contribute to insufficient access to safe water. This research sought to assess three core challenges—water quality, equity, and non-revenue water—faced by the national urban water supplier, Ghana Water Company Limited (GWCL), with the goal of co-designing and piloting interventions to address these issues. This report focuses on the first research component: water quality management. It examines water quality monitoring activities, contamination levels and sources, and water safety management measures.

In collaboration with GWCL, the Urban Resilience by Building and Applying New Evidence in Water, Sanitation, and Hygiene (URBAN WASH) team selected two cities for this assessment: Kumasi and Tamale. Evaluation methods included treatment plant and laboratory visits, analysis of existing water quality data, household surveys among customers and non-customers, *E. coli* and chlorine measurements within households, select metal testing in the distribution network, interviews with local leaders and water managers, focus group discussions in low-income communities, and interviews with water vending associations.

The team found mixed institutional capacity for water quality monitoring. GWCL performs extensive water quality monitoring, with gaps related to equipment breakdowns or consumable shortages, but its largest gaps are the limited use of this water quality data to inform decision-making and accountability to consumers and regulators. Specifically, GWCL has a fully staffed water quality department and monitors an extensive list of parameters in both cities. However, URBAN WASH noted laboratory limitations related to inadequate equipment, challenging procurement procedures, and inconsistent quality assurance activity. More frequent refresher trainings and improved data visualization would help ensure that water quality data effectively guides decision-making. Additionally, GWCL could share water quality information more systematically with consumers to improve downward accountability.

At the point of use (i.e., either the tap or household storage container used to fill drinking water vessels), piped water had high levels of microbial contamination: in almost half the samples, *E. coli* levels exceeded 10 colony-forming units (CFU) per 100 mL. Water from non-piped supplies, such as surface water or rainwater, had even higher levels of fecal indicator bacteria. In contrast, packaged water sampled at the point of use more often did not contain microbial contamination, consistent with several other studies in Ghana. This is likely because packaged water was most commonly piped water that underwent additional treatment before packaging, and thus received better protection from contamination during transport and point-of-use storage. In both cities, poorer households were less likely to drink packaged water, and thus faced greater health risks.

Examining utility-reported data, the team found that turbidity consistently met regulatory standards in Kumasi but not in Tamale. Chlorine levels did not always meet requirements in the water distribution networks. In Kumasi, households located closest to the water treatment plant had sufficient chlorine residuals in their drinking water, but households farther away had less consistent levels. Utility data revealed no microbial contamination in the distribution network; however, the team's findings of microbial contamination at consumer taps indicate potential discrepancies in sampling and analysis methods that warrant further investigation. Periodic power and water service interruptions, as well as frequent pipe breaks, pose risks to drinking water safety.

Regarding water safety management, GWCL has been slow to roll out proactive risk management programming in most parts of Ghana, due in part to a lack of regulatory enforcement. GWCL teams in

both Kumasi and Tamale had drafted Water Safety Plans (WSPs) at the time of reporting and are awaiting feedback from the head office.

Recommendations for addressing water quality challenges included upgrades to water quality testing equipment and methods, supplying laboratories with backup power, optimizing treatment methods (particularly turbidity removal and adjustment of chlorine levels to maintain residual disinfection all the way to the household), and following through with implementation of the WSPs. URBAN WASH discussed these recommendations with GWCL and co-created detailed city-level action plans. These action plans are available as separate documents.

1.0 INTRODUCTION

1.1 BACKGROUND

Rapid urbanization has strained Ghana's urban water systems. Ghana's urban population has more than tripled over the last three decades, rising from approximately five million (1990) to more than 18 million (2021), with over half (57 percent) of the country's population now living in urban areas (GWCL 2022). This rapid rate of urbanization has outstripped expansion of urban water infrastructure. According to recent estimates, approximately 40 percent of Ghana's urban population does not have access to safely managed water, i.e., water from an improved source on premises, available when needed, and free of contamination (WHO/UNICEF 2020).

The government-owned Ghana Water Company Limited (GWCL) utility operates 88 urban water schemes. GWCL's policies and procedures require that water quality meets standards for consumption set by the Ghana Standards Authority (GSA) (Ghana Statistical Service 2019; Ghana Standards Authority 2021). According to international water quality monitoring conducted under the Multiple Indicator Cluster Survey, urban areas do not always meet these standards, with 39 percent of water points exhibiting *E. coli* contamination (Ghana Statistical Service 2018). Contamination may be introduced in raw water sources, within treatment and distribution infrastructure, or at points of use. Agricultural activities, housing development, small-scale illegal mining ("Galamsey"), sand winning (mining), and other commercial and industrial activities degrade the quality of surface water sources. Ghana's 2015 National Drinking Water Quality Management Framework promotes water safety planning, which is a holistic approach to identify and address contamination risks. Uptake has been limited to date nationwide (REAL-Water 2023), but GWCL is increasingly adopting this approach.

Serving low-income communities poses another challenge. Disaggregated water access data reveals persistent regional and wealth disparities across the country (Ghana Statistical Service 2019; Monney and Antwi-Agyei 2018). The poorest households tend to have lower access to piped water, in part due to the costs associated with piped water connections (Franceys 2005; Adams and Vásquez 2019). For households connected to the piped network, GWCL guarantees a "lifeline" water volume at reduced tariff, but in practice such measures often fail to reach the poor, who tend to have more users per connection and exceed the subsidized water volume. Additionally, intermittent service delivery and water rationing commonly affect low-income areas, pushing households to rely on private water supplies or vendors (Twerefou et al. 2015). The Coronavirus Disease 2019 (COVID-19) pandemic and the associated economic shocks have made water access more difficult for consumers, particularly the poorest (USAID 2020), while food, housing, and energy costs have destabilized (*Bloomberg.Com* 2023).

Finally, GWCL's total treated water production accounts for only 60 percent of water demand in urban areas, while non-revenue water (NRW) was estimated at 46 percent in 2021 (GWCL 2022). Aging water supply infrastructure, including existing treatment facilities and piped networks, hampers GWCL's ability to produce potable water at full capacity and leads to high physical water losses. Further, climate change has led to longer periods of dry weather and heavier precipitation and flooding, which along with pollution compromises surface water supply quantity and quality.

Issues of equity, NRW, and water quality are all interconnected. For example, low revenues driven by high commercial losses can hamper a utility's ability to expand services to unconnected, low-income areas. Further, pipe breaks and intermittency promote the entry of contaminants in the distribution network and deteriorate water quality. Finally, water quality issues may affect poor households disproportionally, as they are more likely to rely on off-premises taps, requiring transport and storage, and less likely to purchase packaged water. They also tend to live in peripheral areas in far reaches of the distribution network where intermittency and associated contamination are more common.

1.2 ACTIVITY PURPOSE

On July 5, 2022, the Urban Resilience by Building and Applying New Evidence in Water, Sanitation, and Hygiene (URBAN WASH) project, a centrally funded activity of United States Agency for International Development's (USAID's) Bureau for Resilience and Food Security, received a request from USAID/Ghana to conduct research and pilot new interventions. URBAN WASH is **conducting assessments of three core challenges faced by the urban water sector in Ghana—water quality, equity, and NRW—with the goal of designing and piloting interventions for addressing these issues**.

This study takes a phased approach (Figure 1). Phase 1 consists of initial assessments on water quality management, water equity, and NRW, leading to the co-development of action plans with GWCL. Findings from Phase I will inform Phase 2 of the activity, which includes a pilot of intervention(s) in collaboration with GWCL.

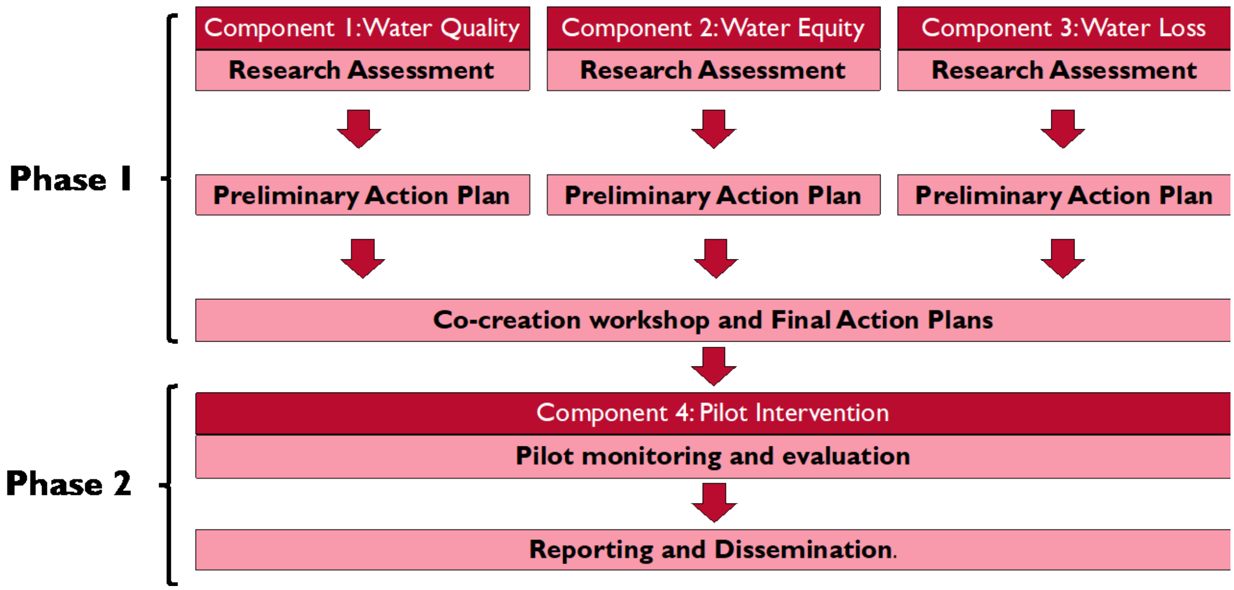

Figure 1: Study framework targeting water quality, equity, and losses

1.3 RESEARCH QUESTIONS

This report focuses on the assessment of water quality management, which was designed to address the research questions listed in Table 1.

Table 1: Research questions examining opportunities to improve water quality management in urban Ghana

Topic	Research Questions
Water quality monitoring	What is the extent and complexity of GWCL's water quality monitoring activities for the distribution systems of the two target cities?

Topic	Research Questions
Water quality and contamination sources	What is the quality of drinking water for GWCL consumers and non-consumers? What are the main sources of water contamination at the source and in the distribution network?
Water safety management measures	What measures or actions are being taken to reduce contamination risks at both the source and in the distribution network? To what extent has GWCL prepared and implemented Water Safety Plans (WSPs) in its operations?
Improvement opportunities	What are the best approaches and respective costs to improve water quality management?

1.4 INTENDED AUDIENCE AND USES

This study primarily serves GWCL and USAID/Ghana decision-makers. It provides GWCL with evidence to guide decisions and interventions to improve urban water quality management. The assessments and pilot interventions will inform USAID/Ghana's future work on urban water quality. Secondary audiences include Ghana's Ministry of Sanitation and Water Resources, the local Metropolitan, Municipal, and District Assemblies, and other urban water project implementers in Ghana and nearby countries.

2.0 STUDY CITIES

URBAN WASH and GWCL collaboratively selected two cities for this activity: Kumasi and Tamale. GWCL provided an initial list of priority cities with known challenges regarding water quality, equity, and/or NRW. Through a desk review and site visits, the team then selected two cities that offered adequate geographical coverage (at least one northern Ghanaian city, in accordance with USAID/Ghana's Country Development Cooperation Strategy); sufficient population and water distribution system size; available and engaged GWCL city-level representatives; available data; and adequate personal safety for researchers.

The city of Kumasi uses surface water from the Ofin River (primary source) and Owabi River (secondary source). The main GWCL treatment plant (Barekese, ~130,000 m^3/day) is located about 19 km from Kumasi, while the secondary treatment plant (Owabi) produces much less treated water (~10,000 m^3/day) and is located 10 km from Kumasi. The city of Tamale similarly uses surface water from the White Volta River (Table 2). A second treatment plant under construction will eventually supplement the primary operating treatment plant (Dalun, ~35,000 m^3/day). Both cities pump water into a single reservoir, after which gravity essentially drives the flow.

Table 2: Characteristics of urban water systems in Kumasi and Tamale

Characteristic	Kumasi (Ashanti North and South Regions)	Tamale (Northern Region)
Region	Ashanti (North and South)	Northern
Water source(s)	Surface water (Ofin and Owabi Rivers)	Surface water (White Volta River)
Production	~129,500 m^3/day	~35,000 m^3/day
Population	3,630,000	701,000
Number of customers	101,327	46,843
Type of customers:		
Residential	85%	92%
Standpipes	1%	2%
Industry/commerce	10%	5%
Institutions/government	4%	2%
Service coverage (% of households served)	46%[1]	58%[1]
Volume billed (m^3, 2021)	22,664,601	6,015,969
Length of distribution network	Over 1,000 km	500 km
Number of staff	510	244
Non-revenue water	50–54%	45%
Metering ratio	>90%	>90%
Operating revenue (2022)	158,000,000 Ghanaian Cedis (GHS)	49,000,000 GHS

[1] Estimate derived from URBAN WASH household survey

3.0 METHODS

To answer the research questions, the URBAN WASH team conducted a **capacity assessment** involving the following: (1) key informant interviews with water managers and operators; and (2) treatment plant and laboratory visits to examine the status of GWCL's water quality monitoring activities, GWCL's capacity to meet water quality monitoring standards and best practices, the level of implementation of WSPs, and the mitigation measures in place to manage water contamination risks.

In addition, the team conducted a **drinking water quality assessment** in both cities. The research team reviewed GWCL's existing water quality data, surveyed consumer and non-consumer households across the city to measure their water quality, and conducted community member interviews and focus groups. Data collection took place from May to August 2023.

3.1 INTERVIEWS WITH WATER MANAGERS

URBAN WASH conducted key informant interviews with water managers in both cities, as shown in Table 3. In each city, the team also visited the treatment plant(s) and the laboratory to review available equipment, procedures, and documentation in detail.

Table 3: Summary of key informant interviews with water managers

Kumasi	Tamale
Ashanti North Region office staff member Ashanti Production Region office staff member	Northern Region office staff (n = 3)
Barekese treatment plant staff (n = 2) Owabi treatment plant staff (n = 2)	Dalun treatment plant staff (n = 2)
Central laboratory staff (n = 2)	Laboratory staff (n = 2)
Public Utility Regulatory Commission (PURC) regional staff member	

To document institutional capacity for water quality monitoring, the team applied a scorecard known as Water Capacity Rating Diagnostic (WaterCaRD), which considers 27 factors comprising accountability, staffing, finances, equipment, and methods (Aquaya 2016). Prior research showed that WaterCaRD scores correlate with an institution's ability to meet regulatory water quality testing targets (Peletz et al. 2018).[1] More importantly in URBAN WASH's case, WaterCaRD provided a checklist to review all dimensions of water quality monitoring and exhaustively evaluate strengths and areas for improvement.

3.2 REVIEW OF GWCL WATER QUALITY DATA

The research team reviewed GWCL's existing water quality data from Kumasi and Tamale. The data included water quality measurements of raw and treated water from three treatment plants (Dalun treatment plant in Tamale and Barekese and Owabi treatment plants in Kumasi), and within the distribution systems of the two cities. The datasets the team received did not specify where measurements came from in the distribution networks (e.g., distance from chlorine booster stations, community standpipes versus households taps), though GWCL reportedly has this information. Measurements included physical parameters (e.g., pH, color, turbidity), metals, anions, nitrogen

[1] Note that WaterCaRD scores are not necessarily indicative of actual water quality, but only of testing activities.

compounds, mineral content, hardness, fecal indicator bacteria, and free chlorine residual. Data covered the period of 2017–2023, though this varied by parameter and city (Appendix A).

3.3 HOUSEHOLD SURVEY AND WATER QUALITY MEASUREMENTS

Trained enumerators conducted surveys and collected water quality samples from 301 households in Kumasi and 305 households in Tamale. The team's target of approximately 300 households per city was dictated by budget constraints and allowed estimating population percentages (e.g., percent of population with access to on-premises piped connections) with a ±6 percent margin of error and 95 percent confidence. Enumerators randomly selected households to represent the overall city population, including low-income areas within and beyond reach of the existing distribution systems. In each section of the city (all 11 administrative districts in Kumasi, and all 6 utility zones in Tamale), the team aimed to survey a number of households proportional to the total population. According to these geographic targets, the team generated several random geographic positioning system (GPS) points using the R software and instructed enumerators to randomly select four households per GPS location. In case of discrepancies between the target and the actual number of surveys conducted in each geographic section, the team corrected for those during data analysis. The statistics presented in this report are therefore population-representative estimates.

Survey questions covered household demographics, water consumption behaviors, perception of GWCL services, and perceptions of water security. URBAN WASH also included questions from the EquityTool[2] to evaluate asset wealth, which allowed the team to categorize respondents into three groups: bottom quintiles (poorest 40 percent), middle quintiles (ranking between 40 percent and 80 percent), and top quintile (wealthiest 20 percent).

Enumerators collected water samples at the point of use for all households surveyed (except for 11 that did not have water at the time of the visit or did not grant permission). If a household used a storage container, the team collected the water sample from it; otherwise, the team asked permission to collect water directly from the tap, sachet, or bottle. The URBAN WASH team collected water samples for microbial analysis in sterile Whirl-pak bags containing sodium thiosulfate, stored them on ice, and analyzed them within eight hours via membrane filtration and incubation on CompactDry plates (UNICEF 2017). The team did not sterilize taps prior to collecting samples to accurately assess the quality of drinking water as typically consumed by customers. The team processed weekly field blanks and one laboratory blank per day; if any of those had detectable *E. coli* (i.e., >=1 CFU/100mL), the team removed data for all samples run that day (this affected 14 samples overall). Overall, URBAN WASH obtained 581 valid *E. coli* measurements at the point of use. For the subset of 397 households using piped water as a primary drinking water source, enumerators tested for free chlorine residual on-site using the Octaslide Chlorine test kit (0.2–3.0 ppm Cl range). Overall, approximately two-thirds of these measurements characterized households' primary drinking water, and the majority characterized stored water, though URBAN WASH also captured data from 74 household taps in Kumasi (Table 4).

To complement the household water quality assessment, in both cities URBAN WASH also collected samples of raw water, after treatment, and at several locations in the distribution network (one near and one far from each treatment plant) to test several metals of concern identified in collaboration with GWCL: aluminum, arsenic, lead, manganese, mercury, and total cyanide (Table 4). The team sent these samples for analysis to the SGS Ghana Limited laboratory in Tema. SGS used the following analysis

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2 Home - Equity Tool

methods: inductively coupled plasma (ICP) optical emission spectroscopy for aluminum; ICP mass spectroscopy for arsenic, lead, manganese, and mercury; and segmented flow analysis for total cyanide.

Table 4: Summary of water quality measurements performed in this study

	Kumasi	Tamale	Total
E. coli* measurements at point of use	**282**	**299**	**581**
Household taps	74	4	78
Household-stored water	208	295	503
Chlorine measurements at point of use*	**185**	**212**	**397**
Household taps	68	2	70
Household-stored water	117	210	327
Metals measurements**	**48**	**20**	**68**
Aluminum	8	4	12
Arsenic	8	4	12
Lead	8	0	8
Manganese	8	4	12
Mercury	8	4	12
Total cyanide	8	4	12

** Performed by the URBAN WASH team*
*** Performed by the commercial laboratory SGS in Tema, Ghana*

3.4 COMMUNITY MEMBER INTERVIEWS AND FOCUS GROUPS

URBAN WASH collected qualitative data through interviews and focus group discussions in both cities to complement the household survey and better understand the perspectives of low-income communities.

Kumasi:

- Interviews with leaders (chiefs or assemblymen) of three low-income communities;
- Interviews with leaders of Water User Associations in three low-income communities, which GWCL previously established as volunteer groups to serve as community liaisons during past implementation of pro-poor connection subsidies; and
- Focus group discussions in three low-income communities (two with women, one with men).

Tamale:

- Interviews with leaders (chiefs or assemblymen) of five low-income communities;
- Interviews with representatives of the tanker truck and bottled/sachet water associations; and
- Focus group discussions in two low-income communities (one with women, one with men).

URBAN WASH analyzed qualitative data from transcripts in Excel using deductive coding (i.e., searching for information related to a predetermined list of themes), followed by inductive coding (allowing additional themes to emerge from the transcripts).

3.5 ETHICAL CONSIDERATIONS

All study participants provided written informed consent. The team loaded quantitative and qualitative data daily onto password-protected computers backed up with a password-protected Dropbox account. The team communicated no personally identifiable information to local stakeholders, and the results present only summary statistics and statements. The team will remove all personal identifiers before uploading data to USAID's Development Data Library. These data collection and sharing protocols were approved by the Council for Scientific and Industrial Research of Ghana, an Institutional Review Board in Ghana.

3.6 LIMITATIONS

The GWCL water quality records that the team examined may have been incomplete. URBAN WASH requested five years of historical data but did not always receive this. For example, Tamale's distribution data on free chlorine residual only covered 2023.[3] Further, the paper-based records that the team reviewed during treatment plant visits indicated a higher testing frequency of physico-chemical parameters than reflected in the electronic data received afterward.

Although UBRAN WASH's household survey aimed to represent the city population, in practice the team over-sampled inner-city areas and under-sampled peripheral areas. To minimize the impact of these sampling discrepancies on the conclusions, the team applied correction factors when computing all household-level statistics presented in this report. In practice, this meant applying a weight larger than 1 to all households in under-represented areas, and a weight smaller than 1 to households living in over-represented areas. Nationwide surveys such as the Demographic and Health Survey commonly use this approach to compute population-representative estimates (USAID, n.d.). Additionally, GWCL selected the low-income communities captured in the survey, interviews, and focus group discussions. While this helped ensure that the research captured GWCL's priority areas of interest, it may limit the generalizability of findings.

Most of the team's water quality measurements characterized household-stored water as opposed to water coming directly from consumer taps (Table 4). Because one of the guiding research questions focused on drinking water (Table 1), the team chose to examine the quality of point-of-use water, i.e., water that household members would drink. This research design ensured that water quality data would reflect households' actual exposure to contamination. However, it limited opportunities to compare URBAN WASH's data with GWCL's distribution data, as it led the team to analyze only a small number of tap samples, particularly in Tamale (Table 4). Additionally, the research design did not allow for a comprehensive assessment of all packaged water providers in Kumasi and Tamale. Therefore, the team could not compare the quality of packaged water with other sources at the point of distribution or sale, but the data still provides a valid comparison at the point of use.

Finally, the assessment of institutional capacity (Section 4.1) relied on one-time visits to the treatment plants and laboratories, as well as electronic water quality data received later. The conditions observed during these visits (particularly the type and functionality of laboratory equipment) may not completely represent long-term conditions. Similarly, the electronic datasets shared were likely incomplete, as mentioned above, and may not reflect the full extent of GWCL's data collection and/or digitization.

[3] URBAN WASH received data on raw and treated water for 2018–2023 and distribution data only for 2023.

4.0 RESULTS

4.1 WATER QUALITY MONITORING

- What is the extent and complexity of GWCL's water quality monitoring activities for the distribution systems of the two target cities?

4.1.1 KUMASI

In Kumasi, GWCL monitors water quality at the two treatment plants and within the distribution network. Treatment plant operators measure turbidity, pH, color, and chlorine multiple times a day. To monitor microbial water quality, staff perform daily presence/absence tests for *E. coli* and total coliforms at the larger treatment plant (Barekese) but not at the smaller treatment plant (Owabi) due to a broken incubator. As a temporary measure, samples from Owabi treatment plant are sent twice a week to the regional laboratory in Suame for microbial water quality analysis. GWCL also tests several other parameters routinely at the treatment plants (temperature, alkalinity, hardness, conductivity, salinity, total dissolved solids) and a list of metals and ions monthly (aluminum, ammonia, calcium, chloride, chromium, copper, fluoride, iron, manganese, nitrate, nitrite, phosphate, sulphate, and zinc). Additionally, GSA analyzes cadmium, chromium, copper, lead, manganese, mercury, zinc, and 33 pesticides once a year. To monitor the Ashanti region distribution network, GWCL reported analyzing 460 samples monthly for pH, color, turbidity, chlorine, and fecal coliform, of which approximately 320 cover the city of Kumasi, according to the data received.

Overall, using Aquaya's WaterCaRD tool for assessing the enabling environment and institutional capacity for water quality monitoring, GWCL Kumasi attained a score of 74 percent (Figure 2, Appendix B). This slightly exceeds typical scoring when compared to 26 other institutions (utilities and public health agencies) in sub-Saharan Africa, which obtained a median score of 66 percent (Peletz et al. 2018), but nevertheless reflects some room for improvement. The following sections provide a detailed assessment for each of the five WaterCaRD categories.

WaterCaRD components	Accountability	Staffing	Program structure	Program finances	Equipment & infrastructure	**TOTAL**
Score	7/12 (58%)	21/24 (88%)	16/24 (67%)	7/9 (78%)	9/12 (75%)	**60/81 (74%)**

Low score (<75%) Medium score (75-85%) High score (> 85%)

Figure 2: Assessment of the enabling environment and institutional capacity for water quality monitoring in Kumasi (details in Appendix B)

Accountability

Ghana's regulatory framework requires GWCL to conduct regular water quality testing and to share test results with PURC at least annually, which they comply with. However, the regulatory framework could promote closer attention and adherence to water safety standards. For example, while PURC shares feedback annually and requires a remediation plan in case of poor water quality, it provides no incentives or sanctions to ensure adherence to water quality standards.[4] Similarly, regulations do not

[4] URBAN WASH understands that this may be the result of past experiences suggesting that sanctions can hurt customers more than GWCL.

require GWCL to share holistic water quality information with customers (only upon request), weakening downward accountability. Although out of their direct control, GWCL might take the opportunity to advocate for regulations more favorable to sustained service performance.

Staffing

GWCL Kumasi has sufficient personnel to conduct water quality monitoring. This includes a full-time water quality manager with no conflicting priorities and laboratory personnel with good theoretical knowledge and practical experience. During in-person visits, staff appeared motivated and proud to meet water quality standards. They reported low staff turnover, and GWCL's human resources department has reliable procedures to hire new water quality staff. Despite these strengths, URBAN WASH found that staff could not mitigate certain risks affecting water quality monitoring activities and the validity of results. This may stem from insufficient refresher trainings for water quality staff as a form of continuing education, as well as external constraints, such as power outages and slow procurement.

Program structure

The large number of water quality tests performed in the distribution network reflect good management of sample collection. Staff reported prioritizing areas with high population density or schools for their sampling plan (though the URBAN WASH team does not know the extent to which the sampling plan includes customer taps).

URBAN WASH, however, noted limitations in water quality analysis methods. Most importantly, the turbidity meter in use during the visit tends to underestimate treated water turbidity, which means that operators lacked precise turbidity information to optimize the coagulation process.[5] Additionally, a few measures could improve the accuracy of free chlorine measurements. The main treatment plant used a manual field kit, whereas a digital meter would enhance accuracy.[6] Further, both treatment plants resort to using reagents for total chlorine when free chlorine reagents run out, potentially leading to overestimates.

With respect to microbial water quality tests, the quality assurance manual documented standard operating procedures, although staff did not always use positive and negative controls for microbial analysis at the Barekese treatment plant. The URBAN WASH team also understood that in the case of test results of treated or distribution water failing water quality standards, the set procedure was to redo the test, but the team did not hear of a systematic process to adjust treatment.

GWCL could optimize data management procedures to better leverage existing investment in the monitoring programs. Additionally, while GWCL maintains electronic records of monthly data and periodically reviews it during management meetings, opportunities may exist to analyze and visualize data more systematically to inform decisions. Additionally, the daily water quality data that treatment plant operators kept on paper-based records at the treatment plant was not part of the electronic datasets that GWCL later shared with URBAN WASH, suggesting that some internal data may be kept on paper only and not digitized. Digitizing data and creating visualizations allowing for frequent review by decision-makers would help to ensure the monitoring evidence appropriately informs management approaches, rather than going unused.

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5 At the time of finalizing this report, GWCL had addressed this issue and procured a low-range turbidity meter.

6 At the time of finalizing this report, GWCL had replaced the field kit with a digital chlorine meter.

Program finances

Although GWCL has a dedicated, earmarked budget for water quality monitoring, staff cited limitations, including lengthy procurement and payment processes, which may partly explain the equipment limitations noted above.

Equipment and infrastructure

GWCL did not report issues in accessing distributors for water quality testing equipment and supplies. However, they experienced difficulties in repairing or servicing existing equipment such as dysfunctional turbidity meters, digital chlorine meters, and incubators.

With respect to infrastructure, the laboratories had dedicated spaces, but these areas had no backup power sources and were subject to frequent power outages. Incubator temperatures can fluctuate with power outages and affect the reliability of microbial test results.

4.1.2 TAMALE

At the Tamale treatment plant, GWCL monitors turbidity and chlorine multiple times a day and fecal coliform once a month. They also routinely monitor color, pH, conductivity, temperature, and total suspended solids. Aluminum, ammonia, chloride, fluoride, iron, manganese, nitrate, nitrite, and sulfates are tested up to monthly. In the distribution network, GWCL performs monthly monitoring of turbidity, chlorine, *E. coli,* pH, and color (88 samples on average), although URBAN WASH only received data from 2023. The laboratory also reported conducting occasional tests for *Salmonella*.

Overall, using Aquaya's WaterCaRD tool for assessing the enabling environment and institutional capacity for water quality monitoring, GWCL Tamale obtained a score of 75 percent (Figure 3, Appendix B). This slightly exceeds typical scoring compared to 26 other institutions (utilities and public health agencies) in sub-Saharan Africa, which obtained a median score of 66 percent, but nevertheless indicates room for improvement.

URBAN WASH's assessment of institutional capacity in Tamale was nearly identical to Kumasi in the categories of accountability, staffing, program finances, and equipment and infrastructure. This should not be surprising as both cities are subject to the same regulatory environment and part of the same utility with centralized procedures for recruitment, procurement, and budgeting. For those categories, the sections below provide a brief account of the team's findings; more details can be found in Section 4.1.1 about Kumasi for reference.

WaterCaRD components	Accountability	Staffing	Program structure	Program finances	Equipment & infrastructure	**TOTAL**
Score	7/12 (58%)	21/24 (88%)	17/24 (71%)	7/9 (78%)	9/12 (75%)	**61/81 (75%)**

Low score (<75%) Medium score (75-85%) High score (> 85%)

Figure 3: Assessment of the enabling environment and institutional capacity for water quality monitoring in Tamale (details in Appendix B)

Accountability

As in Kumasi, the Tamale assessment found limited communication of water quality results to consumers due to the regulatory environment. In addition, PURC did not strictly enforce water quality standards, although GWCL communicates water quality results to PURC at least annually, as required.

Staffing

Similar to Kumasi, the water quality department in Tamale has adequate staffing, low turnover, and established recruitment procedures. The department has a full-time water quality manager with no conflicting priorities and motivated laboratory personnel with good theoretical knowledge and practical experience. Laboratory staff, however, have limited opportunities for refresher training on the measurement and interpretation of priority water quality parameters such as turbidity, chlorine, and *E. coli*.

Program structure

Similar to Kumasi, GWCL in Tamale has a sampling plan prioritizing areas of the distribution network with high population density and sensitive institutions such as schools. However, the data URBAN WASH received included no microbial water quality results prior to 2023, so the team could not ascertain the extent to which sampling targets were met in prior years.

Laboratory methods in Tamale had some of the same (but not all) limitations as Kumasi. Laboratory staff may overestimate chlorine measurements because they sometimes use total chlorine reagents when they lack access to free chlorine reagents. A quality assurance manual documents standard operating procedures, although greater consistency in practice could strengthen its application. For instance, staff in Tamale did not always use positive controls and duplicates systematically for microbial analysis. Unlike in Kumasi, treatment plant staff used an appropriate low-range turbidity meter.

Data management activities, such as expanded data analysis, visualization, and sharing, could better leverage the monitoring program outputs. For example, the team found limitations in how turbidity data informed decision-making, possibly linked to insufficient data visualization and interpretation: even though historical records showed seasonal peaks in turbidity exceeding regulatory standards (see Section 4.2.2), the URBAN WASH team found no indication that GWCL staff used this data to inform changes in coagulation procedures.

Program finances

Similar to Kumasi, staff in Tamale reported lengthy internal procurement and payment processes that GWCL could seek to streamline. The region nevertheless had an earmarked annual budget for water quality monitoring.

Equipment and infrastructure

As in Kumasi, URBAN WASH noted no challenges in accessing distributors of water quality testing equipment, but rather challenges in servicing or repairing equipment. Also, the incubator used for microbial analysis did not have backup power during outages; the resulting fluctuation in incubation temperature may affect the validity of test results.

4.1.3 CONCLUSIONS

GWCL performs extensive monitoring of turbidity, chlorine, and microbial contamination at the treatment plants in both cities. Treatment plants also monitor many metals and physicochemical parameters monthly, and GWCL tests for pesticides in Kumasi once a year. However, microbial tests were on hold at the Owabi treatment plant (Kumasi) due to a broken incubator at the time of the visit, and no monitoring of disinfection byproducts takes place. In the distribution networks, GWCL monitors turbidity, chlorine, and fecal coliform, taking approximately 300 samples per month in Kumasi and 80 per month in Tamale.

Both cities have sufficient laboratory staff, but limitations exist for water quality analysis methods related to inadequate equipment and quality assurance, which may partly result from budget and procurement constraints. Additionally, water quality staff have limited opportunities for refresher trainings, which likely undermines their ability to uphold best practices and respond to issues affecting the validity of results. GWCL could optimize data management and visualization to help ensure that water quality data effectively guides decision-making. Finally, URBAN WASH noted that GWCL operates in a weak regulatory environment for ensuring accountability to consumers and PURC.

4.2 WATER QUALITY AND CONTAMINATION SOURCES

- What is the quality of drinking water for GWCL consumers and non-consumers?
- What are the main sources of water contamination at the source and in the distribution network?

4.2.1 KUMASI

Quality of piped water

The research team's assessment of piped water quality relies on GWCL's records of turbidity, chlorine, and fecal coliforms collected from 2017–2023 (Appendix A), as well as URBAN WASH's own chlorine and *E. coli* measurements at household taps.

The two treatment plants achieved varying degrees of turbidity removal (Figure 4). While raw water turbidity averaged 54 nephelometric turbidity units (NTU), treated water always met the GSA requirement of <5 NTU from January 2017 until December 2022 (n = 144) in Kumasi. However, GWCL could further optimize turbidity removal. First, treatment plant staff may underestimate some measurements due to equipment limitations. Second, only 27 percent of treated water samples (n = 39/144) were below 1 NTU, a more desirable level to ensure effective chlorination and pathogen removal.[7]

[7] The World Health Organization (WHO) recommends a turbidity limit of 1 NTU to support effective disinfection (WHO 2022a). Where impractical (e.g., for small water systems with limited resources), turbidities should be kept below 5 NTU; however, higher chlorine doses or contact times are typically needed.

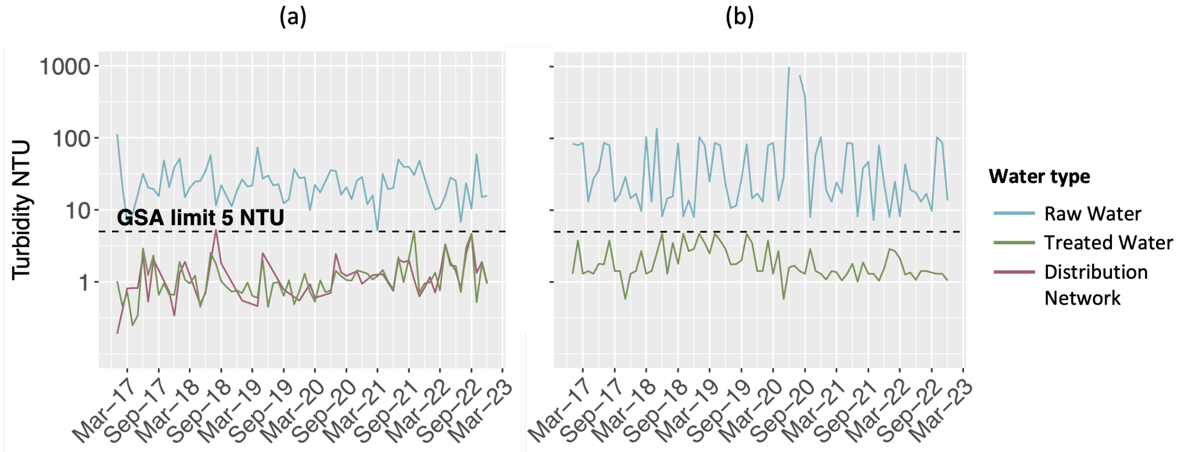

Figure 4: GWCL's turbidity data for the Barekese (panel a) and Owabi (panel b)[8] treatment plants in Kumasi, compared to the GSA limit of 5 NTU

GWCL's daily chlorine measurements at the treatment plants exceeded 0.2 mg/L (the GSA standard) 99 percent of the time between January 2020 and March 2023 (n = 5,392/5,429, Appendix C.1). In the distribution network, chlorine levels were always greater than or equal to 0.2 mg/L in areas located near the treatment plants[9] (averaging 0.4 mg/L, potentially leading to odor and taste issues, n = 1,440/1,441). Chlorine levels dwindled in farther locations, with only 59 percent of samples meeting the GSA standard (average of 0.2 mg/L, n = 4,259/7,230; Appendix C.2).

URBAN WASH's chlorine measurements generally revealed lower levels than those reported by GWCL (Figure 5). Only 22 percent of samples collected from household taps had free chlorine residuals equal to or exceeding 0.2 mg/L (15/68). The discrepancy could stem from differing sampling locations (e.g., proximity to chlorine booster stations), flow conditions on the day of sampling, the fact that URBAN WASH collected measurements exclusively during the rainy season, and/or GWCL measuring total chlorine rather than free chlorine.

For microbial parameters, GWCL records indicated no *E. coli* or total coliform detection between January 2020 and March 2023 in treated water (n = 1,722) or in the distribution network (n = 8,671). In contrast, 74 percent (55/74) of samples collected from household taps via this study had detectable *E. coli* (>= 1 CFU/100 mL) (Figure 5). Similar to chlorine, this discrepancy could stem from different sampling locations, flow conditions, seasonality, and/or GWCL's laboratory method limitations (e.g., incubator power outages), and warrants further investigation. Another explanation might be that this study did not sterilize taps prior to collecting water samples, whereas GWCL (as most utilities) typically does. This cannot, however, be the only cause for the discrepancy, as it would not explain the differences in chlorine residuals that URBAN WASH noted.

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[8] The data URBAN WASH received did not allow the team to identify distribution data from Owabi treatment plant.

[9] This statement concerns the sub-division of North A (Barekese) and Northwest A (Abuakwa/Owabi) only.

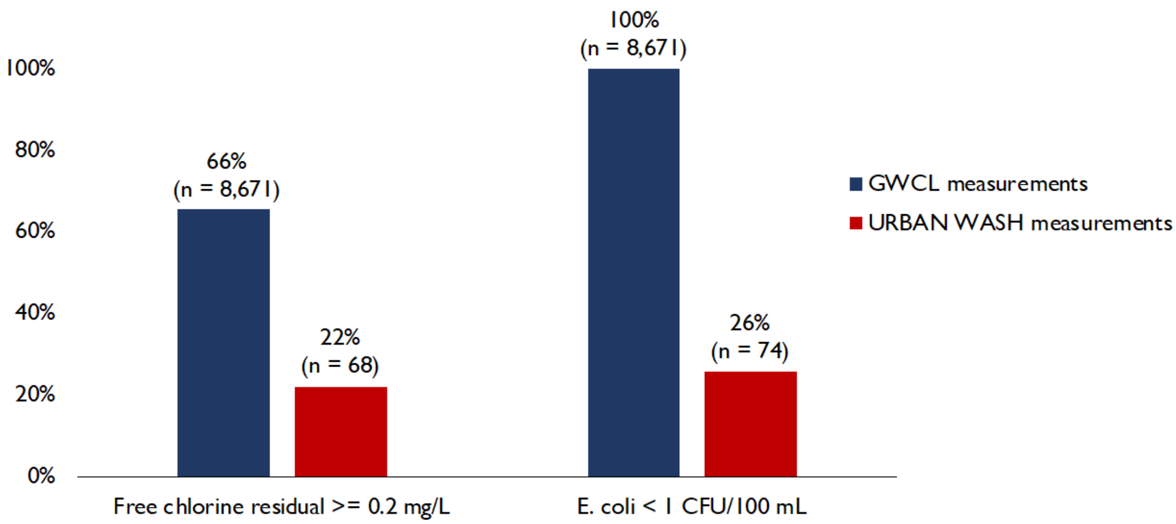

Figure 5: Comparison between the percentage of GWCL and URBAN WASH chlorine and E. coli test results from Kumasi's distribution network meeting desired thresholds

For other parameters, GWCL's measurements of aluminum (n = 140 between January 2017 and December 2022), chromium (n = 141/142[10]), copper (n = 141), fluoride (n = 143), iron (n = 144), manganese (n = 144), nitrates (n = 143), nitrites (n = 144), sulfates (n = 143), and zinc (n = 142) in treated water were all within GSA requirements. URBAN WASH measurements of aluminum, arsenic, cyanide, lead, manganese, and mercury (n = 8 per parameter, performed by SGS laboratory) revealed no concerns, though sample sizes were small.

Intermittency and infrastructure condition

All surveyed GWCL customers reported experiencing at least one service interruption per week. The vast majority (78 percent) reported experiencing daily interruptions, often lasting more than 12 hours. In low-income areas, focus group participants reported that piped water was only available two to five days per week. Intermittency threatens water quality, as contaminants can enter pipes when water pressure drops. Additionally, intermittency can lead households to store water in containers, which may further deteriorate water quality. The URBAN WASH team found that approximately one-third of GWCL consumers stored piped water inside the home, typically in drums or buckets, for up to a few days. Stored piped water had lower levels of chlorine (though similar *E. coli* risk level categories) compared to water coming directly from taps.

In addition to intermittency, the old age (close to one hundred years old in some locations) and poor physical condition of the distribution network in Kumasi poses a risk to water quality: with three to seven pipe breaks per km depending on the area,[11] the distribution network has many entry points for contaminants.

Consumers vs. non-consumers

Of households surveyed, 41 percent were GWCL consumers: 33 percent via on-premises connections, 6 percent via a neighbor's connections, and 2 percent via public standpipes. The rest relied solely on

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[10] One sample exceeded the GSA limit for chromium (0.06 mg/L for a limit of 0.05 mg/L).

[11] As documented in the Component 3 report on NRW.

non-piped water sources.[12] Water quality at the point of use was poor in most cases (Figure 6), although it was worse for non-piped water sources (74 percent with *E. coli* >= 10 CFU/100mL) compared to GWCL piped connections, whether on or off premises (47 percent with *E. coli* >= 10 CFU/100mL). These differences translated into geospatial disparities, with households in Kumasi's central zone having better microbial water quality at the point of use compared to peripheral areas where piped connections were less common (Appendix D.1).

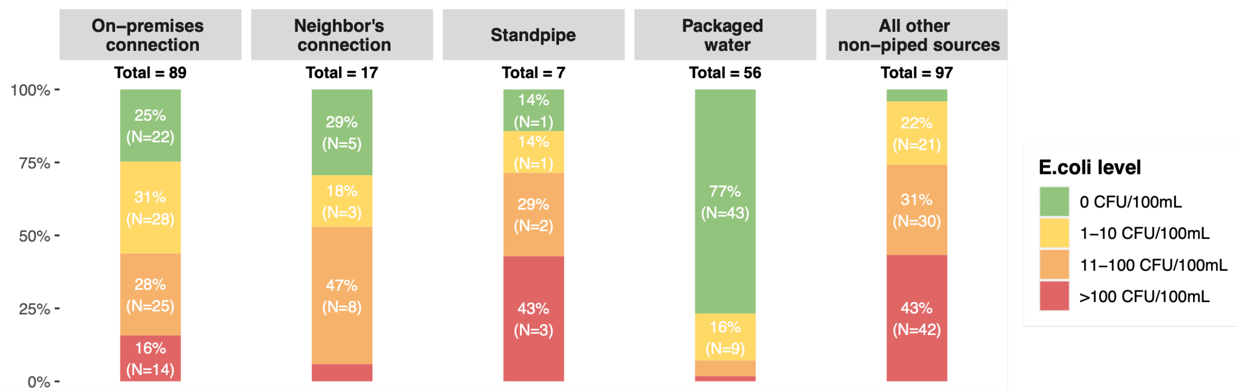

Figure 6: Microbial water quality data at the point of use in Kumasi split by water source

Most households (68 percent of GWCL consumers and 57 percent of non-consumers) reported that they primarily drink packaged water (as opposed to piped water or other sources).[13] Issues with color, taste, smell, or perceived water quality of piped water were mentioned by 62 percent of these households as drivers of the decision to purchase and drink packaged water.

Drinking packaged water was even more common among wealthier households: 88 percent in the wealthiest quintile versus 50 percent in bottom two quintiles (Figure 7). Conversely, drinking piped water or water from other improved sources was more frequent among the poor. URBAN WASH's measurements showed that packaged water had substantially higher microbial quality at the point of use than other water sources (Figure 6), with only 7 percent of samples exceeding 10 CFU/100 mL (compared to 47 percent for piped water and 74 percent for other sources).[14] Similarly, prior studies in Kumasi (Appiah-Effah et al. 2021) and across Ghana (Guzmán and Stoler 2018; Aquaya Institute 2023a; 2023b) found that packaged water had superior quality to piped water at the point of use. Because poor households are less likely to drink packaged water (Figure 7), they are exposed to higher levels of microbial contamination, leading to wealth-based disparities in health risks (Appendix D.2).

12 GWCL customers relied on non-piped sources as well (e.g., rainwater), given the intermittency challenges mentioned above.

13 URBAN WASH's household survey took place in the rainy season; use of packaged water may be higher in the dry season (Kumpel et al. 2017).

14 Despite limited sample sizes, these differences were statistically significant.

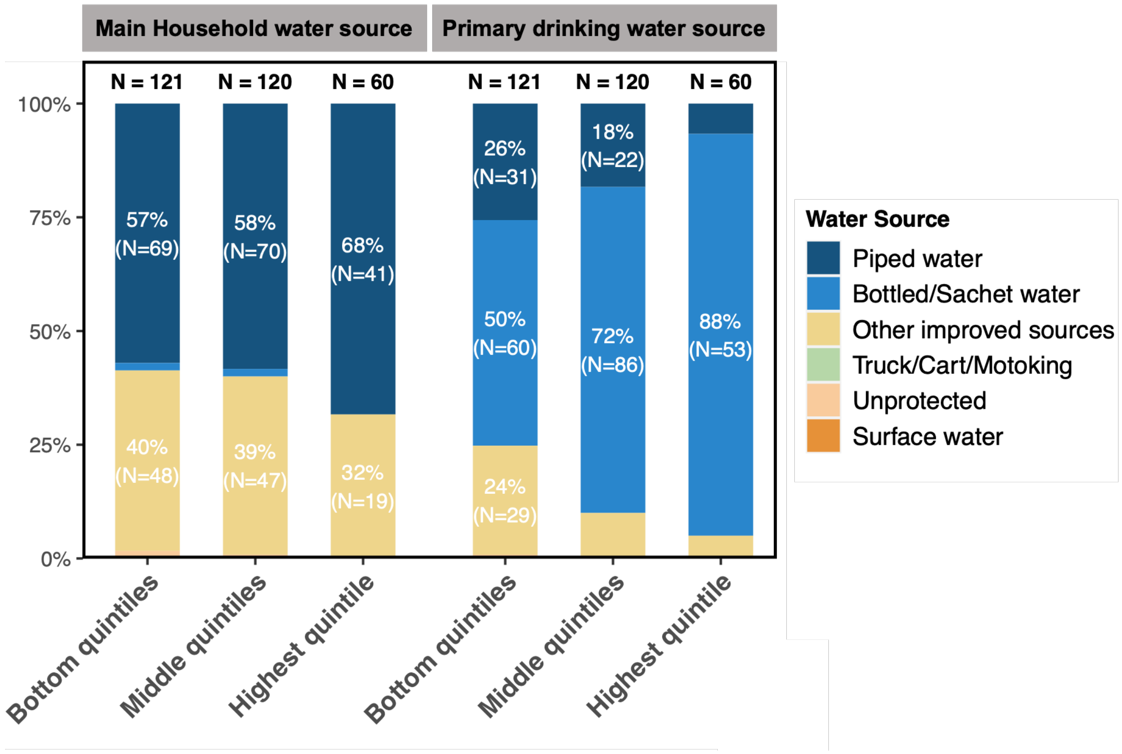

Figure 7: Primary domestic and drinking water sources across wealth categories in Kumasi

4.2.2 TAMALE

Quality of piped water

URBAN WASH's assessment of piped water quality in Tamale relies on GWCL's records of turbidity, chlorine, and fecal coliforms collected from 2018–2022 (Appendix A). Unlike in Kumasi, the team did not analyze samples from the distribution network in Tamale.

In Tamale, turbidity of raw water was particularly high, averaging 273 NTU between October 2018 and December 2022. According to GWCL's monthly records, the Dalun treatment plant reduced turbidity to below 5 NTU 69 percent of the time (n = 35/51). Insufficient turbidity removal was generally associated with increasing turbidity in raw water at the beginning of the rainy season (Figure 8). This suggests that the coagulation process could be improved to more systematically adapt to variations in source water quality. Similarly, the team's aluminum measurement of 0.5 mg/L in treated water suggested that the dose of alum added for coagulation could be better optimized (a higher dose, though more expensive, could reduce both turbidity and residual aluminum).

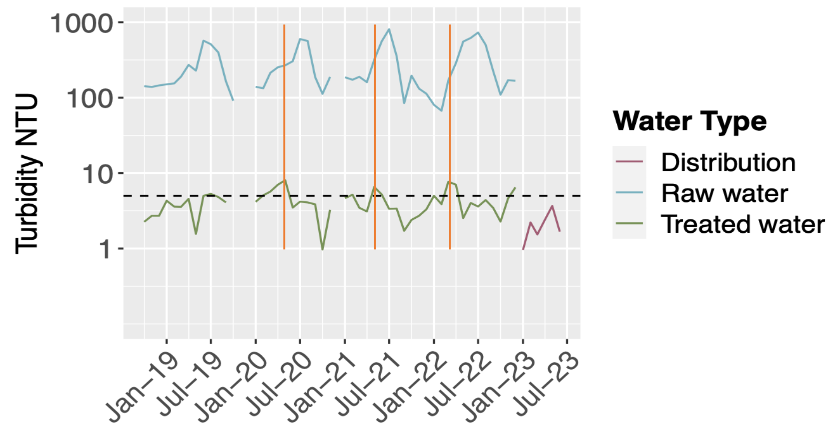

Figure 8: GWCL's turbidity data at the Dalun treatment plant in Tamale, compared to the GSA limit of 5 NTU

GWCL records indicated that chlorine levels meet the GSA standard (>= 0.2 mg/L) in 96 percent of treatment plant samples (n = 44/46, Oct 2018–Dec 2022) and in 62 percent of samples collected in the distribution network (n = 325/528, Jan–Jun 2023) (Appendix C.3). GWCL detected no *E. coli* in treated water (n = 528, Oct 2018–Dec 2022) or in the distribution network (n = 47, Jan–Jun 2023). Unlike in Kumasi, URBAN WASH cannot compare the primary data to these reported statistics, as the team collected few water samples from household taps.

For other parameters, GWCL's measurements of treated water generally met GSA requirements for aluminum (n = 31/39), arsenic (9/9), fluoride (43/43), iron (39/41), manganese (35/35), nitrates (41/41), nitrites (39/40), and sulfates (41/41). URBAN WASH measurements of arsenic, cyanide, manganese, and mercury (n = 4 for each parameter, performed by the SGS laboratory) revealed no concerning metal levels in raw, treated, or distributed water, though sample sizes were small.

Intermittency and infrastructure condition

The majority (67 percent) of GWCL customers reported experiencing service interruptions from one to three days per week, with interruptions lasting up to or more than 12 hours. In low-income communities, focus group participants reported an even more alarming situation, wherein they sometimes went without piped water for up to two months, particularly in the dry season. Utility managers confirmed rationing water supply from once per week to once every six weeks. A staff member noted, "If someone is within an area that gets water every six weeks, and there is a power outage on the day that they are supposed to receive water and water is therefore not produced, they normally have to wait another six weeks before they receive water again." The primary cause for this severe intermittency is the gap between demand and production capacity at the Dalun treatment plant. Power fluctuations affecting intake pumps and the treatment plant are another reason.

URBAN WASH found that 99 percent of GWCL customers stored piped water inside the home, usually in drums, polytanks, cooking pots, or jerrycans, for up to a few days. Storage takes place when users do not have a tap directly into their dwelling but is also a strategy to cope with intermittent water supply. Intermittency can thus have implications for water quality in more than one way; not only does it favor the entry of contaminants in the piped network, but it also promotes household water storage, a practice that can further deteriorate water quality. In addition to intermittency, the poor physical condition of the distribution network poses a risk to water quality, as pipe breaks (one to three per km of network in Tamale)[15] facilitate the entry of contaminants into the distribution network.

Consumers vs. non-consumers

Of the households surveyed, 57 percent were GWCL consumers: 19 percent via on-premises connections, 29 percent via a neighbor's connection, and 9 percent via public standpipes. The rest relied solely on non-piped water sources.[16] Similar to Kumasi, microbial water quality at the point of use was poor across categories and worse among non-piped water sources (84 percent with *E. coli* >= 10 CFU/100mL) compared to GWCL water (56 percent with *E. coli* >= 10 CFU/100mL; Figure 9).

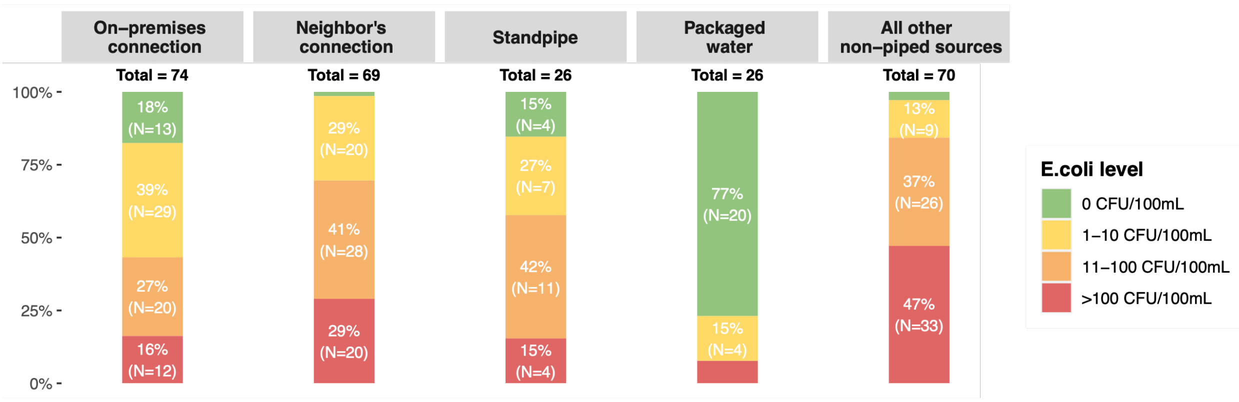

Figure 9: Microbial water quality data at the point of use in Tamale split by water source

Unlike in Kumasi, GWCL consumers reported primarily drinking piped water (93 percent).[17] Purchase of packaged water was much less common (seven percent of GWCL consumers and nine percent of non-consumers), and mostly confined to the wealthiest households (Figure 10). A fraction of households, particularly among the poorest, relied on unprotected water sources or surface water (Figure 10). URBAN WASH measurements showed that packaged water had superior microbial quality compared to piped water at the point of use, which was safer than water from other sources (Figure 9),[18] leading to disparities in drinking water quality across wealth quintiles (Appendix D.2). The team's interview with the head of the sachet and bottled water association indicated that all packaged water in Tamale originates from GWCL pipes and receives further treatment (filtration, reverse osmosis, or UV disinfection depending on the supplier) before packaging. Compared to piped water, packaged water therefore receives additional protection against contamination during transport and point-of-use storage.

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15 As documented in the Component 3 report on NRW.

16 GWCL customers relied on non-piped sources as well, given intermittency challenges.

17 In extended periods without piped water supply, GWCL customers, like non-customers, likely had to rely on other sources of drinking water such as rainwater, protected or unprotected wells, water carts, or surface water. It is also possible that use of packaged water would be higher in the dry season (Kumpel et al. 2017).

18 Despite limited sample sizes, these differences were statistically significant.

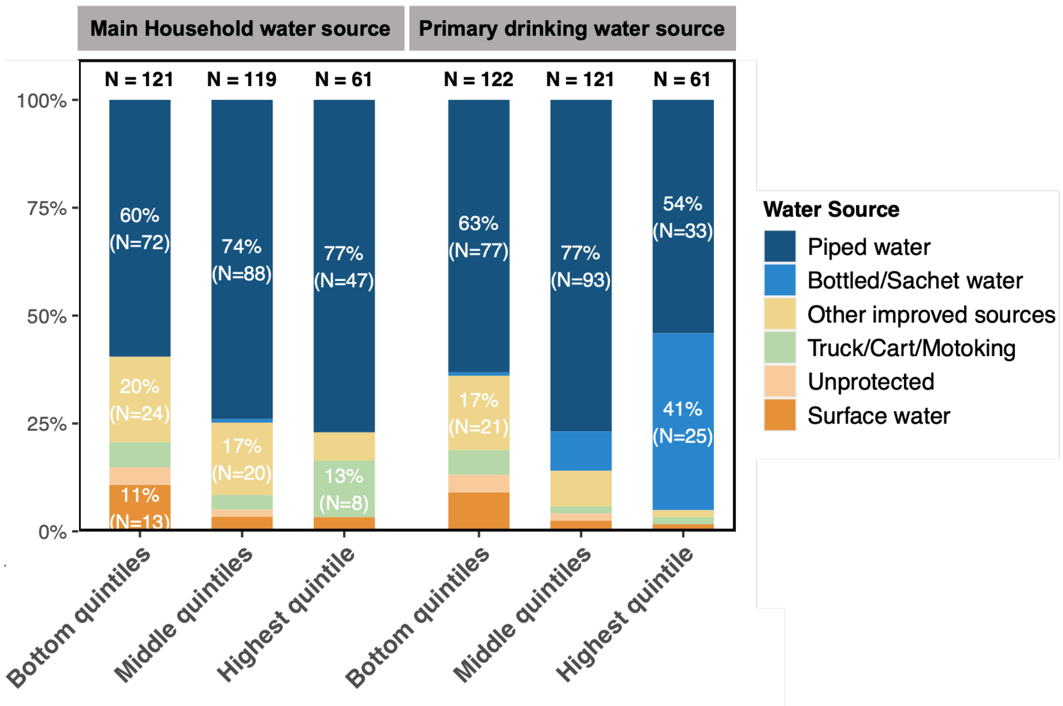

Figure 10: Primary domestic and drinking water sources across wealth categories in Tamale

4.2.3 CONCLUSIONS

Turbidity of piped water consistently meets regulatory requirements (<5 NTU) in Kumasi, but periodically exceeds these limits in Tamale (close to a third of the time) where source water turbidity climbs much higher, particularly nearing the rainy season. Coagulation could be further optimized to reduce treated water turbidity in both cities, as residual turbidity in treated water usually renders the chlorine disinfection step less effective.

Free chlorine residual levels did not consistently ensure consumer protection. Approximately one-third of distribution samples in both cities fell below the required chlorine level of 0.2 mg/L. URBAN WASH's household data in Kumasi suggested these levels may be even lower at household taps. At the point of use,[19] piped water had substantial levels of microbial contamination: *E. coli* was detected in 75 percent of household water samples in Kumasi and 89 percent in Tamale.[20] Intermittent water supply and pipe breaks pose substantial water quality risks, as microbial contaminants can enter the distribution network through broken pipes when water pressure drops. Intermittency also promotes household water storage, which can further degrade water quality.

In Kumasi, most households, including GWCL consumers, reported drinking packaged water. Households less commonly drank packaged water in Tamale, likely due to lower incomes, as this practice was still prevalent among the wealthiest households. In both cities, poorer households were less likely to drink packaged water and more likely to drink piped water or water from untreated sources. Packaged water had far superior microbial quality compared to piped water at the point of use

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19 Depending on the household, the point of use was a storage container (most cases) or directly a tap.

20 In Tamale, point-of-use water from on-premises connections had comparable microbial quality to point-of-use water from standpipes (Figure 9). URBAN WASH did not collect enough samples originating from standpipes in Kumasi (n = 7) to provide a robust comparison (Figure 6).

in both cities, leading to disparities in water quality across wealth quintiles. This is likely because packaged water was most commonly piped water that underwent additional treatment before packaging and thus received better protection from contamination during transport and point-of-use storage.

4.3 WATER SAFETY MANAGEMENT MEASURES

- What measures or actions are being taken to reduce contamination risks at both the source and in the distribution network?
- To what extent has GWCL prepared and implemented WSPs in its operations?

4.3.1 WATER TREATMENT

GWCL reduces water contamination via conventional water treatment steps (Table 5).

Table 5: Description of water treatment processes in Kumasi (both treatment plants) and Tamale

Kumasi	Tamale
• Screening (e.g., remove plastic bottles) • Aeration (Owabi plant only) • Coagulation with aluminum chlorohydrate (dose adjusted with jar tests conducted one to three times per day) • Flocculation • Sedimentation • Filtration • Chlorination (with chlorine gas) • Secondary chlorination (with calcium hypochlorite) at four booster stations within the distribution network	• Screening (e.g., remove plastic bottles) • Coagulation with alum (dosing adjusted with daily jar tests) • Flocculation • Sedimentation • Filtration • Chlorination (with chlorine gas) • pH adjustment with lime

Operators adjust coagulant dosing using daily jar testing. This procedure allows operators to identify the lowest coagulant dose that results in turbidity less than 5 NTU after sedimentation (or <10 NTU in Tamale, with the expectation that filtration will further reduce turbidity after sedimentation). Relying on equipment that tends to underestimate turbidity may bias the procedure in Kumasi. Additionally, a more conservative approach (WHO 2022a) would be to reduce turbidity below 1 NTU (following WHO guidance), although this would require higher coagulant doses and therefore may come at a higher cost. Both the Kumasi and Tamale locations have engaged in ongoing efforts to optimize the coagulant type. After a successful pilot, Kumasi switched to aluminum chlorohydrate instead of alum, which more effectively removes bloodworms and eliminates the need for post-treatment pH adjustment. In Tamale, GWCL staff indicated that coagulant dosers and filter media need replacing.

After the initial treatment steps, GWCL chlorinates the water with chlorine gas. In Kumasi, on-site chlorination generation capacity appears limited to 10 kg/hour, while utility personnel indicated that a higher capacity of 20 kg/hour is needed to produce a sufficient residual dose. Booster chlorination with calcium hypochlorite then takes place at four locations within the distribution network, which could potentially be reduced if chlorination capacity were increased at the treatment plant. Tradeoffs between improving chlorination capacity at treatment plants and maintaining or augmenting booster stations should be further examined. In Tamale, the treatment plant also relies on chlorine gas and no booster chlorination takes place in the distribution system. GWCL staff indicated that chlorine dosers at the treatment plant need replacing. Additionally, chlorine boosting could take place more systematically at the storage tank located just upstream of Tamale city, but this would require replacing the malfunctioning chlorine tablet doser.

4.3.2 WATER SAFETY PLANNING

The extent to which GWCL has prepared and implemented WSPs in its operations remains limited, although they have initiated some activities. Although Ghana's 2015 National Drinking Water Quality Management Framework enshrined the WSP approach, GWCL has piloted WSP efforts in only one water system in the Central Region (REAL-Water 2023). In late 2023, GWCL staff in Kumasi and Tamale received WSP trainings, conducted risk assessments, drafted WSPs, and shared them with the head office for internal review.

To date, GWCL has engaged in limited watershed protection efforts in Kumasi and Tamale. In both cities, parts of the watershed were designated as protected natural areas, but despite this, new developments are underway. Additional threats include sand winning in Tamale (exacerbating raw water turbidity), road pollution in Kumasi (as evidenced by a large volume of solid waste near raw water intakes at the Owabi plant), and stormwater runoff in both cities.

Similarly, it is unclear if GWCL recognizes intermittency and pipe breaks as substantial risks to preserving water quality in the piped network. Addressing these challenges may require more direct communication between personnel in charge of rationing, pipe break detection, and water quality.

Full WSP implementation will require Kumasi and Tamale to go through the 10 module steps defined by the World Health Organization (WHO 2023). These steps include identifying and prioritizing hazards that can compromise drinking water quality, using appropriate operational controls to mitigate risks, and regularly updating the plans to reflect previously unknown risks. While getting started with any level of implementation progress demonstrates good intent and encourages incremental change, completing all steps would maximize the value of this approach. Another important consideration for WSP implementation is to ensure diversity and gender representation in WSP teams to enhance the risk identification and prioritization steps and avoid groupthink (WHO 2019). Challenges hindering WSPs in urban and rural Ghana to date include the lack of a robust regulatory mechanism (e.g., through PURC) to incentivize scale-up, demonstrations of feasibility (which have seen greater progress in rural water systems receiving donor support), and human resource development (REAL-Water 2023).

4.3.3 CONCLUSIONS

GWCL's approach to reducing contamination mainly relies on conventional water treatment (screening, coagulation, filtration, chlorination). However, discrepancies between GWCL's distribution data and URBAN WASH's water quality measurements at consumer taps indicate that GWCL may not have an accurate understanding of water quality all the way to the point of collection. This would limit their ability to optimize chlorine levels and mitigate contamination.

Although Ghana incorporated the WSP approach in its Water Quality Management Framework, it has only implemented this approach in one urban water system in the Central region. In Kumasi and Tamale, WSP trainings took place in 2023 and the teams have begun risk assessments. These ongoing assessments are an opportunity to not only optimize treatment processes but also scrutinize the full water supply chain and recognize source water pollution, intermittency, and poor distribution network as crucial risks to mitigate.

5.0 RECOMMENDATIONS AND NEXT STEPS

5.1 RECOMMENDATIONS

This study identified several immediate and longer-term opportunities to improve water quality management. The URBAN WASH team discussed and refined these recommendations with GWCL management during in-person action planning workshops. Most recommendations apply to both locations, though the team indicated nuances where relevant. Approximate expense ranges marked as *low, medium, or high cost* reflect knowledge from other water utilities outside Ghana. Actual costing must be conducted with GWCL, given potential supply chain, regulatory, logistic, and currency challenges affecting their locations. Additional details on these recommendations are provided in separate city-level action plans.

Water quality monitoring equipment and methods

- *(Low cost)* Purchase low-range turbidity meters for both treatment plants in Kumasi.[21]
- *(Low cost)* Use a digital chlorine meter at Barekese treatment plant in Kumasi and free chlorine reagents in all testing to more accurately assess how much free (unbound) chlorine remains available to disinfect contaminants introduced farther along the water supply chain.
- *(Low cost)* Investigate the cause of discrepancies between GWCL and URBAN WASH measurements in distribution system microbial water quality and chlorine levels in Kumasi. These most likely stem from differences in sampling locations (e.g., distance from chlorine booster stations, or representation of low-income areas), but could also point to possible opportunities for improving GWCL's sampling and analysis methods or spatiotemporal coverage. URBAN WASH recommends that GWCL and URBAN WASH team members conduct side-by-side sampling and testing in both cities as a starting point to clarify differences.
- *(Medium cost)* Consider monitoring disinfection byproducts periodically (e.g., quarterly or annually), a gap in current monitoring procedures, to inform possible adjustments in water treatment procedures (e.g., using chlorine dioxide pre-flocculation to help break down organic matter). In Kumasi, this could align with replacing some of the many parameters monitored monthly, which are less meaningful from a health perspective.
- *(Medium cost)* Pursue installation of backup power for incubators in both cities, as fluctuating incubation temperatures can affect the validity of microbial test results.

Treatment optimization

- *(Low–medium cost)* Target chlorine levels to ensure safety for human consumption at the tap, while balancing taste and odor concerns. A closer understanding (e.g., modelling) of chlorine decay along the distribution network and all the way to the consumer would likely help in this regard.
- *(Medium cost)* Further reduce turbidity during the initial treatment steps, particularly in Tamale, to reduce needed chlorine dosing and boosting. This may require replacement and/or more

[21] At the time of finalizing this report, GWCL Ashanti Production had procured a low-range turbidity meter and a digital chlorine analyzer for Barekese treatment plant.

frequent backwashing of filters. GWCL may consider projecting and comparing costs as a desk exercise and/or through a series of pilot studies.

- *(Medium cost)* In Kumasi, increase chlorination capacity to 20 kg/hour at the treatment plants. Additionally, install new stations for booster chlorination in high-risk locations of the distribution network (e.g., locations with low chlorine levels or locations most affected by intermittency or pipe breaks). Consider mobile stations as vulnerable network locations requiring chlorination boosting may change over time.
- *(Medium cost)* In Tamale, install equipment for chlorine boosting at the storage tank located just upstream of the city. Following this, examine whether the distribution network needs additional chlorine booster stations.
- *(High cost)* Progressively automate treatment processes (e.g., adjusting coagulant doses automatically based on real-time source water quality, backwashing filter when treated water turbidity exceeds a threshold or when the head loss through the filter increases noticeably). GWCL's ongoing pilot in another region can serve as a reference. This is likely a higher priority for Kumasi than Tamale.

Data management for decision-making

- *(Low cost)* Digitize and convert data to visualizations so that trends can be shared and discussed with water managers at regular intervals. Using low-cost software such as Microsoft Excel or Tableau to visualize frequently measured parameters such as turbidity and chlorine could help identify and anticipate seasonal trends, which would be particularly helpful in Tamale. It would also assist the verification monitoring step outlined in WSPs. Shared dashboards displaying turbidity and chlorine compliance by region may also stimulate friendly competition among regions and promote peer learning (Berg and Padowski 2010).
- *(Medium cost)* If not already practiced, combine distribution system water quality information with other monitoring data to inform decision trees and operational alerts. For example, specific management actions might be triggered when (a) source water turbidity rises, (b) chlorine residual drops, (c) flow rates in the distribution system slow down, and/or (d) pipe breaks are detected. This could be aided by installing online sensors and/or Supervisory Control and Data Acquisition software.
- *(Medium cost)* Develop hydraulic models and water quality models for the distribution network in both cities to aid decision-making and identify operational challenges.

Distribution optimization

- *(Low–medium cost)* Leverage the existing customer call center to respond more quickly to system outages and leaks. This could also help to minimize water loss and build trust with consumers.
- *(Low–high cost)* Increase funding available for maintenance of the distribution network and replacement of aged pipes to minimize pipe bursts, exposed pipes, and contamination sources. If possible, any new pipe networks should be laid in locations less subject to erosion and breakage (as opposed to main roads). These changes could be carried out in tandem with GWCL's regional NRW strategic plans.

- *(Medium–high cost)* Mitigating power outages would increase production capacity and reduce the need for water rationing. GWCL has arranged for installation of an automatic voltage regulator and could also consider solar power. In Tamale, securing a second grid electricity line would reduce vulnerability to low voltages during peak hours.
- *(High cost)* In Tamale, increase production capacity to address the widening gap between supply and demand. As a priority, this would entail replacing low-lift pumps at the Dalun treatment plant and fixing leaks in the storage tank. In the longer term, this also necessitates following through with plans for building a second treatment plant.

Training and capacity

- *(Low cost)* Increase frequency of refresher trainings for GWCL staff on appropriate methods for turbidity, chlorine, and *E. coli* analysis; quality assurance; optimizing turbidity removal; waterborne pathogen types; chlorine demand; responding to test results failing water quality standards; water safety planning; and other water quality risks relevant to the location. Internal senior staff and/or external experts could administer the trainings.
- *(Low cost)* Promote better integration and communication between distribution and water quality departments. This could entail periodic training of distribution operators on procedures they should follow to help preserve water quality in the distribution network, such as keeping valve chambers clean or disinfecting and flushing after performing pipe repairs.
- *(Medium cost)* Initiate process benchmarking with high-performing African utilities to receive tailored mentorship on best practices.

Community engagement

- *(Low cost)* Improve proactive communication with communities, including sharing aggregated water quality information within legal limits (e.g., using a high-level report card). Regulations do not currently require systematically sharing water quality monitoring data with customers (only upon customer request), which limits GWCL's social engagement and downward accountability. GWCL could take the opportunity to seek official guidance on the feasibility of broader information sharing.
- *(Medium cost)* Strengthen consumer sensitization campaigns on safe water storage and handling practices to minimize microbial contamination at the point of use. This should include recommendations to periodically disinfect storage tanks.
- *(Medium cost)* Raise community awareness about the importance of keeping vulnerable areas of the distribution network, such as valve chambers, free of human and animal waste.

Holistic water safety planning

- *(Low cost)* Revise drafted WSPs after receiving feedback from the head office.
- *(Low cost)* Establish efficient communication channels among personnel in charge of (1) water supply and rationing, (2) pipe breaks, and (3) water quality. Because intermittency and pipe breaks deteriorate water quality, improved communication among different teams could help to address water quality risks more systematically.
- *(Medium cost)* As WHO recommends, carry out and maintain a full WSP for all water supplies (WHO 2023). This would help to gauge whether such risks remain controlled before the water

could potentially harm the consumer. Establishing high-level buy-in at the national level (Summerill, Pollard, and Smith 2010) and allocating sufficient resources to WSP teams would be logical next steps. Start-up resource allocation should be on the order of 16.2 full-time equivalent person-months per system over the first year, with reduced staff time costs thereafter and variable capital costs (Kayser et al. 2019).

- *(Medium cost)* Proactively seek opportunities to collaborate with the Water Resources Commission and basin boards to minimize watershed pollution. Actions to minimize sand winning are particularly critical in Tamale, where treatment costs account for 40 percent of operational expenses because of high source water turbidity. Other actions may include respecting a buffer zone with reduced economic activities near the riverbanks, planting fast-growing trees, and compensating people whose livelihoods may be affected by these restrictions.
- *(Medium cost)* Strengthen sanitation safety planning and watershed protection through partnerships, which could lower overall costs needed to invest in water treatment over time (WHO 2016; 2022b).
- *(Low cost)* Establish periodic internal and/or external audits of the WSPs to ensure a sustained risk management approach (World Health Organization and International Water Association 2015).

5.2 NEXT STEPS

The URBAN WASH team will collaborate with GWCL to select intervention(s) for the second phase of the program and identify appropriate performance indicators to measure the achievements of the intervention(s).

6.0 REFERENCES

Adams, Ellis Adjei, and William F. Vásquez. 2019. "Do the Urban Poor Want Household Taps? Community Preferences and Willingness to Pay for Household Taps in Accra, Ghana." *Journal of Environmental Management* 247 (October): 570–79. https://doi.org/10.1016/j.jenvman.2019.06.113.

Appiah-Effah, Eugene, Emmanuel Nketiah Ahenkorah, Godwin Armstrong Duku, and Kwabena Biritwum Nyarko. 2021. "Domestic Drinking Water Management: Quality Assessment in Oforikrom Municipality, Ghana." *Science Progress* 104 (3): 00368504211035997. https://doi.org/10.1177/00368504211035997.

Aquaya. 2016. "WaterCaRD: Water Capacity Rating Diagnostic." Guidance Manual.

Aquaya Institute. 2023a. "Water Quality in Asutify North District, Ghana." *Brief*, WaterTRACS (Testing, Research, and Capacity Strengthening), .

———. 2023b. "Water Quality in Wassa East District, Ghana." *Brief*, WaterTRACS (Testing, Research, and Capacity Strengthening).

Berg, Sanford, and Julie C Padowski. 2010. "Overview of Water Utility Benchmarking Methodologies: From Indicators to Incentives." USA: Public Utility Research, University of Florida. https://bear.warrington.ufl.edu/centers/purc/docs/papers/0712_Berg_Overview_of_Water.pdf.

Bloomberg.Com. 2023. "Ghana Inflation Hits Record 54.1% as Food Costs Surge," January 11, 2023. https://www.bloomberg.com/news/articles/2023-01-11/ghana-inflation-hits-record-54-1-as-food-costs-surge.

Franceys, R.W.A. 2005. "Charging to Enter the Water Shop? The Costs of Urban Water Connections for the Poor." *Water Supply* 5 (6): 209–16. https://doi.org/10.2166/ws.2005.0066.

Ghana Standards Authority. 2021. "Draft Ghana Standard DGS 175:2021. Water Quality – Specification for Drinking Water." Ghana Standards Authority.

Ghana Statistical Service. 2018. "Multiple Indicator Cluster Survey (MICS2017/18) Survey Findings Report." https://washdata.org/reports/ghana-2017-2018-mics-report.

———. 2019. "Ghana Living Standard Survey (GLSS 7) 2017." https://www2.statsghana.gov.gh/nada/index.php/catalog/97.

Guzmán, Danice, and Justin Stoler. 2018. "An Evolving Choice in a Diverse Water Market: A Quality Comparison of Sachet Water with Community and Household Water Sources in Ghana." *The American Journal of Tropical Medicine and Hygiene* 99 (2): 526–33. https://doi.org/10.4269/ajtmh.17-0804.

GWCL. 2022. "Proposals for Review of Aggregate Revenue Requirement and Tariff." Ghana Water Company Limited.

Kayser, G., J.F. Loret, K. Setty, C. Blaudin De Thé, J. Martin, C. Puigdomenech, and J. Bartram. 2019. "Water Safety Plans for Water Supply Utilities in China, Cuba, France, Morocco and Spain: Costs, Benefits, and Enabling Environment Elements." *Urban Water Journal* 16 (4): 277–88. https://doi.org/10.1080/1573062X.2019.1669191.

Kumpel, Emily, Alicea Cock-Esteb, Michel Duret, Dominick de Waal, and Ranjiv Khush. 2017. "Seasonal Variation in Drinking and Domestic Water Sources and Quality in Port Harcourt, Nigeria." *The American Journal of Tropical Medicine and Hygiene* 96 (2): 437–45. https://doi.org/10.4269/ajtmh.16-0175.

Monney, Isaac, and Prince Antwi-Agyei. 2018. "Beyond the MDG Water Target to Universal Water Coverage in Ghana: The Key Transformative Shifts Required." *Journal of Water, Sanitation and Hygiene for Development* 8 (2): 127–41. https://doi.org/10.2166/washdev.2018.176.

Peletz, Rachel, Joyce Kisiangani, Mateyo Bonham, Patrick Ronoh, Caroline Delaire, Emily Kumpel, Sara Marks, and Ranjiv Khush. 2018. "Why Do Water Quality Monitoring Programs Succeed or Fail? A Qualitative Comparative Analysis of Regulated Testing Systems in Sub-Saharan Africa."

International Journal of Hygiene and Environmental Health 221 (6): 907–20. https://doi.org/10.1016/j.ijheh.2018.05.010.

REAL-Water. 2023. "Synthesis of Water Safety Planning Efforts in Ghana." United States Agency for International Development (USAID) Rural Evidence and Learning for Water Project.

Summerill, Corinna, Simon J. T. Pollard, and Jennifer A. Smith. 2010. "The Role of Organizational Culture and Leadership in Water Safety Plan Implementation for Improved Risk Management." *Science of The Total Environment* 408 (20): 4319–27. https://doi.org/10.1016/j.scitotenv.2010.06.043.

Twerefou, Daniel Kwabena, Kwadwo A. Tutu, Ebo Botchway, and Samuel Darkwah. 2015. "Willingness-to-Pay for Potable Water in the Accra-Tema Metropolitan Area of Ghana." *Scientific Research Publishing*, December. https://doi.org/10.4236/me.2015.612122.

UNICEF. 2017. "Multiple Indicator Cluster Surveys (MICS) Manual for Water Quality Testing." UNICEF. https://mics.unicef.org/tools#data-collection.

USAID. 2020. "Assessing the Effects of COVID-19 on Access to Water, Sanitation, and Hygiene in USAID High Priority and Strategy-Aligned Countries: Synthesis Report."

———. n.d. "The DHS Program - Analysis FAQs." Demographic and Health Surveys. Accessed November 2, 2023. https://dhsprogram.com/data/analysis-faqs.cfm.

WHO. 2016. *Protecting Surface Water for Health: Identifying, Assessing and Managing Drinking-Water Quality Risks in Surface-Water Catchments*. Geneva: World Health Organization. https://iris.who.int/handle/10665/246196.

———. 2019. "A Guide to Equitable Water Safety Planning: Ensuring No One Is Left Behind." *Geneva: World Health Organization;*

———. 2022a. *Guidelines for Drinking-water Quality: Fourth Edition Incorporating the First and Second Addenda*. World Health Organization. https://apps.who.int/iris/handle/10665/352532.

———. 2022b. "Sanitation Safety Planning: Step-by-Step Risk Management for Safely Managed Sanitation Systems." World Health Organization. https://www.who.int/publications-detail-redirect/9789240062887.

———. 2023. *Water Safety Plan Manual: Step-by-Step Risk Management for Drinking-Water Suppliers, Second Edition*. Geneva: World Health Organization. https://www.who.int/publications-detail-redirect/9789240067691.

WHO/UNICEF. 2020. "Joint Monitoring Programme (JMP) Data." 2020. https://washdata.org/data.

World Health Organization and International Water Association. 2015. *A Practical Guide to Auditing Water Safety Plans*. Geneva, Switzerland: World Health Organization. https://iris.who.int/handle/10665/204280.

APPENDIX A: WATER QUALITY DATA RECEIVED FROM GWCL

	Kumasi		Tamale	
	Treatment plants (raw and treated water)	**Distribution network**	**Treatment plant (raw and treated water)**	**Distribution network**
Turbidity, pH, color	Monthly; Jan 2017–Dec 2022	Monthly; Apr 2021–Jun 2023; 4,983 different locations in 13 divisions	~Monthly; Oct 2018–Dec 2022	Monthly; Jan–Jun 2023; 326 different locations
Chlorine residual	Three times a day; Barekese: Jan 2020–Mar 2023 Owabi: Jun 2021–Mar 2023			
Microbial parameters (*E. coli*)[1]	Daily; Barekese: Jan 2020–Mar 2023 Owabi: Jun 2021–Dec 2022			
Metals	Aluminum, chromium, copper, iron, manganese, zinc; Monthly; Jan 2017–Dec 2022		Aluminum, arsenic, copper, chromium, iron, lead, manganese, zinc; ~Monthly; Oct 2018–Dec 2022	
Other physico-chemical parameters	Temperature, conductivity, total dissolved solids, total hardness, calcium hardness, alkalinity; Monthly; Jan 2017–Dec 2022			
Other ions[2]	Ammonia, chloride, fluoride, nitrate, nitrite, phosphate, sulfates; Monthly; Jan 2017–Dec 2022		Ammonia, nitrate, nitrate, fluoride, sulfate; ~Monthly; Oct 2018–Dec 2022	

[1] Also included total coliforms for Kumasi's distribution network. In Tamale, there is no data for raw water (only treated and distribution water).
[2] In Tamale, only included treated water (not raw water).

APPENDIX B: WATERCARD SCORES

The Water Capacity Rating Diagnostic (WaterCaRD) scorecard assesses multiple dimensions of the enabling environment and institutional capacity for water quality monitoring (Aquaya 2016; Peletz et al. 2018). It focuses solely on water quality monitoring capacity and does not seek to assess institutional performance. For example, it does not evaluate treatment practices or organization-wide financial management. WaterCaRD scores for Ghana Water Company Limited (GWCL) in Kumasi and Tamale indicate key strengths around staffing, as well as several areas of improvements (particularly around equipment, methods, and data management and interpretation).

Table B.1: A summary of WaterCARD scores and calculations for two cities in Ghana shows above-average scoring with some room for improvement

<table>
<tr><th>Topic</th><th>Kumasi</th><th>Tamale</th></tr>
<tr><td>Accountability[1]</td><td>7/12 (58%)</td><td>7/12 (58%)</td></tr>
<tr><td>1.1 Standards</td><td colspan="2">2 (Ghana Standards Authority [GSA] has standards regarding water safety and water quality monitoring, but [1] these standards could be more specific regarding analysis methods, and [2] the turbidity standard of <5 nephelometric turbidity units [NTU] is higher than the ideal target of 1 NTU recommended by the World Health Organization)</td></tr>
<tr><td>1.2 Regulatory Authorities</td><td colspan="2">3 (up to biannual submission of water quality data to the Public Utility Regulatory Commission [PURC])</td></tr>
<tr><td>1.3 Consumers</td><td colspan="2">1 (regulations do not require GWCL to share holistic water quality information with consumers; therefore, water quality data is not regularly shared with the public, only in response to complaints)</td></tr>
<tr><td>1.4 Enforcement</td><td colspan="2">1 (PURC provides feedback annually and requires a remediation plan in case of poor water quality but no incentives or sanctions to ensure adherence to water quality standards)</td></tr>
<tr><td>Staffing</td><td>21/24 (88%)</td><td>21/24 (88%)</td></tr>
<tr><td>2.1 Water Quality Leadership</td><td colspan="2">3 (each city has a full-time water quality manager with no conflicting priorities)</td></tr>
<tr><td>2.2 Roles and Responsibilities</td><td colspan="2">3 (staffing levels are sufficient and roles are clearly defined among water quality staff)</td></tr>
<tr><td>2.3 Knowledge and Experience</td><td colspan="2">3 (laboratory staff have good theoretical knowledge and practical experience)</td></tr>
<tr><td>2.4 Training</td><td colspan="2">2 (periodic but infrequent formal staff trainings)</td></tr>
<tr><td>2.5 Motivation</td><td colspan="2">3 (staff appeared motivated and proud to meet water quality standards)</td></tr>
<tr><td>2.6 Staff Stability</td><td colspan="2">3 (turnover is low and when a staff leaves, other staff can cover for them temporarily)</td></tr>
<tr><td>2.7 Staff Recruitment</td><td colspan="2">3 (human resources department has set procedures to hire new water quality staff)</td></tr>
<tr><td>2.8 Risk Management</td><td colspan="2">1 (power outages affecting incubator and validity of microbial water quality results are not addressed)</td></tr>
<tr><td>Program Structure</td><td>16/24 (67%)</td><td>17/24 (71%)</td></tr>
<tr><td>3.1 Methods</td><td>1 (inappropriate equipment for turbidity measurement at both treatment plants;[2] inappropriate equipment for chlorine testing at Barekese treatment plant; no use of sodium thiosulfate for microbial samples at</td><td>2 (occasional use of total chlorine consumables when free chlorine consumables are unavailable; occasional use of multi-tube fermentation, which is less reliable</td></tr>
</table>

Topic	Kumasi	Tamale
	Barekese treatment plant; occasional use of total chlorine consumables when free chlorine consumables are unavailable; occasional use of multi-tube fermentation, which is less reliable than membrane filtration, and, as performed, provides data on fecal coliform rather than *E. coli*)[3]	than membrane filtration, and, as performed, provides data on fecal coliform rather than *E. coli*)[3]
3.2 Results	2 (water quality results do not optimally guide water safety management; coagulation and chlorination would likely be better optimized if proper measurement equipment was used)	2 (water quality results do not optimally guide water safety management, as turbidity measurements are not used to optimize jar testing)
3.3 Sampling Plans	3 (the utility has testing targets and prioritizes sampling locations based on population density and presence of schools)	
3.4 Sample Collection	2 (data submitted suggests that the target of 460 samples per month is not reached)	2 (data submitted did not include any data points prior to 2023)
3.5 Sampling Logistics	3 (utility personnel has adequate access to vehicles for sample collection)	
3.6 Quality Control	2 (quality assurance/quality control samples are not systematic, particularly at the main treatment plant)	2 (no positive controls; duplicates only when contamination is detected)
3.7 Data Management	2 (data is recorded electronically, but data visualization and analysis seemed limited)	
3.8 Actions	1 (in case of tests not meeting standards in treated water or in the distribution network, the only reported follow-up action is to retest. No mention of adjustments to treatment procedures)	
Program Finances	**7/9 (78%)**	**7/9 (78%)**
4.1 Resources	2 (the lack of proper water testing equipment may be budget related)	2 (budget changes annually)
4.2 Budgeting	3 (regions have a dedicated, earmarked, annual budget for water quality monitoring)	
4.3 Accounting	2 (late payments to vendors result in price increases)	2 (long payment process)
Equipment & Infrastructure	**9/12 (75%)**	**9/12 (75%)**
5.1 Equipment and supplies	3 (GWCL has access to distributors; the issues with inadequate supplies and/or equipment mentioned above are not due to restricted access to distributors)	
5.2 Maintenance	2 (inability to repair turbidity meters, digital chlorine analyzers, and incubators)	
5.3 Procurement	2 (lengthy tender-based procurement)	
5.4 Infrastructure	2 (laboratory subject to power outages)	
TOTAL	**60/81 (74%)**	**61/81 (75%)**

[1] This section primarily rates national standards and the regulatory environment rather than the institution's capacity itself.

[2] In Kumasi, GWCL measured turbidity with a Hach DR900 multi-parameter portable colorimeter, which is appropriate to measure source water turbidity but not to measure turbidities below 20 NTU such as in treated water. A comparison with a different turbidity meter (Hach 2100Q) on the day of the visit showed that the Hach DR900 meter underestimated turbidity. With a more reliable low-range turbidity meter to run jar tests, operators could better identify the optimal coagulant dose and accurately measure the reduction in turbidity during the filtration step.

[3] Staff reported performing the last incubation at 44°C rather than 35–37°C, which selects for all fecal coliforms rather than *E. coli* specifically.

APPENDIX C: FREE CHLORINE RESIDUAL IN DISTRIBUTION NETWORKS

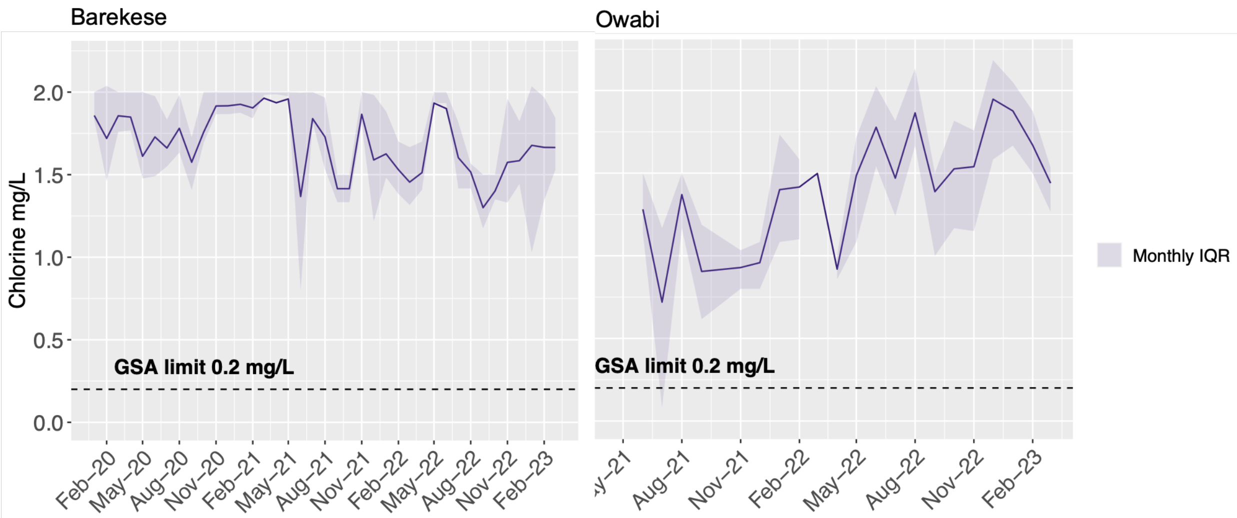

Figure C.1: Free chlorine residual data from two treatment plants in Kumasi, compared to the GSA minimum requirement of 0.2 mg/L

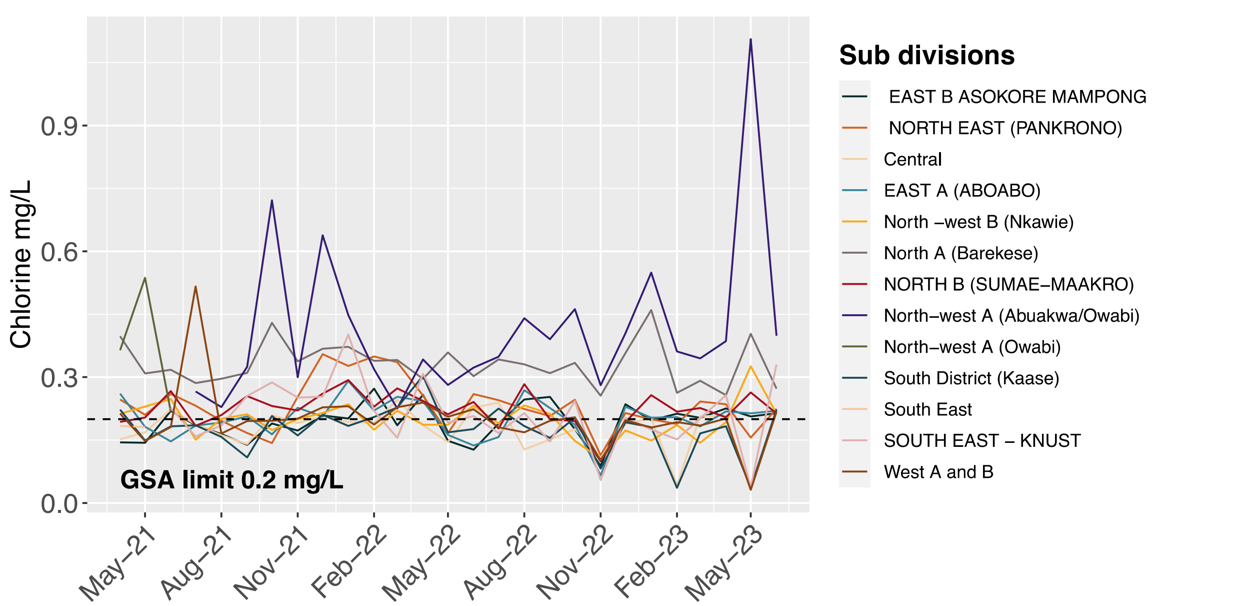

Figure C.2: Free chlorine residual data from Kumasi's distribution system, compared to the GSA minimum requirement of 0.2 mg/L

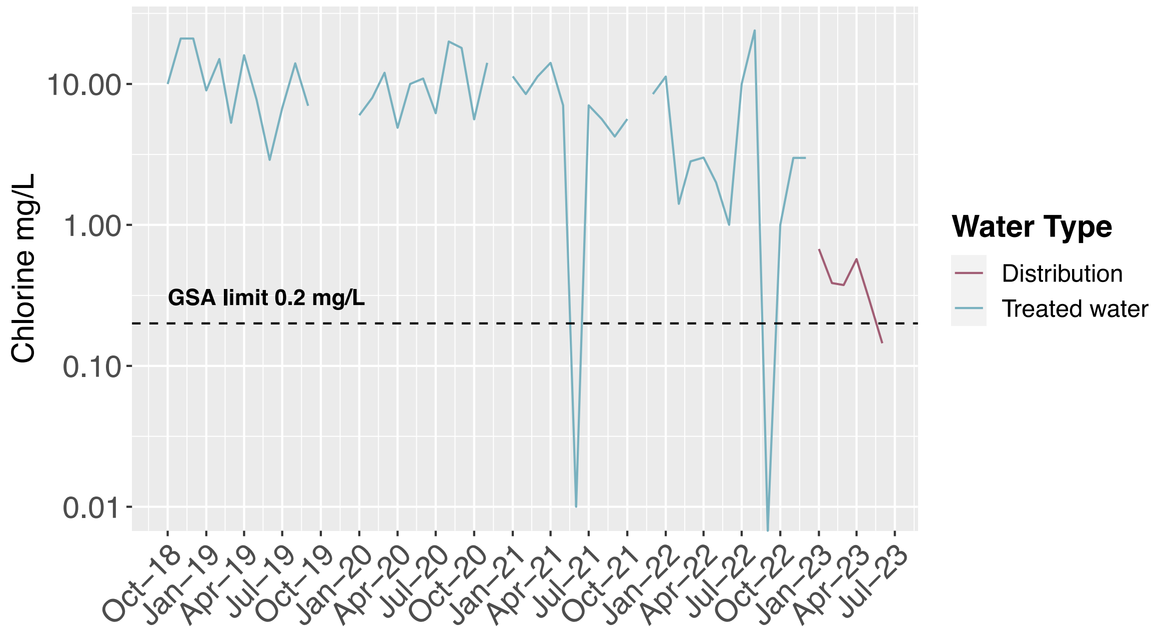

Figure C.3: Free chlorine residual data from the Dalun treatment plant in Tamale, and limited data from the distribution system, compared to the GSA minimum requirement of 0.2 mg/L

APPENDIX D: INEQUITIES IN WATER QUALITY AT THE POINT OF USE

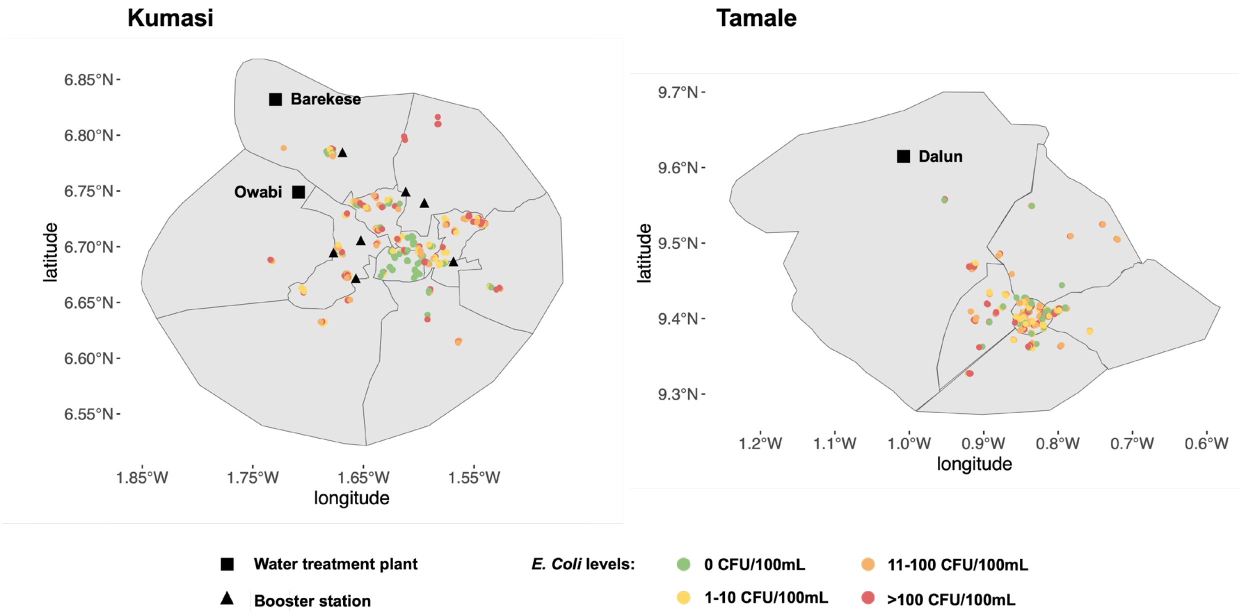

Figure D.1: The geographic distribution of point-of-use microbial water quality in Kumasi (left) and Tamale (right)

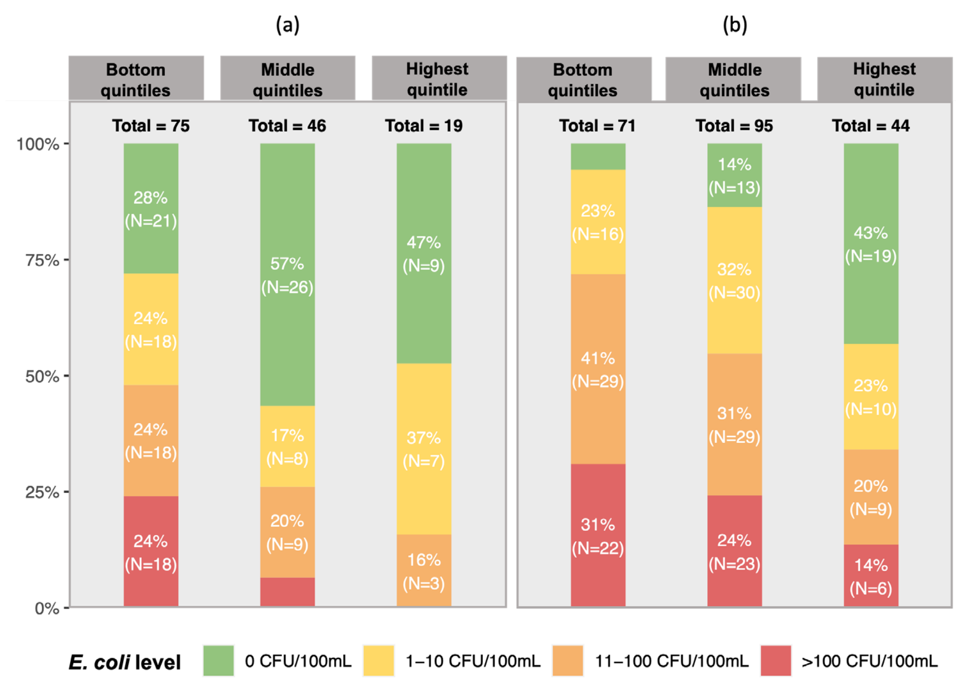

Figure D.2: Water quality data at the point of use for the main drinking water source per wealth quintiles in (a) Kumasi and (b) Tamale

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