Effects of water quality on rural livelihoods: a case of Tamale Metropolis

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ABSTRACT

Water quality issues are a challenge in both developed and developing countries, which affects the people who depend on it. This study aimed at examining the quality of water sources used by the residents of 18 rural areas in Tamale Metropolis and their effects on their livelihoods. This was done by collecting water samples from four different sources used by residents: hand-dug wells, boreholes, Ghana Water Company Limited (GWCL) household tap and dam for laboratory analysis for both dry and rainy seasons. Furthermore, selected respondents from 18 communities in rural Tamale in the Northern region of Ghana who depend on these water sources were interviewed to examine the effect of the water sources on their livelihoods. From the findings, almost all households have access to at least 2 of these water sources with 51% of households storing water due to the lack of year-round water supply. The water quality test also shows that apart from water provided by the GWCL which passed the standard for physico-chemical parameters; dam, well, and borehole test results for colour (10.9-105.0 Hz), turbidity (23.5-226.0 NTU) and iron (0.35-1.99 mg/l) fell beyond the recommended range set by World Health Organization. No water source could meet the bacteriological requirements with a total of 7-1910 CFU and faecal of 7-1200 CFU with coliforms content increasing in the rainy season. 73% of households reported sharing water with animals and 41% perceived to be drinking from unclean sources. Additionally, 70% indicated an increase in diseases such as cholera and diarrhoea while 90% responded that the cost of getting quality or potable water and attending to healthcare affects their household income. The overall implication is that the effect of poor water quality on the livelihoods of rural residents in Tamale Metropolis is significant and requires urgent intervention.

Keywords: potable water, water quality, diseases, households, livelihoods

INTRODUCTION

Water quality issues are a challenge in both developed and developing countries and include the loss of water bodies, and the increase in invasive species (UN, 2018). The United States Safe Drinking Water Act regulates and empowers the Environmental Protection Agency (EPA) to set national standards to determine the maximum contaminant levels allowable to make drinking water safe (Buchholz, 1993).

Unfortunately, in many developing countries water supplies have focused on delivery quantity at the expense of quality, leading to a call for improvement in the quality of chemical and microbial content of water supplies (Barrow, 2005). The Millennium Development Goals (MDGs) categorized sources of drinking water into improved and unimproved with the improved sources considered safe while unimproved are unsafe. Based on this, by 2010, 89% of the world's population depend on improved sources, according to the 2012 United Nations News report. Unfortunately, there is no assurance that using water from improved sources is free from faecal contamination with many domestic water supplies lacking quality guidelines at the global and national levels (World Health Organization/United Nations Children's Fund 2017). Onda et al. (2012) argue that improved source such as piped water supply has "significant sanitary risks". Lee and Schwab (2005) have attributed the contamination of piped water supply to disinfection residual, infiltration of organics and pollutants, leakages during distribution and most important intermittent system operation which causes stagnant water in pipes causing a drastic reduction in water quality. The issue of unsafe pipe water supply was collaborated by a 2013 water quality analysis on Ghana Water Company Limited (GWCL), Tamale data, where 42% of samples did not meet the acceptable guidelines by WHO for residual chlorine with total coliform present in 2% of samples (Allison, 2014).

Water shortage and intermittent supply have led to several households in developing countries using various containers to store water, which further undermines the water quality even for tap water (Akuffo et al., 2013). Seasonal variation with changing weather patterns also influences the quality of drinking water with microbial quality usually deteriorating in the rainy season (Rabiu et al., 2018). Similar data analyses on GWCL water supply in Tamale indicated that pH and turbidity are affected by seasonality consequently influencing the quality of water supplied to consumers (Allison, 2014). Unsafe water is associated with diarrhoea diseases with 5.9million deaths in children under five recorded in 2015 with limited access to potable water, inadequate treatment and poor water storage as the main reasons (World Health Organization, 2015). In Ghana 1,429,990 Outpatient morbidity cases were recorded in 2017 according to the Ghana Health Service (GHS) (2018) with environmental conditions closely link to diarrhoea cases. The GHS and its partners are implementing interventions such as access to clean water, sanitation facilities and hygiene promotion to reduce the incidence of diarrhoea and cholera (Ghana Health Service, 2016). The study therefore aimed at examining the effects of water quality on rural livelihood improvements in the Tamale Metropolis

METHODOLOGY

Study Area
The Metropolis lies between latitude 9°16 and 9° 34 North and longitudes 0° 36 and 0° 57 West geographically and 180 meters above sea level. The Metropolis receives rainfall starting from April/May and ending in September/October with an annual mean rainfall of 1100mm (UNDP, 2011). Out of the 116 communities, 35% are urban, 13% are peri-urban and 52% are categorized as rural. The Metropolis is less endowed with surface water such as rivers and streams. The few streams also dry up in the dry season. The Metropolis depends heavily on piped water supply by GWCL from the treatment plants at Dalun and Nawuni of which the daily production could not meet the demand of the growing population with some dams purposely used for domestic activities and

watering animals (Tamale Metropolitan Assembly [TaMA], 2014). The unimodal rainfall pattern has led to increasing concerns over perceived challenges within the rural communities regarding potable water supply (TaMA, 2014).

Water Sampling
Water samples from four different sources namely; hand-dug wells, boreholes, piped bone water from GWCL household tap and Dam were collected. Within each zonal council, a purposive sampling technique was used to select a water source. For the Lameshagu/Nyohini zonal council, the GWCL source was selected in the Dungu-Kukuo community. Again, in Kakpagyili zonal council Manguli community was selected for the Dam source and in Vittin zonal council, Gukpegu-Tua was selected for the borehole source and Tuya for the hand-dug well source. Dry season samples were collected in February 2019 and rainy season water samples in August 2019 between the hours of 6:30 am to 9:30 am. To avoid samples being contaminated, fundamental principles and procedures (APHA, 2017) for water sampling were adhered to. At each sampling site, water samples were fetched into 1.5l sterilized bottles, stored in an ice chest and carried to the Water Quality Assurance Unit of the GWCL in Tamale for analysis the same day.

Laboratory Analyses
At the Water Quality Assurance Unit of the GWCL in Tamale, APHA (2017), standard procedures for analyses were used for the analyses. Total and Faecal coliform were analysed within 24 hours of arrival. Physico-chemical parameters such as odour, colour, turbidity, total suspended solids, pH, total hardness, fluoride, iron, chloride etc. were later analysed. No onsite analysis was done.

The pour plate method using Molten cooled agar incubated at 37°C for 24-48 hours was used to determine Total and Faecal Coliform. Electrochemical method using pH meter was used to measure pH while Total Dissolved Solids (TDS) meter of HACH, USA was used to measure conductivity, TDS and temperature of the water samples. Colour and turbidity were determined with HACH Lang Spectrophotometer of UK and Hach 2100Q Turbidimeter Kit of USA respectively. Sodium (Na), Nitrate (NO_3^-) and Flouride (F^-) of the water samples were analysed by Flame Photometric (Jenway model PFP 7), hydrazine reduction and SPADNS methods respectively Chloride (Cl^-) contents and total hardness were analysed by argentometric titration and Ethylenediaminetetraacetic Acid (EDTA) titration, respectively. Total Iron (Fe) and Manganese (Mn) were determined using the Direct Aspiration atomic absorption spectrophotometer (AAS: Atomic Absorption Spectrometry) method.

Household Data Collection and Analysis
To understand household perception of water quality, water handling and the effect of the water on their overall livelihood, the research utilized a multi-stage sampling technique to select 198 households in 18 rural communities located in 3 zonal councils. Following the collection of the data through the administration of questionnaires, the data were sorted and analysed. The data collected were entered into the Statistical Package for Social Sciences (SPSS) where the results were analysed. Information collected on variables such as demographics, water, perception of water quality, storage and its effects on livelihood were analysed using descriptive statistics. The map of the survey communities is shown in Figure 1.
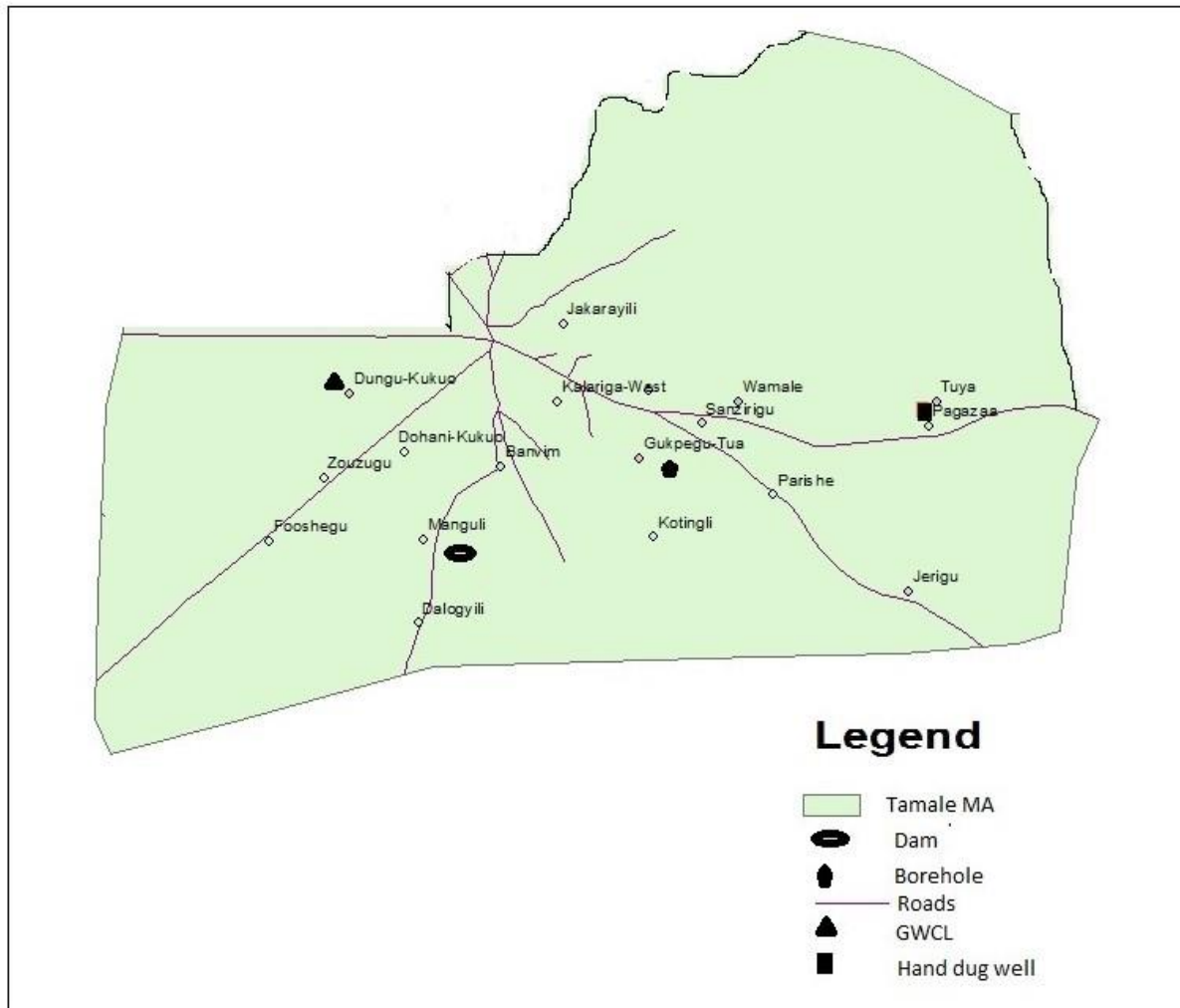
Figure 1: Map of Study Area and Survey Communities

RESULTS AND DISCUSSIONS

Demographic Characteristics of Respondents in the Tamale Metropolis
One hundred and ninety-eight (198) respondents from the three zonal councils of the Tamale Metropolitan Assembly were engaged in the study. The results show that majority of the study's households heads were males with 82% and only 18% were headed by females (Table 1). Studies have revealed that the engagement of both men and women correlates positively with improved sustainability of water supplies (Narayan, 1995). Therefore, with an overwhelming majority of 82% of households headed by men, households in rural Tamale Metropolis will suffer from an insufficient water supply.

The findings also indicated that a majority of the rural population represented by 61% of the sampled respondents had no level of education (Table 1). According to Musa (2015), the rural populace of which the majority are without formal education and unskilled does not have the capacity to effectively appreciate and deal with the issue of unsafe water supply. This implies that most rural households in Tamale Metropolis

are vulnerable to the effect of consuming unsafe water.

Table 1: Demographic Characteristics of Respondents in the Rural Tamale Metropolis

Variable	Categories	Freq.	%
Sex of Household Heads	Male	162	82.0
	Female	36	18.0
Education level of Respondents	None	120	61.0
	Basic School	46	23.0
	Secondary/Technical/ Vocational	24	12.0
	Tertiary	8	4.0
Number of People in household	1	0	0.0
	2-4	8	4.0
	5-7	85	43.0
	More than 7	105	53.0

The number of people in a household may influence the quality of water sources used in a household (Fotuè, 2013). About 53% of households had family sizes that were more than seven with 43 % from five to seven. The findings implied that households with more than seven members would have less water for use. The findings are consistent with those observed by Arouna and Dabbert (2010). The implication is that the 96% of households having family sizes that are five or more would have their incomes adversely affected since there are more people to feed and consequently, less income left to access potable water and thereby use unimproved sources.

Sources of water supply

To carry out the water sampling and quality test, the study ascertained more specifically, the water sources used by the rural residents and the findings are presented in Figure 2.

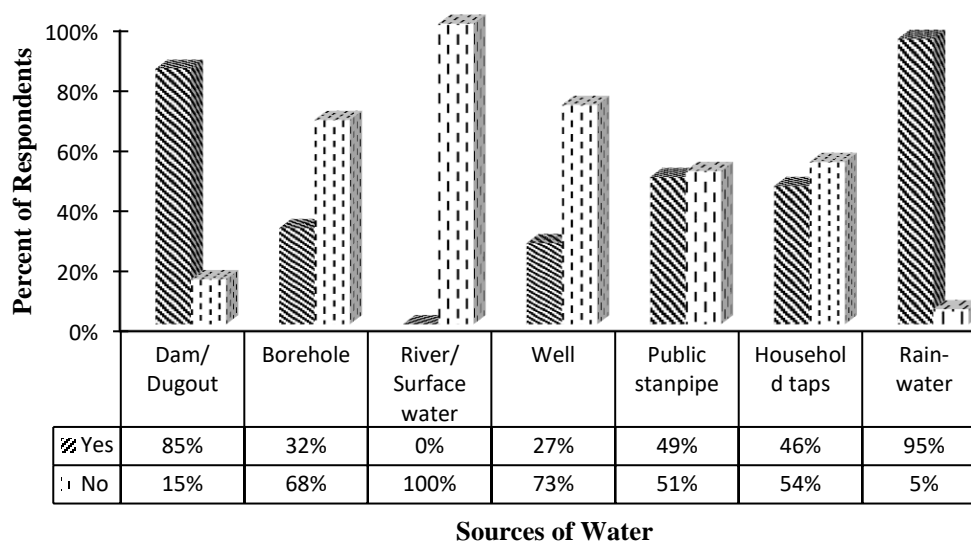|	Dam/ Dugout	Borehole	River/ Surface water	Well	Public stanpipe	Househol d taps	Rain- water
Yes	85%	32%	0%	27%	49%	46%	95%
No	15%	68%	100%	73%	51%	54%	5%

Sources of Water

Figure 2: Sources of Water Used by Rural Residents in Tamale Metropolis

Figure 2 represents the sources of water available to the rural communities in the Metropolis of which most households have access to multiple sources. The non-usage of surface water such as rivers or streams confirms that the Metropolis is less endowed with surface water and the few ones are seasonal (TaMa, 2014). About 85% of residents have either a dam or dugout as a source of water; therefore, it is not surprising that 95% of households depend on rainwater for daily chores including drinking, since it is a much-improved source. Almost half the respondents said they have access to either public standpipes (49%) or household taps (46%) as their source of water, with almost two-thirds relying on boreholes (32%) and hand-dug wells (27%).

Water Storage and Quality
The study also examined households' perception of the quality of water and the handling of water in the homes using a Likert Scale for respondents to indicate the extent to which they agreed or disagreed. The findings are presented in Figure 3.

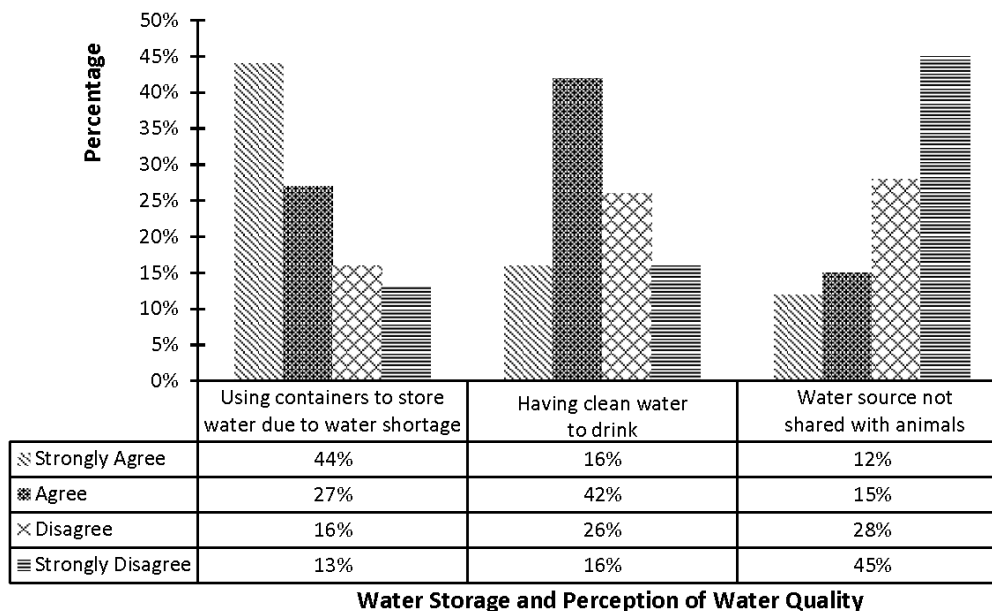|	Using containers to store water due to water shortage	Having clean water to drink	Water source not shared with animals
⩘ Strongly Agree	44%	16%	12%
⁂ Agree	27%	42%	15%
⨯ Disagree	16%	26%	28%
≡ Strongly Disagree	13%	16%	45%

Water Storage and Perception of Water Quality

Figure 3: Perception of Water Quality in the Rural Tamale Metropolis

The findings from Figure 3 indicate that over 70% of households admitted storing water in containers for use due to shortage. This means that households in the rural Tamale metropolis may have to depend on other water sources that may be unsafe to meet daily consumption and to ensure survival. In addition, according to Akuffo et al. (2013) storing safe water in a container could be contaminated due to poor handling and the material type of the storage containers used. Another worrying trend is that over 70% of respondents indicated that they share their water source with animals, and almost 50% suggested the water they use is unclean.

Water Quality Results
Water quality tests were undertaken both in the dry and rainy seasons to control for any deviations or biases in the quality of water

that may be attributed to seasonal variations. For further details see Tables 2 and 3.

Generally, the study found that the physico-chemical parameters were within the WHO standard except for colour, turbidity, pH, iron and Manganese (Tables 2 and 3). Figures 4 and 5 show that colour and turbidity were beyond the WHO optimum levels for Dam and Well sources of water during both the dry and wet seasons while the colour for boreholes fell outside the recommended range in the rainy season. However, there was a sharp reduction in the level of turbidity from the dry to the rainy season for the dam (226mg/l to 142mg/l) and well (61mg/l to 38.6mg/l). The reduction can be attributed to the increase in rainfall within the wet period, which increases the volume of water in dams and wells. The high volume has the tendency of diluting the concentration of organic materials that cause turbidity. Groundwater aquifers usually experience infiltration of surface and runoff water during rainy seasons that may lead to the high dissolution of substances such as silt, organic materials, clay etc. in boreholes (Amankona, 2010). Therefore, the rise in turbidity and colour level beyond the WHO optimum range can be due to percolation. Furthermore, colour is normally found on surface waters and it is not surprising that dams have the highest concentration of colour when compared with water sources from wells and boreholes. A careful study of the Tables 2 and 3 reveals that for each of the water sources that failed to meet the colour standard, it also failed to meet the turbidity requirements during both the dry and rainy seasons. Thus, the presence of turbidity in higher quantities of water could also explain the high water colour

(Akuffo et al., 2013). Tables 2 and 3 further reveal that water sources with high colour and turbidity values beyond the optimum range could not also meet the recommended levels for iron apart from the borehole water source that met the iron standard in the rainy season. Studies have shown that when the minimal iron requirement for water is exceeded, it affects the colour of the water, causes water odour and gives taste to water and cooking utensils; and pipe fixtures and clothes could be stained (Kumar et al., 2017). While colour and turbidity affect the palatability and appearance of drinking water, health implications including infertility, liver and heart-related diseases could be caused by high concentrations of iron (Kumar et al., 2017).

The study recorded a slight variation in pH as shown in Figure 7 from the WHO standard, for wells and boreholes (both seasons) and GWCL source for the wet season. The pH values of 6.9 and 6.6 of water collected from the dam for both the dry and rainy seasons, respectively, agree with similar test results in studies by Abinah (2013) and Rabiu *et al.* (2018). In addition, the slightly low pH of 6.1 for the hand-dug well is also consistent with the test result from wells by Abinah (2013). WHO (2014) has not proposed any health-based guideline for pH. However, pH values higher than 11 are associated with worsening skin disorders and eye irritation. Sensitive individuals may also suffer from gastrointestinal irritation due to low or high pH (WHO, 2004). The test results indicate that the pH of the four water sources tested in the Tamale Metropolis has no significant impact on the welfare of the residents.

Table 2: Water Quality Values in the dry season

Water source	Colour (Hz)	Turbidity (NTU)	pH (pH unit)	EC (µS/cm)	TDS (mg/l)	NO$_3^-$ (mg/l)	F (mg/l)	Fe (mg/l)	TH (mg/l)	Na (mg/l)	Mn (mg/l)	Cl$^-$ (mg/l)	FC (CFU)	TC (CFU)
Dam	75.00	226.00	6.90	327.00	169.00	1.60	0.80	1.99	34.00	23.70	0.53	37.30	200.00	250.00
Well	34.60	61.00	6.10	0.00	0.00	0.50	0.24	1.91	24.00	9.30	0.46	14.30	720.00	845.00
Borehole	0.00	0.00	6.30	0.00	0.00	1.10	0.00	0.14	20.00	10.90	0.11	21.20	18.00	27.00
GWCL	0.60	1.00	6.50	0.00	0.00	1.40	0.00	0.07	33.00	1.60	0.10	13.20	7.00	7.00
WHO Standards	≤5	≤5	6.5-8.5	1000	≤1000	≤50	≤1.5	≤0.3	≤500	≤200	≤0.4	≤250	0	0

Table 3: Water Quality Values in the Rainy Season

Water source	Colour (Hz)	Turbidity (NTU)	pH (pH unit)	EC (µS/cm)	TDS (mg/l)	NO$_3^-$ (mg/l)	F (mg/l)	Fe (mg/l)	TH (mg/l)	Na (mg/l)	Mn (mg/l)	Cl$^-$ (mg/l)	FC (CFU)	TC (CFU)
Dam	105.00	142.00	6.60	132.00	66.68	1.70	0.00	0.73	28.00	7.06	0.24	10.99	1000.00	1280.00
Well	27.60	38.60	6.10	179.90	90.69	0.60	0.38	0.35	35.00	4.74	0.54	8.99	1200.00	1910.00
Borehole	10.90	23.50	6.10	157.60	79.56	0.10	0.42	0.19	26.00	2.90	0.06	16.99	650.00	690.00
GWCL	0.00	0.88	6.30	174.60	85.38	0.40	0.48	0.11	30.00	5.90	0.01	8.99	58.00	67.00
WHO Standards	≤5	≤5	6.5-8.5	1000	≤1000	≤50	≤1.5	≤0.3	≤500	≤200	≤0.4	≤250	0	0

The coliform counts of the study present a worrying situation as shown in Figures 8 and 9. For both seasons, the results of the analyses of dams, wells, boreholes and Ghana Water Company Limited sources did not meet the minimal requirement, which indicates the presence of waste from humans and animals in the tested water sources. This has detrimental health consequences and implications on the livelihoods of the people. The GWCL water tap values being below the recommended values for both Faecal and Total coliforms are consistent with studies by Allison (2013) and Boateng et al. (2013), which attribute the cause to low residual chlorine concentrations in pipelines. The faecal contamination of piped water can also be due to disinfection residual, infiltration of organics and pollutants, leakages during distribution and most important intermittent system operation that causes stagnant water in pipes causing a drastic reduction in water

quality (Lee & Schwab, 2005). Poor waste disposal, open defecation and runoff may be the cause of extremely high counts of both Faecal and Total coliform for dam and well water sources. The increase in coliform levels for the borehole during the rainy season may be also be attributed to the infiltration of human and animal waste during the rainy season. VanDerslice and Briscoe (1995), aver that when an area has poor environmental sanitation, improving drinking water has no effect. As residents are exposed to high levels of coliform bacteria in water for domestic use, there is a high risk of contracting water-related diseases such as diarrhoea and other intestinal diseases, especially in infants (VanDerslice & Briscoe, 1995). The water quality results confirm the perception of almost half of the respondents, who indicated that their water sources are not clean and 70% who indicated that they share water sources with animals (Figure 3).
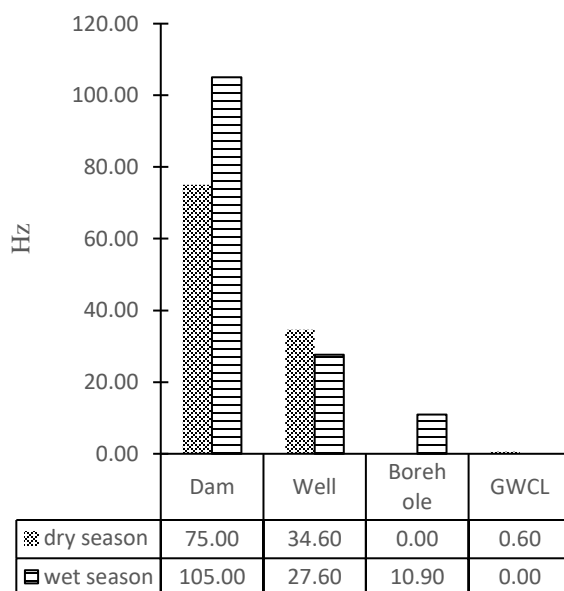

	Dam	Well	Borehole	GWCL
▨ dry season	75.00	34.60	0.00	0.60
☐ wet season	105.00	27.60	10.90	0.00

Fig 4: Colour in water sources for Dry & Wet seasons

	Dam	Well	Borehole	GWCL
▨ dry season	226.00	61.00	0.00	1.00
☐ wet season	142.00	38.60	23.50	0.88
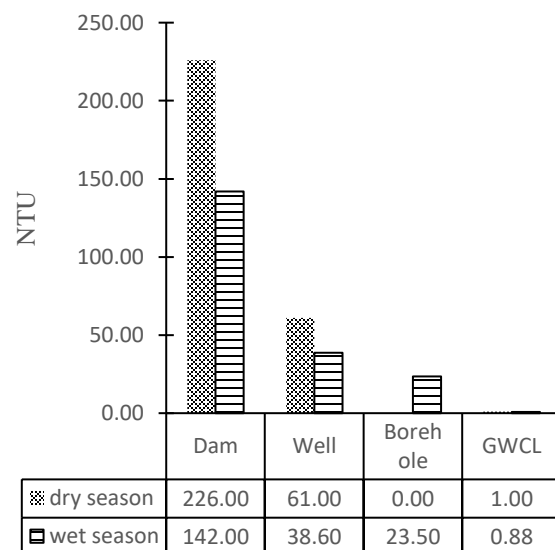
Fig 5: Turbidity in water sources for Dry & Wet Seasons

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	Dam	Well	Borehole	GWCL
dry season	1.99	1.91	0.14	0.07
wet season	0.73	0.35	0.19	0.11
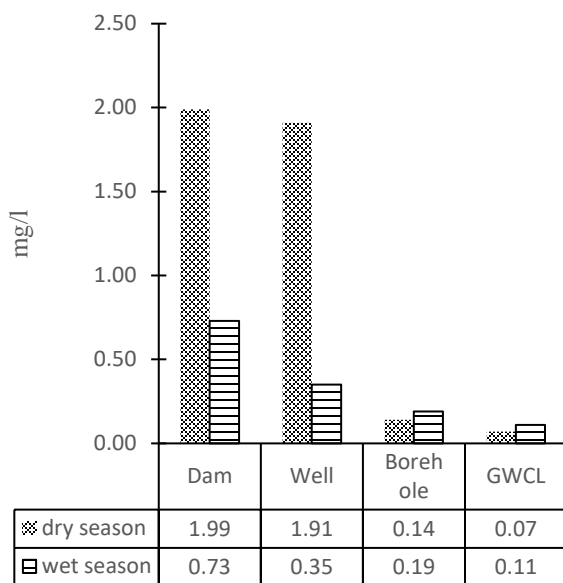
Fig 6: Iron in water sources for Dry & Wet seasons

	Dam	Well	Borehole	GWCL
dry season	6.90	6.10	6.30	6.50
wet season	6.60	6.10	6.10	6.30
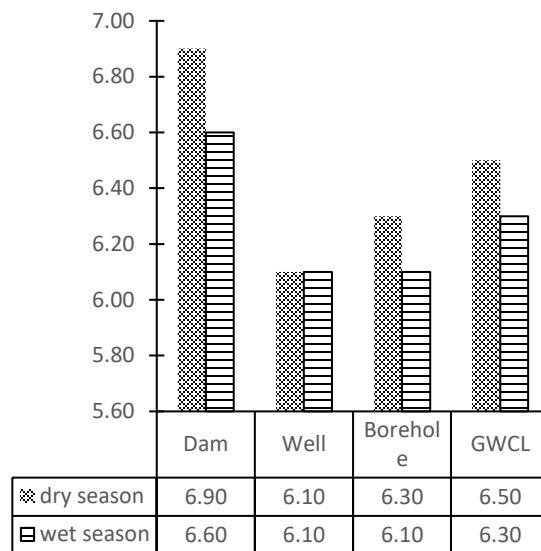
Fig 7: pH in water sources for Dry & Wet Seasons

	Dam	Well	Borehole	GWCL
dry season	200.00	720.00	18.00	7.00
wet season	1000.00	1200.00	650.00	58.00
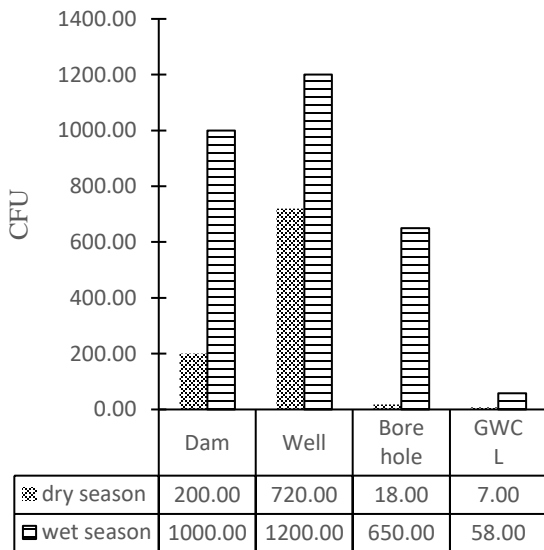
Fig 8: Fecal Coliform in water sources for Dry & Wet seasons

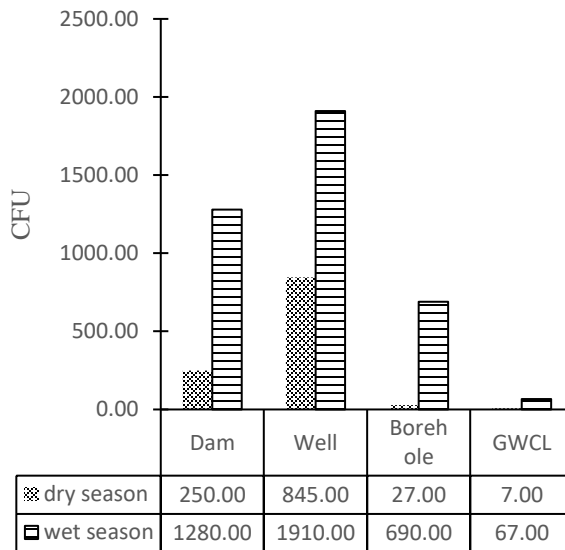|	Dam	Well	Borehole	GWCL
dry season	250.00	845.00	27.00	7.00
wet season	1280.00	1910.00	690.00	67.00

Fig 9: Total Coliform in water sources for Dry & Wet Seasons

Effect of Water Quality on Livelihood Improvement

The study assessed the effect of poor water quality on the livelihood improvement of rural households. Livelihood is used generally here to represent major livelihood indicators such as improved health and increased income.

Table 4: Effect of Water Quality on Household Livelihoods

Variable	Responses (%)			
	Strongly Agree	Agree	Disagree	Strongly Disagree
The cost of accessing quality water affects the level of income for other basic needs	52%	38%	8%	2%
Increase diseases such as cholera and diarrhoea due to poor water sources	7%	63%	23%	7%

The findings from Table 4 show that 90% of household agrees that the cost of getting enough quality water for drinking and other household chores affect income for other basic needs. Consistent with the findings of Longford (2005), the poor buy water from informal vendors at excessive prices or spend more on other alternative means. The implication is that an expensive water supply decreases a household's consumption of other commodities and services. The converse is that a household may be unable to afford and consume an optimal amount of water for good hygiene, which affects the health, and labour productivity of the household and consequently decreases income (Bosch et al., 2001). The high cost of getting enough water may also result in school drop-outs, which is consistent with the demographic details from Figure 4 which shows the trend of school drop-out of respondents from basic level (23%) to tertiary (4%). Table 4 also shows that 70% of households complained of increased disease due to poor water sources. The results agree with many research findings that cholera and diarrhoea diseases are strongly associated with unhygienic water and sanitation (Bosch et al, 2001 & World Health Organization/United Nations Children's Fund, 2014). The findings of the study suggest that households may spend a substantial amount of their incomes on health care and may become less productive, which will consequently affect livelihood. The United Nations (2018) reported that water stress is a symptom of water scarcity and shortage, and is linked to hunger and food insecurity, with a high prevalence of severe food insecurity (29 per cent) in Sub-Sahara Africa. These are central themes of Sustainable Development Goals 2 (Zero Hunger), 3 (Good Health and Well-being) and 6 (Clean Water and Sanitation).

CONCLUSION

The quality of water available to the rural communities is poor with only the water supplied from the GWCL meeting the minimum thresholds of physico-chemical parameters across both dry and rainy seasons. However, coliform bacteria were found for both seasons. Borehole water available to households in the dry season can generally be considered safe except for the concern of the detection of coliform bacteria. The quality of water available to residents in rural Tamale Metropolis may negatively affect their livelihoods as households spend more income to secure potable water and medical care.

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