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TOWARDS SAFELY MANAGED WATER FOR ALL; THE NATURE OF ACCESSIBILITY, QUALITY AND RELIABILITY OF DRINKING WATER SOURCES IN THE UPPER REGIONS OF GHANA

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LIST OF ACRONYMS/ABBREVIATIONS

AFNOR	Association Française de Normalisation
CFU	Coliform Forming Unit
CWSA	Community Water and Sanitation Agency
DFID	Department for International Development
DHS	Demographic Health Survey
EA	Electoral Area
F	Fluoride
FAO	Food and Agriculture Organisation
FC	Faecal Coliform
FGD	Focus Group Discussion
GHS	Ghana Health Service
GLSS	Ghana Living Standard Survey
GSA	Ghana Standard Authority
GSS	Ghana Statistical Service
GWCL	Ghana Water Company Limited
ITCZ	Inter-Tropical Convergence Zone
JMP	Joint Monitoring Programme
KVIP	Kumasi Ventilated Improved Pit
L	Litre
LSMS	Living Standard Measurement Survey
MDGs	Millennium Development Goals
mg	Milligram
MICS	Multi-Indicator Cluster Survey
ml	Millilitre
MMDAs	Metropolitan/Municipal/District Assemblies
PHC	Population and Housing Census
PPD	Physical Planning Department
RCC	Regional Coordinating Council
SDGs	Sustainable Development Goals

STWSS	Small Town Water Supply System
TTC	Thermotolerant Coliforms
UN	United Nations
UNICEF	United Nations Children's Fund
μg	Microgram
WASH	Water, Sanitation and Hygiene
WC	Water Closet
WHO	World Health Organisation

GLOSSARY

Aquifer	An underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials.
Dawadawa	A food flavouring spice made from the seeds of *Parkia biglobosa*, also known as the *African locust bean tree*.
Pito	A drink made from fermented millet or sorghum.
Regoliths	A layer of loose unconsolidated rock atop a bedrock.
Shea butter	Butter extracted from the nut of Shea (Karite) tree.
Tendamba	Spiritual landowners.

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DEDICATION

I dedicate this piece of work to my late father, Mr. Dongzagla Yaw, whose toil has brought me this far.

ABSTRACT

In recognition of the multiple dimensions of access to drinking water, this study explored in detail the nature of accessibility, quality and reliability of drinking water sources in the Upper Regions of Ghana to inform monitoring and the provision of 'safely managed water' for all. Methodologically, the study adopted a mixed method research approach in order to build complementarity and synergy between quantitative and qualitative methods. Quantitative data were collected through a household survey with principal housekeepers and water quality testing of three priority contaminants, comprising of faecal matter, fluoride and arsenic. Qualitative data on the other hand were collected through focus group discussions with women, men, children and water committees, and in-depth interviews with key managers of water supply systems. Results from both quantitative and qualitative data were integrated to enrich the findings of the study. From the results, the nature of accessibility, quality and reliability of drinking water sources in the Upper Regions of Ghana leaves much to be desired. Only 1.9% of the population had access to water in their compound. About 48.6% of the population's roundtrip water collection time exceeded the World Health Organization (WHO) recommended limit of 30 minutes for at least basic access. This proportion increased to 50.8% based on the Joint Monitoring Programme (JMP) indicator of at most 30 minutes roundtrip water collection time from an improved source. In terms of quality, only 58.5% of the population had access to safe drinking water. The remaining 41.5% drinking water was contaminated, mainly with faecal matter, and in a few cases fluoride. Risk of exposure to faecal matter in drinking water was significantly higher in the rainy season than in the dry season. Also, drinking water sources in the rainy season were more reliable than in the dry season with year round access being 74.3%. Access to 'safely managed water' was generally low with marginal differences between the rainy (0.1%) and dry (1.0%) seasons. Based on the findings, the study makes two main conclusions. Firstly, Ghana and other resource-poor countries risk missing target 6.1 of the Sustainable Development Goal unless there is increased commitment to the provision of drinking water supply. Secondly, the JMP risks overestimating access to 'safely managed water' if seasonality in faecal contamination of drinking water sources, seasonality in the reliability of drinking water sources and secondary water sources are not monitored.

1 SETTING THE SCENE

1.1 Introduction

This chapter introduces the study. It is divided into five sections, comprising of the background and research problem, research aim and objectives, research questions, justification of the study area and outline of the thesis.

1.2 Background and Research Problem

Drinking water is indispensable for human survival (United Nations Economic and Social Council, 2002; United Nations Human Rights et al., 2010). The importance of safe and sufficient water supply in achieving goals on poverty, child development, health, education, gender, inequalities, and sustainable cities is well established in the literature (e.g. Fisher, 2008; Pickering & Davis, 2012a; United Nations, 2011; United Nations Economic and Social Council, 2002; United Nations Human Rights et al., 2010; WHO, 2003). In respect of the importance of water supply for human survival, the United Nations General Assembly through Resolution A/RES/64/292, on July 28, 2010, declared access to drinking water (and sanitation) as a human right (Gonzalez et al., 2015; United Nations, 2011; WHO/UNICEF Joint Monitoring Programme, 2011). Drinking water as a human entitlement implies that it should be available, accessible, safe, affordable and acceptable to all persons (United Nations, 2011).

At the end of the Millennium Development Goal (MDG) era in 2015, gains in access to water was reported to be impressive. The global target of 88% improved water coverage was exceeded by three percentage points (United Nations, 2015a; WHO/UNICEF Joint Monitoring Programme, 2015b, 2015f). This success, in the view of many scholars, should be celebrated with modesty (e.g. O'Hara et al., 2008; Obeng-Odoom, 2012; Satterthwaite, 2003). Two main concerns were expressed. First, improved water coverage during the MDG era varies across space. In developed countries, almost all (99%) had access to improved water as against 89% in developing countries (United Nations, 2015a; WHO/UNICEF Joint Monitoring Programme, 2015a, 2015b). Among the regional blocks, improved water coverage ranged from

68% in Sub-Saharan Africa to 96% in Eastern Asia (WHO/UNICEF Joint Monitoring Programme, 2015a). Almost half of the 663 million people that used unimproved water in 2015 lived in Sub-Saharan Africa (United Nations, 2015a; WHO/UNICEF Joint Monitoring Programme, 2015b). Access to improved drinking water in urban areas (96%) was reported to be 12 percentage points higher than in rural areas (84%) (United Nations, 2015a). In Ghana, improved water coverage at the end of the MDG period in 2015 was estimated to be 89% (WHO/UNICEF Joint Monitoring Programme, 2015d, 2015f, 2015g).

The second concern on access to drinking water during the MDG era has do to with the limitations of the 'improved water' metric that was used to monitor access to drinking water. The metric was narrowly defined as the proportion of population that used water sources classified as improved[1] (WHO/UNICEF Joint Monitoring Programme, 2015b, 2015c). Important aspects of drinking water such as quality, accessibility, reliability and affordability were overlooked (Bain et al., 2014; O'Hara et al., 2008; Obeng-Odoom, 2012; Satterthwaite, 2003). Meanwhile, it has been established that the use of an improved water source does not guarantee good water quality (e.g.Bain et al., 2014; Boateng et al., 2013; Cobbina et al., 2012; Kostyla et al., 2015; Mkwate et al., 2016; Onda et al., 2012; WHO/UNICEF Joint Monitoring Programme, 2011), access to continuous and sufficient water at all times (e.g. O'Hara et al., 2008; Satterthwaite, 2003; WHO/UNICEF Joint Monitoring Programme, 2011, 2015e), or access to water within a reasonable distance and time (e.g. Graham et al., 2016; O'Hara et al., 2008; Pickering & Davis, 2012a) especially in developing countries.

Global estimates of population without accessible, safe and reliable drinking water are disturbing (Bain et al., 2014; Bivins et al., 2017; Onda et al., 2012; Pickering & Davis, 2012a; Satterthwaite, 2003; WHO/UNICEF Joint Monitoring Programme, 2011). Over one-third (42%) of the world's population do not have household piped connections (United Nations, 2015a; WHO/UNICEF Joint Monitoring Programme,

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[1] The term improved water sources refers to water sources, which by the nature of their construction are protected from outside contamination, especially faecal coliforms (WHO/UNICEF Joint Monitoring Programme, 2015c, p. 1). They include pipe borne water, public tap/stand pipe, tube well/borehole, protected well, protected spring. and rainwater (WHO/UNICEF Joint Monitoring Programme, 2006b). Bottled/sachet water was classified as improved if household secondary source of improved water for other uses such as personal hygiene and cooking was from an improved source(WHO/UNICEF Joint Monitoring Programme, 2006b).

2015b) and thus spend more time collecting drinking water outside their homes (WHO/UNICEF Joint Monitoring Programme, 2015e). In Sub-Saharan Africa, over a quarter of the population spends more than 30 minutes to collect water in a roundtrip (WHO/UNICEF Joint Monitoring Programme, 2011). On reliability, Bivins et al. (2017) estimated that nearly 1 billion of the world's population is served by Interrupted Water Systems (IWS). In terms of drinking water quality, Onda et al. (2012) in 2010 estimated that about 1.8 billion people worldwide (28% of the global population) used unsafe water, with a majority in developing countries.

Thus, poor access to drinking water continues to undermine development in the global south, especially for women and girls who are responsible for water collection (Boone et al., 2011; Fisher, 2008; Graham et al., 2016; Keefer & Bousalis, 2015; Oxfam, 2017; Sultana, 2011). A review by Fisher (2008) revealed that poor access to water (sanitation and hygiene) affects health, income, economic productivity, education, safety, dignity and well-being of women, girls and their households. For instance, headloading of water over long distances in Africa is reported to cause back, neck and head pains of women and girls (Geere et al., 2018; Graham et al., 2016; Jonah et al., 2015). It also impacts negatively on children's education (Fisher, 2008; Keefer & Bousalis, 2015) and the quantity and quality of water available for household use (García-Valiñas & Miquel-Florensa, 2013; Howard & Bartram, 2003; Nygren et al., 2016; Pickering & Davis, 2012b). In Bangladesh, Crow and Sultana (2002) observed that women and girls are at higher risk of skin diseases due to exposure to excessive arsenic in tubewells, the main source of water. It has also been reported that the emotional pain, stress, struggles, tension, hardships and public shame women undergo to collect adequate and safe water for their households use (Sultana, 2011; Truelove, 2011) affect their position within families, communities and class groups (Truelove, 2011).

In response to the deficiencies of the MDG improved water metric, target 6.1 of the SDG emphasized universal and equitable access to safe and affordable drinking water for all by 2030, with the indicator being, the proportion of population with 'safely managed water'(WHO/UNICEF Joint Monitoring Programme, 2015e, 2015f). A person is said to have access to 'safely managed water' if the drinking water source is located on premises, available when needed and free from faecal and priority chemical contamination (WHO/UNICEF Joint Monitoring Programme, 2015e). Comprehensive and up-to-date data on accessibility, quality and reliability of drinking water sources are required for monitoring and the design of appropriate interventions on drinking water supply if target 6.1 of the SDG is to be realised. However, from the literature, there is a paucity of information on the above three aspects of drinking water supply.

On quality, much of the literature is focused on faecal contamination of drinking water sources (Agensi et al., 2019; Bain et al., 2014; Clasen & Bastable, 2003b; Lavanya & Ravichandran, 2013; Mkwate et al., 2016; Onda et al., 2012; Smiley, 2017), with little attention to harmful chemicals like arsenic and fluoride. Even when they are considered, the proportion of the population exposed to unacceptable levels of microbial and harmful chemicals through drinking water is not quantified (Mkwate et al., 2016). As a corollary, the population at risk of water borne diseases in developing countries maybe higher than is known (Bain et al., 2014; Onda et al., 2012). The risk of underestimation is further increased by emerging evidence of seasonal variations in the contamination of drinking water sources (Kostyla et al., 2015; Kumpel & Nelson, 2016). For example, Kostyla et al. (2015) in a systematic review of 22 studies in developing countries found that faecal contamination of water sources in the rainy season was significantly ($P<0.001$) higher than in the dry season. Similarly, in Nigeria, Kumpel et al. (2017) also reported an increase in the proportion of drinking water sources with faecal matter from 21% in the dry season to 42% in the rainy season.

With regards to reliability, previous studies have paid most attention to piped water systems (Erickson et al., 2017; Guragai et al., 2017; Kumpel & Nelson, 2013) which are limited in coverage in developing countries. This implies that available statistics on access to reliable water in developing countries risk being underestimated (Bivins et al., 2017; Kumpel & Nelson, 2016). In tropical regions like Sub-Saharan Africa, reliability of drinking water sources deserves scholarly attention because gradual decreases in rainfall together with increases in temperature are projected to impact negatively on water resources and livelihoods (McDonald et al., 2011; Serdeczny et al., 2017; UN-Water, 2010; Zango et al., 2014).

Accessibility is another aspect of drinking water that is poorly explored in the global south. It is mostly expressed as a function of distance or water collection time (Howard & Bartram, 2003). Information on distances to water sources and water collection times are relevant for policy-decisions on improving households' water sufficiency as well as reducing the burden associated with water collection. However, available literature on accessibility to drinking water in developing countries is limited in scope and sparse (Ghana Statistical Service et al., 2015; Graham et al., 2016; WHO & UNICEF, 2017). For instance, Graham et al. in their analysis of water collection practices in 24 Sub-Saharan African (SSA) countries described gender differences in water collection by households, water collection labour of children and estimated the absolute number of people who spend more than 30 minutes on a roundtrip of water (Graham et al., 2016). They however failed to explore distances women and children travel to collect water and the means of water collection.

To help fill the above knowledge gaps and contribute to existing geographical work on drinking water (O'Hara et al., 2008; O'Reilly et al., 2009; Sultana, 2011; Truelove, 2011), this study explores in detail the nature of accessibility, quality, and reliability of drinking water sources in the Upper Regions of Ghana to inform monitoring and the provision of 'safely managed water' for all. The significance of the study is associated with:

1. Additions to existing literature on the extent of accessibility, quality and reliability of drinking water sources in developing countries and their implications on livelihoods. In so doing, the study reinforces the need for increased commitment in drinking water supply in developing countries.
2. The provision of new estimates of 'safely managed water' coverage in Ghana that can be used as baseline data for tracking progress of SDG target 6.1.
3. Highlighting seasonal dynamics in access to 'safely managed water' in Ghana, and more broadly in developing countries thereby flagging the risk of overestimating coverage in cross-sectional surveys.
4. Potential to inform recommendations for improving monitoring and access to 'safely managed water' in Ghana and developing countries at large.

1.3 Research Aim and Objectives

The aim of the study was to explore the nature of accessibility, quality and reliability of drinking water sources in the Upper Regions of Ghana, to inform monitoring and the provision of ‘safely managed water’ for all. The study was guided by the following three specific objectives;

1. To examine the extent of accessibility of drinking water sources in the Upper Regions of Ghana.
2. To assess the quality of drinking water sources in the Upper Regions of Ghana.
3. To examine the level of reliability of drinking water sources in the Upper Regions of Ghana.

To set in clear terms the focus of the study, three terminologies require clarification. These are drinking water source accessibility, quality and reliability. I will provide a brief conceptual definition here for each terminology with detailed explanations in section 2.3. The term *accessibility* as used in this study refers to the ease of collecting water from source; in terms of time and distance (WHO, 2011; Howard 2003). *Quality* simply involves compliance of drinking water sources to microbial, chemical and radiological standards (WHO, 2011a). Three quality parameters of significant health concern, both at the global and national scales were assessed: faecal coliforms, fluoride and arsenic. Finally, the term *reliability* as used in this study refers to the frequency of water availability from source over a period of time (WHO, 2011a).

1.4 Research Questions

To achieve the objectives of the study and ultimately the research aim, specific questions were formulated for each research objective (Table 1.1).

Table 1.1: Research Questions

1. To examine the extent of accessibility of drinking water sources in the Upper Regions of Ghana. *1.1. Are there gender differences in water collection?* *1.2. Are there gender differences in the means of water collection?* *1.3. What is the proportion of households/population within/above acceptable distance to drinking water sources?* *1.4. What is the proportion of households/population within/above acceptable roundtrip water collection time?* *1.5. What is the proportion of households/population that are within/above acceptable distance to a water source and roundtrip water collection time?* *1.6. How does inaccessibility to drinking water sources affect water collectors and their households?*
2. To assess the quality of drinking water sources in the Upper Regions of Ghana. ***On faecal coliforms*** *2.1. Does faecal coliform concentration in drinking water sources vary by source types?* *2.2. Does faecal coliform concentration in drinking water sources vary by season?* *2.3. What is the proportion of drinking water sources with acceptable/unacceptable levels of faecal coliforms?* *2.4. What is the proportion of population whose drinking water source has acceptable/unacceptable levels of faecal coliforms?* ***On fluoride*** *2.5. Does fluoride concentration in drinking water sources vary by source types?*

2.6. Does fluoride concentration in groundwater sources differ significantly by geological types?

2.7. What is the proportion of drinking water sources with acceptable/unacceptable levels of fluoride?

2.8. What is the proportion of population whose drinking water source has acceptable/unacceptable levels of fluoride?

On arsenic

2.9. Does arsenic concentration in drinking water sources vary by source types?

2.10. Does arsenic concentration in groundwater sources differ significantly by geological types?

2.11. What is the proportion of drinking water sources with acceptable/unacceptable levels of arsenic?

2.12. What is the proportion of population whose drinking water source has acceptable/unacceptable levels of arsenic?

Cross-cutting

2.13. What is the proportion of population whose drinking water source has acceptable/unacceptable levels of faecal coliforms, fluoride and arsenic?

2.14. How does contamination of drinking water sources affect households?

3. To examine the level of reliability of drinking water sources in the Upper Regions of Ghana.

3.1. How do households perceive the reliability of their drinking water sources?

3.2. What is the proportion of households/population with/without reliable drinking water sources?

3.3. Does households' access to reliable drinking water sources vary by season?

3.4. How does unreliability of drinking water sources affect households?

1.5 Justification of the Study Area

This study was conducted in the Upper Regions of Ghana, comprising of the Upper East and Upper West Regions of Ghana (Fig. 3.1). The choice of the study area was purposive. With the sponsor of the study being the Ghana Education Trust Fund, I conducted the study in Ghana so that the country would benefit directly from the findings and recommendations. The Upper Regions were chosen for investigation because of their exposure to high levels of water poverty. The remainder of this section is devoted to a brief presentation on Ghana's vulnerability to drinking water poverty, with focus on the Upper Regions (see chapter three for further details). A more detailed review on Ghana's vulnerability to water poverty cuts across chapters two (see section 2.4) and three (see sections 3.4 to 3.9).

From the 2010 Population and Housing Census (PHC), 20.2% of households in Ghana practised open defecation, exposing natural ground water to risk of faecal contamination (Ghana Statistical Service, 2013b). At the regional level, open defecation practise varies from 82.4% and 72.9% in the Upper East and Upper West Regions, respectively, to a low of 6.3% in Ashanti Region and 8.2% in Greater-Accra Region (Ghana Statistical Service, 2013c). In addition to poor sanitation, the underlying geology in Ghana, which is mainly granite and metamorphosed sediments exposes groundwater to risks of iron, manganese, fluoride, arsenic (excess) and iodine (deficiency) (Alfredo et al., 2014; Fawell et al., 2006; Smedley et al., 2002). High concentrations of fluoride and iodine deficiency are reported to be predominant in the Upper East Region possibly due to the presence of granites (British Geological Survey, 2000). The granite in the Upper East Region is said to have fluoride-bearing-minerals of biotite, hornblende, amphibole, apatite and sphene (Agyekum & Dapaah-Siakwan, 2008; Edmunds & Smedley, 2005). Meanwhile, water quality testing, which can help inform risk management strategies is rarely done in Sub-Saharan Africa, including Ghana (Peletz et al., 2016). For example, a survey conducted by the Community Water and Sanitation Agency (CWSA) in 2014 revealed that only 1% and 4% of boreholes in the Upper East and Upper West Regions respectively meet the CWSA guideline of regular testing by a certified institute (CWSA, 2015a, 2015c). In the same survey, the CWSA standard of at least one water quality test in a year for network water supply systems was met by only 15% and 13% of the systems in the Upper East and Upper West Regions, respectively.

Besides the risk of poor water quality, some studies have also alluded to poor accessibility to water in Ghana (CWSA, 2015). The CWSA in 2014 revealed that 42% and 38% of boreholes/hand-dug wells in the Upper West and Upper East Regions, respectively, were crowded (CWSA, 2015a, 2015c). About a fifth of network water supply systems were also reported to be crowded (more than 300 users per spout) (CWSA, 2015a, 2015c). Crowding at water sources has far-reaching implication for water collection time and accessibility to water. Furthermore, from the 2014 DHS, 90.8% of the population in Ghana collect water outside their compound with slight variations between southern and northern Ghana (89.7 vs. 95.9%) (Ghana Statistical Service et al., 2015). Considering the dispersed nature of settlements in rural areas, distance to water sources and water collection times can be long for some households.

Poor maintenance culture in developing countries together with the semi-arid climate of Ghana may also affect the reliability of both piped and non-piped water sources. A survey conducted by the CWSA in 2014 revealed that 17.2% of boreholes in the Upper West Region and 13.3% in the Upper East Regions were non-functional (i.e water does not flow at all) (CWSA, 2015a, 2015c). They also rated the performance of 13.4% of boreholes in the Upper West Region and 9.4% in the Upper East Region as sub-optimal (thus, it takes more than five strokes for water to flow). Overall, 9% and 14% of handpumps in the Upper East and Upper West Regions were unreliable. The survey further revealed that only 52% of boreholes in the Upper West Region and 54% in the Upper East Region are repaired within 3 days after breakage. The above findings on borehole functionality and repair period implies that not all households that depend on improved water sources in Ghana have access to a continuous water supply.

From the foregoing discussion, problems of water accessibility, quality and reliability in Ghana are most likely to be highest in the Upper Regions of Ghana. However, empirical evidence on the nature of accessibility, quality and reliability of drinking water sources in the area is limited in space and content (Anku et al., 2009; British Geological Survey, 2000; Cobbina et al., 2012; Ghana Statistical Service, 2014c; Smedley et al., 2002), and thus may not adequately inform policies and programmes on ‘safely managed water’ supply. To help bridge this knowledge gap, the study explored the nature of accessibility, quality and reliability of drinking water sources in the Upper Regions of Ghana.

1.6 Outline of Thesis

The remainder of the thesis is divided into eight chapters. Chapter 2 presents theoretical and empirical literature on access to drinking water, with a focus on accessibility, quality and reliability of drinking water supply. The geography of the study area and the research methodology are outlined in chapters 3 and 4, respectively.

The results of the study, together with discussions are presented in chapters 5 – 8. Specifically, chapter 5 captures respondents and households characteristics. Chapter 6 looks at the extent of accessibility to drinking water sources in the study area while chapters 7 and 8 examined the level of quality and reliability of drinking water sources. The study is concluded in chapter 9.

2 REVIEW OF RELATED LITERATURE ON DRINKING WATER

2.1 Introduction

This chapter is divided into three parts. The first part briefly captures the thematic focus of contemporary geographical work on drinking water. The second part provides conceptual/analytical definitions of key terminologies used in the study. They include improved and unimproved water sources, accessibility, quality and reliability. Part two also outlines the global target and indicator for monitoring drinking water supply in the SDG era as well as global survey questions on drinking water supply to inform data collection and analysis. The third part presents empirical literature on drinking water coverage in the MDG and SDG eras. This is followed by findings of previous studies on the nature of accessibility, quality and reality of drinking water sources.

2.2 Contemporary Geographical Work on Drinking Water

Issues relating to drinking water are multifaceted. As a result, research on drinking water cuts across many disciplines, including geography. Many geographical studies on drinking water seeks to better understand the connections between human, hydrological and ecological systems in potable water availability (Fonstad, 2013). Contemporary contributions by geographers on drinking water is difficult to encircle. However, it can broadly be categorised into three interrelated themes, comprising of access to drinking water, gender-water relations and commodification of water. With regards to access to drinking water, specific areas of focus include water quality (Badejo et al., 2015; Baum et al., 2014; Flanagan et al., 2012; Kostyla et al., 2015; Mkwate et al., 2016), accessibility to water sources (Ho et al., 2014; Wagah et al., 2010), affordability of water tariffs (Fankhauser & Tepic, 2007; García-Valiñas et al., 2010), reliability of piped water systems (Bivins et al., 2017; Kumpel & Nelson, 2016), social inequalities in access to water (Delpla et al., 2015; Dill & Crow, 2014; Wescoat et al., 2007) as well as geographic inequalities (Pullan et al., 2014).

Related to the issue of access to drinking water are debates about the impact of privatisation/commodification of water on the poor in the global south (Bakker, 2007; Goldman, 2005, 2007; Page, 2005). Although partial/full privatisation of drinking water supply in developing countries has existed for a long time (Kazimbaya-Senkwe & Guy, 2007; Page, 2005), it attracted scholarly attention in the 1980s when the International Monetary Fund and World Bank pushed for full cost recovery in water supply through their Economic Recovery Programmes (Agyeman, 2007; Castro, 2007; Yeboah, 2006). These policies were pursued with the mind-set that the private sector is efficient and innovative in the delivery of services (Hall & Lobina, 2007). However, it has been argued that privatisation of water in the global south has not been pro-poor (Bakker, 2007) but rather deepened poverty and inequalities (Castro, 2007); perhaps the reason why Goldman (2007) described the World Bank policy of privatization in the global south as "a vulnerable development regime".

Contemporary geographers are also engaged in studies on gender and water. Research on this theme is usually traced to the work of White, Bradley and White in 1972 on '*Drawers of Water'* in East Africa (O'Reilly et al., 2009). Building on their pioneering work, geographers have examined how gender is created through processes of access, use and control of water resources (Sultana, 2009, 2011), extent of women's and girls' involvement in water collection (Graham et al., 2016) as well as the effects of water collection on women (Crow & Sultana, 2002; Jackson, 1993). This study builds on and contributes to existing geographical work on drinking water quality, accessibility and reliability, gender differences in water collection and the consequences of inadequate water on households, with a focus on women and girls.

2.3 Conceptual and Analytical Frameworks

2.3.1 Improved/improved water sources

The terms improved and unimproved water sources were coined by the JMP in the early 2000s to monitor global targets on safe water coverage, with a focus on target 7c of the MDG. They are technology-based classification of drinking water sources based on the assumption that certain types of technologies are most likely to deliver safe water than others. Table 2.1 contains a list of water sources classified as either improved or unimproved from 2000 to date. An improved drinking water source "is one that by the nature of its construction and design adequately protects the source from outside contamination, in particular by faecal matter. The underlying assumption is that improved sources are more likely to supply safe drinking water than unimproved sources" (WHO, 2011, p.85). Unimproved facilities on the other hand are those, "which by the nature of their design and construction are unlikely to deliver safe water" (United Nations Children's Fund (UNICEF) and World Health Organization, 2018, p. 9).

From Table 2.1, the types of water facilities classified as improved/unimproved have witnessed slight changes over time. In the early 2000s, improved facilities comprised of household connections, public standpipe, borehole, protected dug well, protected spring and rainwater collection with unimproved sources being unprotected well, unprotected spring, vendor provided water, bottled water and tanker truck provided water. Bottled water was considered unimproved because *of "limitations concerning the potential quantity of supplied water, not the quality" (P.4).* In the mid-2000s, the JMP did a minor revision on the classification system. Bottled water, which hitherto was treated as an unimproved source of drinking water was considered improved on condition that the source of water for other domestic uses like personal hygiene and cooking was improved (WHO/UNICEF Joint Monitoring Programme, 2006a). Within the same period, 'household connection' was renamed piped water into dwelling. Piped water into yard/plot was introduced as a new source of improved water. The list of unimproved water sources included surface water and unprotected dug wells, perhaps sub-groupings of unprotected wells as used in the early 2000s.

Following monitoring of water quality, accessibility and availability in the SDG era, the list of facilities considered improved/unimproved saw a major re-alignment in 2018. Tanker-truck, water cart with small tank/drum, water kiosk, bottled water and sachet water, which were previously classified as unimproved sources, are now considered improved (Table 2.1). A brief definition of improved and unimproved water sources is provided in Boxes 2.1 and 2.2. The study adopted the 2018 improved/unimproved water sources classification in data collection, data analysis and presentation of results so that the findings will be relevant for policy decisions on drinking water supply in the SDG era.

Table 2.1: Improved and unimproved water sources

Improved water sources	Unimproved water sources
2000 - 2004	
Household connection	Unprotected well
Public standpipe	Unprotected spring
Borehole	Vendor-provided water
Protected dug well	Bottled water[2]
Protected spring	Tanker truck provision of water
Rainwater collection	
2005 - 2017	
Piped water into dwelling	Unprotected dug well
Piped water into yard/plot	Unprotected spring
Public tap/standpipe	Vendor-provided water
Tubewell/borehole	Tanker truck water
Protected dug well	Surface water (river, stream, dam, lake, pond, canal, irrigation channel)
Protected spring	
Rainwater collection	
Bottled water[3]	
2018 to date	
Piped into dwelling	Unprotected dug well
Piped into compound, yard or plot	Unprotected spring
Piped to neighbour	Surface water
Public tap or standpipe	
Borehole/tubewell	
Protected well	
Protected spring	
Rainwater collection	
Tanker-truck	
Cart with small tank/drum	
Water kiosk	
Bottled water	
Sachet water	

Source: (UNICEF/WHO Joint Monitoring Programme, 2001; United Nations Children’s Fund (UNICEF) and World Health Organization, 2018; WHO/UNICEF Joint Monitoring Programme, 2006a)

[2] *Not considered “improved’ because of limitations concerning the potential quantity of supplied water, not the quality.*

[3] C*onsidered an “improved” source of drinking water only where there is a secondary source of improved water for other uses such as personal hygiene and cooking” (2006, JMP Core questions)*

Box 2.1: Definitions of improved water sources

Piped into dwelling. This is also known as 'household connection'. It involves a connection of a water pipe from a water source (mostly a centralised water supply system) into a house with taps in areas like kitchens or bathrooms.

Piped into compound, yard or plot. Water is obtained from a piped water system through a tap on compound, yard or plot.

Piped to neighbour. This is where a household obtains a piped water supply from a neighbour's house.

Public tap or standpipe. This is also called a public fountain. It involves the collection of water from a public tap, with water supplied from a centralised piped system or from a deep ground well.

Borehole or tubewell. This is a deep underground well drilled by a machine. The well is usually "cased to prevent the small diameter hole from caving in and protect the water source from infiltration by run-off water. Water is delivered through a pump which may be powered by human, animal, wind, electric, diesel or solar means".

Protected well. This is "a hand dug well that is protected from runoff water by a well lining or casing that is raised above ground level to form a headwall and an apron that diverts spilled water away from the well. A protected well is also covered so that contaminated materials (including bird droppings and small animals) cannot enter the well. Water is delivered through a pump or manual lifting device".

Protected spring. This is a natural spring protected by a "spring box", made of brick, masonry, or concrete, that is built around the spring so that water flows directly out of the box into a pipe or cistern, without being exposed to runoff or other sources of contamination.

Rainwater collection. It involves the collection or harvesting of rainwater from roof with containers, tanks or into a constructed ground reservoir.

Tanker-truck. This is a situation whereby households are supplied with water through a motorized truck with a tank.

Cart with small tank/drum. Here households get water from providers from small tanks or drums using donkey carts, small-motorized vehicles and other means.

Water kiosk. This refers to "a water point from which water is sold in small quantities. Households typically bring their own containers to be filled".

Bottled water. This refers to water in small or large bottles, mostly treated and sold by commercial providers.

Sachet water. This is similar to bottled water but is packaged in a plastic bag rather than a bottle.

Source: United Nations Children's Fund (UNICEF) and World Health Organization (2018, p. 9)

Box 2.2: Definitions of unimproved water sources

Unprotected well. This is a dug well that lacks any of the following: "a lining or casing that is raised above ground level to form a headwall; an apron that diverts spilled water away from the well; a cover which prevents contaminated materials (including bird droppings and small animals) from entering the well; or a pump or manual lifting device".

Unprotected spring. This refers to a natural spring that lacks a "spring box" to protect against run off and other sources of contamination (including bird droppings and animals).

Surface water. This is an open water source located on the earth surface. They include rivers, reservoirs, lakes, ponds, streams, canals, dugouts, dams and irrigation channels.

Source: United Nations Children's Fund (UNICEF) and World Health Organization (2018, p. 9)

2.3.2 Accessibility to water sources

Accessibility is an important dimension in evaluating access to services (Handy & Niemeier, 1997), including drinking water (United Nations Economic and Social Council, 2002). Accessibility analysis can help address social inequities in access to services and activities (Boisjoly & El-Geneidy, 2017; Chapman & Weir, 2008; Handy & Niemeier, 1997). Accessibility in its simplest form is the ease of reaching a service or an activity (Boisjoly & El-Geneidy, 2017; Chapman & Weir, 2008). Broadly, it is the ease with which an individual, particular group or community can reach an activity/service (destination) from a specified location (origin) using the available modes and means of transport (Chapman & Weir, 2008; Geurs, 2006; Kwan & Weber, 2008).

Generally, accessibility measures can be classified into two – quantitative and qualitative measures (Chapman & Weir, 2008). Quantitative metrics are the commonest forms of accessibility assessment. They usually have two elements; a transportation element (resistance or impedance) and an activity element (motivation or attraction) (Chapman & Weir, 2008; Handy & Niemeier, 1997). The transportation element is the ease of travel from a destination to an activity or service point in space, and is measured by travel distance, time or cost while the activity element reflects the spatial distribution and attractiveness of activities (Handy & Niemeier, 1997).

Many scholars have categorised quantitative measures into two or more groups (Chapman & Weir, 2008; Curl et al., 2011; Handy & Niemeier, 1997). One of the most citied classifications is provided by Handy and Niemeier (1996) in their work entitled *Measuring accessibility: an exploration of issues and alternatives*. They classified accessibility measures into three, comprising of cumulative opportunities measures, gravity-based measures and utility-based measures. The cumulative opportunities measures are the simplest of all. "These measures of accessibility count the number of opportunities that can be reached within a given travel time (or distance)" (Handy & Niemeier, 1997, p. 3). Gravity-based metrics are more complex. These types of metrics weight the cost, time or distance it takes to reach a service or activity. The smaller the impedance, the greater the accessibility (Handy & Clifton, 2001; Handy & Niemeier, 1997). The third group, utility-based measures, is grounded on random utility theory. Thus, "the probability of an individual making a particular choice depends on the utility of that choice relative to the utility of all choices" (Handy & Niemeier, 1997, p. 3). Concerning choice of metrics, Handy and Niemeier (1997) opined that there is no best measure; rather this is dependent on the situation and purpose of the analysis.

Accessibility is an important dimension in evaluating access to drinking water (United Nations Economic and Social Council, 2002; WHO/UNICEF Joint Monitoring Programme, 2015e). The human right to water in part states that "water facilities and services, must be within safe physical reach for all sections of the population. Sufficient, safe and acceptable water must be accessible within, or in the immediate vicinity, of each household, educational institution and workplace"(United Nations Economic and Social Council, 2002, p. 6). In water supply studies, accessibility is primarily a function of distance to water source or water collection time (Howard & Bartram, 2003; WHO, 2011a). It is a key determinant of the volume of water available to a household for use (Howard & Bartram, 2003; WHO, 2011a). According to the WHO (2011a), a distance of 1km to a water source from a dwelling unit or 30 minutes round-trip water collection time will guarantee basic access to water for household use. At this threshold, the likely volume of water to be collected is 20litres/capita/day (Howard & Bartram, 2003; WHO, 2011a). More health gains are expected to accrue if water collection time is less than 30 minutes or distance is less than 1km (Howard & Bartram, 2003; WHO, 2011a). Post 2015, the JMP as part of its plan to provide disaggregated data on levels of access to drinking water has adapted the WHO definition of basic access to water in relation to collection time. To the JMP, basic access to water is guaranteed when round-trip water collection time from an improved source is within 30 minutes (WHO/UNICEF Joint Monitoring Programme, 2015e). Furthermore, from the SDG water ladder (Table 2.4), a 'safely managed water' source, among others must be located on the premises.

Ghana's standard on households' accessibility to water sources has been defined in terms of only distance. The Community Water and Sanitation Agency defined 'access to potable water' to include improved water sources reachable to households at a distance of not more than 500m (Government of Ghana, 2015b). In this study, accessibility to water sources was measured in terms of distance to water sources and collection time.

2.3.3 Water quality

Water borne diseases arising from contamination of drinking water pose a major challenge to human health, especially in developing countries. For this reason, the United Nations has recognized access to safe water as a human right. The Committee on Economic, Social and Cultural Rights defined safe water as water that is "free from micro-organisms, chemical substances and radiological hazards that pose a threat to human health….the water should be of an acceptable colour, odour and taste for personal or domestic use" (United Nations Economic and Social Council, 2002, p. 5). Similarly the WHO (2011, p.2) asserted that safe drinking water is "water that does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages". In order to reduce the risk of diseases in drinking water, the WHO calls for monitoring and management of contaminants in drinking water.

There are over 100 known drinking water contaminants that are injurious to human health (WHO, 2011a). The WHO broadly categorised water contaminants into three, comprising of microbial, chemical and radiological contaminants (WHO, 2011a). In this study, contaminants tested were limited to microbial, arsenic and fluoride. The delimitation and choice of contaminants was informed by the following five reasons:

1. Limited financial resources. It is not economically and practically feasible to monitor the over 100 microbes, chemicals and radionuclides that can pollute drinking water. In the face of limited resources for monitoring of drinking water contaminants, the WHO is of the view that monitoring should focus on contaminants that are of relatively major significance to public health (WHO, 2011a).

2. Exposure to microbes, arsenic and fluoride through drinking water are of significant major concern to public health worldwide (Fawell & Nieuwenhuijsen, 2003; Government of Ghana, 2015b; WHO, 2011a). Their identification and remediation are therefore of grave concern in the fight against water-borne diseases, particularly cholera in Sub-Sahara Africa.

3. Furthermore, microbial, arsenic and fluoride contaminations of drinking water are of priority to the JMP, the leading global organization responsible for monitoring access to water. Due to evidence of contamination of improved water sources during the period of the MDGs, the JMP's post-2015 monitoring agenda intends to monitor faecal contamination and some priority chemicals, especially fluoride and arsenic (WHO & UNICEF, 2016).

4. Also, selected contaminants are of national priority in Ghana. For monitoring purposes, the MWWR in Ghana has categorised drinking water contaminants into three levels based on health risk. In descending order, they are;
   - "waterborne microbial pathogens,

- priority chemicals arising from natural contamination – arsenic, fluoride, nitrates, lead,
- iron and manganese and high salinity which adversely affects aesthetic water quality problems" (Government of Ghana, 2015b, p. 78).

5. The last but not the least reason has to do with high public concern over waterborne diseases in Northern Ghana (the study area) due to faecal, fluoride and arsenic contamination of drinking water (Anku et al., 2009; Atipoka, 2009; Community Water and Sanitation Agency, n.d; Ghana Statistical Service, 2014c; Government of Ghana, 2015b). Faecal contamination, in particular, poses a great risk to human health in Northern Ghana because 70% of the population in 2014 practiced open defecation (Ghana Statistical Service et al., 2015). Aside from faecal contamination, the geological formation of the region, which is predominantly granite makes groundwater vulnerable to fluoride and arsenic pollution (British Geological Survey, 2000).

In order to appreciate the level of quality of water sources in the study area, benchmarks are required for analysis. This informed the below review on water quality guidelines/standards for each of the three contaminants of interest. The review highlights standards at both the global and national scales.

i. Microbial contaminants

The most common and greatest health risk associated with drinking water is microbial contamination (Government of Ghana, 2015b; WHO, 2011a). The problem arises as a result of faecal contamination of water from humans and animals (Fawell & Nieuwenhuijsen, 2003; WHO, 2011a). The most widely used and recommended indicators for measuring faecal contamination of drinking water are faecal coliforms (also known as Thermotolerant Coliforms) and E. Coli. The Faecal Indicator Bacteria (FIB) adopted in this study is faecal coliform. This is because, the materials – 3M Petrifilm Coliform Count Plates - provided by the School of Geography Lab were appropriate for testing of faecal coliform but not E.coli. It is worth to mentioning that the FIB adopted in the study has been used in many previous studies (Clasen & Bastable, 2003a; Kirby et al., 2016; Kumpel et al., 2017).

The WHO and Ghana Standard Authority (GSA) standards regarding *Faecal Coliform* concentration in drinking water are same. Both bodies are of the view that water intended for human consumption should contain no *Faecal Coliform* for any 100m sample (WHO, 2011a). Health risk is proportional to the amount of faecal coliforms in drinking water. The WHO in its 4th edition of water quality guidelines classified faecal coliforms based on risk-to-heath as follows; > 1CFU/100mL as low risk, 1-10 CFU/100mL as intermediate risk; 11-100 CFU/100mL as high risk and above 100 CFU/100mL as very high risk (WHO, 2011a).

ii. Fluoride

Fluoride is one of the naturally occurring chemicals that is of great concern to human health. Though it is needed for the protection of the teeth and bones, excesses of it can give rise to dental fluorosis (an unsightly brown mottling of teeth) or skeletal fluorosis (bone fractures and crippling skeletal deformity) (Community Water and Sanitation Agency, n.d; Fawell & Nieuwenhuijsen, 2003). A review of literature reveals that there is no global standard for fluoride concentration in drinking water. What exists is a health-based guideline value of at most 1.5mg of fluoride per litre of drinking water, set by the World Health Organisation (WHO, 2011a). Based on this guideline value, countries are encouraged to set national standards taking into account local environmental, social, economic and cultural conditions (WHO, 2011a). Consequently, national standards of fluoride vary markedly across the world; ranging from 0.7 mg/L in Jordan to 8.0 mg/L in Tanzania (Aliev et al., 2010; Properzi, 2010; Smedley et al., 2002; UNICEF & WHO, 2010). In Ghana, the World Health Organisation guideline value of 1.5mg/l has been adopted as the national standard (Community Water and Sanitation Agency, n.d; Government of Ghana, 2015b; Kumi et al., 2015; Smedley et al., 2002)

Smedley et al. (2002) in their assessment of fluoride concentration in the Upper East Region of Ghana and parts of central Tanzania classified fluoride concentration in drinking water into four levels based on risk-to-health as follows;

- <0.7mg/l (low concentration),
- 0.7 -1.5mg/l (moderate concentration),
- 1.6-2mg/l (high concentration) and
- >2mg/l (very high concentration).

iii. Arsenic

Arsenic is another naturally occurring chemical contaminant of groundwater and a major cause of diseases in many parts of the world (Kumi et al., 2015). It is the only contaminant that is known to cause human cancer following exposure in drinking water (Kumi et al., 2015). In Ghana, waterborne arsenic has been recognised as a human carcinogen since the 1990s (Ghana Statistical Service, 2014c).

The WHO maximum permissible value of arsenic concentration in drinking water is 0.01mg/l or 10µg/l (WHO, 2011a). This benchmark according to WHO is "provisional because calculated guideline value is below the achievable quantification level" and also below a "level that can be achieved through practical treatment method" (WHO, 2011a, p. 178). The Ghana Standard Authority (GSA) standard on arsenic level in drinking water is not different from the WHO recommended value (Ghana Statistical Service, 2014c).

2.3.4 Reliability of water sources

Reliability of water source influences the volume and quality of water households collect (WHO, 2011a). From the literature, there is no universal definition and measure of water supply reliability (Galaitsi et al., 2016; Majuru et al., 2018). This perhaps reflects the multi-attribute nature of the concept of reliability in water supply (Galaitsi et al., 2016; Majuru et al., 2018)

Majuru et al. (2018) in a systematic review of 33 papers identified four scholarly definitions of (un) reliability of water supply systems;

1. "availability of water at a point of consumption (household or public stand-pipe) for 24 hours a day, 7 days a week, 365 days a year (Shah, 2003);
2. "a service is reliable if it is provided in time, and with the quality and the quantity required" (Zérah, 2000);
3. "discontinuity of source - the physical absence of water flowing from the source" (Howard, 2002) and
4. "source functionality - proper physical state of water supply projects in relation to their present working condition at the time of the survey" (Admassu et al., 2003).

Although the above four definitions vary considerably, common features in them include the functionality of a water source and the extent to which it meets the needs of water users. Majuru et al. (2018) further identified 20 different measures of water supply reliability (Table 2.3).

Table 2.2: Measures of reliability of water supply

S/N	Measure	Number of times measure has been employed
1	Frequency of supply per week	2
2	Frequency of supply in days per week	3
3	Duration of supply in hours per day	12
4	Fraction of the time water is available	1
5	Frequency and length of service interruptions	1
6	Interruption in supply in the previous week	1
7	Pressure	2
8	Proportion of systems with intermittence	1
9	Proportion of Population served by intermittent systems	1
10	Age of water supply system	3
11	Breakdowns in previous 6 months	2
12	Breakdowns in study period	1
13	Down time	5
14	Duration of supply hours per day	2
15	Duration of supply days per week	1

16	Duration of supply interruptions in hours/day and days/week	1
17	Ease of operation of handpumps	2
18	Flow rate Hours/days water was available per week	1
19	Lifespan of water system (proportion functional over a period of time)	4
20	Number of pumps in use at time of survey	1
21	Proportion of taps supplying water at time of survey and preceding 3 months	1
22	Proportion of functional water sources at time of survey	8
23	Proportion of non-functional water sources at time of survey	1
24	Ratio of functional water systems in the population	1
25	Sources with major repairs within last month	1

Source: Majuru et al. (2018)

From Table 2.3, the measures of water supply reliability largely relate to the duration of water supply from source over time, proportion of systems with intermittent supply, proportion of population served by intermittent systems, age of water supply system, functionality of system and pressure/flow rate. The most widely used measure was the duration of water supply in hours per day. This measure reflects the WHO definition of reliability of water supply as "the percentage of the time during which drinking water is available (daily, weekly and seasonally)" (WHO, 2011a, p. 83). According to Majuru et al. (2018, p. 1) "the most common measure in urban settings was the duration/continuity of supply in hours per day, while in rural settings, the proportion of functional water systems was commonly used". The functional measure is binary in nature, and thus fails to indicate the level of system performance (Majuru et al., 2018). Majuru et al. (2018) conceptualised reliability of water supply in terms of four interlinked attributes. They include continuity (e.g., available 24 hours a day every day), predictability (e.g., supply not continuous, but available at regular intervals), functionality (e.g., breakdown in the system); and pressure (i.e where fluctuations may result in limited or no supply) ".

In Ghana, the CWSA defines a reliable water source as one that is functional at least 95% of the year (CWSA, 2015a, 2015c). A hand pump is considered as "fully functional if water flows within 5 strokes, sub-optimally functional if it takes more than 5 strokes for water to flow and not functional if water does not flow" (CWSA, 2015a, 2015c). A piped scheme is considered "fully functional if all its household connections are functional, sub-optimally functional if one or more of its household connections are not functional and not functional if none of its household connections are functional"(CWSA, 2015a, 2015c)

To allow for characterization of individual systems, comparisons between case studies, and the generalization of successful solutions, the WHO (2011) classified reliability of water sources into four levels, depending on the frequency of water supply from source in a year;

- Level 1: year-round service from a reliable source with no interruption of flow at the tap or source;
- Level 2: year-round service with frequent (daily or weekly) interruptions;
- Level 3: seasonal service variation resulting from source fluctuation; and
- Level 4: compounded frequent and seasonal discontinuity (WHO, 2011a).

Drawing on the literature, the term *reliability* as used in this study refers to the frequency in water availability from source over a period. A five point likert-scale was used to measure reliability of water sources from the perspectives of households in the study area (Table 2.4). Reliability of water sources were assessed in both rainy and dry seasons.

Table 2.3: Measurement of reliability of water sources

Likert scale	Level of flow of water from source
4	Continuously - continuous flow of source without interruptions over a period
3	Very often - experienced interruptions in water flow once a while with a defined period
2	Occasionally - hours/days/weeks of flow and interruptions almost the same)
1	Rarely - numerous interruptions/discontinuity in water flow from source)
0	Not at all - source not flowing

Source: Adopted from WHO (2011)

2.3.5 Drinking water supply target and monitoring indicator in the SDG era

Due to the importance of water for human survival, its supply features prominently in the SDGs. Goal 6 calls for the "availability and sustainable management of water and sanitation for all" by 2030 (United Nations, 2015b, p. 22). Target 6.1 specifically focuses on drinking water. It seeks to "achieve universal and equitable access to safe and affordable drinking water for all by 2030" (United Nations, 2015b, p. 22). For purposes of monitoring, the indictor for target 6.1 is the "proportion of population using safely managed drinking water services" (United Nations Children's Fund (UNICEF) and World Health Organization, 2018). In the words of the JMP a 'safely managed water' is "drinking water from an improved water source that is located on premises, available when needed and free from faecal and priority chemical contamination"(United Nations Children's Fund (UNICEF) and World Health Organization, 2018).

In the JMP's drinking water service ladder (Table 2.2), the SDG 'safely managed water' indicator builds on the MDG improved water indicator. As depicted in Table. 2.2, improved water is disaggregated into three levels, comprising of safely managed, basic and limited services in descending order of preference. The core questions for measuring 'safely managed water' service and their potential limitations is discussed in section 2.2.6.4.

Table 2.4: JMP water service ladder

Service levels	Definition
Safely managed	Drinking water from an improved water source that is located on premises, available when needed and free from faecal and priority chemical contamination
Basic	Drinking water from an improved source, provided collection time is not more than 30 minutes for a round trip, including queuing
Limited	Drinking water from an improved source for which collection time exceeds 30 minutes for a round trip, including queuing
Unimproved	Drinking water from an unprotected dug well or unprotected spring
Surface water	Drinking water directly from a river, dam, lake, pond, stream, canal or irrigation canal

Source: United Nations Children's Fund (UNICEF) and World Health Organization, (2018, p.7) and WHO & UNICEF (2017, p.8)

2.3.6 Measures of access to drinking water

This section reviews measures on access to drinking water, with the aim of adapting or adopting relevant questions for this study. The review first examines the three largest global household surveys - MICS, DHS and LSMS – which are the main sources of data for the JMP in tracking progress on access to drinking water. This is followed by a review of the JMP core questions on drinking water, a proposed framework for measuring access to drinking water in the SDG era.

2.3.6.1 Multiple Indicator Cluster Survey (MICS)

The Multiple Indicator Cluster Survey (MICS) is an international household survey initiated by the United Nations Children's Fund (UNICEF) to assist countries in collecting and analysing data for monitoring the well-being of children and women every 5 years (Ghana Statistical Service, 2013e). It has enabled many countries to produce statistically sound and internationally comparable estimates on a range of indicators in the areas of health, education, child protection, HIV/AIDS, among others (Ghana Statistical Service, 2013e). The MICS was originally developed around the mid-1990s in response to the need to monitor progress of the World Summit for Children (WSC) Goals and its Mid-Decade Goals. Data arising from the MICS have been used extensively in tracking global development goals, and thus influencing policy decisions and programme interventions, particularly on child and maternal health issues (Ghana Statistical Service, 2013e). Since the mid-1990s, five different rounds of MICS have been carried out. The sixth round of MICS is currently under design and will be rolled out soon. In all, over 300 surveys have been successfully conducted in 108 countries across the world (UNICEF, 2016e).

The first round of MICS (MICS 1) was conducted between 1993 and 1998 in 64 countries (UNICEF, 2016e). It was primarily designed to measure the 13 Mid-Decade Goals (1995) which were borne out of the WSC Goals adopted by the United Nations in 1990 (UNICEF, 1994, 1995). The Mid-Decade goals were basically minimum levels of attainment needed as stepping stones towards achieving the WSC Goals by the year 2000 (UNICEF, 1994, 2002). One of the targeted goals (Goal 13) focused on sanitation and water supply. It reads as follows; "increased water supply and sanitation so as to narrow the gap between the 1990 levels and universal access by the year 2000 of water supply by one-fourth and of sanitation by one-tenth" (UNICEF, 1995, p. 2). Two main indicators were defined to measure goal 13, one on water supply and the other on sanitation. The water supply related indicator (13.1) measured the "population with access to an adequate amount of safe drinking water located within a convenient distance from the user's dwelling" (UNICEF, 1995, p. 7).

The indicator on water supply in MICS 1 placed emphasis on three aspects of access to drinking water – adequate amount of water, safe water supply and convenient distance to water source from dwelling. These three aspects were, however, poorly assessed. Three questions were formulated on drinking water (Box 2.3); one on households' main source of drinking water and the other two on accessibility of water source. The type of water source was used as a proxy indicator to measure "safe" water supply. "Convenient distance" as captured in the operational definition of the water supply indicator was assessed in terms of distance to water source and water collection time. There was no question on 'adequate amount' of water supply.

Box 2.3: MICS 1 household survey questions on drinking water: 1993 - 1998

- *What is the source of drinking water for members of your household?*
- *How far is this source from your dwelling?*
- *How long does it take to get there, get water and come back?*

Source: UNICEF (1995, p. 25)

The second round of the Multiple Indicator Cluster Survey (MICS2) was conducted in 65 countries, starting 1999 to 2003 with 80% being conducted in the year 2000 (UNICEF, 2016e). It measures well-being of women and children at the end of the decade (1999) with primary focus on the WSC Goals (UNICEF, 2000b). MICS 2 also laid the foundation for measuring change in the next decade (UNICEF, 2000b). The main modules in MICS 2 were same as MICS 1 (household modules, Modules for Women and Optional modules) (UNICEF, 2000b). However, MICS2 saw an expansion of sub-modules to reflect all of the end-decade goals and incorporate experience gained in conducting MICS1 (UNICEF, 2000c).

Goal 4 of the WSC focused on water – "universal access to safe drinking water" (UNICEF, 2000b, p. 16). Its associated indicator was the "proportion of population who use any of the following water sources: piped water; public tap; borehole/pump; protected well; protected spring; rainwater" (UNICEF, 2000b, p. 16). Nonetheless, the questions on drinking water in the household survey did not only assess drinking water sources but also water collection time (Box 2.4).

Box 2.4: MICS 2 household survey questions on drinking water: 1999 - 2003

- *What is the main source of drinking water for members of your household?*
- *How long does it take to go there, get water and come back?*

Source:(UNICEF, 2000a, p. 9)

The third round of Multiple Cluster Indicator Survey (MIC 3) was carried out in 53 countries within the period 2005-2009 (UNICEF, 2016e). MICS 3 was carried out to help generate data as part of efforts in monitoring the MDGs, the World Fit for

Children initiative and other international commitments using a set of agreed indicators which are comparable across countries and over time (UNICEF, 2006). Owing to this broader need, MICS 3 covered a wide range of issues than MICS2 (UNICEF, 2006). The third round of MICS had two indicators on drinking water. The first one adopted from the MDG indicators was on the proportion of population that use improved sources of water. The MICS for the first time introduced an indicator on water treatment. The indicator measures the "proportion of household members that use water treated to make it safer to drink" (UNICEF, 2006, p. 24). Household survey questions on drinking water (Table 2.5), however, were not limited to issues of household sources of drinking water and water treatment but included gender and age of water collectors and collection time (UNICEF, 2006).

Table 2.5: MICS 3 household survey questions on drinking water: 2005 - 2006

What is the main source of drinking water for members of your household?
What is the main source of water used by your household for other purposes such as cooking and handwashing?
How long does it take to go there, get water and come back?
Who usually goes to this source to fetch the water for your household? Probe: is this person under age 15? What sex?
Do you treat your water in any way to make it safer to drink?
What do you usually do to the water to make it safer to drink?

Source: UNICEF (2006, p. 256)

The fourth round of Multiple Indicator Cluster Survey (MICS 4) took place in 64 countries from 2010 – 2013 (UNICEF, 2016e). It was primarily aimed at providing data for measuring the MDGs and other global commitments. Like MICS 3, MICS 4 also had two water-related indicators. One on the use of improved drinking water and the other on water treatment (UNICEF, 2012b). From the household questionnaire, questions on drinking water were on households' main source of drinking water, the location of the water sources, water collection time, age and gender of water collectors, and water treatment (Table 2.6).

Table 2.6: MICS 4 household survey questions on drinking water: 2010 - 2013

What is the main source of drinking water for members of your household?
What is the main source of water used by your household for other purposes such as cooking and handwashing?
Where is that water source located?
How long does it take to go there, get water and come back?
Who usually goes to this source to fetch the water for your household? Probe: is this person under age 15? What sex?
Do you treat your water in any way to make it safer to drink?
What do you usually do to the water to make it safer to drink?

Source: (UNICEF, 2012a, pp. 5-6)

The fifth round of the Multiple Indicator Cluster Survey began in 2013 to 2017, in 52 countries (UNICEF, 2016e). The overarching aim of MICS 5 was to provide data to help evaluate the MDGs. The household survey questions on drinking water were aimed at assessing the MDG indicator on the proportion of population that used improved water sources (UNICEF, 2013b). MICS 5 household survey questions on drinking water were basically adopted from MICS 4. The questions assessed households' major sources of drinking water, the location of water sources, water collection time, age and gender of water collectors, and water treatment (Table 2.7). Similar to previous MICS, issues of water quality, reliability, and affordability were sidestepped.

Table 2.7: MICS 5 household survey questions on drinking water: 2013 - 2015

What is the main source of drinking water for members of your household?
What is the main source of water used by your household for other purposes such as cooking and handwashing?
Where is that water source located?
How long does it take to go there, get water and come back?
Who usually goes to this source to fetch the water for your household? Probe: is this person under age 15? What sex?
Do you treat your water in any way to make it safer to drink?
What do you usually do to the water to make it safer to drink?

Source: (UNICEF, 2013a) 13, p25-16

Currently, the sixth round of the Multiple Indicator Cluster Survey (MICS 6) is on-going in 60 countries and completed in only seven countries (UNICEF, 2019). It started in 2017 and is expected to end in 2020 (UNICEF, 2019). According to UNICEF (2016b, p. 2), MICS 6 has undergone "rigorous methodological and validation work to broaden the scope of the tools and include new topics that reflect the SDGs indicators and emerging issues in the 2030 Agenda for Sustainable Development context". MICS 6 seeks to generate baseline data for measuring the SDGs while at the same time monitoring other global commitments on women and children.

The sixth round of MICS questions on drinking water were formulated with a focus on the SDGs drinking water target - 'safely managed water' for all (UNICEF, 2016d).

With an increase in the scope of the SDGs target on drinking water, MICS 6 has more questions on drinking water compared to previous MICS. Under the water and sanitation module in the household questionnaire, 10 questions relate to access to safe drinking water (Table 2.8). In addition to the questions in the household questionnaire, UNICEF has developed a 4-page step by step questionnaire for testing of water quality (UNICEF, 2016c). Water samples (100ml) are usually collected both at source and storage points and tested for the presence of faecal coliform bacteria, following 24 – 48 hrs of incubation and counting of blue colonies (UNICEF, 2016c) .

Table 2.8: MICS 6 questions on drinking water in household questionnaire

What is the main source of drinking water used by members of your household?
What is the main source of water used by members of your household for other purposes such as cooking and handwashing?
Where is that water source located?
How long does it take for members of your household to go there, get water, and come back?
Who usually goes to this source to collect the water for your household?
Since last (day of the week), how many times has this person collected water?
In the last month, has there been any time when your household did not have sufficient quantities of drinking water?
What was the main reason that you were unable to access water in sufficient quantities when needed?
Do you do anything to the water to make it safer to drink?
What do you usually do to make the water safer to drink?

Source: (UNICEF, 2016a)

2.3.6.2 Demographic Health Survey

The Demographic and Health Survey (DHS) is a United State Agency for International Development (USAID) funded global household survey in developing regions. Its aim is to provide data on a wide range of monitoring and impact evaluation indicators, particularly in the areas of population, health and nutrition for planning and decision making (USAID, 2016a). The DHS is noted for two types of surveys; (a) a standard DHS with large sample sizes ranging between 5,000 and 30,000 households, and mostly conducted every 5 years and (b) an interim DHS that focuses on the collection of information on key performance monitoring indicators (USAID, 2016a). Interim surveys are usually conducted between rounds of the standard DHS and have shorter questionnaires and smaller sample sizes (USAID, 2016a). The review of DHS questions on drinking water focuses on the standard DHSs because of their large sample sizes and extensive thematic coverage. It is worth also mentioning that the review is based on the universal questionnaires developed by USAID at the beginning of each standard DHS phase for countries to adapt. Country-based surveillance bodies are however permitted to make a few modifications to the instrument if necessary, but in consultation with USAID. Since 1984, USAID has funded seven different phases of standard DHS (USAID, 2016b). In all, over 260 surveys have been conducted in nearly 100 developing countries (USAID, 2016b).

The first phase of the standard DHS (DHS – I) took place in 27 countries beginning from 1984 to 1989 (USAID, 2016b). The core questionnaire covered a wide range of modules including water (Institute for Resource Development (IRD), 1987a, 1987b) According to the Institute for Resource Development (IRD) (1987a, p. 8), the questions on water and sanitation were "intended to elucidate determinants of international variations in infant and child mortality". Two questions were formulated on drinking water (Box 2.5). These questions were aimed at gathering information on household sources of water for drinking and also for handwashing and dishwashing.

Box 2.5: DHS - I core questions on water

- *"What is the major source of drinking water for members of your household?"*
- *"What is the major source of water for household use other than drinking (e.g., handwashing, cooking) for members of your household?"*

Source: Institute for Resource Development (IRD) (1987a)

Phase two of the standard DHS (DHS-II) also occurred within the period 1988 – 1993 in 27 developing countries (USAID, 2016b). Like DHS-I, the questions on water and sanitation were "intended to elucidate determinants of international variations in infant and child mortality and morbidity" (Institute for Resource Development (IRD)/Macro International Inc., 1990). The IRD indicated in DHS-II that, the questions on water were aimed at obtaining information on the quantity of water available for household use rather than on the quality of available water (Institute for Resource Development (IRD)/Macro International Inc., 1990). DHS-II had four questions on drinking water (Box 2.6). The two questions on household source of water for drinking and handwashing/dishwashing in DHS-I were adapted into three questions in DHS-II as an indirect pointer of the quantity of water available for household use (Institute for Resource Development (IRD)/Macro International Inc., 1990). A question on household water collection time was introduced for the first time in DHS 2.

Box 2.6: DHS-II core questions on water

- *What is the source of water your household uses for handwashing and dishwashing?*
- *How long does it take to go there, get water and come back?*
- *Does your household get drinking water from this same source?*
- *What is the source of drinking water for members of your household?*

Source: (Institute for Resource Development (IRD)/Macro International Inc., 1990)

The third phase of the standard Demographic Health Survey (DHS-III) started in 1992 through 1997 in 46 developing countries (USAID, 2016b). The reason put forward in DHS 3 for collecting information on water and sanitation was same as in DHS-II. Data on water and sanitation were necessary to help understand variations in infant and child mortality and morbidity across the world (Macro International Inc., 1995). From Box 2.7, two questions were asked on drinking water - one on household main source of drinking water and the other on household water collection time (Macro International Inc., 1995). The question on household source of water for handwashing and dishwashing which featured in DHS 2 was dropped.

Box 2.7: DHS-III core questions on water

- *What is the main source of drinking water for members of your household?*
- *How long does it take to go there, get water and come back?*

Source: (Macro International Inc., 1995)

Phase four of the Demographic Health Survey (DHS-IV) took place over 50 countries from 1997 – 2003 (USAID, 2016b). The questions on drinking water in DHS-III were adopted for DHS-IV (Box 2.8). Therefore, like DHS-III, the data generated on drinking water was limited to household sources of drinking water and water collection time.

Box 2.8: DHS-IV core questions on water

- *What is the main source of drinking water for members of your household?*
- *How long does it take you to go there, get water and come back?*

Source: (ORC Macro, 2001)

Phase five of the standard Demographic Health Survey (DHS-V) started in 2003 and ended in 2005 in over 40 countries (USAID, 2016b). DHS-V saw an expansion in the scope of the issues captured on drinking water. This resulted in an increase in the number of questions on water from about two in previous surveys to 7 (Measure DHS, 2008). In addition to previous questions on household main drinking water source and water collection time, new questions were introduced on the location of the water source, household members involved in water collection, treatment of drinking water and household main water source of water for other domestic uses (Box 2.9) (Measure DHS, 2008).

Box 2.9: DHS-V core questions on water

- *Where is that water source located?*
- *How long does it take to go there, get water and come back?*
- *Who usually goes to this source to fetch the water for your household?*
- *Do you do anything to the water to make it safer to drink?*
- *What do you usually do to make the water safer to drink?*
- *What is the main source of water used by your household for other purposes such as cooking and handwashing?*

Source: (Measure DHS, 2008)

Phase six of the Demographic Health Survey (DHS-VI) also started from 2008 to 2013 across over 45 countries (USAID, 2016b). The questions on water in DHS 6 were not very different from DHS-V. Five questions were formulated on water aimed at assessing households' main source of drinking water, the location of source, water collection time and treatment of water (Box 2.10). Two questions in DHS-VI on water collectors and sources of water for other domestic uses were dropped.

Box 2.10: DHS-VI core questions on water

- *What is the main source of drinking water for members of your household?*
- *Where is that water source located?*
- *How long does it take to go there, get water and come back?*
- *Do you do anything to the water to make it safer to drink?*
- *What do you usually do to make the water safer to drink?*

Source: (ICF International, 2011)

The seventh phase of the standard demographic Health Survey (DHS-VII) started in 2013 and is projected to end in 2019 (USAID, 2016b). The household survey questions on water in DHS-VII are similar to those asked in previous phases (Box 2.11). The only new question introduced assesses the reliability of households' drinking water sources in the past 2 weeks preceding the survey.

Box 2.11: DHS-VII core questions on water

- *What is the main source of drinking water for members of your household?*
- *What is the main source of water used by your household for other purposes such as cooking and handwashing?*
- *Where is that water source located?*
- *How long does it take to go there, get water and come back?*
- *In the past two weeks, was the water from this source not available for at least one full day?*
- *Do you do anything to the water to make it safer to drink?*
- *What do you usually do to make the water safer to drink?*

Source: (The DHS Program, 2015)

Since the inception of the DHS in 1984, Ghana has participated in six surveys; 1988, 1993, 1998, 2003, 2008 and 2014 (USAID, 2016b). These years correspond to phases I, III, IV, IV, VI and VII of the DHS. In all six GDHSs, the questions on water are similar to those in the universal survey questionnaire provided by USAID for countries to adapt. For instance, the 2014 GDHS adopted 6 of the 7 questions on water in the universal questionnaire (Ghana Statistical Service et al., 2015). The question "*in the past two weeks, was the water from this source not available for at least one full day?*" as contained in the general questionnaire was replaced with the question "*how does your household store water?"* (Ghana Statistical Service et al., 2015; The DHS Program, 2015).

From the review, it is evident that the standard DHS questionnaire, since its development in the mid-1980s, has undergone six different revisions at the beginning of phases II, III, IV, V, VI and VII. However, the scope of questions on water is limited on household major sources of drinking water, water collection time, age and gender of water collectors, methods of water treatment and reliability (i.e. two weeks preceding survey). The USAID in its standard DHSs is yet to consider some important determinants of access to safe water like quality and affordability. Phase VII of the DHS, which started two years before the end of the MDGs still ignored or gave little attention to important aspects of water supply like quality, reliability and affordability. Considering the fact that the SDGs indicator on drinking water encompasses issues of water quality, accessibility and reliability, there is a need for the DHS to revise its questions on water in order to make data relevant.

2.3.6.3 Living Standards Measurement Study (LSMS)

The Living Standards Measurement Study (LSMS) is a multi-topic household survey program established by the World Bank in 1980 (The International Bank for Reconstruction and Development, 1996). According to the World Bank, the goal of the LSMS is "to facilitate the use of household survey data for evidence-based policymaking" (The World Bank Group, 2016a, p. 1). At the heart of the LSMS is the generation and dissemination of high-quality data, improvement in survey methods, and capacity building of national statistical bodies (The World Bank Group, 2016a).

Unlike the DHS and MICS, the LSMS is not conducted periodically. In most LSMS countries, survey interval ranges from 1 – 5 years. Countries are often supported to carry out surveys as and when there is the need for up-to-date household data to better inform planning and policy decisions. Since the inception of LSMS in the 1980s, over 100 surveys have been carried out in more than 40 developing countries (The World Bank Group, 2016b).

Regarding questionnaire design, the World Bank provides technical assistance to national statistical bodies to design and implement their own questionnaires. The World Bank is of the view that the content of LSMS questionnaires should be driven by local analysts and policy needs (The International Bank for Reconstruction and Development, 1996). The review of the LSMS questionnaire in this study is focused on Ghana for two main reasons. First, it is the country of study and as such equips the researcher with information on the kind of household data that has been gathered on drinking water over the years. Secondly, Ghana has conducted 6 LSMS within the period 1987 and 2014, which provides valuable data on the scope and pattern of both past and present LSMS questions on drinking water.

In Ghana, the LSMS are labelled Ghana Living Standard Surveys (GLSS). The first round of the Ghana Living Standards Survey was conducted in the years 1987 and 1988 (The World Bank Group, 2016b). From Box 2.12, the scope of the questions on drinking water was limited to households' source of drinking water, water bill, amount and quantity of water sold, distance to water sources and water sources for other domestic uses (Box 10). The Ghana Living Standards Survey 2 (GLSS2), which spanned from 1988-1989 had the same questionnaire on drinking water as in GLSS 1 (Ghana Statistical Service, 1987, 1988).

Box 2.12: Ghana Livings Standards Survey 1 & 2 questions on drinking water

- *What is the source of drinking water for your household?*
- *How much was your household's last water bill? probe if joint meter or shared bill*
- *Did you sell any of this water to someone else?*
- *What fraction of this water was sold?*
- *What amount of time was covered by that bill?*
- *Is this (source of drinking water) used by your household only or shared with others?*
- *How far (meters) is this (source of drinking water) from your dwelling?*
- *What is your household's main source of water for laundry and bathing?*
- *Is this (source of water for laundry and bathing) used only by your household or other households also?*

Sources: Ghana Statistical Service (1987, pp. 10-11) and Ghana Statistical Service (1988, pp. 10-11)

GLSS 3 and 4 were conducted in 1991/1992 and 1998/1999, respectively (The World Bank Group, 2016b). The nature and scope of GLSS 3 and 4 survey questions on drinking water were the same (Box 2.13), and also not very different from that of GLSS 1 and 2. GLSS 3 and 4 survey questions on drinking water examined households' sources of drinking water, water bills, amounts and quantities of water sold and distances to water sources (Box 11). In GLSS 3 and 4, two questions on households' sources of water for other domestic uses which featured in GLSS 1 and 2 were excluded.

Box 2.13: Ghana Livings Standards Survey 3 & 4 questionnaires on drinking water

- *What is the source of drinking water for your household?*
- *How far is this (source of water) from your dwelling?*
- *Do you pay or share a regular bill from the water company?*
- *How much was your last bill? (only your part if joint meter or shared bill)*
- *How much have you paid to a private water vendor, neighbour or standpipe in the last2 weeks?*
- *Did you sell any of this water to someone else?*
- *How much money did you receive for the water sold in the last 2 weeks?*

Source: Ghana Statistical Service (1991, p. 37) and Ghana Statistical Service (1998, p. 51)

Round five of the Ghana Living Standards Survey (GLSS 5) started in 2008 through 2009 (The World Bank Group, 2016b). Compared to previous GLSSs, the scope and number of questions on drinking water increased. New aspects of drinking water assessed for the first time were households' water collection time, regularity of water supply, the quantity of water households used daily and methods of household water treatment (Box 2.14).

Box 2.14: Ghana Living Standards Survey 5 questions on drinking water

- *What is the main source of water supply for this household? Probe for drinking and also for general use*
- *How far is this source of water from your dwelling? Probe for drinking and also for general use*
- *How long does it take to go there, get water and come back?*
- *How regular is your source of water supply?*
- *How much water does your household use in a day?*
- *Do you treat your water in any way to make it safer to drink?*
- *What do you usually do to the water to make it safer to drink?*
- *How much was your last bill? (only your part, if joint or shared bill)*
- *How much did your household pay to a private water vendor, neighbour or standpipe in the last 2 weeks?*
- *Did your household sell any water to someone else?*
- *How much did your household receive for the water sold in the last 2 weeks*

Source: ISSER - University of Ghana and EGC - Yale University (2009, pp. 163-164)

Round six of the Ghana Living Standards Survey (GLSS 6) was conducted within the period 2012 and 2013 (Ghana Statistical Service, 2014c). It is by far the most extensive GLSS, capturing many aspects of drinking water at the household level. Questions were asked on households' main sources of water for drinking, sources of water for general use, water treatment methods, distances to water sources, water collection time, regularity of water supply, daily water requirements, sustainability of water sources, provider of water sources, operation and management of water sources, water bills and quantities and amounts of water sold (Box 2.15). Also, for the first time, the GLSS assessed household water storage practices, distances of water sources to latrines/septic tanks, age and gender of water collectors, daily water demands and perceived water quality (Box 2.15). Furthermore, in GLSS 6, samples of water were taken at both water sources and storage points and tested for E-coli and arsenic. Notwithstanding the increase in the scope of questions on drinking water in GLSS 6, some aspects of water were poorly addressed. For instance, water quality testing was limited to E-coli and arsenic. Other known harmful chemicals including fluoride were not evaluated. Also, the assessment of regularity of water supply failed to account for seasonal variations.

Box 2.15: Ghana Living Standards Survey 5 questions on drinking water

- *What is the main source of water supply for this household? Probe for drinking and also for general use*
- *How does your household store drinking water? Ask permission to observe*
- *Is household identified/earmarked for water quality testing?*
- *Do you think your drinking water has any quality problems?*
- *What do you usually do to the water to make it safer to drink?*
- *How far is this source of water from your dwelling? Probe for drinking water source distance and also for general use water source distance*
- *How long does it take to go there, get water and come back? Probe for drinking water source and also for general use water source*
- *How far is your water source from the nearest latrine/ septic tank? Probe for distance to drinking water source and also distance for general use water source*
- *Who usually goes to this source to collect the water for your household?*
- *How regular is your source of water supply?*
- *When was the last time the water facility broke down?*
- *Last time the water facility broke down, how long did it take to have it fixed and working again?*
- *How much water does your household use in a day?*
- *How much water does your household require in a day?*
- *Which organisation provided/ facilitated the provision of your source of water?*
- *How is the water supply system operated and managed?*
- *Does the household pay a regular bill for this water supply system?*
- *How much was your last bill? (only your part, if joint metre or shared bill)*
- *How much did your household pay to a private water vendor, neighbour or standpipe in the last 2 weeks?*
- *Did your household sell any water to someone else?*
- *How much did your household receive for the water sold in the last 2 weeks?*

Source: (Ghana Statistical Service, 2013f, pp. 60-61)

2.3.6.4 *The Joint Monitoring Programme (JMP) Core Questions on Drinking Water*

Although the JMP is mandated to track progress on global drinking water and sanitation targets, it does not carry out surveys. Instead, it depends on international and national survey programmes such as the Demographic Health Survey (DHS), Living Standards Measurement Study (LSMS), Multiple Indicator Cluster Survey (MICS), and national censuses for data. Prior to 2006, the JMP observed variations in household survey questions on drinking water and sanitation among surveillance organisations resulting in problems of results comparability (WHO/UNICEF Joint Monitoring Programme, 2006a). To help ensure effective comparability of survey results across countries and over time, the JMP in 2006 developed and published what it called *core questions on drinking water and sanitation for household surveys* (WHO/UNICEF Joint Monitoring Programme, 2006a). Following publication of the JMP core questions in 2006, "international survey programmes have aligned their questions on drinking water to the JMP core questions leading to increase harmonization of national WASH data" (p.5). In 2018, the JMP updated its core questions to reflect the SDG 'safely managed water' target (Table 2.9).

Table 2.9: JMP Core questions on drinking water for household survey

W1. Main drinking water source	
What is the main source of drinking water for members of your household?	Piped water Piped into dwelling Piped into compound, yard or plot Piped to neighbour Public tap / standpipe Borehole or tubewell Dug well Protected well Unprotected well Water from spring Protected spring Unprotected spring Rainwater collection

	Delivered water Tanker-truck Cart with small tank / drum Water kiosk Packaged water Bottled water Sachet water Surface water (river, stream, dam, lake, pond, canal, irrigation channel) Other (specify) ....
W2. Secondary water source for users of packaged water	
What is the main source of water used by members of your household for other purposes, such as cooking and hand washing?	Same options as in W1
W3. Location of drinking water source	
Where is that water collected from?	In own dwelling In own yard / plot Elsewhere
W4. Time to collect drinking water	
How long does it take to go there, get water, and come back?	Members do not collect Number of minutes………… Don't know
W5. Availability of drinking water	
In the last month, has there been any time when your household did not have sufficient quantities of drinking water when needed?	Yes, at least once No, always sufficient Don't know
W6. Drinking water quality at the source	
Can you please show me where the members of your household collect drinking water so that I can test the water quality? *Conduct tests within 30 mins of collecting samples.* *Record 3 digit count of colonies*	Number of E. coli detected in 100 mL sample Source water test……………….

Source: United Nations Children's Fund (UNICEF) and World Health Organization (2018, pp. 8-10) P8 - 10

Although target 6.1 of the SDG sets out to monitor accessibility, reliability and quality of drinking water, the JMP core questions appear to be limited, and may lead to the generation of "obscured inaccurate statistics" as in the MDG era (Satterthwaite, 2003). To begin with, the JMP core questions do not directly measure reliability of drinking water sources but rather measure availability of water at home as a proxy indicator; "*in the last month, has there been any time when your household did not have sufficient quantities of drinking water when needed ?"* (United Nations Children's Fund (UNICEF) and World Health Organization, 2018, p. 10). This proxy measure fails to account for risk of seasonality in water availability at home. In arid regions where prolonged dry season impacts negatively on water supply (McDonald et al., 2011; Serdeczny et al., 2017; UN-Water, 2010), the JMP risk overestimating the population with access to sufficient quantities of water.

Furthermore, water quality test is restricted to only faecal contamination at source (United Nations Children's Fund (UNICEF) and World Health Organization, 2018) although the 'safely managed water' indicator equally emphasized priority chemicals. The core measures also fail to capture seasonal variations in water quality (Kostyla et al., 2015). On accessibility, the JMP core measures focus on location of water source (in own dwelling, in own yard or elsewhere) and water collection time (United Nations Children's Fund (UNICEF) and World Health Organization, 2018). Distance to water source, which has implications on access to water and livelihoods of water collectors (mainly women and girls) and their households in developing countries (Boone et al., 2011; Demie et al., 2016) is ignored. Additionally, information is collected on only household main water source (except packaged water users) (United Nations Children's Fund (UNICEF) and World Health Organization, 2018), despite evidence of stacking in the use of WASH services in developing countries (Jewitt et al., 2018). With the aim of contributing to knowledge on 'safely managed water' supply, majority of the JMP core questions for monitoring drinking water in the SDG era (W1, W3, W4 and W6) were adopted in this study.

2.4 Empirical Review

2.4.1 Introduction

The empirical review is divided into five sub-sections. The first section presents statistics on improved water coverage in the MDGs era at the global and national scales. The second section presents statistics on 'safely managed water' coverage in the SDG era. The last three sections are devoted to findings of related studies on accessibility, quality and reliability of drinking water sources.

2.4.2 Access to drinking water in the Millennium Development Goals era

(a) Global scale

In the year 2000, which marked the beginning of a new millennium, the United Nations subscribed to a broad vision to fight poverty. That vision was translated into eight goals tagged as the Millennium Development Goals (MDGs) with 2015 as the end point (United Nations, 2015a). Goal 7 of the MDGs focused on environmental sustainability, with target 7c aim to halve by 2015 the proportion of (1990) population without sustainable access to safe drinking water and basic sanitation (United Nations, 2015a; WHO/UNICEF Joint Monitoring Programme, 2015b, 2015c). The Joint Monitoring Programme (JMP), established in 1990, was mandated to monitor and report progress of target 7c of the MDGs (WHO/UNICEF Joint Monitoring Programme, 2015e, 2015f). The JMP monitored access to drinking water using an indicator known as 'improved water' (refer to section 2.2.1 for definition).

Globally, the MDG target on access to improved drinking water (88%) was met in 2010, five years ahead of time (United Nations, 2015a; WHO/UNICEF Joint Monitoring Programme, 2015b, 2015f). Between 1990 and 2015, the proportion of the global population using an improved drinking water source increased from 76% to 91%, surpassing the MDG target by 3 percentage points (United Nations, 2015a). The additional 15% gained in access to improved drinking water source translates into 2.6 billion people (United Nations, 2015a; WHO/UNICEF Joint Monitoring Programme, 2015b). Of the 91% of the global population who had access to improved drinking water source, 58% had piped on premises while 33% used other improved water sources (United Nations, 2015a; WHO/UNICEF Joint Monitoring Programme, 2015b). By 2015, 147 countries met their drinking water targets (United Nations, 2015a; WHO/UNICEF Joint Monitoring Programme, 2015f).

Despite the successes chalked in improved water coverage over the MDG period, the JMP admits that a great deal remained to be done (WHO/UNICEF Joint Monitoring Programme, 2015b). In 2015, the JMP estimates that 663 million people constituting 9% of the world's population still use unimproved drinking water sources (United Nations, 2015a; WHO/UNICEF Joint Monitoring Programme, 2015b, 2015f). Also, only six out of every ten people had access to piped on premises, the most preferred source of water (WHO/UNICEF Joint Monitoring Programme, 2015f). Furthermore, behind the global figures, significant differences exists in improved water coverage across space (United Nations, 2015a; WHO/UNICEF Joint Monitoring Programme, 2015b). Whereas only 1% of population in developed regions use unimproved drinking water sources, in developing regions, it is as high as 11% (United Nations, 2015a; WHO/UNICEF Joint Monitoring Programme, 2015b). The lowest levels of coverage were found in the 48 countries designated by the United Nations as Least Developed Countries (WHO/UNICEF Joint Monitoring Programme, 2015b).

Even among developing regions, remarkable differences exist in access to drinking water. Of the nine developing regions, five (South-Eastern Asia, Southern Asia, Latin America and the Caribbean, Eastern Asia and Western Asia) met their MDG drinking water target, while the rest (Sub-Saharan Africa, Oceania, Caucasus and Central Asia and Northern Africa) did not (United Nations, 2015a; WHO/UNICEF Joint Monitoring Programme, 2015b). Although water coverage in Sub-Saharan Africa increased from 48% in 1990 to 68 % by 2015, it still fell short of its MDG target (United Nations, 2015a; WHO/UNICEF Joint Monitoring Programme, 2015b). Almost half of the 663 million reported to be using unimproved water sources as at 2015 live in Sub- Saharan Africa (United Nations, 2015a; WHO/UNICEF Joint Monitoring Programme, 2015b).

Significant differences also exist between rural and urban areas in improved water coverage. In 2015, 96% of urban population were reported to have access to improved drinking water compared to 84% in rural areas (United Nations, 2015a). Furthermore, over two-thirds (79%) of population in urban areas had piped water on premises compared to a third (33%) in rural areas (United Nations, 2015a). Approximately, 80% of population without access to improved drinking water sources live in rural areas (WHO/UNICEF Joint Monitoring Programme, 2015b).

In addition to concerns of disparities in improved water coverage across space, many scholars have questioned the assumptions and validity of the JMP improved water metric that was used to track access to safe drinking water in the MDG era (e.g. O'Hara et al., 2008; Obeng-Odoom, 2012; Satterthwaite, 2003). This is because the metric only measures the proportion of population that use water sources classified as 'improved' without accounting for important aspects of water, such as water quality, accessibility, reliability and affordability. This implies that statistics on improved water coverage reported by the JMP during the MDG period would drop if issues of quality, accessibility and reliability were accounted for in the 'improved' water metric. The JMP affirmed this assertion through a water quality survey in four developing countries in 2008. It observed that access to improved water in Nicaragua, Ethiopia, Nigeria and Tajikistan in 2008 would be reduced by 16, 11, 10 and 7 percentage points, respectively, if water quality were considered (WHO/UNICEF Joint Monitoring Programme, 2011). Based on this finding, the JMP in its publication titled "*Drinking Water: Equity, Safety and Sustainability"* in 2011 avers as follows;

> "although the MDG drinking water target refers to sustainable access to safe drinking water, the MDG indicator – 'use of an improved drinking water source' – does not include a measurement of either drinking water safety or sustainable access. This means that accurate estimates of the proportion of the global population with sustainable access to safe drinking water are likely to be significantly lower than estimates of those reportedly using improved drinking water sources" (WHO/UNICEF Joint Monitoring Programme, 2011, p. 11).

(b) Ghana

Statistics on improved water coverage in Ghana at the end of the MDGs period in 2015 look impressive. According to the JMP, Ghana within the MDGs period recorded an increase in access to improved water from 56% in 1990 to 89% in 2015 (WHO/UNICEF Joint Monitoring Programme, 2015d, 2015f, 2015g). Furthermore, reports from the JMP indicate that Ghana met its MDGs water target (78per cent) in 2010 and had actually surpassed it by 11 percentage points by the close of the MDG period in 2015 (WHO/UNICEF Joint Monitoring Programme, 2015d, 2015f, 2015g). Data from the latest MICS report in Ghana, which dates back to 2011, corroborates the JMP report that Ghana met its MDG target in 2010. From the MICS report, 79.3% of Ghanaians had access to improved water as at 2011 (Ghana Statistical Service, 2011).

Results on access to drinking water in Ghana from the 2010 PHC report, 2013 GLSS Round 6 and 2014 DHS contrast with the JMP estimates. The 2010 PHC recorded a national improved drinking water coverage of 76.7% (Ghana Statistical Service, 2013d), a little below the MDG water target of 78% which the JMP claimed was met in 2010 (WHO/UNICEF Joint Monitoring Programme, 2015f, 2015g). The 2013 GLSS Round 6 and 2014 DHS revealed improved water coverage of 59.6% and 64.2%, respectively (Ghana Statistical Service, 2014c; Ghana Statistical Service et al., 2015). These coverage figures are no way near the 89% coverage reported by the JMP in 2015 (WHO/UNICEF Joint Monitoring Programme, 2015d, 2015f, 2015g). If these statistics are anything to go by, then one is bound to conclude that Ghana did not meet its MDG target of 78% as reported by the JMP.

Analysis of global surveys and census reports revealed disparities in access to improved water between urban and rural areas in Ghana during the MDG period. The 2010 PHC report revealed that access to improved water in urban areas (80.5%) was higher than rural areas (71.1%) (Ghana Statistical Service, 2013d). The MICS, which was carried out a year later, reported a similar pattern. Thus, 90.7% of population in urban areas were found to have access to improved water compared to 68.6% in rural areas (Ghana Statistical Service, 2011). In contrast, the 2013 GLSS Round 6 and 2014 DHS revealed that access to improved drinking water sources in rural areas was rather higher than in urban areas. The GLSS R6 revealed 68.5% improved water coverage in rural areas as against 52.3% in urban areas (Ghana Statistical Service, 2014c). Similarly, the 2014 DHS also reported 57% improved water coverage in urban areas as against 71.4% in rural areas (Ghana Statistical Service et al., 2015). Reports from the JMP in 2015 took a sharp departure from the findings of the 2013 GLSS Round 6 and 2014 DHS reports but agreed with that of the 2010 PHC report and 2011 MICS that improved water coverage in urban areas is higher than in rural areas. According to the JMP, approximately nine out of every 10 persons (94%) in urban areas had access to improved water compared to eight out of 10 (84%) in rural areas (WHO/UNICEF Joint Monitoring Programme, 2015d, 2015f, 2015g).

Borehole is the main source of water in Ghana. From the 2014 DHS, 44.7% of rural population and 27% of urban population depended on borehole. In the same survey, access to household piped connections was reported to be low with significant disparities between urban (8.4%) and rural (0.5%) populations. The 2011 MICS and 2013 GLSS Round 6 equally reported significant differences in household piped connections between urban and rural areas;

- In the 2011 MICS, 5.3% of urban population had household piped connections as against 0.3% in rural areas (Ghana Statistical Service, 2011);
- In the 2013 GLSS Round 6, 8.9% of urban population were found to have access to household piped connections as against 0.9% in rural areas (Ghana Statistical Service, 2014c).

Analysis of disaggregated data at regional level as presented in the 2010 PHC report and 2011 MICS also reveal wide variations in access to improved sources of drinking water. From the 2010 PHC, improved water coverage at the regional level varies from 67.1% in the Greater Accra Region to 89.4% in the Ashanti Region (Ghana Statistical Service, 2013d). Also, five out of the 10 regions were found to have improved water coverage figures below the national average of 76.7% (Ghana Statistical Service, 2013d). These were Greater Accra (67.1%), Northern (69.4%), Volta (69.9%), Western (72%) and Eastern (72.8%) Regions (Ghana Statistical Service, 2013d). The regional differentials recorded in access to improved water in the 2010 population and housing census were not very different from the 2011 Multiple Indicator Cluster Survey. Coverage figures ranged from a low of 61.8% in the Volta Region to a high of 90.5% in the Ashanti Region (Ghana Statistical Service, 2011). In the 2011 MICS, five regions also recorded improved water coverages below the national average of 79.3% (Ghana Statistical Service, 2011). These were Volta (61.8%), Northern (68.4%), Wester (71.5%), Eastern (76.5%) and Upper East (78.3%) Regions (Ghana Statistical Service, 2011). With the exception of the Greater Accra Region, all other regions that recorded improved water coverage figure below the national average in the 2010 PHC did the same in the 2011 Multiple Cluster Indicator Survey.

2.4.3 Access to drinking water in the Sustainable Development Goals era

As mentioned in section 2.2.3, the United Nations, through SDG target 6.1, seeks to achieve universal and equitable access to safe and affordable drinking water for all by 2030. This target is being monitored with an indicator known as 'safely managed water' (see section 2.2.3 for definition). In addition to 'safely managed water', the JMP also monitors access to basic and limited water (Table 2.2). Since the beginning of the SDGs in 2015, the JMP has released only one report on 'safely managed water' coverage. This report released in 2017 contains baseline estimates of 'safely managed water' for 96 countries and four out of the eight SDG regions. The four regions include Sub-Saharan Africa, Central Asia and Southern Asia, Latin America and the Caribbean, and Northern America and Europe.

According to the JMP, 5.2 billion people representing 71% of the world's population as at 2015 had access to 'safely managed water' (Figure 2.2). Significant differences however exist across space. Of the four SDGs regions in which data was available for 'safely managed water', coverage ranged from 24% in Sub-Saharan Africa to 94% in North America and Europe (Figure 2.2). Also, access to 'safely managed water' in urban settings (85%) is 30 percentage points higher than in rural settings (55%) (WHO & UNICEF, 2017). In Ghana, the JMP estimated access to 'safely managed water' service to be less than 25% in 2015 while basic access ranged from 76-90%. The remaining three sections of the empirical review present findings of previous studies on accessibility, quality and reliability of drinking water sources in developing countries.

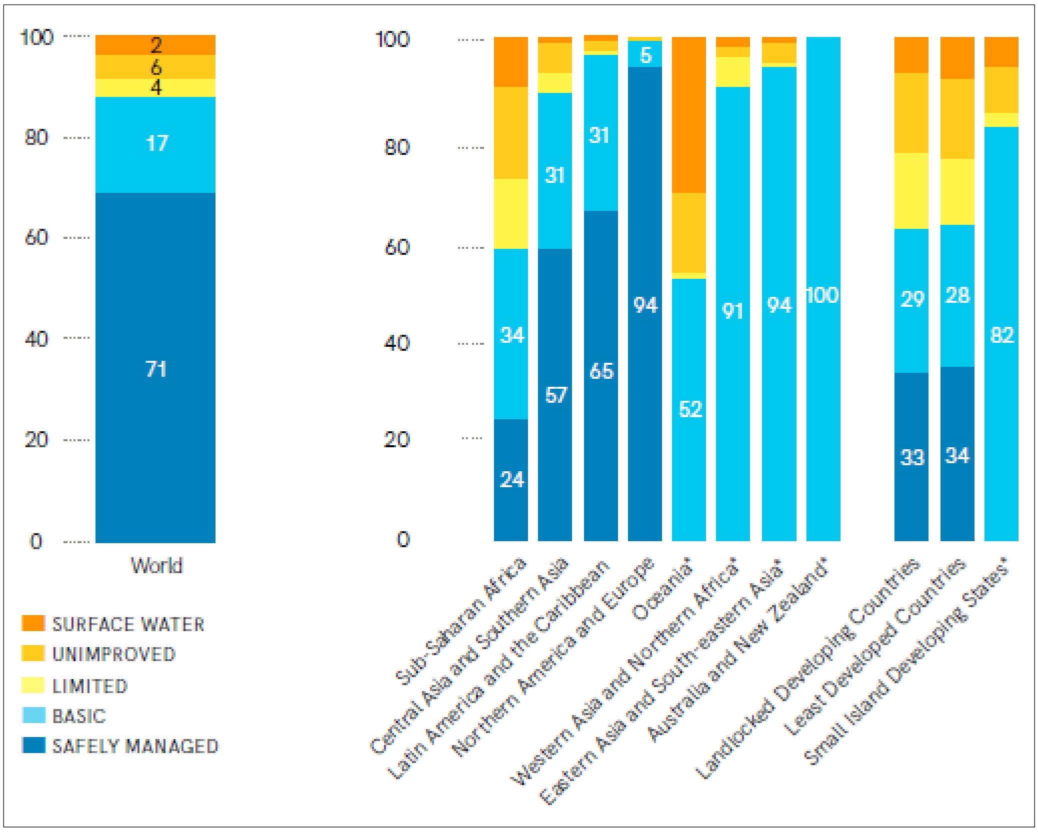


Figure 2.1: Estimates of 'safely managed water' coverage, 2015.

*Insufficient data to estimate 'safely managed water' services

Source: WHO and UNICEF (2017)

2.4.4 Accessibility to drinking water sources

Accessibility to water sources based on guidelines presented in section 2.2.2 leaves much to be desired. Over one-third (42%) of the world's population do not have household piped connections (United Nations, 2015a; WHO/UNICEF Joint Monitoring Programme, 2015b) and therefore have to travel outside their homes to collect drinking water (WHO/UNICEF Joint Monitoring Programme, 2015e). Water collection outside the home is time consuming for many households. Globally, 7% of the population spends more than 30 minutes on a round trip of water (WHO & UNICEF, 2017).

Distance to water sources and water collection times in developing countries are reported to be long (Ghana Statistical Service et al., 2015; Graham et al., 2016; Nygren et al., 2016; United Nations Human Rights et al., 2010; WHO/UNICEF Joint Monitoring Programme, 2011). On average, water collectors in Africa travel 6 kilometres to collect water (United Nations Human Rights et al., 2010). Between urban and rural areas, distance to water sources in the latter is generally higher than in the former. For instance, in Madagascar, Boone et al. (2011) noted that the average distance to water source in rural areas (243m) was 123m higher than in urban areas (110).

Long distances to water sources together with long waiting time at source in developing countries increase water collection times. In Sub-Saharan Africa, over a quarter of the population spends more than 30 minutes to collect a roundtrip of water (WHO/UNICEF Joint Monitoring Programme, 2011). Graham et al. (2016) found that many rural households in SSA spend more than 30 minutes to collect water compared to urban households. They noted that between 2% to 58% of households in rural areas and 3% to 39% in urban areas spend more than 30 minutes on a roundtrip of water. The GSS in the 2014 DHS in Ghana also established high water collection time in rural areas compared to urban areas (Ghana Statistical Service et al., 2015). From the report, 91.9% of urban population in Ghana collect a roundtrip of water within 30 minutes as against 70.6% in rural areas, with the average being 92.6%. The United Nations University (1991) found that the time women in the Upper East Region of Ghana spend on water collection in the dry season is higher than in the rainy season.

In many developing countries, especially in Africa and Asia, the burden of water collection rests primarily on women and children (Graham et al., 2016; Keefer & Bousalis, 2015; Oxfam, 2017; Sorenson et al., 2011; Sultana, 2011; WHO/UNICEF Joint Monitoring Programme, 2011, 2015e). Graham et al. (2016) in their analysis of water collection burdens in 24 Sub-Saharan African Countries using DHS and MICS data found that women were primary water collectors in both rural and urban areas. Similarly, in Zimbabwe, Oxfam (2017) noted that women were traditionally responsible for all domestic work while “men are responsible for productive and income-generating activities”. Culture is the main reason for the continuous ascription of water collection to women (Oxfam, 2017). Consequently, children’s roles are determined by tradition from birth (Oxfam, 2017; Rubio, 2018). About 3.36 million children in Sub-Saharan Africa, mainly girls, are also estimated to spend over 30 minutes on a roundtrip of water (Graham et al., 2016). Women and girls in Africa therefore bear a large portion of the suffering associated with water collection (Boone et al., 2011).

Long distances to water sources and collection time limit the quantity and quality of water households collect (García-Valiñas & Miquel-Florensa, 2013; Howard & Bartram, 2003; Pickering & Davis, 2012a). When water collection time is more than 30 minutes or distance to source is greater than 1km, the quantity of water collected is likely to fall below the basic requirement of 20 litres/capita/day leading to poor consumption, limited hygiene practice and health problems (Howard & Bartram, 2003). Also, water risks being contaminated when carried over a long distance (García-Valiñas & Miquel-Florensa, 2013) due to poor handling.

Furthermore, headloading of water in developing has dire consequences on the health of water collectors (largely women and children) (Fisher, 2008; Geere et al., 2018; Jonah et al., 2015). Geere et al. (2018) in their cross-sectional survey in South Africa, Ghana and Vietnam found that general body pains are associated with carrying of water, especially on the head. Similarly, a study by Oxfam (2017) in Zimbabwe linked backache, early ageing, high blood pressure, miscarriages and depression of women and girls to domestic work, including water collection. In Kenya, Jonah et al. (2015) reported that water collection negatively affects the physical development of children in Nakuru county. This perhaps explains why musculoskeletal disorders are more prevalent in women than men in Ghana (Nakua et al., 2015). Nygren et al. (2016) in their study in Kenya found that when round trip water collection time is greater than 30 minutes, children are at risk of moderate to severe diarrhoea in households that did not collect rainwater for the past 7 days. Pickering and Davis (2012a) also reported a strong correlation between time spent walking to a household's main water source aand under-five child health in Sub-Saharan Africa. They found that a 15 minute decrease in one-way walk time to water source to be associated with a 41% average relative reduction in diarrhoea prevalence and a 11% relative reduction in under-five child mortality. Moreover, long distance to water source and high water collection time are time consuming and hence limit economic productivity and income of women and their households (Fisher, 2008; Jonah et al., 2015; Keefer & Bousalis, 2015; Oxfam, 2017; WHO/UNICEF Joint Monitoring Programme, 2011). It also affects the education of children, particularly girls. This arises from a reduction in learning hours through sicknesses, lateness to school and tiredness (Fisher, 2008; Jonah et al., 2015; Osumanu et al., 2010; Oxfam, 2017). Furthermore, long distances to water sources and high water collection time can limit access to water by vulnerable groups like disabled people and pregnant women. According to Jones et al. (2003 cited in Jones et al., 2012, p. 3) “many disabled or frail older people are unable to walk long distances to a water point, stand in a queue for long periods, operate the heavy handle of a handpump or carry a 20L container of water back home”.

2.4.5 Quality of drinking water sources

Although the WHO has identified over 100 possible contaminants of drinking water, the review is centred on the three contaminants explored in this study - faecal matter, fluoride and arsenic. Spatially, the review largely focused on developing countries because the study was conducted in a similar setting.

2.4.5.1 Faecal contamination of drinking water

Faecal contamination has been documented in all types of water sources (e.g. Bain et al., 2014; Boateng et al., 2013; Cobbina et al., 2012; Kostyla et al., 2015; Mkwate et al., 2016; WHO/UNICEF Joint Monitoring Programme, 2015e). Globally, 1.8 billion people (28%) are estimated to be exposed to faecal matter through drinking water (Bain et al., 2014; Onda et al., 2012). The estimated 1.8 billion people that used faecal contaminated water is 17% higher than the JMP estimate of 783 million people (11%) that used unimproved water sources in 2010 (United Nations, 2015a; WHO/UNICEF Joint Monitoring Programme, 2015b). This implies that some improved water sources were contaminated with faeces.

Feacal contamination of drinking water sources varies in space. Rural populations (41 %) are at higher risk of drinking faecal contaminated water than urban populations (12%) (Bain et al., 2014). Also, exposure to faecal contamination is more pronounced in developing countries, especially Africa (53%) and South-East Asia (35%) (Bain et al., 2014). High faecal contamination of drinking water sources in developing countries implies that improved water coverages reported during the MDG era were overestimated. The JMP affirmed this in the late 2000s through a faecal contamination survey in improved drinking water sources in five developing countries - Ethiopia, Jordan, Nicaragua, Nigeria and Tajikistan (WHO/UNICEF Joint Monitoring Programme, 2011). From the study, 13 to 32% of improved sources were contaminated at levels exceeding WHO guideline values in four of the five countries (WHO/UNICEF Joint Monitoring Programme, 2011). The JMP estimated that access to improved water in Nicaragua, Ethiopia, Nigeria and Tajikistan in 2008 would be reduced by 16, 11, 10 and 7 percentage points, respectively, if water quality is accounted for (WHO/UNICEF Joint Monitoring Programme, 2011).

Faecal contamination in drinking water sources varies by source types. Generally, unimproved water sources are at high risk compared to unimproved water sources. Also, among the improved water sources, risk of contamination of non-piped water sources is higher than piped water systems and packaged water. For instance, analysis of Total Coliforms (TC) concentrations in drinking water sources in Kisoro District in Uganda by Agensi et al. (2019) revealed 100% contamination of all pond and river samples, 8.3% contamination of spring samples and no contamination for tap water. In the same study, the proportion of pond and river samples contaminated with *Escherichia coli* were 100% and 66.7% respectively. Samples from spring and tap water were not contaminated with *Escherichia coli.* For all samples, 43.2% were contaminated with TC and 34.1% with *E. coli*. In rural Malawi, Smiley (2017) tested 27 drinking water samples for TC, comprising of 15 shallow wells, eight boreholes, two surface water sources and two piped water systems. None of the borehole samples contained TC but all samples (100%) from shallow wells and one sample (50%) each from piped and surface water contained TC. In Ghana, the 2014 Demographic Health Survey showed that 43.5% of water sources were contaminated with *E-coli* with significant differences between improved (48.8%) and unimproved (70.8%) water sources (Ghana Statistical Service et al., 2015). In the same DHS survey, the percentage of samples with detected *E. coli* was lowest for sachet/bottled water samples (10.8%), followed by pipe-borne (30%), standpipe (47.2%), borehole (53%), protected hand-dug well (69%), surface water (70.9%) and unprotected hand-dug wells (90.1%%). Some other studies have reported variations in faecal contamination of drinking water sources by source types (Kirby et al., 2016; Kumpel et al., 2016).

From the literature, there is emerging evidence of seasonal variations in faecal contamination of drinking water sources (Kostyla et al., 2015; Kumpel et al., 2017). Kostyla et al. (2015) in a systematic review of 22 studies in developing countries found that faecal contamination of water sources in the rainy season was significantly ($P<0.001$) higher than in the dry season across all faecal indicators, source types and climatic types. In Nigeria, Kumpel et al. (2017) also reported an increase in the proportion of drinking water sources with faecal matter from 21% in the dry season to 42% in the rainy season. In the rainy season, cumulative rainfall further increases risk of water source to contamination (Kirby et al., 2016).

Furthermore, faecal concentration in drinking water at home is generally higher than at source due to poor handling of water (Clasen & Bastable, 2003b; Lavanya & Ravichandran, 2013). Agensi et al. (2019) found otherwise. They however attributed the low microbial contamination of drinking water at home compared to source to high water treatment practices by households (88.7%). Factors linked to faecal contamination of drinking water sources include open disposal of solid waste (Kirby et al., 2016), open defecation (Mkwate et al., 2016), nearness of water sources to unsanitary latrines (Escamilla et al., 2013; Mkwate et al., 2016), rainfall (Kirby et al., 2016), location of water sources in low elevation areas (Kirby et al., 2016), leaking of pipes (Grady et al., 2014) and intermittent water supply (WHO, 2011a).

2.4.5.2 Fluoride concentration in drinking water

Fluoride is an essential element for human health (Fawell et al., 2006; Smedley et al., 2002). However, its deficiency or excess in the human body poses health problems. The main source of fluoride ingestion into the human body is through drinking water (Fawell et al., 2006). Fluoride levels between 0.7 and 1.2 mg/l in drinking water promotes healthy teeth and bone development (Freeze & Lehr, 2009), but high intake of more than 1.5 mg/l can give rise to dental fluorosis and in extreme cases skeletal fluorosis (Fawell & Nieuwenhuijsen, 2003; Majumdar, 2011; Smedley et al., 2002). Fluoride concentrations in drinking water above the WHO recommended limit of 1.5mg/l is widely reported across the world with the worst affected countries being USA, India, China, Kenya, Tanzania and Ethiopia (Agensi et al., 2019; Beltran-Aguilar et al., 2010; Majumdar, 2011; Malago et al., 2017; WHO., 2010). Globally, over 200 million people are thought to be drinking water with fluoride in excess of the WHO guideline value of 1.5mg/l (Edmunds & Smedley, 2005; Smedley et al., 2002) with more than 46.6 million and 19.8 million suffering from dental and skeletal fluorosis respectively (Fewtrell et al., 2006).

Not only does excessive fluoride in drinking water poses a health challenge but low fluoride well as. Fluoride concentration of less than 0.7 mg/l in drinking water exposes population to risk of dental caries (Fawell et al., 2006). Dental decay is very high when fluoride concentration in drinking water is less than 0.1 mg/l (Fawell et al., 2006; Smedley et al., 1995). Globally, 60–90% of school children and a vast majority of adults are at risk of dental decay (Petersen & Ogawa, 2016). To avert this, a combination of measures including fluoridation of drinking water, use of fluoride toothpastes and mouthwashes have been introduced (Azami-Aghdash et al., 2013; Iheozor-Ejiofor et al., 2015). However, Petersen and Ogawa (2016) observed that low and middle-income countries of Africa, Asia, and Latin America lack dental decay preventive programmes as well as adequate health systems and health professionals to treat dental problems. Consequently, "tooth loss and impaired quality of life are therefore expected to increase as a public health problem in many developing countries" (Petersen & Ogawa, 2016, p. 1). Although some scholars have expressed reservations about the health benefits of water fluoridisation (Armfield, 2005), many epidemiological studies have affirmed its effectiveness in preventing dental decay (McGrady et al., 2012; Public Health England, 2014; Slade et al., 2018).

Fluoride occurrence in groundwater is closely linked to its abundance in minerals and rocks (Edmunds & Smedley, 2005; Malago et al., 2017). Fluoride constitutes about 0.06–0.09 percent of the earth's crust (Fawell et al., 2006). Consequently, low to high concentrations of fluoride can be found in groundwater depending on the nature of the rock and mineral (Fawell et al., 2006). Fawell et al. (2006) noted that groundwater with high fluoride concentrations occurs in large and extensive geographical belts associated with sediments of marine origin in mountainous areas, volcanic rock, granitic rock and gneissic rock. Exposure to excessive fluoride is also influenced by climatic type; persons in hot climatic areas are at risk of excessive fluoride intake due to the consumption of large volumes of water (Fawell et al., 2006). Daily fluoride exposure in a temperate climate ranged from 0.6 to 2.0 mg per day (WHO, 1984).

The hot climate in Ghana together with the crystalline basement rocks in the country expose population to risk of high fluoride intake through drinking water (British Geological Survey, 2000; Craig et al., 2015). However, there is a paucity of data on fluoride concentrations in Ghana. Available studies are limited to the Upper East Region (Alfredo et al., 2014; Apambire, 2001; Atipoka, 2009; Firempong et al., 2013; Smedley et al., 1995; Smedley et al., 2002), perhaps because of observed dental fluorosis among residents in the area. Firempong et al. (2013) reported the prevalence of dental fluorosis among schoolchildren in the Bongo Township of the Upper East Region to be 63% and 10% outside the Bongo Township. Similarly, Smedley et al. (2002) estimated the prevalence of dental fluorosis among school children in Tarongo in the Upper East Region to be between 20% to 50%.

Fluoride concentrations in surface and groundwater sources in the Upper East Region of Ghana are reported to range from 0.01 to 5.80 mg/l, with Bongo district being the worst affected area (Apambire, 2001; Atipoka, 2009; Malago et al., 2017; Smedley et al., 1995; Smedley et al., 2002). Smedley et al. (1995) in their study in the Upper East Region observed that, “for samples with fluoride concentration above the WHO maximum concentration of 1.5mg/l in the Bongo granitic suites, fluoride concentration increases considerably with well depth” (Smedley et al., 1995, p. 65). A few years later, Smedley et al. (2002) and Alfredo et al. (2014) made similar observations. They found that although the Vea dam in the Upper East Region is located within the Bongo granite, a notable high fluoride area, fluoride concentration was low, due to little water-rock interaction. According to Edmunds and Smedley (2005), water at such shallow depth recirculate within the superficial weathered overburden layer rather than fractured rocks at deep depth.

2.4.5.3 Arsenic concentration in drinking water

Arsenic is a naturally occurring chemical in groundwater that is known to cause many morbidities (such cancer, skin lesions, cardiovascular disorders, diabetes, low intelligent quotient) and millions of deaths if consumed in elevated quantities (Ahmad et al., 2018; Flanagan et al., 2012; WHO, 2011a, 2018a) . Globally, about 150 million people across 50 countries are estimated to be drinking water with arsenic concentrations above the WHO health guideline of 10 μg/L (WHO, 2018a). Excessive concentrations have been widely reported in Argentina, Chile, China, Hungary, Mexico, Nepal, Taiwan, and USA with the worst affected countries being India and Bangladesh (Ahmad et al., 2018). About 45 million people in Bangladesh are exposed to arsenic in drinking water above the WHO permissible value of 10 μg/L (Flanagan et al., 2012).

Bangladesh has become a social laboratory for analysing the socio-economic impact of population exposure to excessive arsenic. Exposure to arsenic in drinking water above 10 μg/L accounts for 43,000 deaths annually in Bangladesh (Flanagan et al., 2012). Between 2013 and 2033, Flanagan et al. (2012) estimated that adult deaths arising from arsenic contamination in drinking water could cost Bangladesh US$ 13 billion in terms of economic burden. Besides deaths arising from dermatological and non-communicable diseases, elevated arsenic in drinking water also has dire consequences on pregnancy outcomes and the cognitive development of children (Ahmad et al., 2018). Vulnerable groups, especially poor households and women suffer disproportionally from the impact of arsenic contamination of tube wells in Bangladesh (Crow & Sultana, 2002; Sultana, 2007b). This is because rich households often use deep tube wells which are at low risk of contamination while a majority of the poor collect water form shallow arsenic contaminated wells (Crow & Sultana, 2002). Consequently, poor households suffer most from the burden of accessing safe water in terms of cost of treatment, poor health, loss of time, loss of productivity and loss of income as well as social stigmatization (Sultana, 2007b). Also, because women and girls in Bangladesh are responsible for water collection, they are at a higher risk of skin diseases associated with arsenic (Crow & Sultana, 2002). Moreover, women undergo a lot of emotional pain, struggles, hardship and tensions in an attempt to provide their households with uncontaminated arsenic water (Sultana, 2011). Sultana (2011) observed that the emotional geography of water comprised of both positive and negative feelings;

> *"the emotional geography of water comprised of not just the sentiments brought to the fore from the water crises,…beyond the commonly felt sufferings and pain, there is also recounting of previous pleasure in fetching and/or controlling safer/closer water resources, of feeling relief in being able to obtain safe water with ease, of talking about the joy of having one's own uncontaminated well, or the pleasure in going far to get water as an escape out of the house*" (Sultana, 2011, p. 8) .

Unlike other continents, arsenic concentration in Africa is not well defined, largely due to limited studies (Ahoulé et al., 2015). Consequently, there seems to be less attention on arsenic concentration in drinking water in Africa, creating an impression as if concentrations are within acceptable limits. A review of arsenic concentration in Africa by Ahoulé et al. (2015) points to high levels of arsenic in south Africa, Botswana, Zimbabwe, Tanzania, Ethiopia, Nigeria, Ghana, Togo Burkina Faso, Morocco (above 50 μg/L), Benin, Egypt (10 – 50 μg/L), Malawi and Libya (< 10 μg/L). This underscored the need for spatial mapping of fluoride levels in drinking water sources for management. Like many countries in Africa, the spatial concentration of arsenic in Ghana is not well explored. Most empirical works on arsenic concentration in Ghana are limited to the mining areas in southern Ghana (Akabzaa, Banoeng-Yakubo, et al., 2009; Akabzaa, Jamieson, et al., 2009; Akabzaa & Yidana, 2012; Asante et al., 2007; Bhattacharya et al., 2012; Kusimi & Kusimi, 2012; Serfor-Armah et al., 2006). However, the geology of the country, which is largely composed of birimian and granite expose groundwater to risk of high arsenic concentrations (British Geological Survey, 2000).

2.4.6 Reliability of water sources

Much of the literature on reliability of water sources focused on piped water systems (Bivins et al., 2017; Kumpel & Nelson, 2016) perhaps because it is the most preferred source of water. Statistics on the number of people exposed to unreliable water sources are worrying. In 2016, Kumpel and Nelson (2016) reported that about 309 million people worldwide are served by unreliable pipe water systems – water flows for less than 24 hours in a day. A year later, Bivins et al. (2017) estimated that nearly 1 billion of the world population is served by IWS (less than 23 hours of water supply in a day). The statistics would have been much higher if data for non-piped water sources were available. With projected increases in temperature, decreases in rainfall, increases in urbanisation and population, the number of people faced with intermittent water supply is expected to increase (Kumpel & Nelson, 2016).

Intermittent piped water supply is more pronounced in developing countries (Bivins et al., 2017; Kumpel & Nelson, 2016). Of the 309 million people in 2016 who experienced intermittent piped water supply, about 39% (118.8 million) live in Sub-Saharan Africa and 38% (116.6 million) in South Asia (Kumpel & Nelson, 2016). Similarly, Bivins et al., (2017) noted that over 50% of the population served by intermittent water piped systems live in Africa and South East Asia. From Table 2.10, only two out of 10 piped water systems in Sub-Saharan Africa supply 24 hours uninterrupted water.

Table 2.10: Prevalence of intermittent piped water supply

Regions	Countries	Utilities	Pop. With IWS	Supply duration
	IWS/total	IWS/total	Millions	Mean hrs (range)
East Asia and Pacific	9/32	54/479	15	16.7 (1−23)
Europe and Central Asia	17/41	162/960	25.4	13 (0.2−23.7)
Latin America, North America, Caribbean	8/21	79/1403	28.4	16 (2−24)
Middle East and Northern Africa	1/2	12/13	4.6	3 (3−3)
South Asia	5/6	104/107	116.6	7.2 (0.3−23)
Sub-Saharan Africa	19/40	249/314	118.8	12.8 (1−23.5)
Total	59/142	660/3276	308.9	12.5 (0.2−24)

Source: (Kumpel & Nelson, 2016)

In Ghana, piped water systems are not only limited in coverage but also characterised with intermittent water supply. The situation is usually pervasive in the dry season due to increasing demand on pipe borne water. For instance, in January 26, 2018, the management of the Ghana Water Company Limited (GWCL) issued a press statement apologizing for intermittent water supply;

> *"The Management of Ghana Water Company Limited wishes to announce that with the onset of the dry season, we are experiencing some challenges with water supply in Accra and most parts of the country. We are sorry to inform the consuming public that, the situation has led to intermittent water supply in most Cities and Towns in the country. It must be emphasized that during this season, a number of consumers resort to the use of treated water for keeping*

> *lawns green, for commercial washing of vehicles etc. The dry season is on and consumers with greater dependence on rainwater have also compounded the problem by taking to treated water use. These practices ease the pressures in the pipelines thereby causing low pressure and no flow in some areas, especially areas located in high elevations…."* (Ghana News Agency, 2018; The Herald, 2018).

A survey conducted by the CSWA in 2014 also point to unreliability of small town piped schemes (CWSA, 2015a, 2015b, 2015c) . From the survey, 8% of small town water piped schemes in the Upper West Region and 20% in the Upper East Regions were unreliable (CWSA, 2015a). Poor services of piped water systems are largely due to inadequate funds arising from low tariffs and uncollected revenues for operations and maintenance because they are self-financing (Kumasi, 2018; Nedjoh & Esseku, 2016). Due to high poverty levels in Ghana (Ghana Statistical Service, 2018), management of water supply systems and regulators deliberately keep tariffs low to motivate households use safe water (Kumasi, 2018).

The problem of Intermittent Water Supply (IWS) in developing countries is not only associated with piped water systems but also non-piped water sources. Boreholes, the most common source of water is characterised with breakages and low levels of services (Harvey, 2004). In 2009, about 36% of handpumps in Sub-Saharan Africa were reported to be non-functional (Rural Water Supply Network, 2009). In Ghana, the CWSA in 2015 reported that 17.2% of boreholes in the Upper West Region and 13.3% in the Upper East Regions were non-functional (i.e water does not flow) (CWSA, 2015a, 2015c). They also rated the performance of 13.4% of boreholes in the Upper West Region and 9.4% in the Upper East Region as sub-optimal (thus, it takes more than five strokes for water to flow) (CWSA, 2015a, 2015c). Overall, 9% and 14% of handpumps in the Upper East and Upper West Regions were unreliable (CWSA, 2015a, 2015c). Harvey (2004, p.1) observed that "the likelihood of a borehole failure in Ghana increased by a factor of six when drilled in the rainy season". He attributed the causes of borehole failure to the confluence of limited knowledge of the hydrogeological conditions by operating staff, inadequate equipment and lack of effective government regulation and supervision of drillers, largely private contractors and NGOs.

In periods of borehole failures, quick repair can help moderate the impact of water unavailability. However, repair periods in developing countries are high. In Ghana, the CWSA revealed that only 52% of boreholes in the Upper West Region and 54% in the Upper East Region are repaired within 3 days after breakage (CWSA, 2015a, 2015c).

Unreliable water supply has dire consequences for the health of population. First of all, it increases risk of water borne diseases (Bivins et al., 2017; Hunter et al., 2009; Lechtenfeld, 2012; Majuru et al., 2013; Nygård et al., 2007) through ingress of contaminants in openings around pipes during pressure losses or households using unsafe water sources during interruptions (Kumpel & Nelson, 2016; Majuru et al., 2013). A microbial risk assessment of IWS by Bivins et al. (2017) in developing countries revealed that IWS may account for 17.2 million infections, causing 4.52 million cases of diarrhoea and 1,560 deaths each year. They indicated that the burden of diarrheal disease associated with IWS exceeds the WHO health-based normative guideline for drinking water of 10^{-6} DALYs per person per year (Bivins et al., 2017, p. 1). Unreliable water supply also undermines food security, income and educational attainment of water collectors and their households due to lack of water for production and high water collection time from alternative sources (Majuru et al., 2016; Subbaraman et al., 2012).

2.5 Conclusion

To sum up, drinking water availability is a subject of interest in many disciplines including geography. Contemporary geographical work on drinking water include but not limited to access to drinking water, gender-water relations and commodification of water. This study builds on and contributes to access to drinking water. The review has shown that the improved water metric employed by the JMP to measure access to drinking water in the MDG era was narrow. It fails to address important aspects of drinking water supply like accessibility, quality, and reliability. Consequently, gains in water coverage did not correlate with improvements in health, especially in developing countries. In recognition of the deficiency of the MDG improved water metric, a more robust indicator known as 'safely managed water' was adopted in the SDG era. It encapsulates three important aspects of drinking water supply –

accessibility, quality and reliability. Using the Upper Regions of Ghana as a case study, the study explores the extent of accessibility, quality and reliability of drinking water sources in a developing setting to inform monitoring and the provision of safely managed water for all by 2030 as envisioned by target 6.1 of the SDG.

As mentioned earlier, the term *accessibility* as used in this study refers to the ease of collecting water from source in terms of time and distance (WHO, 2011; Howard 2003). *Quality* simply involves compliance of drinking water sources to microbial, chemical and radiological standards (WHO, 2011a). Three quality parameters of significant health concern, both at the global and national scales were assessed: faecal matter, fluoride and arsenic. Finally, the term *reliability* as used in this study refers to the frequency of water availability from source over a period of time (WHO, 2011a).

3 THE GEOGRAPHY OF GHANA

The geography of Ghana presented here focuses on key physical, environmental, political and socio-economic characteristics that lend relevance to the study, with emphasis on the Upper Regions of Ghana, the study area. They include location and size, population, political and administrative structures, climate and ecology, geology and hydrology, sanitation, educational attainment, occupational distribution and incidence of poverty.

3.1 Location and Size

Ghana is situated in West Africa on the Guinea coast with a total land area of 238, 537km^2 (Ghana Statistical Service et al., 2015). It lies close to the equator between latitude 11.5^0 N and 4.5^0 S and longitude 3.5^0 W and 1.3^0 E (Government of Ghana, 2015a). The country has a north-south extent of about 670 km and a maximum east-west stretch of about 560 km (FAO, 2005b). It is bordered by Côte d'Ivoire to the west, Burkina Faso to the north, Togo to the east and to the south by the Gulf of Guinea (Ghana Statistical Service et al., 2015).

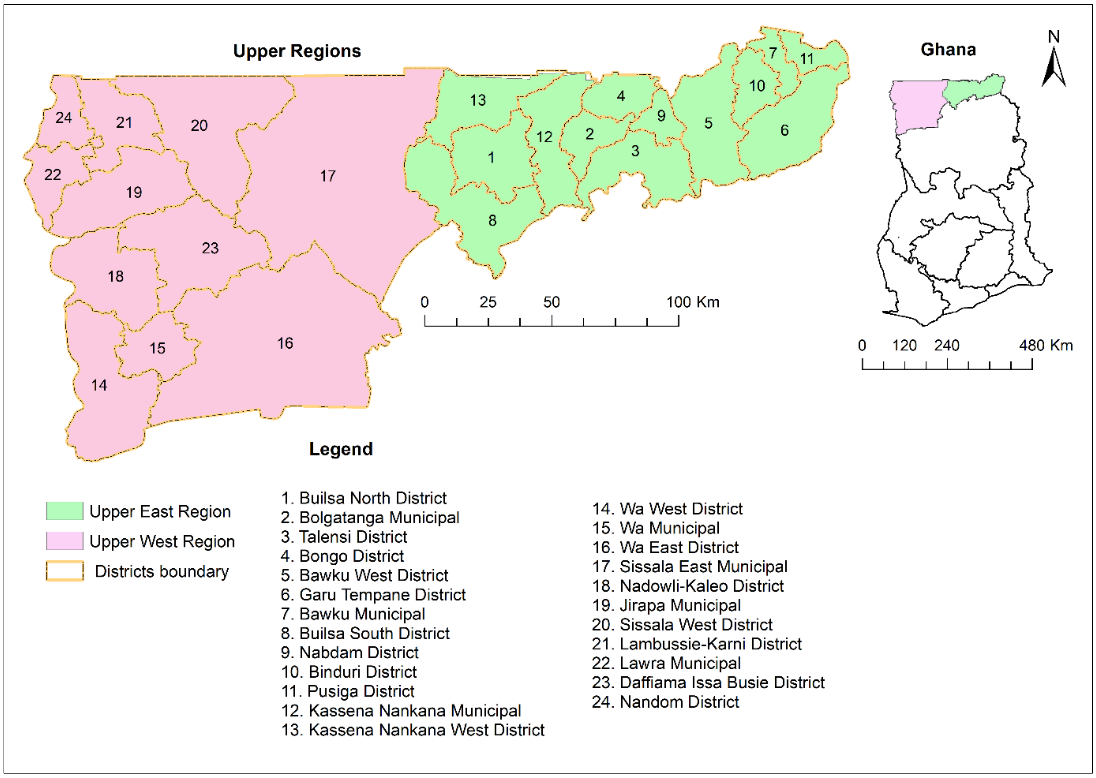


Figure 3.1: Map showing locations of Upper East and Upper West Regions in Ghana

Source: Author's construct, November 2018

The study was conducted in the two Upper Regions of Ghana - Upper West and Upper East Regions (Fig. 3.2). These two regions are located in the uppermost part of Ghana. The Upper East Region of Ghana is located in the north-eastern part of Ghana, and lies within longitudes 0^o 02' E - 1^o 32' W and latitudes 10^o 22' N - 11^o 11' N (Agyekum & Dapaah-Siakwan, 2008). It is bordered to the north by Burkina Faso, to the east by Togo and to the south and west by Northern Region and the Upper West Regions of Ghana, respectively. The region covers a total land area of 8,842km^2, representing 2.7% of the total land area of Ghana (GSS, 2013b). The Upper West Region on the other hand is situated in the north-western part of Ghana with Wa as its capital. It shares boundary with Burkina Faso to the north, Upper East Region to the east, Northern Region to the south and Côte d' Ivoire to the west. The region lies within latitude 9^{o}40$'$ W - 11^{o}5$'$ W and longitude 1^{o}20$'$ N - 2^{o}55$'$ N (GSS, 2013a). It covers a total land area of 18,476 square kilometres, constituting 12.7% of the total land area of Ghana

3.2 Population Size and Composition

The Population of Ghana as recorded in the 2010 Population and Housing Census was 24,658,823, an increase of 30.7% over the figure recorded in the 2000 Population Census (Ghana Statistical Service, 2013d). The average annual growth rate between 2000 and 2010 was 2.5% (Ghana Statistical Service, 2013d). Based on this annual growth rate, the population of Ghana for 2016 was projected to be 28,596,675. The proportion of females recorded in the 2010 Population and Housing Census was slightly higher (51%) than males (49 per cent) (Ghana Statistical Service, 2013d).

The regional distribution of the population is uneven. From the 2010 Population and Housing census, Ashanti region (19.4 per cent) recorded the highest proportion of total population, followed by the Greater Accra Region (16.3%) (Ghana Statistical Service, 2013d). Upper West and Upper East Regions, both in Northern Ghana recorded the lowest proportions of total population, that is, 2.8% and 4.2% respectively (Ghana Statistical Service, 2013d). Although Northern Ghana occupies approximately 41% of total land area of Ghana, its share of population was 17.1% (Ghana Statistical Service, 2013d). The area is therefore less populated compared to southern Ghana. From the 2010 population and housing census, the average population density for all three regions of the north is 64 persons per square kilometre, almost half of the national average (103 persons per square kilometre) (Ghana Statistical Service, 2013d). Northern Region had the least population density (35 persons per square kilometre), followed by the Upper West Region (38 persons per persons per square kilometre) (Ghana Statistical Service, 2013d). The low population density of Northern Ghana is often attributed to north-south migration.

Low socio-economic development of Northern Ghana compared to Southern Ghana, coupled with the harsh environmental/climatic conditions limits agricultural activities, the main source of livelihood of the people. This triggers temporary out-migration and in some cases permanent out-migration of population from Northern Ghana to Southern Ghana, in search of greener pastures. Whereas men out-migrate to engage in farming and 'galamsey' (small scale illegal mining) activities, women, particularly young girls are engaged as house helps or are 'kaayayee' (head potters) in urban areas.

The 2010 Population and Housing Census (PHC) revealed for the first time that more people live in urban areas in Ghana than in rural areas. The proportion of urban population was found to have increased from 23.1% in 1960 to 50.9% in 2010 (Ghana Statistical Service, 2013d). The three northern regions, however, remain largely rural. The proportions of urban population in the Upper East, Upper West and Northern regions were 21%, 16.3% and 30.3%, respectively (Ghana Statistical Service, 2013d).

The population structure of Ghana mirrors that of a pyramid, which is typical of most developing countries. It has a broad base consisting of large numbers of children and a conical top of a small number of aged persons. The results of the 2010 Population and Housing Census showed that 38% of persons are less than 15 years, 57% between 14 and 65 years, and 4.7% above 65 years plus (Ghana Statistical Service, 2013d).

3.3 Political and Administrative Structure

Administratively, Ghana is divided into 10 regions, namely, Greater Accra, Central, Eastern, Volta, Western, Ashanti, Brong-Ahafo, Northern, Upper East and Upper West Regions (see Map 1). The main administrative structure at the regional level is the Regional Co-ordinating Council (RCC), headed by the Regional Minister. Northern Ghana is made up of three regions, that is, Northern, Upper East and Northern Regions (Fig. 1). It covers a geographic area of 97,700 km^2, representing 41% of the total land area of Ghana.

Each of the 10 regions is sub-divided into Metropolitan Areas/Municipalities/Districts (MMDs)[4]. Currently, there are 6 Metropolitan Areas, 56 Municipalities and 154 Districts in Ghana (Commonwealth Local Government Forum, 2016). MMDs have sub-administrative structures. The Metropolitan Areas have a four-tiered administrative structure whereas Municipal Areas and District have a three-tiered administrative system (see Fig. 1)(Commonwealth Local Government Forum, 2016).

[4] The minimum population threshold for Metropolitan Area, Municipality and District are 250,000, 95,000 and 70,000 respectively

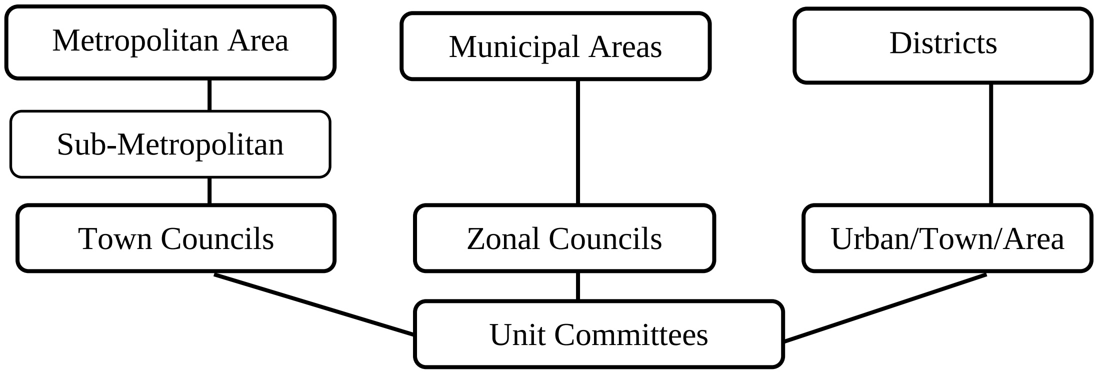


Figure 3.2: Local government administrative structure in Ghana

The highest political authority at the MMD level is the Assembly with deliberative, legislative and executive powers. For the purpose of electing local representatives into the Assemblies, Urban/Zonal/Town/Area Councils are zoned into electoral areas. Each electoral area elects people into the Assembly for a period of 4 years. Electoral areas also constitute the unit for the election of Unit Committee members who support elected Assembly members in their work at the community level. Due to the vastness of the Upper Regions, the study draws on the local government structure to select MMDs and further electoral areas for detail study through multi-stage sampling.

3.4 Climate and Ecology

Ghana has a tropical climate which is strongly influenced by the West African Monsoon (Oxford University, 2008). The rainfall seasons of the country are controlled by the movement of the tropical rain belt (also known as the Inter-Tropical Convergence Zone (ITCZ), which oscillates between the northern and southern tropics over the course of the year (Oxford University, 2008).

The northern[5] and southern parts of the country experience different rainfall regimes. Southern Ghana has two wet seasons, one from March to July, and a shorter wet season from September to November, corresponding to the northern and southern passages of the ITCZ across the region (Oxford University, 2008). Conversely, Northern Ghana

[5] Upper West, Upper East and Northern Regions

has a single wet season occurring between May and October (Oxford University, 2008). The area, however, remains relatively dry from November – April (Oxford University, 2008). The amount of rainfall recorded annually varies between 750 millimetres and 1,050 millimetres (Ghana Statistical Service, 2013a).

Annual rainfall in Ghana is highly variable on inter annual and inter decadal timescales (Oxford University, 2008), particularly in Northern Ghana. This implies that rainfall patterns are difficult to predict (Oxford University, 2008). In the past two decades, high incidence of rainfall variability and drought are more pronounced in northern Ghana. An average decline of 2.3 mm of rainfall per month (2.4per cent) per decade occurred between 1960 and 2006 (Oxford University, 2008). This has negative impacts on both surface water and ground water availability (Government of Ghana, 2015a).

The oscillation of the ITCZ between the southern and northern tropics in the course of the year also impacts on temperature levels. The northern part of the country which remains dry for half of the year (November – April) due to the harmattan winds records higher temperature compared to the south. During the harmattan period, particularly from December to March, temperature in Northern Ghana may vary between 14°C at night and a high of 40°C during the day (Government of Ghana, 2016). Humidity is, however, very low making the daytime high temperature uncomfortable (Ghana Statistical Service, 2013b). The high daily temperatures recorded in the dry season result in high evapotranspiration, and thus limits ground water recharge (Smedley et al., 2002). Mean annual temperature in Ghana is reported to have increased by 1.0°C since 1960, an average rate of 0.21°C per decade (Oxford University, 2008). The rate of increase has generally been more rapid in Northern Ghana than in the south (Oxford University, 2008). Mean annual temperature is projected to increase by 1.0 to 3.0°C by the 2060s (Oxford University, 2008).

The country is divided into six agro-ecological zones on the basis of their climate (FAO, 2005a; Government of Ghana, 2015a). These agro-ecological zones from north to south are: Sudan Savannah Zone, Guinea Savannah Zone, Transition Zone, Semi-deciduous Forest zone, Rain Forest Zone and the Coastal Savannah Zone (FAO, 2005a; Government of Ghana, 2015a). The ecological zones in Northern Ghana consists of Guinea and Sudan Savannahs. They are characterized by short scattered drought-resistant trees and grass that gets burnt by bushfire or scorched by the sun during the long dry season (Ghana Statistical Service, 2013b). The semi-arid nature of the region limits groundwater availability and reliability of water sources (Smedley et al., 2002).

3.5 Geology and Hydrology

The Geology of Ghana is largely dominated by crystalline basement rocks, consisting of metamorphosed sediments and granites (British Geological Survey, 2000). A simplified geological map of Ghana (Fig. 3.3) is presented by the British Geological Survey in its report titled '*Groundwater Quality: Ghana'* (British Geological Survey, 2000, p. 1). The spatial distribution of the geology is summarized as follows;

- The north-western part is mainly made up of granites;
- The upper most part of north-east, which lies within the Upper East Region, have a mix of granites and birimian (middle precambrian)
- The south-western part is made up of birimian, with pockets of granites;
- The central part, stretching all the way to the north-eastern part of the country consists of the voltaian formation (late precambrian/early palaeozoic)
- From the Guinea coast in the south-east all the way to the eastern part is made up of younger sediments (sand, clay and gravel) of the coastal basin

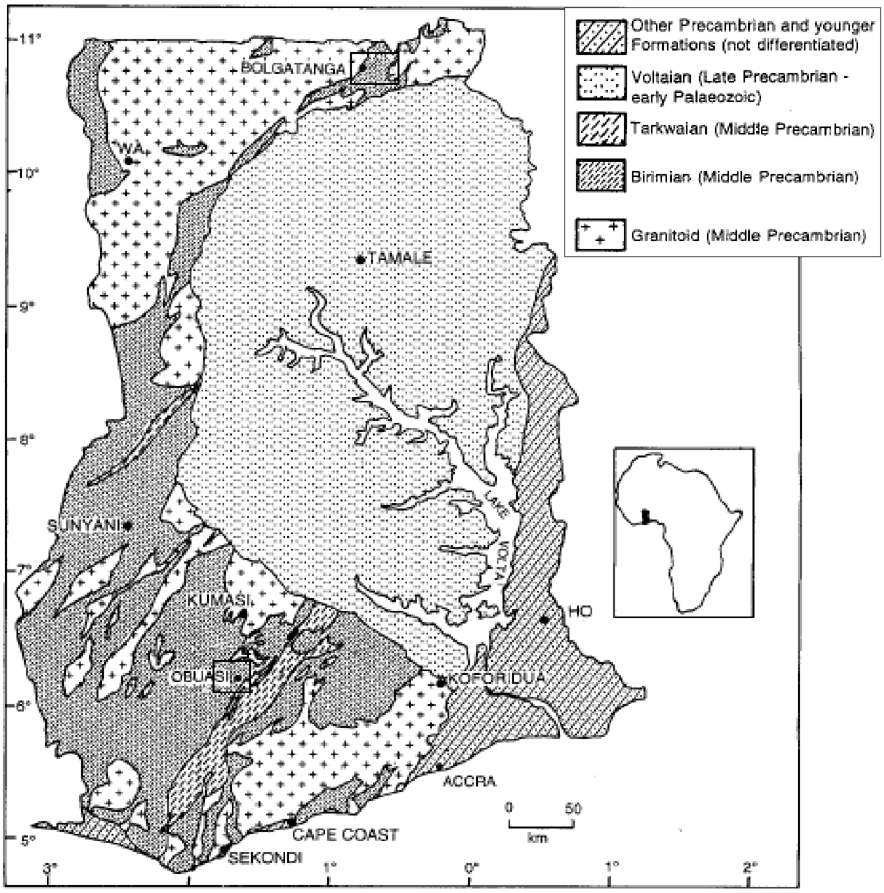


Figure 3.3: Simplified geological map of Ghana (British Geological Survey, 2000)

A recent geological mapping by the Physical Planning Department (PPD) of the Upper Regions of Ghana showed that the area is dominated by crystalline rocks of granite (42%), followed by alluvium (31%), Voltaian sandstone (18%), sandstone (8%) and Birimian (1%) (Fig. 3). The PPD geological classification is slightly different from the work of the British Geological Survey (2000). The mapping of the British Geological Survey (2000) if compared to the work of the PPD of Ghana revealed that the alluvium is a recent formation and a surface geology, covering parts of Birimian and granite. For instance, the alluvium formation, which stretches from the north-east to south-west in the Upper East Region (Fig. 3.4) is symmetrical to the area classed by the BGS as Birimian (Figure 3.3). The perennial flash flood Ghana has experienced over the past decade might have caused the deposition of large alluvium in many areas of the country.

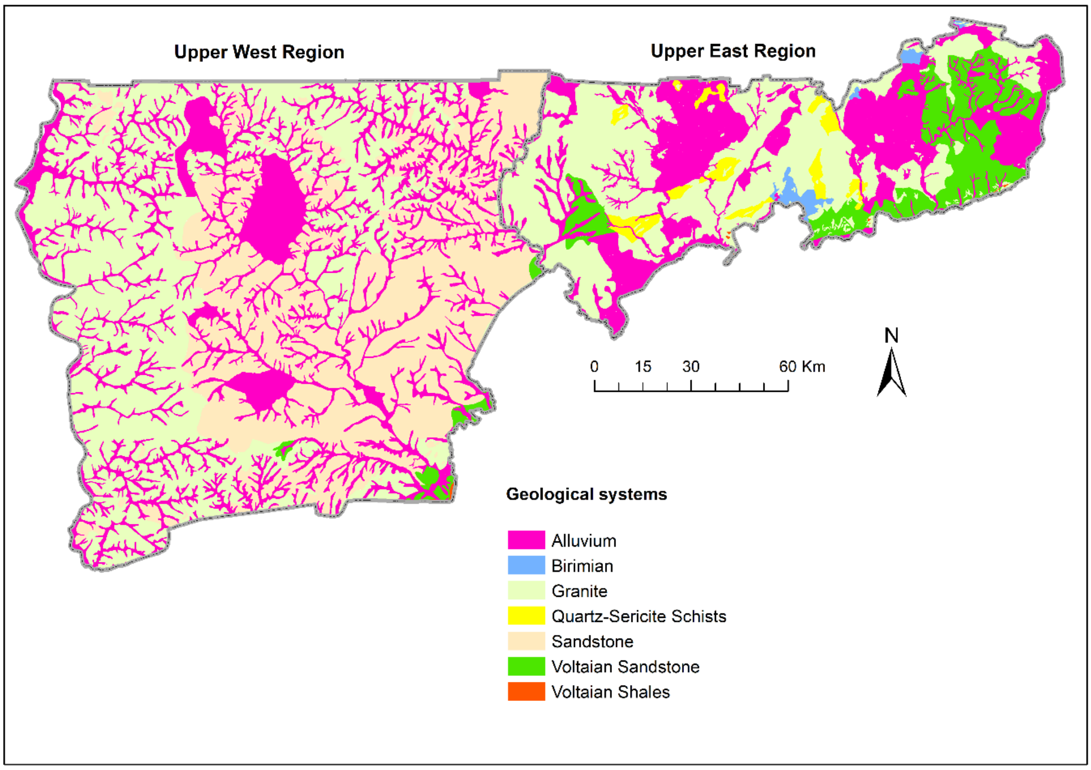


Figure 3.4: Geological systems in the Upper Regions of Ghana

Source: Author's construct (2018) with data from Physical Planning Department (2015)

The geology of Ghana impacts groundwater quality (British Geological Survey, 2000). The British Geological Survey (2000) in its review on groundwater quality in Ghana in the year 2000, linked the presence of excess iron, fluoride, manganese, arsenic and iodine deficiency in Ghana to its geology (British Geological Survey, 2000). Excessive iron and manganese were associated with all aquifers and for that matter present in many parts of the country (British Geological Survey, 2000). High concentration of fluoride and iodine deficiency (the most serious direct health problems related to drinking water) are reported to be predominant in the Upper East Region possibly due to the presence of granites (British Geological Survey, 2000). South-west Ghana, with large presence of Birimian rock was also earmarked as an area of excessive arsenic (British Geological Survey, 2000).

The granite in the Upper East Region is reported to have fluoride bearing minerals of biotite, hornblende, amphibole, apatite and sphene (Agyekum and Dapaah-Siakwan, 2008; Edmunds and Smedley, 2005). Smedley et al., (1995) found that the granite extending from the north to the south of the Upper East Region contains up to 0.2% of fluoride. This exposes groundwater in the region to risk of high fluoride concentration.

The underlying crystalline rocks in Ghana limits ground water supply as yield is mostly restricted to joints and fractures (British Geological Survey, 2000; Smedley et al., 2002). The situation in Northern Ghana is further compounded by the semi-arid nature of the ecology[6]. In the Upper East Region, borehole success rates (yields of 0.1 L s^{-1} or greater) vary between 50% and 95% (Smedley et al., 2002) . Borehole depths ranges from 28 to 60 m (Agyekum & Dapaah-Siakwan, 2008). Estimated yield of boreholes ranges from 0.1 to 6 l/s, with the average being 0.8 l/s (Agyekum & Dapaa-Siakwan, 2008). High yields are recorded in highly fractured granitic and Birimian rocks (Agyekum & Dapaa-Siakwan, 2008).

3.6 Sanitation

Poor sanitation is an issue of major health concern in developing countries. Open defecation in particular poses a threat to food safety, including drinking water (Mkwate et al., 2016). In Ghana, poor sanitation is linked to preventable diseases like acute respiratory infections, cholera and diarrhoea (Ghana Statistical Service et al., 2015). From the 2014 DHS, only 15% of the population in Ghana had access to improved[7] toilet facilities (Ghana Statistical Service et al., 2015). In the same survey, 54.7% of population were reported to be using improved facilities but shared toilets. The remaining 30.3% used unimproved facilities, of which 21% practise open defecation. The findings of the 2014 DHS are not very different from the JMP estimates at the end of the MDG period in 2015 (WHO/UNICEF Joint Monitoring Programme, 2015d). Like the DHS, the JMP estimates put improved toilet coverage in Ghana at 15% (WHO/UNICEF Joint Monitoring Programme, 2015d). The proportion of population using improved but shared facilities and unimproved facilities were 60% and 35% respectively. Of the population using unimproved toilet facilities, the JMP estimates

[6] See section 4 above
[7] Includes flush or pour–flush facility to piped sewer system, septic tank or pit latrine; ventilated improved pit latrine, pit latrine with slab and composting toilet that are not shared or public (WHO/UNICEF Joint Monitoring Programme, 2006b).

revealed that 19% were practising open defecation (WHO/UNICEF Joint Monitoring Programme, 2015d).

Significant disparities exist in access to toilet facilities across space. Relatively, access to improved toilet facilities in urban areas is higher than in rural areas. Form the 2014 DHS, 9.6% of population in rural areas were using improved toilet facilities that were not shared compared to 20.5% in urban areas (Ghana Statistical Service et al., 2015). About three out of 10 people in rural areas practise open defecation compared to one out of 10 in urban areas. Besides rural-urban disparities, access to toilet facilities also varies by regions. Disaggregated data by types of toilet facilities in the 2010 PHC revealed that access to Water Closets (WC) was very low in Northern (2.4%), Upper West (3.1%) and Upper East (3.4%) regions compared to Ashanti (23.2%), Western (13.4%) and Greater-Accra (31%) regions (Ghana Statistical Service, 2013c). Furthermore, in each of the three regions of northern Ghana (Upper West, Upper East and Northern) over 70% of the population practise open defecation compared to less than 30% in regions of southern Ghana (Ghana Statistical Service, 2013c). This implies that the impact of open defecation on health is disproportionally higher in northern Ghana.

Poor solid waste management further worsens the sanitation situation in Ghana. In 2015, Miezah et al. (2015) estimated that about 12,710 tons of solid waste is generated per day in Ghana. Meanwhile, from the 2010 PHC report, less than half of households' dispose of waste appropriately; 14.4% of households have their waste collected, 23.8% dumped waste in public containers while 3.3% burned waste (Ghana Statistical Service, 2013c). The remaining households were engaged in various forms of inappropriate waste disposal methods, comprising of burning (10.7%), dumping in a central public space (37.7%) as well as indiscriminate dumping (9.1%) (Ghana Statistical Service, 2013b). Due to lack of controlled waste management systems in most settlements in Ghana (Bowan et al., 2014), waste collected also ends up in the open. Household waste often contains children's and animal faeces, and thus exposes both surface and groundwater to risks of contamination through leachate if not well managed.

3.7 Educational Attainments

Educational attainment in Ghana is generally low. An analysis of the educational level of persons aged 6 years and above in the 2010 PHC revealed that only 5.7% had tertiary education, 3.5% had secondary education, 64.8% had basic education, 2.5% completed only nursery/kindergarten and 23.5% never attended school (Ghana Statistical Service, 2013d). The proportion of females who have never been to school (28.3%) was 10 percentage points higher than males (18.3%).

The 2010 PHC revealed spatial variations in the educational attainment of the population in Ghana (Ghana Statistical Service, 2013d). The proportion of population that have had tertiary education ranged from 2.5% in Volta and Northern Regions to 11.4% in Greater Accra Region. Also, the proportion of persons aged 6 years and above who never attended school was highest in the Northern (56.6%), followed by Upper West (48.2%) Upper East (45.8%) Brong-Ahafo (26.7%), Volta (24.1%), Western (20.8%), Eastern (17.1%), Central (19.2%), Ashanti (15.4%) and Greater Accra (10%) Regions. From the census, the education level of urban population is higher than that of rural population; whereas one out of every 10 persons in urban areas has never attended school, in rural areas it is three out of every 10 persons.

The findings of the 2014 GLSS compared to the 2010 PHC revealed marginal improvement in the educational attainment of Ghana's population. The proportion of population with at least secondary education increased from 9.2% in 2010 to 14.7% in 2014 (Ghana Statistical Service, 2013d, 2014c). From the 2014 GLSS, 24.3% of females have never been to school i.e., four percentage points lower than that recorded in the 2010 PHC. Although the 2014 GLSS revealed a reduction in the proportion of females who have never been to school, the percentage difference compared to males remained 10% higher like the 2010 PHC.

The generally low educational attainment of Ghana's population, especially females who are responsible for water collection, can affect access to safe water. Gomez et al. (2019), in their analysis of socio-economic factors affecting access to water in rural areas in developing countries found a positive association between female primary school completion rate and access to improved water; an increase of 1% in female primary completion rates will translate into a 0.23% increase in improved water coverage. They argued that women are the primary collectors of water in developing countries, and thus will put pressure on duty-bearers to provide water if educated.

3.8 Occupational Distribution

As with most developing economies, the main occupation in Ghana is agriculture. From the 2010 PHC, 45.8% (2,503,006) of households in Ghana were engaged in the agricultural sector (Ghana Statistical Service, 2013d). The main agricultural activity of households was crop farming. Half of agricultural households were engaged in crop farming for consumption, income and cultural purposes. A few households were engaged in tree planting and fish farming (Ghana Statistical Service, 2013d). Furthermore, the 2010 PHC revealed that the proportion of rural households (75.3%) engaged in agriculture is three times higher than those in urban areas (22%). With the exception of Greater Accra, Ashanti, Northern and Western Regions, over 50% of households in all other regions are into agriculture. The Upper East Region recorded the highest proportion of households in agriculture (83.7%), followed by the Upper West Region (77.1%) (Ghana Statistical Service, 2013d).

From Table 3.1, the occupational distribution of persons recorded in the 2014 GLSS is not very different from the 2010 PHC. Almost half (44.3%) of employed persons above 14 years were working in the agricultural sector, with significant disparities between rural and urban areas. About seven out of every 10 employed persons in rural areas are into agriculture compared to two out of 10 in urban areas. From the 2014 GLSS, the dominant occupation in urban areas is service or sale work (Table 3.1).

Table 3.1: Occupational distribution of employed persons aged 15 years and above

Main occupations	Urban	Rural	Total
Legislators/managers	2.4	0.5	1.4
Professionals	7.8	2.2	4.9
Technicians and associate professionals	3.1	0.5	1.8
Clerical support workers	2.3	0.3	1.3
Service/sales workers	38.7	11.1	24.5
Agricultural workers	16.5	70.7	44.3
Craft and related trades workers	17.6	8.1	12.7
Plant machine operators and assemblers	6.5	2.4	4.4
Elementary occupations	4.9	4.2	4.5
Other occupations	0.1	0	0.1
All	100	100	100

Source: (Ghana Statistical Service, 2014c)

Crop farming, the major agricultural activity in Ghana is mostly done on a small-scale basis. With the exception of industrial crops, farm holdings for a majority of farmers are less than two hectares (MoFA-Ghana, 2016). Crop farming is largely labour-intensive with the main implements being hoe and cutlass (MoFA-Ghana, 2016). Hence, high water collection time can affect the hours spent on agricultural production leading to low output.

3.9 Incidence of Poverty

Based on a poverty line of Ghc1,314.00 ($297.00), 23.4% (approximately 7 million) of the population in Ghana in 2016/17 were estimated to be poor (Ghana Statistical Service, 2018); a reduction of 0.8 percentage points compared to 2012/13 (Ghana Statistical Service, 2018). However, in absolute terms, the number of poor people within the same period (2012/13 to 2016/17) increased by 400,000 (Ghana Statistical Service, 2018).

Figure 3.5 shows regional disparities in the incidence of poverty. In 2016/17, it ranged from 2.5% in Greater-Accra Region to 70.9% in the Upper West Region. For the past 15 years, the incidence of poverty in the Upper West, Upper East and Northern Regions is generally high compared to other regions (Ghana Statistical Service, 2015, 2018). This reflects the underdevelopment of northern Ghana; a situation scholars and international development agencies have largely attributed to unfavourable soil and climatic conditions, neglect by colonial governments and poor policies of post-independent governments (Dickson, 1968; Plange, 1979; World Bank, 2006).

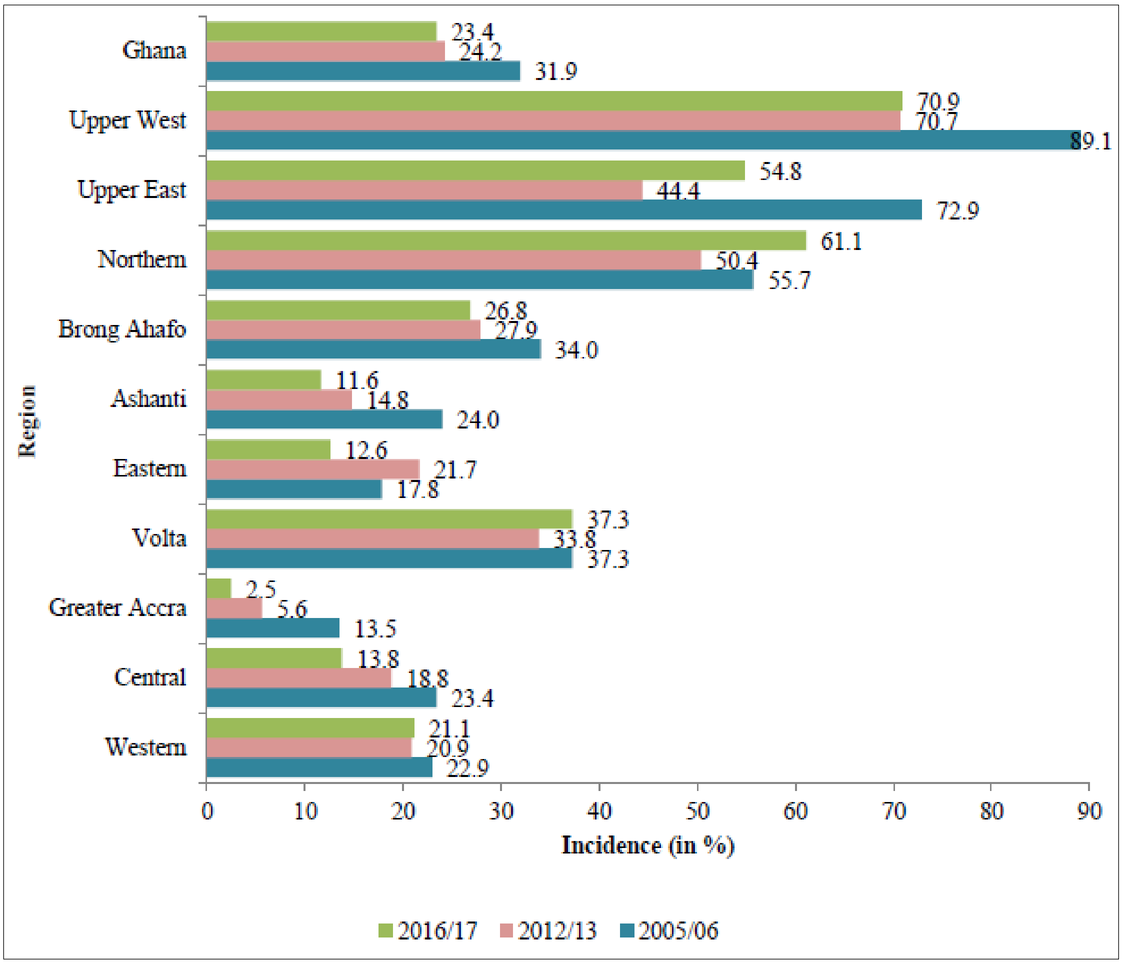


Figure 3.5: Incidence of poverty by region, poverty line = GH¢1,314

Source: (Ghana Statistical Service, 2018)

The incidence of poverty in rural areas is higher than in urban areas. Available statistics showed that in 2016/17, the incidence of poverty in rural areas was 39.5% compared to 7.8% in urban areas (Ghana Statistical Service, 2018). Whereas the incidence of poverty in urban areas has reduced by 2.8% within the period 2005 – 2017, it has increased by 1.6% in rural areas.

4 RESEARCH METHODOLOGY

4.1 Introduction

This chapter systematically outlines the research methods. First, it sheds light on the research approach and design employed in the study. This is followed by a detailed description of the study population, sample size and design, data collection methods, fieldwork, data preparation and analysis, positionality, ethical issues and methodological limitations.

4.2 Research Approaches[8]

A research approach is the general orientation to the conduct of social research (Bryman, 2016). Traditionally, there are two broad types of research approaches. These are qualitative and quantitative approaches (Bryman, 2016; Creswell, 2009; Kumar, 2011). Quantitative and qualitative approaches are often viewed as discrete entities at the opposite end of a continuum (Creswell, 2009). The difference between them is based on their epistemological and ontological orientations (Bryman, 2016; Creswell, 2009).

Quantitative research emphasizes measurements in the collection and analysis of data (Bryman, 2016; Creswell, 2009). It is deeply inclined to positivism and post-positivism epistemological worldviews (Bryman, 2016; Creswell, 2009). One of its basic tenets is objectivity of social reality (Bryman, 2016). Subscribers to this approach believe in testing theories deductively, building in protection against bias, and being able to generalise and replicate findings (Creswell, 2009). Variables are measured so that numeric data can be generated and analysed using statistical procedures (Creswell, 2009).

In contrast, qualitative research is viewed as research that lays stress on words rather than quantification in the collection and analysis of data (Bryman, 2016). It is more aligned to social constructivism epistemological worldviews and its underlying

[8] Used variously as research approaches(Creswell, 2009), research strategies (Bryman, 2016), research types (Kumar, 2011)

scientific method of inquiry (Bryman, 2016; Creswell, 2009). Qualitative researchers often seek to explore, understand and explain the meaning individuals or groups ascribe to social phenomena (Creswell, 2009). To qualitative researchers, the meanings individuals attach to social phenomena are varied and multiple, driving them to dig deep to unravel these complex meanings rather than narrowing meanings into a few categories or ideas (Creswell, 2009). Data analysis in qualitative research takes the form of inductive analysis, thus from particular to general themes (Bryman, 2016; Creswell, 2009).

Both quantitative and qualitative approaches have shortcomings, and hence are sometimes unable to establish, independently, adequate facts for drawing new conclusions. In search of strategies to overcome the weaknesses of using one approach, the use of both approaches in a single study has evolved, and is gaining wider popularity in social research (Bryman, 2016; Creswell, 2009). The combination of both quantitative and qualitative strategies in a single study is popularly known as mixed methods research[9] (Bryman, 2016; Creswell, 2009). This approach maximises the strength of both qualitative and quantitative research, providing an in-depth understanding of research problem (Creswell, 2009). It is most suitable in studies where the researcher wants to generalise the findings to a population and also provide detailed explanations on the issue considered for investigation (Creswell, 2009). In contemporary times, several journals encourage the application of mixed methods research. They include but are not limited to the journals of *Mixed Methods Research*, *Quality and Quantity,* and *Field Methods*. Though a relatively new approach, it has been widely used in the social and human sciences (Creswell, 2009). The approach is, however, not without challenges. It is data demanding and time consuming (Creswell, 2009). The investigator must also have expertise in both qualitative and quantitative methods (Creswell, 2009). In respect of the strengths of a mixed method research, it was adopted in this study. Both quantitative and qualitative methods were combined in data collection and interpretation of results. The next section indicates the specific mixed method design or strategy employed in the study. This is followed by the sampling design, data collection methods and data analysis methods.

[9] Also refers to as integrating, synthesis, quantitative and qualitative methods, multimethod, and mixed methodology (Creswell, 2009)

4.3 Research Design[10]

Research design is the framework for the collection, analysis and presentation of data (Bryman, 2016). Research designs vary by approach and the ones discussed here are limited to mixed methods research, the approach adopted in the study. After highlighting the typologies of mixed methods designs, the review focuses on the design employed in the study. John W. Creswell, the most cited scholar in mixed methods research, identified six typologies of mixed methods research, depending on the phases in qualitative and quantitative data collection (concurrent or sequential), weight of qualitative and quantitative methods (equal or unequal), how data is mixed (separate or combined) and whether the study is being shaped explicitly or implicitly by a theory (Creswell, 2009). The six typologies or designs include sequential explanatory design, sequential exploratory design, sequential transformative design, concurrent triangulation design, concurrent embedded design and current transformative design.

This study adopted a concurrent embedded mixed method design. This design involves "the collection of both qualitative and quantitative data in a single study with priority given to one method over the other. The method that receives less emphasis is embedded, or nested within the predominant method. Data from the two methods is mixed to gain a broader perspective of the issue being investigated" (Creswell, 2009, p.215). In this study, priority was given to quantitative data in answering the research questions with less emphasis on qualitative data. To a large degree, qualitative data was used to cross-validate the quantitative data. It is suitable when the researcher wants to apply different methods of data collection to study different groups (Creswell, 2009, p.215) as carried out in this study. This design was also chosen because it allowed for the collection of both quantitative and qualitative data in one phase, thereby saving data collection time. This approach is not without limitations, however. If the two data are compared, discrepancies may occur that need to be resolved. Also, because the two methods are unequal, this approach leads to unequal evidence in a study, which may be a disadvantage when interpreting results" (Creswell, 2009, p.215).

[10] Creswell calls it strategy of inquiry

4.4 Study Population

Before describing the study population, it is worth restating that the Upper Regions of Ghana, comprising of Upper East and Upper West Regions were purposively chosen for the study. The choice of study area is justified in section 1.5.

In social research, a study population is simply a collection of all units that can provide answers to the phenomena under investigation. Answers to the research questions posed in this study can reliably be elicited from households, because it is the level at which decisions regarding water consumption are made. Households[11] therefore constitute the main population in this study. Data were also gathered from three key institutions with direct responsibility in water supply and management to corroborate the household data. They include Water and Sanitation Committees, Community Water and Sanitation Agency and Ghana Water Company Limited. The total number of units within each population sub-group is presented in Table 4.1.

Table 4.1: Study population

S/N	Population sub-groups	Total
1.	Households	334,181[12]
3.	Community Water and Sanitation Agency	24
4	Small Town Water Supply Systems	21
5.	GWCL	3
6.	WATSANC	6,660[13]

[11] This study adopts the Ghana Statistical Service definition of a household - "a person or a group of persons, who live together in the same house or compound, share the same house-keeping arrangements and recognize one person as the head of household"

[12] An exponential projection of the total number of households in the Upper Regions as at 2016 based on the total number of households reported in the 2000 and 2010 Population and Housing Censuses for Upper West and Upper East Regions (GSS et al., 2013).

[13] Based on the following assumptions; (a) all 6,530 boreholes in the Upper West and Upper East Regions as at 2014 (CWSA, 2015) have WATSAN committees and (b) 1% annual increase in boreholes.

4.5 Sample Size and Design

4.5.1 Households

Households constitute the main unit of analysis in this study. However, it was not economically feasible to collect data from all households in the Upper Regions. Therefore, a representative sample of households was determined using Taro (1973) sample size formula;[14]

$$n = \frac{N}{1 + Ne^2}$$

Where n = Sample size

N = Population (334,181)

e = Level of precision or Sampling error (±5%)

The above formula is widely used in social science research for determining sample sizes (Dika et al., 2018; Fai-kam et al., 2016; Menkiti & Agunwamba, 2015; Tanwapa & Nakonthep, 2017). The formula is appropriate when the population is known (Israel, 2003). It assumes a conservative confidence level of 95%. It also assumes a maximum degree of variability/heterogeneity (p=0.5) within the population (Taro, 1973), and thus appropriate for determining a conservative sample size i.e., the sample size may be larger than if the true variability of the population attribute was used (Israel, 2003; Singh & Masuku, 2014). Based on a precision level (e) of ±5, a representative sample size of 400 households was obtained. This was increased by 20% to cater for non-responses and data rejections, bringing the sample to 480 households. Households were selected through a four level multi-stage sampling procedure (Fig. 4.1);

1. Firstly, the study area (Upper Regions) was stratified by administrative regions – Upper West (UWR) and Upper East (Gomez et al.). The 480 sample households were proportionally distributed between the two regions (Upper East[15] and Upper West[16]) based on projected number of households in each

[14] It assumes a maximum degree of variability/heterogeneity within the population (Yamane,1973 p1088)
[15] 281,484 households
[16] 132,697 households

region as at 2016. Thus, 289 households were earmarked for Upper East and 191 households for Upper West

2. Secondly, in each region, one district was sampled through simple random sampling for a detailed study rather than a thin spread of households across the entire region. Jirapa Municipality was selected in the Upper West Region while Kassena Nankana Municipality was selected in the Upper East Region (Fig. 3.1).

3. Thirdly, in each selected district, Electoral Areas (Measure DHS) were grouped into five geographic zones (north, south, east, west and central), and one EA sampled from each through simple random sampling. Of the five Electoral Areas selected in each district, one was urban and the remaining rural. This ensured a fair representation of both urban and rural households in the study because about one-fifth of EAs in Jirapa and Kassena Nankana Municipalities are urban. In total, 10 EAs (two urban and eight rural) were selected. Pre-field work, the total number of households in sampled EAs could not be accessed for a proportionate distribution of households. Hence, the targeted number of households in each district was distributed evenly among the five EAs. In Jirapa, 39 households were allocated to each EA while in Kassena Nankana Municipality 58 households were assigned to each EA.

4. Furthermore, in each Electoral Area (EA), households were selected through simple random sampling from a list of households obtained from gatekeepers. During fieldwork, the assigned samples for each Electoral Area in Jirapa Municipality was exceeded by 14/15 households and in Kassena Nankana Municipality by two households. In total, data were collected from 568 households, comprising of 268 from Jirapa Municipality and 300 from Kassena Nankana Municipality.

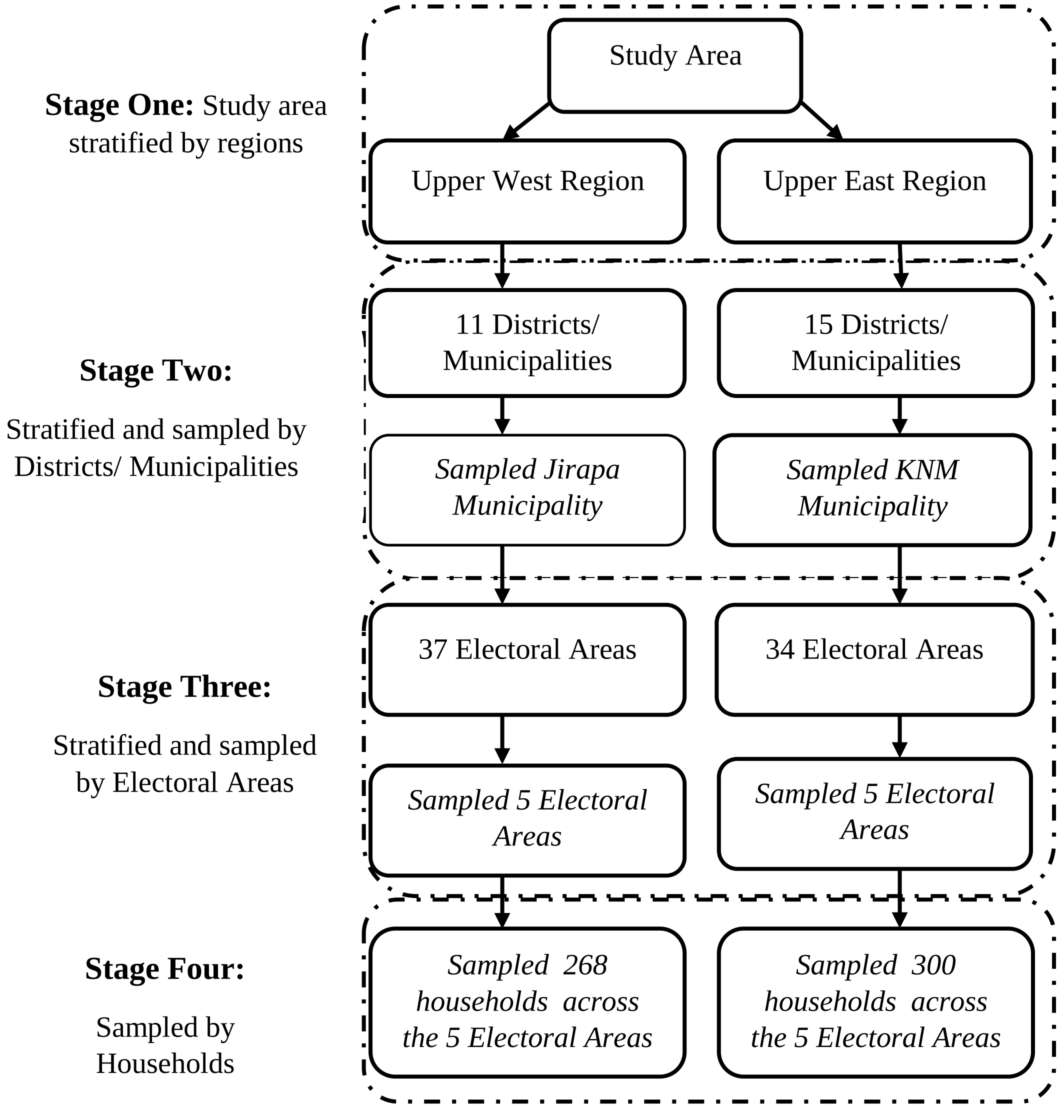


Figure 4.1: Multistage sampling of households

4.5.2 Community Water and Sanitation Agency

The CWSA is a statutory body with the mandate to provide technical support to DAs in the supply of water to rural communities and small towns in Ghana. The agency has secretariats in all 24 Municipals and Districts in the Upper Regions. In each sampled Municipality (Jirapa and Kassena Nankana), the hydrogeologist was purposively selected for data collection because of their key role in drinking water supply. In all, two Hydrogeologists were interviewed.

4.5.3 Small Town Water Supply Systems/ Ghana Water Company Ltd

Hitherto 2016, District Assemblies managed Small Town Water Supply Systems (STWSS) with technical support from Community Water and Sanitation Agency. The system supplies piped water via taps on compound or standpipes in Small Towns, mostly in District capitals. At the time of field data collection, small town water supply systems were present in 21 Municipal/District capitals. Following inefficiencies in the operations of these systems by the District Assemblies, the CWSA in 2016 took over the operations.

In urban centres, the Ghana Water Company Limited (GWCL) is mandated to supply water to households. Like the Small Town Water Supply systems, the Company supplies pipe borne water to households via taps on compound or standpipes at a central location. At the time of data collection, the GWCL operated in three urban centres in the Upper Regions of Ghana. In the two sampled districts, STWSS operates in Jirapa Municipality whereas GWCL operates in Kassena Nankana Municipality. The Managers of the two systems were purposively chosen to elicit views on issues of water quality, accessibility and reliability.

4.5.4 Water and Sanitation Committees (WATSAN)

The Water and Sanitation Committees are community based formal institutions responsible for the management of communal water sources, mostly boreholes. They are the brainchild of the CWSA. Their functions include maintenance and servicing of water sources as well as keeping the immediate environment tidy. Almost every public water source at the community level has a WATSAN. In each sampled EA, executives of WATSAN were purposively targeted for data.

4.6 Data Collection Methods

Four data collection methods were employed in this study to build synergy and complementarity. These are questionnaire administration, testing of water quality, geospatial mapping of water sources, focus group discussions and in-depth interviews. Table 4.2 presents a summary of primary data sources together with target respondents, key data requirements and data collection methods.

Table 4.2: Primary data collection matrix

Data sources	Target units/objects	Key data required	Data collection Method
Households	Principal housekeepers	Key socio-economic characteristics of respondents; sources of water for domestic use; perceptions of water quality ; methods of water treatment; effects of water quality on livelihood outcomes; round trip water collection time; distances to water sources; number of persons involved in water collection by different age groups and gender; water collection responsibility; effects of distance to water source /water collection time on livelihood outcomes; perception on water source reliability and level of yield; effects of water source reliability/yield on water supply and livelihoods outcomes	Questionnaire Interviews
	Children	Sources of water for domestic use; perceptions of water quality; methods of water treatment; effects of water quality on livelihood outcomes; round trip water collection time; distances to water sources; number of persons involved in water collection by different age groups and gender; water collection responsibility; effects of distance to water source /water collection time on livelihood outcomes; viewpoint of a reliable water source; perception on water source reliability and level of yield; effects of water source reliability/yield on water supply and livelihoods outcomes	FGD
	Men	Sources of water for domestic use; perceptions of water quality; methods of water treatment; effects of water quality on livelihood outcomes; round trip water collection time; distances to water sources; number of persons involved in water collection by different age groups and gender; water collection responsibility; effects of distance to water source /water collection time on livelihood outcomes; perception on water source reliability and level of yield; effects of water source reliability/yield on water supply and livelihoods outcomes	FGD
	Women		FGD
	Drinking water sources	Amount of faecal coliforms, arsenic & fluoride in drinking water at source	Water quality testing
		Geographic coordinates of water points	Geospatial mapping
	Location of households	Geographic coordinates of households	Geospatial mapping
WATSAN	Executives/ leaders	Reliability of water source (functionality, yield, frequency of breakdowns); perception of water quality; water source access rules/regulations	FGD
CWSA	Hydrogeologists	Perspective on the concept of adequate water supply; view point on the quality, accessibility and reliability of water sources in the region, interventions in scaling up adequate water supply; operational challenges	In-depth interviews
STWSS / GWCL	Manager	Network water supply coverage; quality, accessibility and reliability of the system, interventions/strategies in scaling up adequate water supply; operational challenges	In-depth interviews

4.6.1 Water quality testing

As mentioned in section 2.2.3, water quality testing was limited to three contaminants of significant health concern both at the national and global scales. They include microbial (with the indicative organism being Faecal Coliform), fluoride and arsenic. All three contaminants were monitored in the 10 sampled Electoral Areas across the two study districts. Before the collection of water samples in an Electoral Area (EA), functional drinking water sources were mapped for all communities within the catchment of the EA with the help of Gatekeepers. For each water source, key attribute information such as source type, source name and community name were collected during the mapping exercise. Water sources were also assigned unique numbers.

Water samples were collected with 400 mL plastic bottles. Bottles were sterilised to prevent cross-contamination of samples. Methylated spirit was first used to disinfect bottles, followed by distilled water to clear any residual methylated spirit in bottles. Also, plastic bottles were rinsed three times with source water before samples were drawn. On the day of sample collection, sterilised bottles were kept in an ice chest and transported to the EA either on a motorbike or car depending on the condition of the road. Within the EAs, I was led by community contact persons to drinking water points either on foot or on a motorbike for the collection of samples and geographic coordinates of water points as well. In line with best practice, water sources (borehole, standpipe and pipe borne) which were not in operation at the time of visit, were allowed to flow for 1-2 minutes before samples were drawn. The rationale was to get rid of residual water within pipes and any possible bacteria around the outlet.

Water samples were collected in two rounds from the same sources. First, in the rainy season, and second, in the dry season. The rationale was to analyse seasonal variations[17] in faecal concentration in drinking water sources to inform appropriate timing with regards to microbial monitoring in Ghana. Rainy reason water sample collection took place during the peak of the season, from 24th June – 19th August 2017 while the dry season was from 18th January to 1st February 2018. Though the dry

[17] Kostyla et al. (2015), through a systematic review, found mixed findings on seasonal variation in faecal contamination of drinking water sources.

season officially began in October 2017, sample collection did not start immediately until the season was firmly established in January 2018.

A total of 141 water samples, from five different water sources were collected in the rainy season. The sources consist of boreholes (77.3%, n=108), pipe-borne (7.1%, n=10), protected wells (5.7%, n=8), unprotected wells (5%, n=7), public tap/standpipes (3.5%, n=5) and dugouts/dams (1.4%, n=2) (Table 6.1). In the dry season, a total of 128 water samples were collected – a reduction of 13 samples if compared to the 141 samples collected in the rainy season (Table 4.3). With the exception of pipe-borne, all other source types witnessed a slight reduction in the number of water samples collected in the dry season (Table 4.3). The reduction in samples for boreholes and standpipe sources were largely due to break down of water infrastructure. Similarly, in the case of protected/unprotected wells and dugouts/dams, some sources were found to have dried up in the dry season.

Table 4.3: Number of water samples collected and tested by source types in the rainy and dry seasons

Source types	Rainy season	Dry season
Pipe-borne into plot	10	10
Public tap/standpipe	5	4
Borehole	109	105
Protected well	8	7
Unprotected well	7	2
Dugout/Dam	2	0
Total	141	128

Source: Field survey, 2017

Water quality testing was personally conducted in the field using portable test kits. Compared to commercial laboratory testing, portable test kits are easy to transport, easy to use, less expensive and produce rapid results (Centre for Affordable Water and Sanitation Technology, 2013). Faecal coliform was tested for in both the rainy and dry seasons' water samples using 3M Petrifilm Coliform Count Plate. Petrifilms are sample-ready-culture plating systems designed by the food safety division of 3M Corporation for the enumeration of coliforms in the food and beverage industries. 3M

Petrifilm aerobic count plates have official recognition, approval and certification from a wide range of international and national regulatory bodies such as AOAC International, Association Française de Normalisation (AFNOR), United States Food and Drug Administration, Canada Health Protection Branch, Australia Victorian Dairy Industry Authority etc. (3M, 2018a; Diez-Gonzalez, 2014). Though originally designed for microbial testing in food and beverages, they have proven to be strongly correlated and statistically significant with other commonly used methods of microbial analysis in water (Schraft & Watterworth, 2005; Vail et al., 2003). 3M Petrifilm plates are time saving, cost saving, sample-ready and easy to use (3M, 2018b; Vail et al., 2003). They come in a variety of forms depending on the aerobic bacteria of interest. In this study, 3M Petrifilm Coliform Count Plates were used to enumerate faecal coliforms in drinking water. AFNOR has certified 3M Petrifilm Coliform Count Plates in comparison to NF V08-0603 for the enumeration of faecal coliforms (3M, 2015).

For each water sample, a 3M Petrifilm Coliform Count plate was inoculated with 1mL of water sample and incubated at 44 ^{0}C for 24 hours +/- 2 hours based on NF V08 060 reference method (Adria Development et al., 2014) using *HIS25 Rocking Hybridisation Incubator*. Incubation began in not more than eight hours of sample collection. Where faecal coliforms were present in water, they grew on plates as red colonies with or without gas bubbles after incubation (Adria Development et al., 2014). Colonies were counted and expressed as Colony Forming Units (CFU)/ 1mL.

Whereas faecal coliform concentration in drinking water was tested in both rainy and dry seasons, fluoride and arsenic tests were limited to only the rainy season to save time and cost. Fluoride testing was conducted using *Palintest visual standard comparator kits*. The test kit includes a contour colour comparator disc (CD179 fluoride), dilution tube with a 10ml mark and a stirring/crushing rod. The Disc covers the range 0 - 1.5 mg/l fluoride in steps 0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4 and 1.5 (Palintest Ltd, n.d). In line with the test protocol specified by Palintest (Palintest Ltd, n.d), Palintest Fluoride No. 1 and Fluoride No. 2 tablets were added one after the other into a test tube filled with 10ml of water sample and stirred to dissolve. After 5 minutes, a test tube was placed in the comparator and matched against contour colour discs (refer to methodology for detail on test procedure). Results were read and rerecorded as mg/L Fluoride. Before a test was conducted, sample water was used to wash test tubes and stirring rods. The *Palintest visual standard comparator kit* is simple to use. Nonetheless, it is uncompromising in terms of precision and reproducibility of results (Palintest Ltd, n.d).

Arsenic concentration in drinking water was tested using a P*alintest Visual Arsenic Detection Kit*. The operation equipment included a 100ml reaction vessel, tri-filter arsenic trap (bung), hydrogen sulphide filters, destruction filter holder (x4), detection filter holder (x4), visual comparison chart, forceps, dilution tube, cuvette brush, and reagents (A1 power and A2 tablets). Arsenic A1 powder and Arsenic A2 tablets were added one after the other into the vessel with 50ml water sample. A loaded bung was immediately pushed into the vessel to cover it firmly, and results read after 20 minutes by comparing the black filter from the bung device with colour chart (refer to methodology for details). The colour chart against which results are read ranges from 0-500ug/l. Before each test, the vessel was first washed twice with distilled water and once with sample water.

4.6.2 Questionnaire administration

Questionnaires are an efficient and convenient method of collecting numeric data (Kumar, 2011; Twumasi, 2001). Many respondents can be reached within a short time (Twumasi, 2001). Questionnaires were administered in 568 sampled households. At the household level, housekeepers or their assistants were targeted because of their key role in household management, including water collection. Key data collected from housekeepers are listed in Table 4.1 and a copy of the questionnaire used can be found in Appendix III.

To ensure validity of questions, some questions from the 2014 Demographic Health Survey, 2014 Ghana Living Standard Survey instrument and JMP Core questions on drinking water supply that were relevant to the study were adopted/adapted. Moreover, questions were reviewed and approved by both internal supervisors.

SurveyCTO, a web-based survey tool was used for data collection. Questions were programmed online (www.surveycto.com) and deployed to smartphones via a surveyCTO app. This web-based survey application limits data collection errors through the creation of automatic skip patterns. It also eliminates the burden involved in data entry. Due to the high illiteracy rate of the study population, trained surveyors translated the questionnaire for respondents in their local languages (Dagaare, Gurunsi and Nankam).

4.6.3 Focus Group Discussion (FGD)

FGDs were employed to gain in-depth knowledge on the topic under investigation to supplement results of the household survey and water quality testing. At the community level, FGDs were held separately with women, men, children and water committees in order to avoid intimation or domination of some groups by others. A total of 32 FGDs were conducted - eight (8) each with men, women, boys, girls and water committees. They were spread across all ten EAs sampled for the household survey. Men and women who showed interest in the topic during the household survey were selected to participate in the men's and women's FGDs, respectively. Similarly, water committee members that showed interest in the topic during the community entry process were selected for the water committee FGDs. With regard to the selection of children for the FGDs, community focal persons were asked to draw children from households that participated in the survey for the discussion, subject to their willingness and permission from parents.

FGD guides were prepared (Appendices V and VI), and used to moderate the discussions. Based on previous experience in facilitating FGDs, the number of participants for each focus group session ranged from 8 - 10. A FGD of this composition makes it easier to moderate discussions and keep sessions active throughout. This range is not very different from what is recommended in literature (Twumasi, 2001). All FGDs were audio recorded.

4.6.4 In-depth interview

Four in-depth interviews were conducted with key informants of water supply institutions in the two sampled Municipalities aimed at eliciting their views on the quality, accessibility and reliability of water sources. Specifically, interviews were held with two Hydrogeologists from the Community Water and Sanitation Agency, the Manager of Ghana Water Company Limited in Kassena Nankana Municipality and the Manager of Jirapa Town Water Supply System. For each category of interviewees, a detailed guide was used for the discussion (Appendix IV). All interviews were audio recorded.

4.6.5 Geospatial mapping of households and water sources

Geographic coordinates of surveyed households and water sources were needed for spatial analysis and mapping, especially the level of contaminants in drinking water sources. Coordinates were collected for all water points with an accuracy of less than 10 metres using Garmin hand held Global Positioning System (GPS).

In the case of households, geographic coordinates were collected with the aid of the SurveyCTO app that was used to conduct the survey. Of the 568 surveyed households, coordinates were collected for 522 households. Due to poor weather at the time of data collection in some households, coordinates could not be collected for 46 households. Even of the 522 households in which coordinates were collected, 18 households had poor accuracy (above 10 metres).

4.7 Fieldwork

Fieldwork took place in Ghana from May 2017 to March 2018. It was staggered in two interrelated phases, comprising of a pilot study and actual data collection. Before the pilot, three research assistants were oriented on 12th June, 2017, in the Office of EDS Ghana, Wa, to support in pretesting of instruments and subsequently field data collection in Jirapa Municipality. Two of the Research Assistants hold Masters degrees while one was an Mphil. Student at the University for Development Studies, Ghana. All three Assistants were staff of EDS Ghana, a research and consultancy firm in Ghana, and thus familiar with field data collection.

The orientation began with a brief presentation on the aims and methodology of the study to Research Assistants. This was followed by translation of the survey instrument (question by question) from English to Dagaare, the local language in which interviews were conducted in Jirapa Municipality. This was necessary to avoid variations in translation of questions by Assistants. Where it was difficult to directly translate a question from English to Dagaare, the team agreed on a common probing strategy of eliciting data. After the translation, there was a demonstration session where Research Assistants and I administered survey instruments to each other in Dagaare to help assess our translation abilities. It was evident from the demonstration session that the Research Assistants had mastered the translations, including vocabularies we developed.

After training the Research Assistants, a pilot study was conducted in Piisi Electoral Area in the Wa Municipality of the Upper West Region from 14^{th} – 19^{th} June, 2017. The idea of the pilot study was to evaluate the practicability of mapping households for selection of samples, assess the effectiveness of mobile technology in data collection, assess the validity of questions, measure duration of interviews and familiarise with water quality testing. Lessons from the pilot phase were fed into the main data collection.

Questionnaires were administered to 16 housekeepers in different households. Major revisions made on the survey instrument after the pilot phase are summarized in Table 4.4. The mobile technology (SurveyCTO) employed for questionnaire administration worked fairly well. There were, however, a few instances where skip patterns were not well programmed. Such questions were identified during a debriefing session and re-programmed. It was a source of relief to have not carried bulky paper-questionnaires to the field and also to not worry about data entry. All questionnaires were administered within an hour. The time ranged from 33 minutes to 56 minutes, with the average being 41mins.

Table 4.4: Observations/revisions of some questions after pilot study

<table>
<tr><th>Original question</th><th>Comment</th><th>Revised question (if applicable)</th></tr>
<tr><td>C5. In the past week, how many buckets of drinking water had your household collected in total from your main drinking water source? (numeric)</td><td rowspan="3">Households mostly use medium size aluminium basin (48 litres) to collect water. As a result, the unit of measurement was changed to basin.</td><td>C5. What quantity of drinking water had your household collected in total from your main drinking water source in the past week (using medium size aluminium basin as unit of measurement)?</td></tr>
<tr><td>K5. In the past week, how many buckets of water has your household collected in total from main source for cooking, washing and personal hygiene? (numeric)</td><td>K5. What quantity of water has your household collected in total from main source for cooking, washing and personal hygiene in the past week (using medium size aluminium basin as unit of measurement)?</td></tr>
<tr><td>L1. On average, how many buckets of water does your household use for cooking, washing and personal hygiene in a day?</td><td>L1. On average, how many medium size basins of water does your household use for cooking, washing and personal hygiene in a day?</td></tr>
<tr><td>R14. Monthly net income (GHC) of household head in the past month (including remittances)</td><td>It was difficult for principal/assistant housekeepers to provide information on income of household heads for month preceding the survey. However, after further probes, respondents were able to approximate.

The difficulty in accessing data on income could be attributed to the fact that household heads are mostly farmers and do not earn regular income. They sell farm produce or animals to finance household expenditure when the need arises. Sometimes they do this without the knowledge of housekeepers.</td><td>Going forward, survey respondents (housekeepers) were encouraged to consult household heads on monthly income.</td></tr>
</table>

Water samples were also collected from boreholes and tested in the pilot phase. The idea was to accustom myself with the test kits and the procedures involved in testing fluoride, arsenic (based on Palintest reagents and colour comparators) and faecal coliforms (using 3M Petri films Coliform Count Plates). With guidance from Teresa Needham (School of Geography Laboratory Technician), YouTube tutorials and tests manuals, I successfully carried out the tests and read the results.

The pilot phase was followed by actual data collection, first in the rainy season and second in the dry season. The rainy season data collection phase began from 4th week of June 2017 to 2nd week of October. In both sampled Municipalities (Jirapa and Kassena Nankana), consent was sought from the Municipal Chief Executives at the District level. At the community level, consent was also sought from principal gatekeepers (chiefs, Tendamba, Assembly persons). Field activities in the rainy season included questionnaire administration to housekeepers, water quality testing, mapping of water points, and focus group discussions with men, women and children[18]. Due to the lack of a database on households in Ghana, households were mapped for all sampled EAs with the aid of community gatekeepers and used to sample households for questionnaire administration. A simple random sampling technique was adopted to sample households.

Due to language differences, the three research assistants used in Jirapa Municipality could not be engaged in Kassena Nankana Municipality. As a result, five new surveyors were contracted and trained to support in questionnaire administration in the Kassena Nankana Municipality. They also acted as interpreters in the focus group sessions. The dry season data collection phase spanned from January – March 2018. It focused on faecal coliform testing in drinking water sources and in-depth interviews with Hydrogeologists of CWSA and Managers of STWSS/GWCL.

[18] Ethical issues regarding children participation are addressed in section 4.10

4.8 Data Preparation, Analysis and Presentation of Results

Quantitative and qualitative data were analysed separately, and results combined. Quantitative data was generated from the water quality test and the household survey. From the water quality test, the amount of faecal coliforms, fluoride and arsenic recorded in drinking water sources were captured in SPSS. With regards to the household survey, the dataset was downloaded from the SurveyCTO platform in csv format and imported into SPSS (version 24) for preparation and analysis.

A combination of descriptive and inferential statistical tools were employed to analyse specific variables or ascertain relationship between variables in the water quality and household survey datasets to help answer the research questions (Table 4.5). The descriptive statistics generated include frequency distribution, mean, minimum and maximum. To test the significance of relationship between some variables, inferential analysis was carried out. Specifically, Kruskal-Wallis and Mann Whitney-U tests were employed to determine the significance or otherwise in faecal coliform/fluoride concentrations in drinking water sources by seasons and source types. Furthermore, a McNemar test was employed to ascertain whether seasonal variations in households' access to reliable water sources was significant. The results of the water quality and household survey datasets were presented in simple percentages, tables, graphs and maps. Due to the unattractiveness of SPSS graphs, all graphs were prepared in Microsoft Excel (2016) using outputs of frequency distributions from SPSS.

The results of quantitative data analysis have been presented in chapter 5 – 8. Specifically, chapter 5 captures respondents and households' characteristics. Chapter 6 focuses on accessibility to drinking water sources and its effects on livelihoods (objective 1). Chapter 7 examines drinking water quality and its consequences for livelihoods (objective 2). Chapter 8 addresses reliability of water sources and livelihoods (objective 3).

Table 4.5: SPSS tools used to analysis survey data

Broad Themes	Issues explored	Tools
Respondents and household characteristics	Gender of respondents	Descriptive statistics
	Educational attainment of respondents	Descriptive statistics
	Age of respondents	Descriptive statistics
	Household size	Descriptive statistics
	Occupation of respondents	Descriptive statistics
	Monthly income of household head	Descriptive statistics
	Household sources of drinking water	Descriptive statistics
Accessibility to drinking and water sources livelihoods	Water collection responsibility	Descriptive statistics
	Means of water collection	Descriptive statistics
	Water collection time	Descriptive statistics
	Distance to water sources	Descriptive statistics
	Effects of poor accessibility on livelihoods	Descriptive statistics
	Combined accessibility	Descriptive statistics
Drinking water quality and livelihoods	Amount of faecal coliform concentrations	Descriptive statistics
	Seasonal variations in faecal coliform concentrations	Wilcoxon Signed Rank Test
	Variations in faecal coliforms by source types	Kruskal-Wallis test
	Risk level of water sources and population by faecal coliforms	Descriptive statistics
	Amount of fluoride concentrations in water	Descriptive statistics
	Risk level of fluoride in drinking water by source types and population	Descriptive statistics
	Variations in fluoride concentration by source types	Descriptive statistics / Kruskal-Wallis
	Variations in fluoride concentration by geology	Descriptive statistics / Mann Whitney U test

	Arsenic concentration in drinking water	Descriptive statistics
	Combined access to safe water	Descriptive statistics
Reliability of drinking water sources and livelihoods	Level of reliability of water sources	Descriptive statistics
	Seasonal variation in households' access to reliable water sources	McNemar test
	Population access to reliable water sources	Descriptive statistics
	Effects of unreliable water sources on livelihoods	Descriptive statistics

Quantitative data was illuminated by qualitative data, collected through focus group discussions held with women, men, children and water committees, and in-depth interviews conducted with Hydrogeologists of CWSA and Managers of water supply systems. The following five iterative steps were adapted from Rapley (2011, p. 277) to manually analyse the qualitative data;

- Close detail examination of audio transcripts and field notes;
- Labelling of key, essential, striking, odd and interesting findings;
- Sorting of labels (findings) by themes;
- Harmonisation of findings around themes i.e. presentation of an explanatory account that highlights patterns, including key verbal quotes.

The above steps are consistent with a qualitative data analytic approach called framework analysis (Rapley, 2011; Ritchie & Spencer, 1994; Srivastava & Thomson, 2009). The approach involves "a systematic process of sifting, charting and sorting material according to key issues and themes" (Ritchie & Spencer, 1994, p. 177). Even though framework analysis can lead to the generation of theories, its main aim is to describe and interpret a phenomenon (Srivastava & Thomson, 2009). This approach was suitable because "the study has specific questions, limited time frame, pre-designed sample and priori issues" (Srivastava & Thomson, 2009, p. 1).

For each section in the results chapter, the quantitative data is first presented, followed by the qualitative data, where applicable. The sequence of data presentation was informed by the study design – concurrent embedded mixed methods design which emphasized quantitative data over qualitative.

4.9 Positionality

Positionality is an important subject in primary research where the researcher is the data collection instrument (Bourke, 2014; Collins & Cooper, 2014; Qin, 2016). It is defined as “the stance or positioning of a researcher in relation to the social and political context of the study — the community, the organization or the participant group” (Rowe, 2014, p. 1). Thus, it can affect the research process, especially in data collection (Rowe, 2014). The positionality of the researcher in data collection is expressed in terms of the researcher being either an insider or outsider relative to the community engaged in the inquiry (Rowe, 2014). The degree of relatedness of the researcher to the study participants is dependent on many factors. These include but are not limited to race, nationality, ethnicity, culture, class, gender, age, religion, education, sexuality, social and political beliefs, intellectual history and lived experiences of both the researcher and his subjects (Qin, 2016; Rowe, 2014). The achieved and ascribed nature of the elements of positionality (Muhammad et al., 2015; Qin, 2016) create a situation whereby researchers maybe differently positioned before their participants. Thus, the insider/outsider position of a researcher in relation to his or her subjects can therefore be viewed as a continuum (Herr & Anderson, 2005) and one that varies overtime (Ospina et al., 2008; Rowe, 2014).

In line with positivist tradition, some scholars (Burgess, 1984; Mensah, 2006; Qin, 2016; Sultana, 2007a) argue that the outsider perspective is considered optimal for an “objective” and “accurate” account of a study, while insiders, who possessed deeper insights about the study area, including research participants, are likely to hold a biased position. Burgess (1984) claimed that a researcher who knows his study area very well is likely to take certain issues for granted, resulting in limited understanding and interpretation of the issue being investigated. Similarly, Sultana (2007a) and Mensah (2006) are of the view that a researcher is less likely to undertake a thorough and in-depth investigation of a topic if he is familiar with the research topic, the study area and participants. On the contrary, Coteerill and Letherby (1994) argue that when the participants in a study perceive the researcher as an insider with whom they share similar experiences, they are less likely to be suspicious about his intentions and the purpose of the research. From the ongoing discussion, a researcher position within the insider-outsider continuum may enhance or ruin the research process (Moss, 2001;

Qin, 2016). It is therefore important for researchers to know their positions in relation to their subjects, and most importantly take appropriate steps to minimise the influence of their identities in the research process.

Before and during field data collection, I was mindful of how my positionality could either inhibit or enable certain research findings. Key issues of positionality discussed here include insider-outsider relationships, social differentiation and participants' perception about research. With regards to the insider-outsider relationship, I bear attributes of both insider and outsider. As a Ghanaian researching in my home country, I regard myself as an insider (compared with a foreigner researching in Ghana). I was familiar with the geography of the country and knew where sampled Municipalities (Jirapa and Kassena-Nankana) were located. Furthermore, I am of the same ethnic origin of research participants in Jirapa Municipality, and thus share the same local language with them. Though I do not share the same ethnic origin with research participants in Kassena Nankana Municipality, a long-established joking relationship exist between my ethnic group and theirs. Despite these insider attributes, I was also an outsider to my participants in some aspects. I say so because I had never met my research participants before I commenced the study. Besides, I did not know the locations of the sampled electoral areas, and hence was led by contact persons to all sampled electoral areas.

My insider/outsider attributes did not inhibit field data collection but rather enhanced it. As an insider, I gained the cooperation of most gatekeepers and research participants. I also travelled to study regions and Municipalities with ease. My position as an outsider placed me in a state where I knew nothing about the quality, accessibility and reliability of drinking water sources in the study area prior to data collection. I saw myself as a student while my participants were teachers. As a curious student, I asked many questions and paid attention to details in my interactions with research participants aimed at gaining deeper understanding of the topic.

In terms of social differentiation, I was much aware of how my gender, age and educational level could influence responses of some participants. As a male researcher interacting with largely female research participants, I was concerned that the gender difference could conceal sensitive information that relates to men. However, in practice, I found that female respondents spoke freely without any fear, largely due to their awareness of the purpose of the study as well as my insider attributes. Also, when engaging in discussions with children, I was aware that their unfamiliarity with me could inhibit the depth of the discussion and responses. To avoid this, one or two elder persons agreed to sit a few metres away to where discussions were held with children. Also, I took my time to introduce myself and explained the purpose of the study to children. Moreover, in every meeting with children, I began with jokes to ease any fear they might have had about me. My level of education and place of study (Europe) led research participants to position me as a potential development agent. For instance, some respondents told me that I should try and look for some organisations in the UK to come and drill boreholes for them. This perception could have led to possible exaggeration of the nature of access to water aimed at winning my sympathy and support. To overcome the risk of exaggeration of information, I always explained the purpose of my study to my respondents and encouraged them to be honest in their responses.

A few respondents also perceived research as a futile exercise. They claimed it does not have benefit to them and thus a waste of time participating in it. According to them, they had shared their problems with many researchers in the past, yet their livelihoods had not seen much improvement. I was aware that this perception could bring about apathy in the way they responded to questions and thus affected research findings. To minimise this, I explained to participants that studies like mine have the potential to enable development problems to be better understood and result in better defined policies and programs. After this explanation, a majority of those who perceived research as a futile activity participated.

4.10 Ethical Issues

Research ethics are the "moral principles guiding research, from its inception through to completion and publication of results and beyond" (University of Nottingham, 2016, p. 20). Research involving human participants like this study often raise ethical issues, and hence need to be addressed (Economic and Social Research Council, 2010; University of Nottingham, 2016; WHO, 2011b). Adherence to ethical principles protects the dignity, rights and welfare of research participants while at the same time enhancing the integrity of the research (University of Nottingham, 2016; WHO, 2011b). This study was conducted in line with the University of Nottingham's research ethics protocol (University of Nottingham, 2016). Key ethical issues addressed in the study include access to study sites and participants, informed consent of participants, confidentiality of information, anonymity of participants and safety of child participants.

To access the study sites and participants, consent of relevant gatekeepers was sought. In each of the two study Municipalities, written consent was sought from the Municipal Chief Executive. They were fully made aware of my identity, the purpose of the study, duration of data collection, sampled electoral areas and target participants. At the community level, I also sought verbal consent from community leaders (Chiefs, Tendamba and Assemblypersons). I disclosed my identity and the purpose of the study to them to avoid any suspicion. In addition, I made them aware of the duration of data collection and target participants. Furthermore, to gain access to housekeepers and children at the household level, permission was sought from men, who are traditionally the gatekeepers of households.

Another key ethical issue in research is informed consent of participants. Based on the University of Nottingham research ethics guidelines (University of Nottingham, 2016), written informed consent was sought from all participants. Although the informed consent statement was written in English, it was translated for participants in a language that they could understand. The informant consent sheet captured sufficient information about the purpose of the study, optionality in participation and right of participants not to answer a question or withdraw from the study at any time. Also, I made participants aware that there would be no direct benefit in participating in the study or cost if they chose not to participate. As part of the informed consent, the duration of the interaction was also made known to participants. For each participant, two copies of the informant consent sheets were co-signed (or thumbprinted in the case of participants with limited literacy) by me and the participant, and a copy kept by each party. Consent was also sought from participants before taking pictures. They were made aware that the pictures were going to be used exclusively in my PhD thesis. In a few cases, some participants declined to be pictured.

Another important ethical issue expected to be addressed in research involving human participants is confidentiality of information and anonymity of participants. In line with the University of Nottingham's research ethics protocol, the data have not been shared with any person not involved in the study. The only persons with whom data have been shared are my supervisors. With regards to anonymity of participants, personal data such as names and addresses of participants were excluded in reporting research findings. As a result, it would be difficult for anyone to trace a participant. Information on faecal coliforms, fluoride and arsenic in drinking water sources have been presented in aggregates at municipal level, making it impossible for anyone to trace a particular source.

Ethically, researchers are also expected to undertake appropriate steps to guarantee the safety of child participants. This principle was strongly adhered to in this study. In all discussions with children, one or two elderly persons to whom the children were familiar with sat a few metres away from the places the discussions were held. This was to guarantee their safety and also ease any fear they might have had interacting with a stranger.

4.11 Methodological Limitations

Methodologically, inadequate financial resources limited the study design. Prior to fieldwork, I had planned to work in three districts/municipalities; one from each of the three regions of northern Ghana. I also planned to test faecal coliform, fluoride and arsenic concentrations in drinking water sources in both rainy and dry seasons to ascertain seasonal variations in water quality. To implement this design, I needed about £10,000 for transportation, accommodation, purchase of water testing reagents, communication and payment of allowances to research assistants. Unfortunately, I could not raise this amount because my sponsor (Ghana Education Trust Fund) to whom I had relied on told me that my sponsorship package did not include fieldwork cost, and that they expected the University of Nottingham to finance my fieldwork.

Though I got financial and logistical support from the University, it was not enough for me to fully implement the envisioned design.

With a strong desire to conduct the study, I decided to finance the remainder of my fieldwork budget from my monthly stipend but it did not suffice. As a result, I had to review the initial study design. In the end, I collected data from two municipalities instead of three as earlier planned. Also, testing of arsenic and fluoride in drinking water sources were done only in the rainy season. I could not procure enough reagents for the dry season test as was done for the faecal coliforms. The reduction in the study Municipalities and cross-sectional testing of fluoride and arsenic may limit the generalisation of findings.

5 RESPONDENTS' AND HOUSEHOLDS' CHARACTERISTICS

5.1 Introduction

This chapter presents and discusses key socio-demographic and economic characteristics of respondents and their households. Issues captured include respondents' gender, educational attainment, age, household size, occupation, income and sources of drinking water.

5.2 Gender

Of the 568 housekeepers who participated in the household survey, 94.7% are females and 5.3% males (Fig.5.1). It is not surprising to see a majority of housekeepers being women because housekeeping in Ghana is traditionally the role of women. However, in homes where mature women are not available, men take up the responsibility of housekeeping.

The views of men on the subject under investigation were well captured in the focus group sessions. Approximately 50% (80) of focus group discussants were men. Of the 24 FGDs conducted, eight each were held with men and women only. Another eight were conducted with water and sanitation committees, comprising of both men and women.

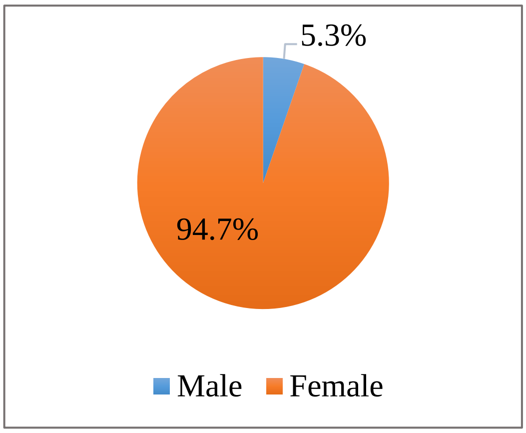


Figure 5.1: Gender distribution of survey respondents

Source: Field survey, 2017

5.3 Educational Attainment

The survey results show that a majority (61.1%) of housekeepers have never been to school (Table 5.1). The proportion of housekeepers with pre-basic, basic, secondary and tertiary education is 1.1%, 33.8%, 3.4% and 0.7% respectively (Table 5.1).

Table 5.1: Educational attainment of respondents

Educational levels	Percent (%)
Never attended school	61.1%
Nursery/Kindergarten	1.1%
Primary School	13.9%
Middle School/JSS/JHS	15.3%
SSS/SHS	4.6%
Vocational/Technical School	1.1%
Post-Secondary Certificate/Diploma	2.3%
Bachelor Degree	0.7%
Total percent (%)	100.0%
Total respondents (N)	568

Source: Field survey, 2017

5.4 Age

The ages of respondents (housekeepers) who participated in the household survey range from 14 – 81 years, with the average being 41 years. The age distribution of respondents further shows that about 6% of housekeepers were children (under 19 years) while 15.8% were 60 years and above (Table 5.2).

Table 5.2: Age distribution of respondents

Age ranges	Percent (%)
Under 15 years	0.4%
15 - 19 years	5.5%
20 - 24 years	9.2%
25 - 29 years	11.6%
30 - 34 years	9.7%
35 - 39 years	13.4%
40 - 44 years	11.6%
45 - 49 years	10.7%
50 - 54 years	7.2%
55 - 59 years	4.9%
60+ years	15.8%
Total percent (%)	100.0%
Total number of respondents	568

Source: Field survey, 2017

5.5 Household Size

From the survey, household sizes range from one to 23 persons, with the average being seven. It can be inferred from Table 5.3 that the study area (Upper Regions of Ghana) has large household sizes. About 64% of households have at least six persons with the majority (23.1%) having a membership of more than 10 persons (Table 5.3).

Table 5.3: Percentage distribution of household sizes

Household size	Percent (%)
1 person	0.5%
2 persons	2.3%
3 persons	6.7%
4 persons	11.6%
5 persons	14.8%
6 persons	14.6%
7 persons	10.0%
8 persons	9.9%
9 persons	6.5%
10+ persons	23.1%
Total percent (%)	100.0%
Total number of respondents	568

Source: Field survey, 2017

5.6 Occupation

The main occupation reported by a majority (82.4%) of respondents was agriculture (Table 5.4). Only a few (7.3%) people were engaged in professional/service-related jobs. About 6% of respondents were either unemployed or dependents.

Table 5.4: Percentage distribution of major occupation

Occupations	Percent (%)
Agriculture	82.4%
Trade/Business related work	3.3%
Casual work	1.1%
Artisan	4.9%
Education professional	0.9%
Health professional	0.7%
Banking/financial related work	0.4%
Service/sale related work	0.4%
No employment/dependent	5.9%
Total percent (%)	100.0%
Total number of respondents	568

Source: Field survey, 2017

5.7 Monthly Income of Household Head

Earnings of household heads in the month preceding the survey ranged from 0 – GHS 3,200.00 (0 – $727.00), with the average being GHS 252.00 ($57.00) (Table 5.5). The large standard deviation ($92.00) reveals high levels of inequalities in income among household heads in the study area with a majority being poor. More than half (50.2%) of household heads earned less than $30.00 in the month preceding the survey. In other words, they earned less than one US Dollar a day.

Table 5.5: Monthly income of household heads

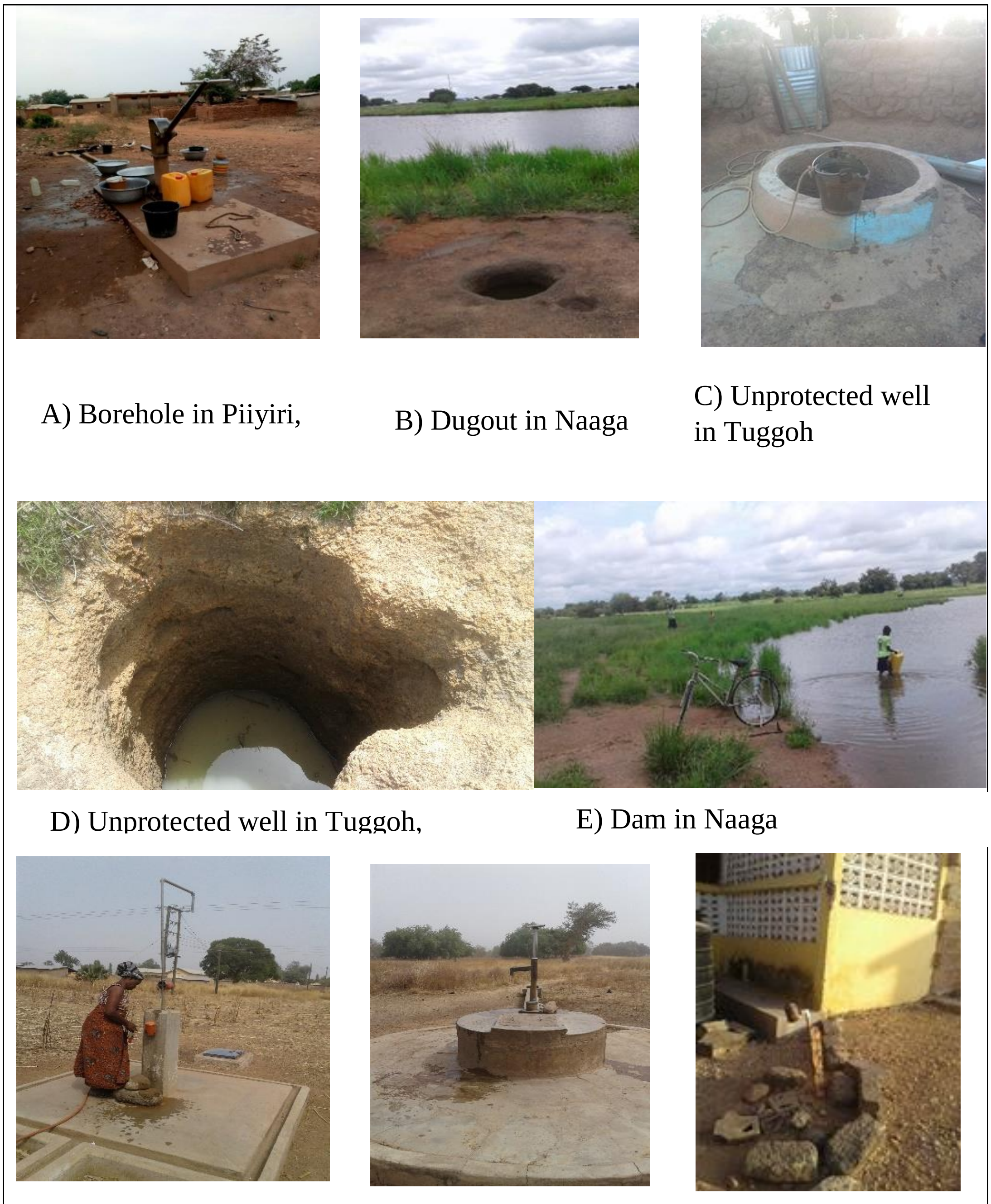
Monthly income (In Ghana Cedis)	Percent (%)
Less than GHS 132	50.2%
132 - 263	26.1%
264 - 527	12.7%
528 - 791	2.6%
792 - 1055	4.8%
1056 plus	3.7%
Total percent (%)	100.0%
Total number of households	568

Source: Field survey, 2017

5.8 Sources of Drinking Water

Households in the study area (upper Ghana) depend not only on improved water sources but unimproved sources as well for domestic use. They include bottled/sachet water, pipe-borne (i.e. piped water into compound), standpipes, boreholes, protected wells, rain water, unprotected wells and dugouts/dams. Photographs of the main sources are presented in Figure 5.2. Boreholes are deep ground wells fitted with a hand pump. According to the Upper West Regional Hydro-Geologist, the depth of most boreholes in the study area is less than 50 metres. Unlike boreholes, protected and unprotected wells are hand-dug with depths ranging from 4 – 10 metres. Protected wells are covered and lined (plastered with cement). Conversely, unprotected wells are not covered and the inside of most are unlined. Some protected wells have hand pumps fitted on them. Water is drawn from unprotected and some protected wells (without pump handles) through a container connected to a rope.

Standpipes are also deep ground wells like boreholes but use power (electricity) to pump water from underground. This lessens the burden of pumping by hand as in the case of boreholes. All households that depend on pipe-borne water access it on compounds via a tap. In both Jirapa and Kassena Nankana Municipals, pipe-borne water is sourced from electricity powered boreholes. Water is pumped from the boreholes into a centralised reservoir where it under-goes treatment and supply to households through a network of pipes. In addition to the above sources, dams and dugouts are also relied upon by some households. Dugouts are very shallow hand-dug wells located in low lying areas, mostly by a dam or pond.



A) Borehole in Piiyiri, B) Dugout in Naaga C) Unprotected well in Tuggoh

D) Unprotected well in Tuggoh, E) Dam in Naaga

F) Standpipe in Kologu G) Well fitted with a hand pump in Kologu H) Pipe-borne tap on compound

Figure 5.2: Photographs of main water sources in the study area

Source: Field survey, 2017

The results of the study show that households' main sources of drinking water are not significantly different from the sources for other domestic uses (cooking, washing and bathing). In response to the question '*is your household main drinking water source different from the main source for other domestic uses*?' 98.4% of respondents said no. Of the 568 household-respondents, only nine (1.6%) reported that their household's main source of drinking water is different from the source for other domestic uses.

Of the 568 households surveyed, 91.8% depend mainly on boreholes, 2.3% on pipe-borne on compound, 1.7% on protected hand-dug wells, another 1.7% on unprotected hand-dug wells, 1.3% on standpipes and 1.2% on dugouts/dams for domestic use (Table 5.6). In terms of population coverage by main source types, 92.8% mainly use boreholes. A small proportion of the population also rely on pipe-borne sources on compound (1.9), standpipes (1%), protected wells (1.7%), unprotected wells (1.6%) and dugouts/dams (1%) as their main source of drinking water (Figure 5.3).

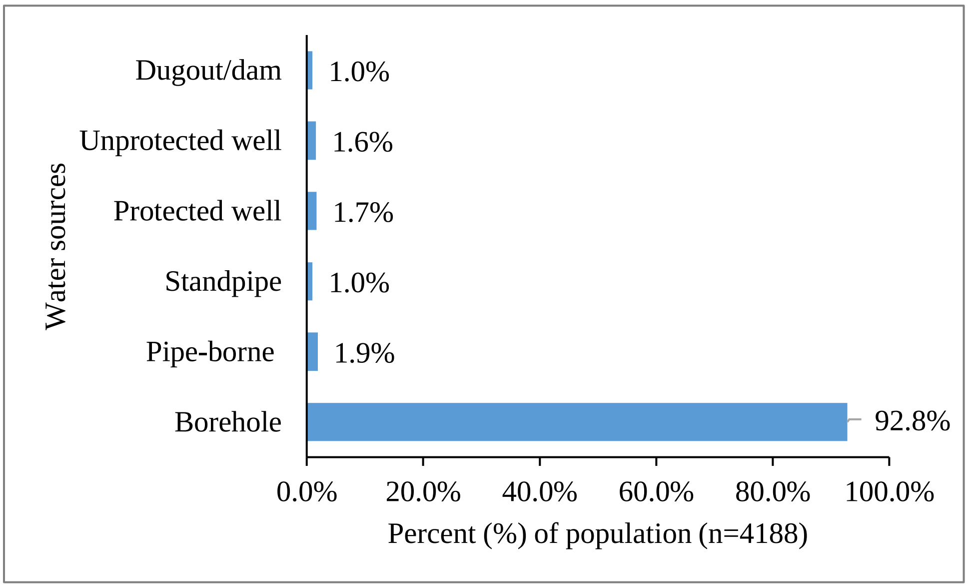


Figure 5.3: Percent distribution of population by main drinking water source

Source: Field survey, 2017

The main source of drinking water for urban (89.3%) and rural (93.6%) populations is borehole (Figure 5.4). In urban settings, 10.7% of population depend on pipe-borne as their main source of drinking water. This source, however, does not exist in rural areas. In addition to borehole, rural populations depend on standpipes (1.2%), protected wells (2%), unprotected wells (1.9%) and dugouts/dams (1.2%) whereas improved water coverage in urban settings is 100%, it is 94.8% in rural areas.

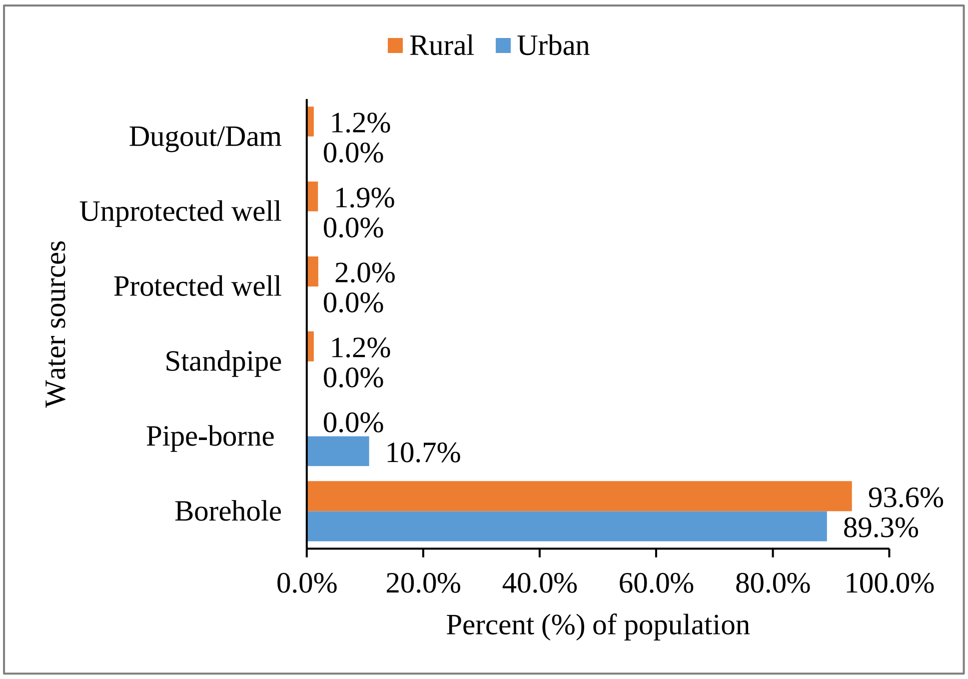


Figure 5.4: Main source of drinking water in urban and rural settings

Source: Field survey, 2017

The study revealed that, over 50% of households were engaged in stacking of water sources i.e in addition to their main water point, they rely on other secondary water points (Fig. 5.5). Reasons cited by respondents for depending on two or more water points include break down of main drinking water point (68.6%), long waiting time at main point (25.9%), non-availability of water from main source at home (17.4%), long distance to main water source/accessibility of secondary source (15.4%), secondary water source quality better than main source (5.5%), drying up of main source (2.4%) and lack of power to operate main source, especially mechanised standpipes and pipe borne sources (1%) (Figure 5.4).

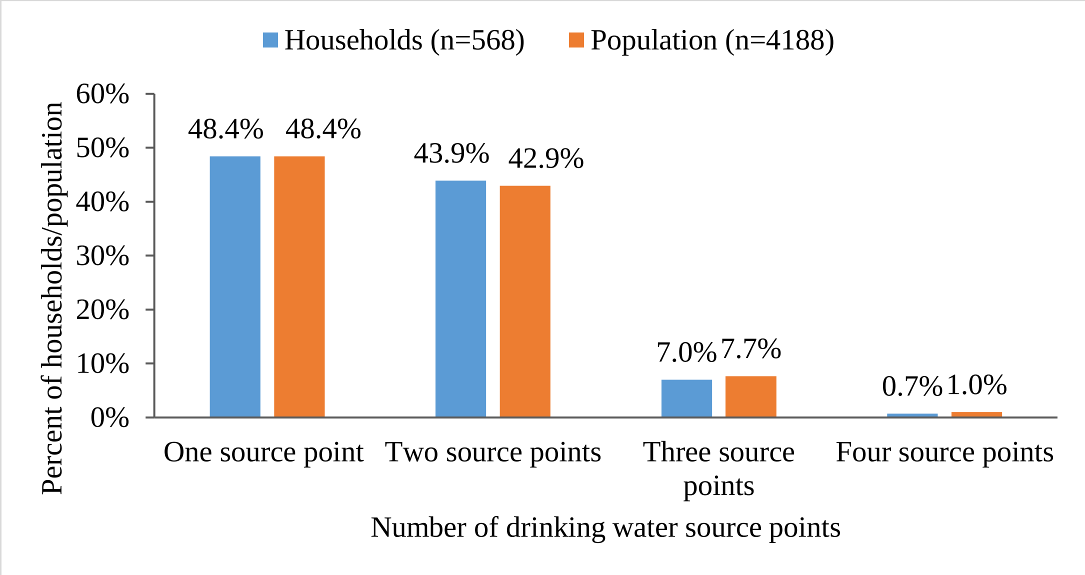


Figure 5.5: Percent distribution of households/population by number of water source points they depend on

The reasons cited by respondents for their dependence on two or more water source points in the household survey is not different from results of the FGDs held with men, women, girls and boys. Some discussants are quoted as follows;

> *…because we don't have boreholes but only wells, we prefer to drink rain water in the rainy season* (Female Discussant, Tuggoh Baazu in Jirapa Muncipal).

> *My brother, it isn't our desire to drink or use the well water to cook. Of course, the borehole water is potable compared to the well. But just imagine that you've returned from farm, tired and thirsty, no water at home and the borehole is also crowded, what would you do? You can't sit with the thirst waiting for the borehole water. You don't even know when the woman will get the water home…if the borehole is crowded, the women have no option than to use the well water to cook* (Male Discussant, Kologu in Kassena Nankana Municipal).

> *From December to April, our well dried up, so we have to travel long distance to the borehole to collect water* (Male Discussant, Kologu in Kassena Nankana Municipal).

> *Our borehole got spoiled for about a month. During that period, we have to walk all the way to Kabari to get water. Sometimes, if we were tired to go to Kabari, we used the well water for drinking and cooking* (Female discussant, Naaga in Kassena Nankana Municipal).

A cross-tabulation of household first and second major water source points reveals that households whose main source is an improved source do not necessarily use improved water throughout the year but make use of unimproved sources as well. Of the 97.1% households whose main source is improved, 2.7% also use unimproved secondary sources, comprising of unprotected hand-dug wells, rivers/streams and dugouts/dams as their second major source point (Table 5.6).

Table 5.6: Percent distribution of households by first and second major water sources

		Households second major water sources										
	Water source types	Pipe-borne on compound	Standpipe	Borehole	Protected well	Rain water	Sachet water	Unprotected well	River/ stream	Dugout/ Dam	No secondary source	Total households (n=568)
Households first major water sources	Pipe-borne on compound	0.0%	0.0%	0.4%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	1.7%	2.3%
	Standpipe	0.0%	0.0%	1.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	1.3%
	Borehole	3.2%	3.0%	32.9%	0.5%	4.0%	0.0%	0.2%	1.4%	0.7%	46%	91.9%
	Protected well	0.2%	0.0%	0.9%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.2%	1.7%
	Unprotected well	0.0%	0.0%	0.9%	0.0%	0.0%	0.0%	0.0%	0.2%	0.2%	0.3%	1.6%
	Dugout /Dam	0.0%	0.0%	0.7%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	1.2%
	Total households (n=568)	3.4%	3.0%	36.9%	0.5%	4.5%	0.2%	0.6%	1.6%	0.9%	48.4%	100.0%

5.9 Discussion

This section discussed key findings on the socio-demographic characteristics of respondents and households. From the results, a majority (94.7%) of housekeepers who participated in the survey were females. Results on the ages of housekeepers showed that females as early as 14 years assume principal housekeeping responsibilities. The findings reflect gendered division of household work in Ghana. Traditionally, women in Ghana are primarily responsible for housekeeping (FAO, 2012). The ascribed role of women in housekeeping affects their educational attainment (Rubio, 2018). From the results, more than half of housekeepers have never been to school. Similarly, in the 2010 PHC, 52.7% of females in the Upper Regions of Ghana have never been to school (Ghana Statistical Service, 2013d). The low educational attainment of females and for that matter housekeepers can undermine safe water handling and treatment practices.

The large family sizes recorded in the Upper Regions of Ghana reflect the low educational attainment of housekeepers. Almost 50% of households have at least 7 persons living in them. Large household sizes imply high water demand for household use. The average household sizes recorded in KNM (7) and JM (8) are slightly higher compared to the 2010 PHC. The average household sizes for Jirapa and Kassena-Nankana Municipalities in the 2010 PHC were 6.3 and 5.4, respectively (Ghana Statistical Service, 2014a, 2014b).

The low educational level of housekeepers limits their access to white-collar jobs (i.e., professional, managerial and administrative related jobs). Consequently, a majority of housekeepers are engaged in crop farming. Eight out of every 10 housekeepers were mainly into crop farming. Farming in the Upper Regions is largely subsistence in nature and undertaken on a small-scale basis. It is mainly rainfed, and takes place in the rainy season from May to September. The main crops households cultivate include millet, maize, sorghum, groundnuts, rice, beans, bambara beans and soya beans. The method of farming is predominantly traditional. Only a few households employ modern farming methods such as agro-chemical applications and ploughing with tractors. In addition to crop farming, almost all households are involved in rearing poultry and animals such as fowl, guinea fowl, goats, sheep and cows for consumption and income. Rearing is viewed as a safety net for households in times of adversities, especially during crop failures.

Income levels in the Upper Regions are low. In the month preceding the survey, more than half (50.2%) of household heads earned less than one US Dollar a day. This reflects the high incidence of poverty in the area. A recent survey by the GSS (2018) revealed that the Upper West and Upper East Regions are among the three poorest regions in Ghana with an incidence of 54.8% and 70.9%, respectively. The low-income levels of households affect investment in water resources, including repair and maintenance of water infrastructure.

From the results, households' major sources of drinking water were not significantly different from major sources for other domestic use (washing, cooking and bathing). Almost all households collect water from the same source for consumption, cooking, washing and bathing. Based on this evidence, the findings of the study can strongly be generalised beyond drinking water sources to include sources used for cooking, bathing and washing. The collection of water from one water point for all domestic uses has the potential of increasing pressure on water infrastructure, especially for communal facilities. This can lead to long waiting times at source, poor yield and frequent breakdowns of water infrastructure.

The results further showed that a majority (97.4%) of the population mainly use improved water, comprising of borehole, pipe-borne, standpipe and protected hand-dug well. Only a few (2.6%) individuals, all in rural areas, still depend heavily on unimproved sources. The main source of water in both urban and rural areas was borehole. This underscores the importance of groundwater to inhabitants in the Upper Regions of Ghana. Less than 2% of households, all in urban areas have a pipe borne water supply on their compound. A majority of households therefore collect water outside their compounds; a situation which adversely affects livelihoods due to high water collection and long distances to water sources (Chapter 6). The findings on improved water coverage are not very different from the 2014 DHS conducted by the Ghana Statistical Service (Ghana Statistical Service et al., 2015). Improved water coverage in the Upper West and Upper East Regions were 94.5% and 65.7%, respectively, with the main source being borehole. Less than 5% of the population depended on pipe-borne water. In both regions, improved water coverage in urban areas was slightly higher than in rural areas. For instance, in the Upper West Region, 99% of population in urban areas used improved water compared to 93.6% in rural areas.

Stacking of water sources was found to be common in the study area. From the results, more than half of households surveyed relied on two or more water sources. This implies that household main water sources are unable to deliver safe and/or sufficient water throughout the water. Stacking of services can be viewed as a coping mechanism to meeting household needs in developing countries. Jewitt et al. (2018) reported stacking of sanitation facilities by households in India while Masera et al. (2000) reported the same for cooking fuel use in Mexico. Echoing Jewitt et al. (2018) findings in Assam, stacking of water sources was associated with backsliding of households from improved to unimproved water sources. Therefore, in Ghana and other developing countries where stacking of services is common, the JMP and its surveying bodies (DHS, LSMS MIC etc.) risk over-estimating populations with access to 'safely managed water' if they continue to focus on only household main water source.

5.10 Conclusion

The socio-demographic and economic characteristics of respondents and their households show that the study setting (Upper Region of Ghana) is not different from any rural economy in the global south. The economy is predominantly agrarian in nature and characterised by high illiteracy rates, large family sizes and high levels of poverty.

In terms of drinking water, the results revealed very high access to improved water in the Upper Regions of Ghana. However, the level of quality, accessibility and reliability of improved water sources is unknown. The ensuing three chapters present and discuss results on accessibility (chapter 6), quality (Chapter 7) and reliability (chapter 8) of water sources.

6 ACCESSIBILITY TO DRINKING WATER SOURCES

6.1 Introduction

Accessibility is an important dimension in evaluating access to drinking water (United Nations Economic and Social Council, 2002; WHO/UNICEF Joint Monitoring Programme, 2015e). In water supply studies, accessibility is primarily a function of distance to water source or collection time (Howard & Bartram, 2003; WHO, 2011). According to the WHO (2011), a distance of 1km to a water source from a dwelling unit or 30 minutes round-trip collection time will guarantee basic access to water for household use. At that threshold, the likely volume of water to be collected is 20 litres/capita/day (Howard & Bartram, 2003; WHO, 2011). Where distance to a water source is more than 1km or collection time is greater than 30 minutes, household water needs are most likely not to be met leading to poor health outcomes (Howard & Bartram, 2003; WHO, 2011). To optimise the health benefits associated with large volumes of water collection, the JMP encourages access to water on premises (WHO/UNICEF Joint Monitoring Programme, 2015e).

This chapter examined the extent of accessibility of drinking water sources in the Upper Regions of Ghana. Data were collected through a combination of household surveys with housekeepers and focus group discussions with men, women and children. In the survey, accessibility was measured in terms of distance to water sources and roundtrip water collection times. Furthermore, data were collected on two key determinants of household accessibility to water sources – water collection responsibility and means of water collection. The study also explored the effects of poor accessibility to drinking water sources on livelihoods. The results are presented in the first six sections, followed by a discussion in the seventh section.

6.2 Water Collection Responsibility

The study revealed that water collection in the Upper Regions of Ghana is primarily the responsibility of women, with support from children, especially girls. In a majority (89.8%) of households surveyed, the main collectors of water were women, followed by girls (Figure 6.1). Men and boys were reported as the main collectors of water in only 0.7% and 0.5% of households, respectively. Men only collect water when there are no able women or girls in the household. Indeed, during fieldwork, it was rare to see men collecting water (Figure 6.2).

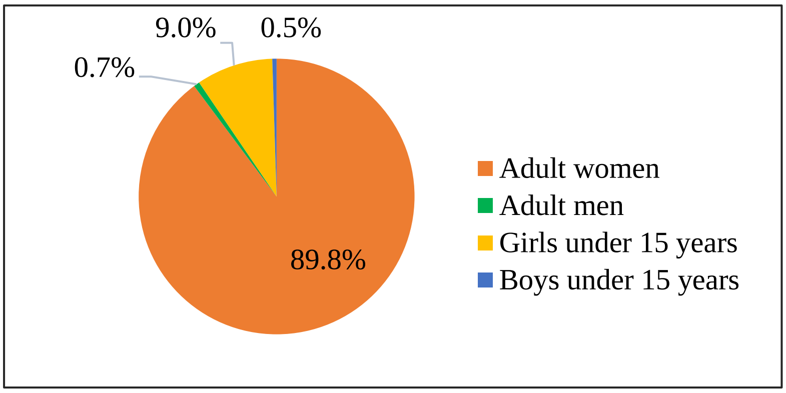


Figure 6.1: Main water collectors in households

(a) Girls collecting water in Tampaala, Jirapa Municipal, 24.06.2017

(b) Girls and boys collecting water in Akrugudaboo, Kassena Nankana Municipal, 29.10.2017.

(c)Women collecting water in Ulkpong, Jirapa Municipal, 22.02.2017

Figure 6.2: Women and children collecting water

Source: Field photos, 2017

From the household survey, responses by the main collectors of water in rural and urban areas are not very different. Regardless of the setting, women are the primary collectors of water. From Figure 6.3, women were reported as main collectors of water in 90.2% of rural households. Similarly, in urban settings, they were reported as the main collectors in 89.6% of households. In both settings, men and boys were reported as the main collectors of water in less than 1% of households.

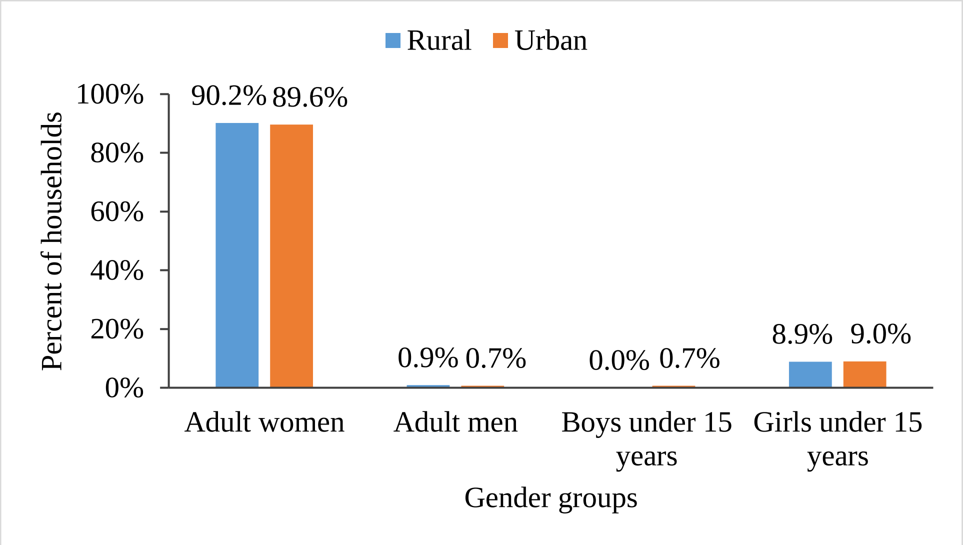


Figure 6.3: Main water collectors in households in urban and rural areas

In the focus group discussions with men and women, the study explored the reasons why water collection is the primary responsibility of women. It was established that it is an age long tradition passed on from generation to generation. A majority of discussants argued that their forebears assigned domestic duties (perceived as less physical demanding) to women, and farm work (considered as physical demanding) to men based on their physiological make up. Therefore, when a man goes to seek a woman's hand in marriage, it is normally said that he wants to take her home to be collecting water while he farms. Furthermore, it was reported that women are principal collectors of water because they have more water needs compared to men. For instance, whereas women need water for menstrual hygiene management, men do not. Some verbal responses are presented below.

Our forefathers' assigned household responsibilities by looking at the physiological make-up of men and women, and that tradition has been upheld to date. Women have responsibility for household chores including water collection and men have *responsibility for farming and other arduous tasks because men are physically stronger than women. So depending on your sex at birth, you are trained according to these gendered roles. … As per our tradition, farming is the responsibility of men whereas household chores are carried out by women. That's why when a man wakes up, he prepares and leaves for the farm while the woman stays at home to discharge all household chores and prepare food for the man on the farm. After she is done with household chores, she then joins the man on the farm with the food. Even on the farm, not all activities can be undertaken by women. They mostly support in sowing, weeding and harvesting* (Male discussants in Tampaala in the Jirapa Municipality, 21.11.2017).

When a man goes to a woman's house to seek her hand in marriage, he tells the woman's parents that I want your daughter to come and help me collect water. This statement implies that water collection is central among her roles. Why then would she sit down for the man to collect water for her? …The women's responsibility is also to cook and if there is no water she can't cook….Women always want to be clean. So they have to get water for that (Male Discussants in Atosale-Azaasi in the Kassena Nankana Municipality, 30.10.2017).

The proportions of adult women and girls involved in water collection are higher compared to men and boys. From the survey, 70.3% of adult women were involved in water collection compared to 2% of adult men (Figure 6.4). With respect to children, 46% of girls were involved in water collection compared to 9.9% of boys (Figure 6.4). The pattern is not very different in Jirapa and Kassena Nankana Municipalities (Figure 6.4). Analysis by rural and urban areas reveals that the proportion of adult women, adult men and boys in rural areas who collect water was slightly higher than in urban areas. Conversely, more girls in urban areas (46.8%) collect water than in rural areas (45.6%) (Figure 6.5).

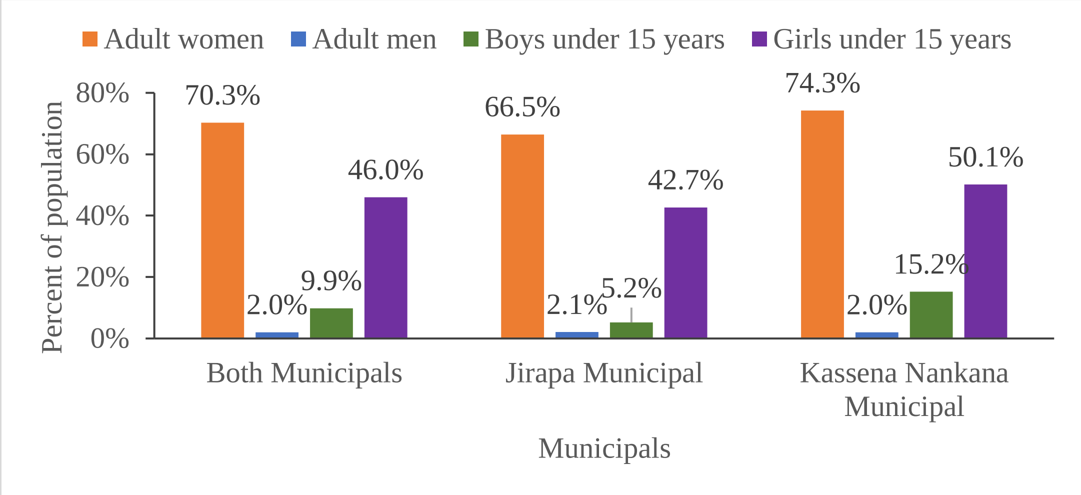


Figure 6.4: Proportion of women, men, girls and boys that collect water

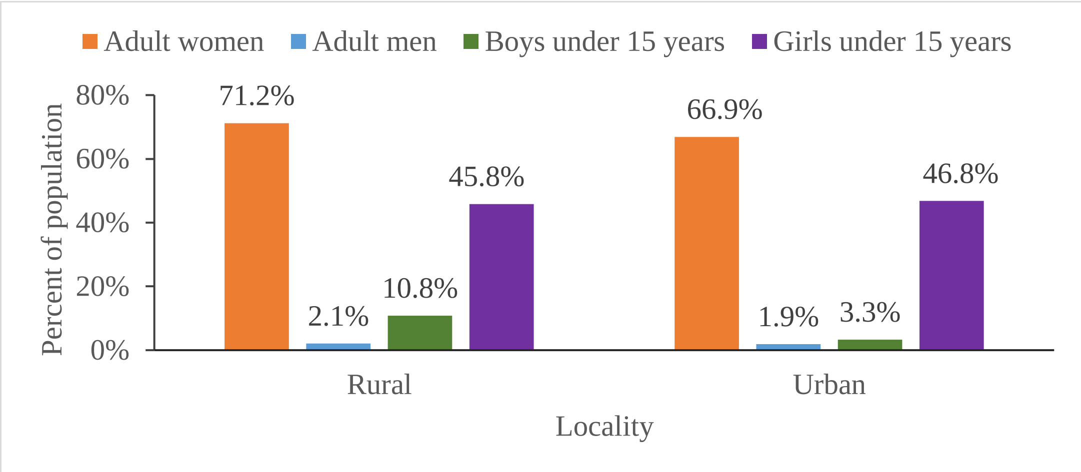


Figure 6.5: Proportion of women, men, girls and boys that collect water in urban and rural areas

6.3 Means of Water Collection

Table 6.1 contains the main means of water collection by gender and age groups. The results show that women and girls commonly collect water by means of head loading while men and boys use bicycles. In 97.2% of households, adult women collect water by means of head loading compared to 29.4% of adult men (Table 6.1). Also, in 52.9% of households, adult men collect water using bicycles compared to 1.1% of adult women. The results for boys and girls are not very different. From the qualitative data, gender differentials also exist in the use of containers for water collection. Adult men and boys, regardless of the means of water collection commonly use a 25 litre plastic jerrycan whereas adult women and girls use aluminium basins when carrying water on their heads, and plastic jerrycans when collecting water by means of bicycle, animal drawn cart and a hand pulled cart (Figure 6.6).

Table 6.1: Means of water collection by gender groups in households

Means of water collection	Gender groups			
	Adult women	Adult men	Girls under 15 years	Boys under 15 years
Headloading	97.2%	29.4%	98.0%	53.0%
On a bicycle	1.1%	52.9%	0.8%	42.4%
With a hand pulled cart	0.4%	0.0%	0.8%	0.0%
With animal drawn cart	0.4%	0.0%	0.4%	3.0%
Using hose	0.9%	17.7%	0.0%	1.6%
Total %	100.0%	100.0%	100.0%	100.0%
No. of households	534	17	225	66

Source: Field survey, 2017

Girls carrying water on head at Sagbaalong, Jirapa Municipal, 21.11.2017

Boy carrying water on a bicycle at Atosale, Kassena Nankana Muncipal, 09.08.2017

Figure 6.6: Some means of collecting water

6.4 Water Collection Time

From the household survey, round trip water collection times ranged from 3 minutes for households with water sources in their compound to 240 minutes for households who collect water outside their compounds with the average being 42 minutes. Analysis by households and population reveals that 52.8% of households and 51.4%

of population collect water within 30 minutes (Table 6.2). The rest spend more than 30 minutes on a roundtrip of water (Table 6.2). Of the 96.9% of households and 97.1% of population that drink mainly from improved water sources, only 50.5% and 49.2% respectively collect water within 30 minutes (Table 6.2).

Table 6.2: Households and population by round-trip water collection time in the study area

Time	Percent of HH[19] (n=517)			Percent of population (n=3748)		
	Improved source	Unimproved source	Total	Improved source	Unimproved source	Total
< = 30mins	50.5%	2.3%	52.8%	49.2%	2.2%	51.4%
31 - 59 mins	18.4%	0.6%	19.0%	19.9%	0.5%	20.4%
1 - 2 hours	25.5%	0.2%	25.7%	25.9%	0.2%	26.1%
> 2 hours	2.5%	0.0%	2.5%	2.1%	0%	2.1%
Total %	96.9%	3.1%	100.0%	97.1%	2.9%	100.0%

Source: Source: Field survey, 2017

Between the two study districts, water collection time in Jirapa Municipal is lower than in Kassena Nankana Municipal. The average water collection time per trip in Jirapa Municipal is 37 minutes compared to 46 minutes in Kessena Nankana Municipal. Also, from Tables 6.3 and 6.4, the proportion of households and population that collect water within 30 minutes in Jirapa Municipal is slightly higher than in Kassena Nankana Municipal. For instance, 56.5% of households in Jirapa Municipal collect water within 30 minutes as against 50% in Kassena Nankana Municipal. The results further show that 4.4% of households in Kessena Nankana Municipal spend more than 2 hours to collect water whereas in Jirapa Municipal, no household spends more than 2 hours to collect water (Tables 6.3 and 6.4).

[19] 51 households in which homemakers could not provide data on water collection time were excluded.

Table 6.3: Households and population by water collection time in Jirapa Municipal

Time	Percent of HH[20] (n=223)			Percent of population (n=1772)		
	Improved source	Unimproved source	Total	Improved source	Unimproved source	Total
< = 30mins	52.9%	3.6%	56.5%	50.8%	3.5%	54.3%
31 - 59 mins	17.0%	0.9%	17.9%	19.4%	0.7%	20.0%
1 - 2 hours	25.6%	0.0%	25.6%	25.6%	0.0%	25.6%
> 2 hours	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total %	95.5%	4.5%	100.0%	95.8%	4.2%	100.0%

Table 6.4: Households and population by water collection time in Kassena Nankana Municipality

Time	Percent of HH[21] (n=294)			Percent of population (n=1976)		
	Improved source	Unimproved source	Total	Improved source	Unimproved source	Total
< = 30mins	48.6%	1.4%	50.0%	47.8%	1.0%	48.8%
31 - 59 mins	19.4%	0.3%	19.7%	20.3%	0.3%	20.6%
1 - 2 hours	25.6%	0.3%	25.9%	26.2%	0.4%	26.5%
> 2 hours	4.4%	0.0%	4.4%	4.0%	0.0%	4.0%
Total %	98.0%	2.0%	100.0%	98.3%	1.7%	100.0%

Significant disparities exist in water collection time between urban and rural areas. The situation in urban areas is better than in rural areas. Average water collection time in urban areas (28 minutes) was almost half that of rural area (46 minutes). Also, whereas 72.2% of households / population in urban areas collect water within 30 minutes, in rural areas, only 48.1% households representing 46.8% of population collect water within 30 minutes (Tables 6.5 and 6.6). Although all urban populations use improved drinking water, only 72.2% collect water within 30 minutes. In rural areas, 44.2% out of the 96.5% of population who use improved water collect water within 30 minutes. (Tables 6.5 and 6.6).

[20] Valid responses
[21] Valid responses

Table 6.5: Households and population by water collection time in urban areas

Time	Percent of HH[22] (n=101)			Percent of population (n=677)		
	Improved source	Unimproved source	Total	Improved source	Unimproved source	Total
< = 30mins	72.2%	0.0%	72.2%	72.2%	0.0%	72.2%
31 - 59 mins	14.9%	0.0%	14.9%	15.7%	0.0%	15.7%
1 - 2 hours	12.9%	0.0%	12.9%	12.1%	0.0%	12.1%
> 2 hours	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total %	100.0%	0.0%	100.0%	100.0%	0.0%	100.0%

Table 6.6: Households and population by water collection time in rural areas

Time	Percent of HH[23] (n=416)			Percent of population (n=3071)		
	Improved source	Unimproved source	Total	Improved source	Unimproved source	Total
< = 30mins	45.2%	2.9%	48.1%	44.2%	2.6%	46.8%
31 - 59 mins	19.2%	0.8%	20.0%	20.8%	0.6%	21.4%
1 - 2 hours	28.6%	0.2%	28.8%	28.9%	0.3%	29.2%
> 2 hours	3.1%	0.0%	3.1%	2.6%	0.0%	2.6%
Total %	96.1%	3.9%	100%	96.5	3.5%	100%

6.5 Distance to Water Source

Distance to water sources in the study area varies from 0 meters within compounds to 2000 metres away from compounds, with the average being 363 metres. Analysis by households and population reveals that 5.6% of households and 5.9% of the sample population travel beyond the WHO threshold distance of 1000 metres to collect water (Table 6.7). Of the 97.4% of households with access to improved water sources, 5.9% travel more than 1000 metres to collect water (Table 6.7).

[22] Valid responses
[23] Valid responses

Table 6.7: Households and population by distance to water source in the study area

Distance	Percent of HH (n=568)			Percent of population (n=4188)		
	Improved source	Unimproved source	Total	Improved source	Unimproved source	Total
< = 500m	76.6%	2.6%	79.2%	73.8%	2.5%	76.3%
500 - 1000m	15.0%	0.2%	15.2%	17.7%	0.1%	17.8%
>1000m	5.6%	0.0%	5.6%	5.9%	0.0%	5.9%
Total %	97.2%	2.8%	100.0%	97.4%	2.6%	100.0%

Significant differences exist between Jirapa and Kassena Nankana Municipalities in terms of distance to water sources. The average distance to a water source from a dwelling unit in Jirapa Municipal (429m) is higher than in Kassena Nankana Municipal (303 m). Also, the proportion of households that travel more than 1000 metres to collect water in Jirapa (9.3%) is higher than in Kassena Nankana Municipal (2.3%) (Tables 6.8 and 6.9). The results are not different in terms of population.

Table 6.8: Households and population by distance to water source in Jirapa Municipal

Distance	Percent of HH (n=268)			Percent of population (n=2181)		
	Improved source	Unimproved source	Total	Improved source	Unimproved source	Total
< = 500m	68.3%	3.4%	71.7%	65.7%	3.2%	68.9%
500 - 1000m	18.6%	0.4%	19.0%	21.8%	0.2%	22.0%
>1000m	9.3%	0.0%	9.3%	9.1%	0.0%	9.1%
Total %	96.2%	3.8%	100.0 %	96.6%	3.4%	100.0 %

Table 6.9: Households and population by distance to water source in Kassena Nankana Municipal

Distance	Percent of HH (n=300)			Percent of population (n=2007)		
	Improved source	Unimproved source	Total	Improved source	Unimproved source	Total
< = 500m	84.0%	2.0%	86.0%	82.7%	1.6%	84.3%
500 - 1000m	11.7%	0.0%	11.7%	13.2%	0.0%	13.2%
>1000m	2.3%	0.0%	2.3%	2.5%	0.0%	2.5%
Total %	98.0%	2.0%	100.0 %	98.4%	1.6%	100.0 %

Between urban and rural areas, distance to water source in the latter is generally higher than in the former. For instance, average distance to water sources in urban areas is 308m compared to 376m in rural areas. Also, the proportion of households that travel more than 1000m to collect water in rural areas is 6.6% as against 1.7% in urban areas (Tables 6.10 and 6.11). Similarly, the proportion of the sample population that travels more than 1000m to collect water in rural areas (6.8%) is higher than in urban areas (2%) (Tables 6.10 and 6.11).

Table 6.10: Households and population by distance to water source in urban areas

Distance	Percent of HH (n=112)			Percent of population (n=747)		
	Improved source	Unimproved source	Total	Improved source	Unimproved source	Total
< = 500m	81.3%	0.0%	81.3%	81.3%	0.0%	81.3%
500 - 1000m	17.0%	0.0%	17.0%	16.7%	0.0%	16.7%
>1000m	1.7%	0.0%	1.7%	2.0%	0.0%	2.0%
Total %	100.0%	0.0%	100.0 %	100.0%	0.0%	100.0 %

Table 6.11: Households and population by distance to water source in rural areas

Distance	Percent of HH (n=456)			Percent of population (n=3441)		
	Improved source	Unimproved source	Total	Improved source	Unimproved source	Total
< = 500m	75.4%	3.3%	78.7%	72.2%	3.0%	75.2%
500 - 1000m	14.5%	0.2%	14.7%	17.8%	0.1%	18.0%
>1000m	6.6%	0.0%	6.6%	6.8%	0.0%	6.8%
Total %	96.5%	3.5%	100.0 %	96.9%	3.1%	100.0 %

6.6 Combined Accessibility to Water Sources

In line with the WHO definition of basic access to water i.e collection time within 30 minutes or source within 1km, the study estimated the proportion of households and population that meet the two criteria. The results show that 52.8% of households are within 1km reach to a water source and at the same time collect water within 30 minutes. The figure dropped to 50.5% for households that use improved water. The proportion of households that are within 1km reach to a water source and at the same time collect water within 30 minutes varies slightly between the two study Municipalities (56.5% in Jirapa vs. 50% in Kassena Nankana), and significantly between rural and urban areas (49.1% vs. 72.3%).

Table 6.12: Combined accessibility to water sources by households (n=517)

Spatial scale	Water collection time within 30 minutes and distance within 1km (**basic access**)		Water collection time > 30 minutes and/or distance > 1km (**No access**)		Total
	Improved Source	Unimproved source	Improved source	Unimproved source	
All households	50.5%	2.3%	46.4%	0.8%	100%
Municipality					
Jirapa	52.9%	3.6%	42.6%	0.9%	100%
Kassena Nankana	48.6%	1.4%	49.3%	0.7%	100%
Area					
Rural	45.2%	2.9%	51.0%	1.0%	100%
Urban	72.3%	0.0%	27.7%	0.0	100%

In terms of population, 53.4% are within 1km reach to a water source and at the same time collect water within 30 minutes (Table 6.13). The proportion of population that meet both the distance and time criteria in Jirapa Municipality (54.3%) was slightly higher than Kassena Nankana Municipality (48.8%) (Table 6.13). Between rural and urban areas, the proportion of population that met the two criteria in the latter (72.2%) is significantly higher than in the former (46.9%) (Table 6.13).

Table 6.13: Combined accessibility to water sources by population

Spatial scale	Water collection time within 30 minutes and distance within 1km (basic access)		Water collection time > 30 minutes and/or distance > 1km (No access)		Total
	Improved Source	Unimproved source	Improved source	Unimproved source	
Total Population	49.2%	4.2%	47.9%	0.7%	100%
Municipality					
Jirapa	50.8%	3.5%	45.0%	0.7%	100%
Kassena Nankana	47.8%	1.0%	50.5%	0.7%	100%
Area					
Rural	44.2%	2.7%	52.3%	0.8%	100%
Urban	72.2%	0.0%	27.8%	0.0%	100%

6.7 Effects of Poor Accessibility to Water Sources on Livelihoods

The effects of poor accessibility to water sources on the sample population were explored in terms of long distance to water sources and/or long waiting time. The study revealed that the effects of poor accessibility to water sources are not entirely negative. However, there was a consensus among participants that the negative effects far outstripped the positive effects. The results are presented below.

6.7.1 Positives

Of the 568 homemakers surveyed, 20.1% asserted that long water collection time has some positive effects. First, 15.8% of homemakers, largely women, who collect water said they share and receive information from each other during water collection. In the focus group sessions, women discussants affirmed that they interact with each other at the water point, especially when waiting times are long, thereby sharing information about funerals, anti-natal and post-natal days, forthcoming markets, households with pito[24], social events, among others. Related to sharing of information, 13% of survey respondents said that long water collection times offer water collectors the opportunity to share and discuss private matters. According to both men and women discussants, this explains why women often move in pairs during water collection.

Furthermore, 6.5% of survey respondents cited socialisation among water collectors as a benefit of long waiting times at the water point. According to discussants, while waiting to collect water, they talk to each other, make new friends and sometimes play as well. Children in particular are noted for playing during water collection. Children in focus group discussions affirmed this; they indicated that their parents often do not allow them to play at home, so when they meet friends at water points they play before bringing water home.

In addition, 10.2% of homemakers opined that water collection, which involves walking, carrying of water on head and pumping of borehole with hands, is a form of exercise, and thus improves body function and health. Moreover, in the survey, 9.3% of homemakers said that children, especially girls, walking for long distance to collect water is part of their upbringing. It was widely reported in the focus group sessions by male and female discussants that the ability of a women to carry water on her head increases her value. In other words, women who cannot carry water on their head are undervalued, and are less preferred for marriage by men.

6.7.2 Negatives

From the household survey, 55.1% of respondents (homemakers) mentioned a range of negative effects of long water collection times and distance on their livelihoods (Table 6.14). Major among them are body pains[25] (50%), fatigue (40%) and low food production/agro-processing (34.7%).

[24] Drink brewed with guinea corn
[25] Leading to early arthritis

Table 6.14: Negative effects on long water collection time on households

Negative effects	Related to: Long distance to source	Related to: Long waiting time at source	Percent of respondents[26]
1. Body pains (neck/spinal/head pains)	✓		49.8%
2. Fatigue	✓		39.8%
3. Low food production and agro-processing	✓	✓	34.7%
4. Poor home management	✓	✓	28.3%
5. Quarrels over water		✓	26.9%
6. Contamination of water	✓		24.1%
7. Spinal deformities due to head loading of water	✓		15.0%
8. Poor academic performance of children	✓	✓	10.9%
9. Musculoskeletal damage /soft tissue damage	✓		7.7%
10. Stunted growth of children	✓		7.6%
11. Reptile bites	✓		6.0%

The negative effects of long water collection times revealed in the survey were not very different from those reported in the focus group discussions held with men, women and children. However, the focus group discussions provided in-depth information on the effects reported by homemakers in the survey.

Firstly, it was reported by men, women and children across all focus group sessions that long distances to water sources undermine their health. Specifically, discussants mentioned neck pains, waist pains, spinals pains, knee pains, musculoskeletal damage and stunted growth caused by carrying of water on head over long distance. Water collectors also suffer from snakebites and scorpion stings. It was observed that the paths to water sources are often bushy, increasing the risk of snakebite and scorpion stings, especially in the night as people trek to collect water. Deaths arising from snakebites during water collection were reported in both Jirapa and Kassena Nankana Municipalities.

[26] Multiple response and hence percent (%) not adding up to 100

Secondly, it was widely reported in the focus group sessions that women spend many hours on water collection, thereby losing working-hours. On average, a woman in the Upper Regions of Ghana spends not less than 2 hours daily on water collection. This according to discussants reduces the amount of time women spend on farm work, the main source of livelihood in the study area. During the farming season in the Upper Regions of Ghana, men usually leave for their farms in the morning while women undertake household chores, including water collection before they join their husbands on the farm. However, it was reported that women often delay going to their farms due to crowding and long waiting time at water points.

Furthermore, it was revealed that long waiting times at water points brings about quarrels among water collectors. Conventionally, water collection at source is based on the principle of first come first served. Therefore, any attempt by a latecomer to skip others often generates disagreements and quarrels. Some women and children admitted to having sustained injuries such as broken teeth, broken arms, and bruises due to quarrels over water. This according to discussants does not promote unity and community development.

The study also uncovered that long water collection time leads to the collection of insufficient water for domestic use. This adversely affects cooking and hygiene practices of households. In over two-third of the focus group discussions, participants recounted how their households even went to bed without food because they couldn’t get water from source on time to prepare food. Insufficient water collection also limits income-generating activities of women such as pito brewing, dawa processing and sheabutter extraction. When boreholes are crowded, households sometimes cope by collecting water from unsafe sources like dams, open wells and dugouts, which expose them to water borne diseases.

Long water collection time also affects children’s education. When children wake up in the morning and there is no water at home for them to bath, they usually go to the borehole to collect water. When boreholes are crowded, they may spend long hours collecting water resulting in lateness to school. In some instances, they don’t even make it to school. Also, after school in the afternoon, children are engaged in water collection till evening, and hence unable to study and carry out homework. Furthermore, it was reported that water collection sometimes acts an excuse for some girls to visit their boyfriends which can result in teenage pregnancies and school dropout. According to parents, when they confront girls over delays in water collection, they attribute it to long waiting time at water points.

In addition, it was reported by men in the focus group sessions that long water collection times have dire consequences on marriage stability. According to male discussants, its offers women the opportunity to discuss their husbands' sexuality, the things they give them and also the love their husbands show them. Women who feel they are less loved or badly treated by their husbands compared to their friends often feel empowered to demand the same from their husbands. Men claimed that if a woman makes demands such as an increase in housekeeping money or support in household chores, it is mostly due to influence from other women. Failure on the part of men to meet the demands of women brings quarrels and sometimes divorce.

It was also reported in about one-third of FGDs held with men and women that long water collection times negatively affects their sexual life. According to discussants, instead of women resting on returning from the farm, they have to trek again for long distances to collect and carry water home. This compounds their tiredness, and they are sometimes unwilling to meet their husbands' sexual demands when they retire to bed. At dawn too, women wake up early to collect water to avoid crowding of boreholes. Sometimes, women wake up as early as 4 am to collect water.

6.8 Discussion

The results of the study showed that water collection in the study area is the primary responsibility of adult females, with support from children, largely girls in both rural and urban areas. Men as breadwinners of families were involved in productive and income generating activities like crop farming, animal rearing and trading. It is socially unacceptable for a man to collect water, except when able women and children are not available. The findings on water collection responsibility is consistent with gendered divisions of household work as practise in many developing countries, particularly in Africa (Graham et al., 2016; Oxfam, 2017). Graham et al. (2016) in their analysis of water collection burdens in 24 Sub-Saharan African Countries using DHS and MICS data found that women were primary water collectors in both rural and urban areas. Similarly, in Zimbabwe, Oxfam (2017) noted that, women were traditionally responsible for all domestic work while “men are responsible for productive and income-generating activities”. Consequently, children’s roles are determined by tradition from birth (Oxfam, 2017; Rubio, 2018). Although early work by Jackson also identified women as being responsible for the collection of fuel wood and water in developing countries, he observed that “they are not static but mutable, contested and responsive to changes in societal level gender relations and also in periods of crises” (Jackson, 1993, p. 12). In both rural and urban areas, the proportion of women and girls involved in water collection is higher than men and boys. This is consistent with the findings of Graham et al. (2016) in 24 Sub-Saharan Africa countries and Boone et al. (2011) in Madagascar. Women and girls in Africa therefore bear a large portion of the sufferings associated with water collection (Boone et al., 2011).

Water collection as the primary responsibility of women in the Upper Regions of Ghana is a socially accepted norm. In line with the findings of Oxfam (2017) in Zimbabwe, culture is the main reason for the continuous ascription of water collection to women. It was found that water collection was expressed proverbially as one of the duties of women in marriage. According to Oxfam (2017), such expressions reinforce gendered norms and may discourage male involvement in water collection.

Significant variations exist in the means of water collection between adult females and girls, and adult males and boys on the other hand. Adult females, the primary collectors of water, mainly collect water by means of headloading while adult males, who collect the least collect amount of water use bicycles. Almost all girls collect water by means of headloading. Boys are more likely to use bicycles for water collection than girls (42.4% vs. 0.8% respectively). This implies that adult females, followed by girls suffer most from the drudgery associated with headloading of water.

The average distance to drinking water sources in the study area was 363 metres. This far lower than the 2,780 metres reported by Demie et al. (2016) in Ethiopia. A majority of households’ drinking water sources were within the WHO and CWSA distance thresholds. About eight out of every 10 households were within the Ghana CWSA threshold of 500 metres and nine out of every 10 households within the WHO threshold of 1km. The findings are not very different from households that use improved water. Distance to water sources in rural areas is slightly lower than in urban areas. As a result, the proportion of households that travel long distance (greater than 1km) to collect water in rural areas is higher than in urban areas. This implies that the adverse effects of distance on water collection are much felt in rural areas compared to urban areas. The average distance to water sources recorded in this study for rural (376m) and urban areas (308m) are higher than that reported by Boone et al. (2011) in Madagascar (243m for rural and 110 for urban).

Water collection time in the Upper Regions of Ghana was generally high with the average being 42 minutes. The results showed that almost half of households/population spend more than 30 minutes on a round trip of water. The remaining half collect water within 30 minutes as recommended by the WHO. This is far lower than the national average of 92.6% households that were reported to collect water within 30 minutes in the 2014 Demographic Health Survey (Ghana Statistical Service et al., 2015). The results further revealed that three out of every 10 households spend one hour or more on a round trip of water. Of the 97.1% of population who used improved water sources, almost half spend more than 30 minutes to collect water.

The results revealed spatial disparities in water collection time between rural and urban areas, and between the two study Municipalities. Water collection time in urban areas is significantly lower than in rural areas. As a result, the population with basic access to drinking water (collection time within 30 minutes) in urban areas (72.2%) is significantly higher than in rural areas (44.2%). Similarly, Graham et al. (2016) found that many rural households in SSA spend more than 30 minutes to collect water compared to urban households. The proportion of rural (51.9%) and urban (37.8%) households who spent more than 30 minutes to collect water in this study is within the range reported by Graham et al. (2016) for rural (2% to 58%) and urban areas (3% to 39%) across 24 countries in SSA. The GSS in the 2014 DHS in Ghana also established high water collection time in rural areas compared to urban areas (Ghana Statistical Service et al., 2015). From the 2014 DHS, 91.9% of population in urban areas collect water within 30 minutes as against 70.6% in rural areas. Results of water collection time between the two Municipalities further affirmed variation in water collection time in space. Water collection time is the Jirapa Municipality was found to be slightly lower than in Kassena Nankana Municipality. As a result, the proportion of households/population with basic access to drinking water in Jirapa Municipality is slightly higher than in Kassena Nankana Municipality.

Based on the WHO distance threshold of 1km (WHO, 2011a), it appears that 97.4% of the population have basic access to improved water. However, when the equivalent 30 minutes round trip water collection time is considered (WHO, 2011a), basic access to improved water dropped to 49.2%. This implies that a distance of 1km to a source does not guarantee water collection within 30 minutes. This reflects high waiting times at water points. Consequently, analysis of basic access to water based on the WHO 1km distance to water source can lead to overestimation of the population/households with access to drinking water in Ghana and other developing countries where waiting time at source is high. Long water collection times in the study area largely reflects the overreliance of the population on communal water facilities. About 98% of the population depend on communal facilities, largely boreholes. Meanwhile, the nature of borehole design does not promote fast water collection because water is sourced manually from only one outlet.

Long distance to water sources and collection time limit the quantity and quality of water households collect (García-Valiñas & Miquel-Florensa, 2013; Howard & Bartram, 2003). When water collection time is more than 30 minutes or distance to source is greater than 1km, the quantity of water collected is likely to fall below the basic requirement of 20 litres/capita/day leading to poor consumption, limited hygiene practice and health problems (Howard & Bartram, 2003). Also, water risk being contaminated when carried over a long distance (García-Valiñas & Miquel-Florensa, 2013) due to poor handling. Moreover, water collection outside the home, especially where distances are long will limit access to water by vulnerable groups such as the aged, physically challenged, pregnant women and children (Jones et al., 2012).

The results showed that poor accessibility to water sources have negative livelihood outcomes. Foremost, headloading of water, especially over long distances undermine the health of women and girls through body pains, fatigue, spinal deformities, contamination of transported water and reptile bites. The results explain why musculoskeletal disorders are highly prevalent in women than men in Ghana (Nakua et al., 2015). The impact of water collection on the health of water collectors – largely women and children- is widespread in Africa (Fisher, 2008; Geere et al., 2018; Jonah et al., 2015). Geere et al. (2018) in their cross-sectional survey in South Africa, Ghana and Vietnam found that general body pains are associated with carrying of water, especially on the head. In Zimbabwe, both men and women attributed backache, ageing, high blood pressure, miscarriage and depression, which women and children experience to domestic workload, including carrying of water. In Kenya, Jonah et al. (2015) reported that water collection negatively affects the physical development of children in Nakuru county. Nygren et al. (2016) in their study in Kenya, found that when round trip water collection time is greater than 30 minutes, children are at risk of moderate to severe diarrhoea in households that did not collect rainwater for the past 7 days.

Secondly, poor accessibility to water impacts negatively on income levels of women and food production. The huge time women spend on water collection limits their engagement in production and income generating activities like farming. This predisposes women to low income and poverty. Between 2005 – and 2017, the incidence of poverty among female-headed households in Ghana was higher than among male-headed households (Ghana Statistical Service, 2018). The impact of water collection on food production and income of women and their households in developing countries has been reported in earlier studies. Jonah et al. (2015) found that long water collection time in Kenya limits women participation in other household chores and income generating activities (Jonah et al., 2015). In Zimbabwe, women reported that domestic work, including water collection consume most of their time and thus have limited time to engage in productive and income generating activities (Oxfam, 2017). Therefore, improving accessibility to water (e.g taps in compounds) will help poor households save time on water collection and direct it to other productive ventures.

Thirdly, water collection also has dire consequences for the education of children, especially girls. It was uncovered that children after school used their study time to collect water resulting in poor academic performance. In addition, water collection by children in the morning leads to lateness to school and lack of concentration in class due to tiredness. These factors can culminate in poor performance of children, especially girls, who are mostly engaged in water collection. A trend analysis of the Basic Education Certificate Examination (BECE) pass rates of girls and boys support the findings of the study. For instance, the proportion of girls who passed the 2018 BECE in Jirapa Municipality is 26% as against 46% for boys (Ghana Education Service, 2018). Similarly, in 2017, 53% of boys passed as against 31% of girls (Ghana

Education Service, 2017). This situation leads to school dropout, low educational attainment, lack of decent jobs, low income and finally low quality of life of women. The impact of water collection on children's education in Africa has been reported in earlier studies (Jonah et al., 2015; Osumanu et al., 2010; Oxfam, 2017).

Fourthly, conflict at water points is yet another negative outcome of long water collection times. Conflict between water collectors was reported to be either overt, subtle or both. Overt conflict takes the form of arguments, exchanges of words, skirmishes, verbal insults, exchanges of blows and wrestling (Sultana, 2011). Subtle conflicts emerging from struggles over water include humiliation, loss of pride, shame stress, emotional distress, sadness, anxiety and depression (Sultana, 2011). Conflict, be it overt or subtle has embodied emotions of unhappiness in women and also between their families.

In addition, the study also uncovered poor marriages and sexual lives of women due to inaccessibility to drinking water sources. This situation is borne out of marital gossip during water collection by women, tiredness and water collection at dawn. Similarly, in Zimbabwe, Oxfam reported that domestic workload makes women tired and unhappy leading to divorce and poor sexual lives with partners (Oxfam, 2017). Although, TrueLove did not identify any implication of poor access to water and sanitation services on marriage and sexual live in Delhi, he observed that "due to a lack of local toilet facilities, women rise at 4:45 am, and begin a half hour early morning walk to find a relatively uninhabited forest area to urinate and defecate" (TrueLove, 2011, p.6).

The results of the study showed that, the effects of poor accessibility to water on livelihood are not entirely negative. A few positive effects were uncovered. These include, access to information, socialisation, exercise and increase in dignity for meeting household water demand. The findings are consistent with the assertion of Sultana (2011) that the emotional geography of water comprised of both positive and negative feelings;

> *"the emotional geography of water comprised of not just the sentiments brought to the fore from the water crises,…beyond the commonly felt sufferings and pain, there is also recounting of previous pleasure in fetching and/or controlling safer/closer water resources, of feeling relief in being able to*

obtain safe water with ease, of talking about the joy of having one's own uncontaminated well, or the pleasure in going far to get water as an escape out of the house" (Sultana, 2011, p. 8).

6.9 Conclusion

In conclusion, accessibility to drinking water sources in the Upper Regions of Ghana is poor. Distances to water sources were found to be great with the average being 363 metres. A fifth of households travel more than 500 metres to collect water. Even when drinking water sources are less than 500 metres, water collection time could be high. Average roundtrip water collection time was estimated to be 42 minutes with almost half of households spending more than 30 minutes on a roundtrip of water. Of the 97.4% improved water coverage recorded in the study area, 94.1% of the population drinking water sources were within the WHO recommended distance threshold of 1km to a water source from dwelling. It dropped significantly to 51.4% when the WHO recommended roundtrip water collection time limit of 30 minutes was applied, and further to 49.2% for the JMP roundtrip water collection time limit of 30 minutes for at least basic access. This implies that a distance of 1 km to a water source does not necessarily guarantee a roundtrip water collection time of 30 minutes or less.

Poor accessibility to drinking water sources leads to inadequate water collection for household use. It also has adverse socio-economic and emotional effects on the lives of water collectors and their households. Major among them are poor health, low educational attainment, low income, low economic productivity, unstable marriages (socio-economic consequences), tiredness, psychological stress and sadness (embodied emotions).

7 DRINKING WATER QUALITY

7.1 Introduction

This chapter addresses objective two of the study. It assessed the quality of drinking water sources in the Upper Regions of Ghana. The main source of data was water quality testing of households' drinking water sources, focusing on three priority contaminants - faecal coliforms, arsenic and fluoride. This was complemented by a household survey with principal housekeepers and focus group discussions with men, women, boys and girls on perceived water quality. The household survey and water quality data were analysed quantitatively in SPSS using relevant descriptive and inferential statistical tools. The results have been presented around seven (7) broad themes. They include faecal coliforms concentration in drinking water sources, fluoride concentration in drinking water sources, arsenic concentration in drinking water sources, overall access to safe water sources, households' perceptions of water quality, water treatment practices and finally consequences of poor water quality on livelihoods. This was followed by a discussion and a conclusion.

7.2 Faecal Coliform Concentration in Drinking Water at Source

7.2.1 Level of faecal coliform concentration

The level of faecal coliform concentration in drinking water sources in both rainy and dry season samples was explored through analysis of descriptive statistics – minimum, maximum, average and standard deviation (Table 7.1). In the rainy season, the amount of Faecal Coliforms (FC) in household water sources ranged from 0 – 800 CFU/1mL with an average of 45 CFU/1mL for all sources. A standard deviation of 122.6 CFU/1mL shows a significant variation in FC concentration level among water sources in the rainy season. Significant disparity exists in average concentration levels between improved water sources (31 CFU/1mL) and unimproved water sources (240 CFU/1mL) in the rainy season. Analysis by source types in the rainy season reveals that boreholes have the highest concentration in FC (800 CFU/1mL), followed by unprotected wells (440), dugouts/dams (420 CFU/1mL), protected wells (280 CFU/1mL), standpipes (14 CFU/1mL) and lastly pipe-borne (13 CFU/1mL). In terms of average FC concentration levels in the rainy season, dugouts/dams have the highest (420 CFU/1mL), followed by unprotected wells (234 CFU/1mL), protected wells (112 CFU/1mL), boreholes (29 CFU/1mL), standpipes (5 CFU/1mL) and lastly pipe-borne sources (2 CFU/1mL). Of the seven protected wells tested in the rainy season, none was free from FC.

In the dry season, FC concentration in household water sources ranged from 0 – 600 CFU/1mL with an average of 12 CFU/1mL (Table 7.1). The average concentration of FC in improved water sources (11 CFU/1mL) is almost seven times lower than that of unimproved water sources (73 CFU/1mL). Analysis by source types shows that protected wells have the highest average FC concentration in the dry season – 141 CFU/1mL, followed by unprotected wells (73 CFU/1mL), standpipes (13 CFU/1mL), boreholes (3 CFU/1mL) and pipe-borne (1 CFU/1mL).

Table 7.1: Descriptive statistics on FC concentration in drinking water (CFU/mL)

Source types	Min.		Max.		Average		SD		No. of samples	
	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS
Pipe-borne	0	0	13	3	2	1	4	1	10	10
Public tap/standpipe	0	0	14	50	5	13	5	25	5	4
Borehole	0	0	800	180	29	3	112	19	109	105
Protected well	22	13	280	300	112	141	100	214	8	7
Unprotected well	51	45	440	101	234	73	176	40	7	2
Dugouts/Dam	104	-	420	-	262	-	223	-	2	-
Improved sources	0	0	800	600	31	11	107	59	132	126
Unimproved sources	51	45	440	101	240	73	172	40	9	2
All sources	0	0	800	600	44.5	12.2	122.6	59.6	141	128

Min. (Minimum Value); Max. (Maximum Value); RS (Rainy Season); DS (Dry Season); SD (Standard Deviation)

Source: Field survey, 2017

7.2.2 Seasonal variations in faecal coliforms concentration in drinking water

The descriptive statistics presented in Table 7.2 show some level of variation in FC concentration between rainy and dry seasons. With the exception of standpipes and protected wells, the average concentration levels for all other sources in the rainy season is higher compared to the dry season. For instance, the average concentration for all sources combined in the rainy season is 45 CFU/1mL as against 12 CFU/1mL in the dry season (Tables 7.2). Also, FC concentration in water sources in the rainy season ranged from 0 – 800 CFU/1mL compared to 0 – 600 CFU/1mL in the dry season.

A statistical test was conducted to ascertain if the observed seasonal variations in the descriptive statistics are significant. The test was founded on the following eight research questions;

- Does faecal coliform concentration in drinking water sources differ significantly between seasons?
- Does faecal coliform concentration in improved water sources differ significantly between seasons?
- Does faecal coliform concentration in unimproved water sources differ significantly between seasons?
- Does faecal coliform concentration in pipe-borne water differ significantly between seasons?
- Does faecal coliform concentration in standpipes differ significantly between seasons?
- Does faecal coliform concentration in boreholes differ significantly between seasons?
- Does faecal coliform concentration in protected wells differ significantly between seasons?
- Does faecal coliform concentration in unprotected wells differ significantly between seasons?

A Wilcoxon Signed Rank test was suitable because it is used for comparing two sets of non-normally distributed data that comes from the same participants (Field, 2013). The normality of the data was verified based on K-S and Shapiro-Wilk normality test. From the test statistics, FC concentrations for all sources, improved sources, unimproved sources, piped borne, standpipe, unprotected well and unprotected wells in both rainy and dry seasons were significantly different from normal ($P < 0.05$) (Appendix I). The test was carried out in SPSS with guidance from Field (2013). The null hypothesis in a Wilcoxon Signed Rank test assumes that the median difference between pairs of observations is zero while the alternate hypothesis assumes otherwise (McDonald, 2014). With reference to the afore-stated research questions, the hypotheses for the Wilcoxon signed rank test are presented in Table 7.2.

Table 7.2: Questions and hypotheses for Wilcoxon signed-rank test of seasonal variations of FC concentration in drinking water sources

Questions	Null hypothesis (H_0)	Alternate hypothesis (H_1)
• Does faecal coliform concentration in drinking water sources differ significantly between seasons?	H_0: median difference in faecal coliform concentration in drinking water sources between seasons is zero.	H_1: median difference in faecal coliform concentration in drinking water source between seasons is not zero.
• Does faecal coliform concentration in improved water sources differ significantly between seasons?	H_0: median difference in faecal coliform concentration in improved water sources between seasons is zero.	H_1: median difference in faecal coliform concentration in improved water sources between seasons is not zero.
• Does faecal coliform concentration in unimproved water sources differ significantly between seasons?	H_0: median difference in faecal coliform concentration in unimproved water sources between seasons is zero.	H_1: median difference in faecal coliform concentration in unimproved water sources between seasons is not zero.
• Does faecal coliform concentration in pipe-borne water differ significantly between seasons?	H_0: median difference in faecal coliform concentration pipe-borne water between seasons is zero.	H_1: median difference in faecal coliform concentration in pipe-borne water between seasons is not zero.
• Does faecal coliform concentration in standpipes differ significantly between seasons?	H_0: median difference in faecal coliform concentration in standpipes between seasons is zero.	H_1: median difference in faecal coliform concentration in standpipes between seasons is not zero.
• Does faecal coliform concentration in boreholes differ significantly between seasons?	H_0: median difference in faecal coliform concentration in boreholes between seasons is zero.	H_1: median difference in faecal coliform concentration in boreholes between seasons is not zero.
• Does faecal coliform concentration in protected wells differ significantly between seasons?	H_0: median difference in faecal coliform concentration in protected wells between seasons is zero.	H_1: median difference in faecal coliform concentration in protected wells between seasons is not zero.

• Does faecal coliform concentration in un protected wells differ significantly between seasons?	H_0: median difference in faecal coliform concentration in unprotected wells between seasons is zero.	H_1: median difference in faecal coliform concentration in unprotected wells between seasons is not zero.

Source: Author construct, 2018

From Table 7.3, the Wilcoxon Signed Rank test statistics show significant differences (z = -0.53, p < 0.05, r = -0.41) in faecal coliform concentrations in drinking water between rainy and dry seasons for all sources. The results also show evidence of significant seasonal variations in FC concentration for improved water sources (z = -4.39, P < 0.05, r = -0.39). For unimproved water sources, the results show no significant seasonal variation in FC (z = -1.342, P > 0.05, r = -0.12). With the exception of boreholes, FC concentration between seasons by source types is statistically significant (P > 0.05) (Table 7.3). From the test statistics, the null hypothesis stating that the median difference in FC concentration between seasons is zero is true for pipe-borne, standpipes, protected wells, unprotected wells and improved water sources (Table 7.3). For boreholes, improved sources and all sources combined, the null hypotheses are rejected, and the alternate hypotheses accepted (Table 7.3).

Table 7.3: Wilcoxon Signed Rank Test statistics on seasonal variations in faecal coliform concentration in drinking water by source types, improved sources, and unimproved sources and all sources

Water sources	N	Median (Mdn)		Z score	P value (2-tailed)	Effect Size (r)
		RS	DS			
Pipe-borne	10	0	0	$-.530^{b}$	0.596	-0.05
Public taps/standpipes	4	5	0.5	$-.365^{b}$	0.715	-0.03
Boreholes	105	0	0	-4.294^{b}	0.000	-0.38
Protected wells	7	113	37	-1.014^{b}	0.310	-0.09
Unprotected wells	2	410	73	-1.342^{b}	0.180	-0.12
Improved sources	126	0	0	-4.390b	0.000	-0.39
Unimproved sources	2	410	73	-1.342b	0.180	-0.12
All sources combined	**128**	0.5	0	-4.599^{b}	0.000	-0.41

b. Based on positive ranks. RS = Rainy Season. DS = Dry Season

Source: Field survey, 2017

7.2.3 Variations in faecal coliforms concentration in drinking water by source types

Whereas improved water sources are expected to deliver safe water, some studies have shown that it is not always the case (Bain et al., 2014; Baum et al., 2014; Onda et al., 2012; WHO/UNICEF Joint Monitoring Programme, 2011). It is against this backdrop that a statistical test was conducted to answer the following two specific research questions;

- Does FC concentration in drinking water vary significantly by source type?
- Does FC concentration in drinking water vary significantly between improved and unimproved sources?

Kruskal-Wallis test was found to be appropriate because it is suitable for examining differences of non-normally distributed scores between two or more groups[27] (Field, 2013). The normality of the data was verified based on K-S and Shapiro Wilk test statistics in SPSS. From the test statistics, FC concentrations in drinking water by source types in both rainy and dry seasons were non-normal ($P < 0.05$, except for standpipe and unprotected well in the rainy season) (Appendix I). Also, FC distribution by improved and unimproved sources in both rainy and dry seasons were not approximately normal ($P < 0.05$).

From Table 7.4, the Kruskal-Wallis test statistics reveal significant disparity ($P < 0.05$) in FC concentration in drinking water by source types in both rainy and dry seasons in the study area. This is evident by differential mean ranks in concentration among source types. In the rainy season, the source with the least FC mean rank (in CFU/1mL) is pipe-borne (55), followed by borehole (63), standpipe (85), protected well (122), unprotected well (130) and lastly dugout/dam (131). Similarly, in the dry season, the source with the least FC mean rank is pipe-borne (59), followed by borehole (60), standpipe (78), protected well (121) and lastly unprotected well (123). Analysis of the effect size shows that in both rainy and dry seasons, source type accounts for 30% of variation in FC concentration in drinking water at source.

[27] NB: Source types were six in number

The Kruskal-Wallis test also reveals significant differences in FC concentration between improved and unimproved sources in both dry and rainy seasons (P<0.05). The mean ranks in FC concentration for improved and unimproved sources in the rainy season are 67 and 130 CFU/L, whereas in the dry season, they are 64 and 123 CFU/L, respectively. The effect size shows that, in the rainy season, 16% of differences in FC concentration in drinking water at source is dependent on whether the source is improved/unimproved. In the dry season, however, it is 6%.

Table 7.4: Mean ranks from a Kruskal-Wallis test of variations in FC concentration between water sources

Test groups	Water sources	Number of samples	Mean Ranks
Between source types (rainy season)	Pipe-borne	10	55
	Public tap/standpipe	5	85
	Borehole	109	63
	Protected well	8	122
	Unprotected well	7	130
	Dugout/Pond/Lake/Dam	2	131
	Total	141	
Between improved & unimproved sources (rainy season)	Improve sources	132	67
	Unimproved sources	9	130
	Total	141	
Between source types (dry season)	Pipe-borne	10	59
	Public tap/standpipe	4	78
	Borehole	105	60
	Protected well	7	121
	Unprotected well	2	123
	Total	128	
Between improved & unimproved sources (dry season)	Improve sources	126	64
	Unimproved sources	2	123
	Total	128	

Source: Field survey, 2017

Table 7.5: Test statistics from a Kruskal-Wallis test of variations in FC concentration between water sources

Test groups	Chi-Square	df	P-value	Effect size (r)
Between source types (rainy season)	42.107	5	0.000	0.299
Between improved & unimproved sources (rainy season)	22.738	1	0.000	0.161
Between source types (dry season)	38.873	4	0.000	0.304
Between improved & unimproved sources (dry season)	8.201	1	0.004	0.064

Source: Field survey, 2017

7.2.4 Risk levels of water sources and population by faecal coliform concentration in drinking water

This section presents results on health risks associated with drinking water sources and population based on faecal coliform concentration in water samples. The World Health Organisation E.coli-risk-to-health classification framework was adopted. The organisation in its 4th edition of water quality guidelines classified E.coli based on risk-to-health as follows; > 1CFU/100mL as low risk, 1-10 CFU/100mL as intermediate risk; 11-100 CFU/100mL as high risk and above 100 CFU/100mL as very high risk. In line with this framework, CFU were classified into the same four levels/ risk categories and count ranges.

The results reveal seasonal disparity in the proportion of water sources classified as low risk, intermediate risk, high risk and very high risk (Figures 7.1 and 7.2). For instance, in the rainy season, 48.2% of water sources are low risk as against 72.7% in the dry season. Again, in the rainy season, 12.1% of sources fall within very high risk category compared to 3.1% in the dry season.

Analysis by improved/unimproved sources reveals that, in the rainy season, 51.5% of improved sources have no faecal coliforms (low risk), 25.8% have FC ranging from 1 – 10 CFU/1mL (intermediate risk), 15.2% have FC ranging from 11 – 100 CFU/1mL (high risk) and 7.6% have FC above 100 CFU/1mL (very high risk) (Figure 7.1). In the dry season, 73.8% of improved water sources have no FC (low risk), 15.1% have FC ranging from 1 – 10 CFU/1mL (intermediate risk), 8.7% have FC ranging from 11 – 100 CFU/1mL (high risk) and 2.1% have FC above 100 CFU/1mL (very high risk)

(Figure 7.2). All unimproved water sources have FC with levels ranging from high (11-100 CFU/1mL) to very high risks (above 100CFU/1mL). In both seasons, pipe-borne record the highest percentage of FC-free samples (Figures 7.1 and 7.2).

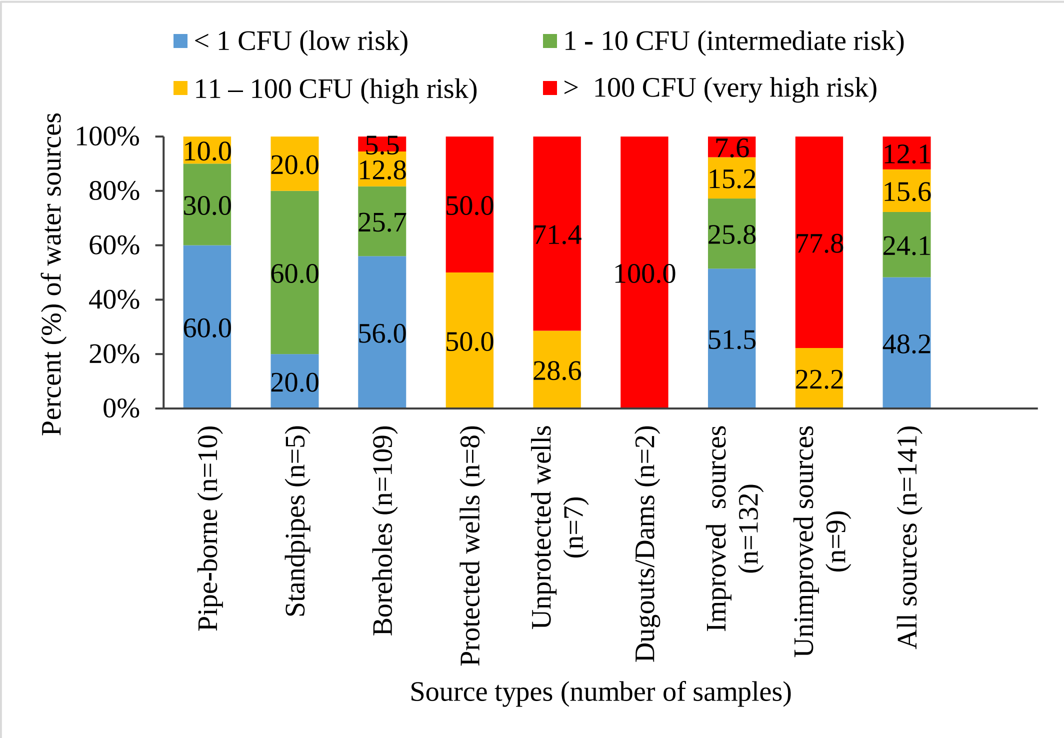


Figure 7.1: Distribution of water sources by levels of faecal coliform concentration (CFU/1mL) /risk-to-health in the rainy season

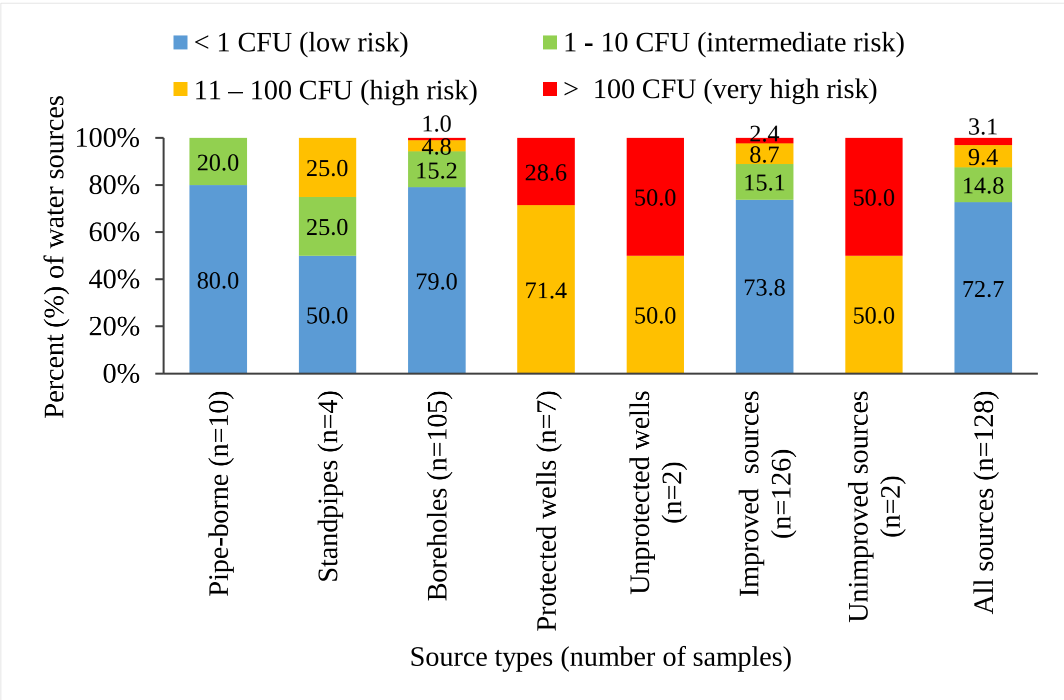


Figure 7.2: Distribution of water sources by levels of faecal coliform concentration (CFU/1mL) /risk-to-health in the dry season

The proportion of population exposed to faecal matter in drinking water is higher in the rainy season than in the dry season. From Figure 7.3, 49.5% of the sample population's drinking water was contaminated with faeces in the rainy season as against 24.5% in the dry season. Of the 97.4% sampled population that mainly used improved water, 23.1% were exposed to faeces in the dry season. In the rainy season, it increased to 39.9% (Figure 7.3).

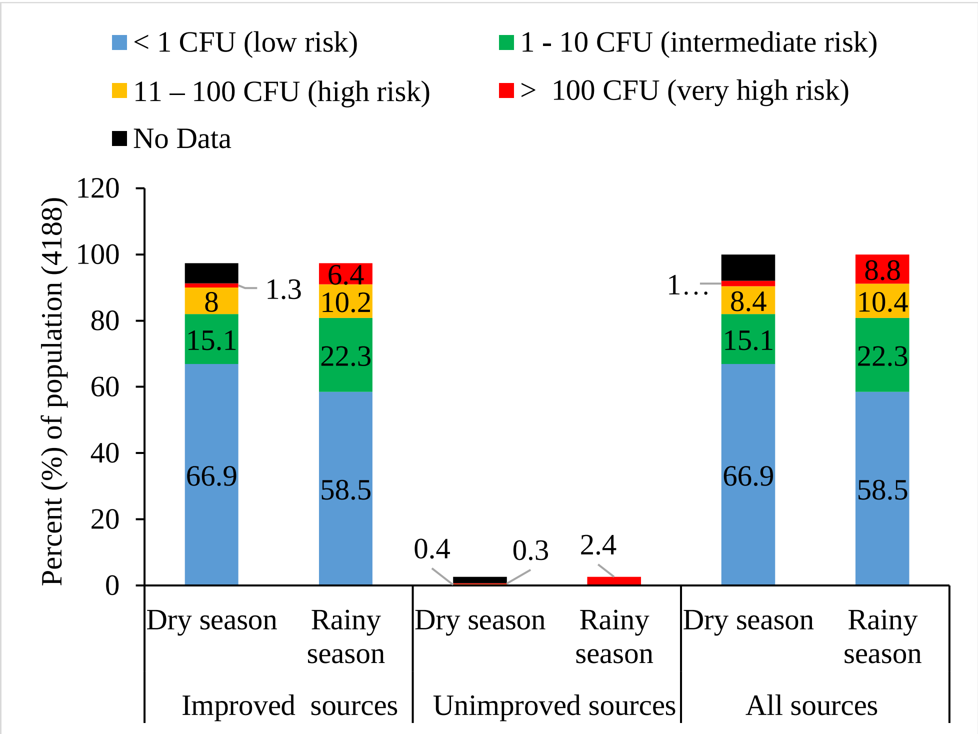


Figure 7.3: Distribution of population by the level faecal coliform concentration

Source: Field survey, 2017

From Figure 7.4, exposure to faecal matter in drinking water is higher in rural areas than in urban areas. In the rainy season, 45.1% of population in rural areas were exposed to faeces in drinking water as compared to 24.5% in urban areas. Similarly, in the dry season 26% of population in rural areas were exposed to faeces in drinking water as against 21% in urban areas.

(Figure 7.4).

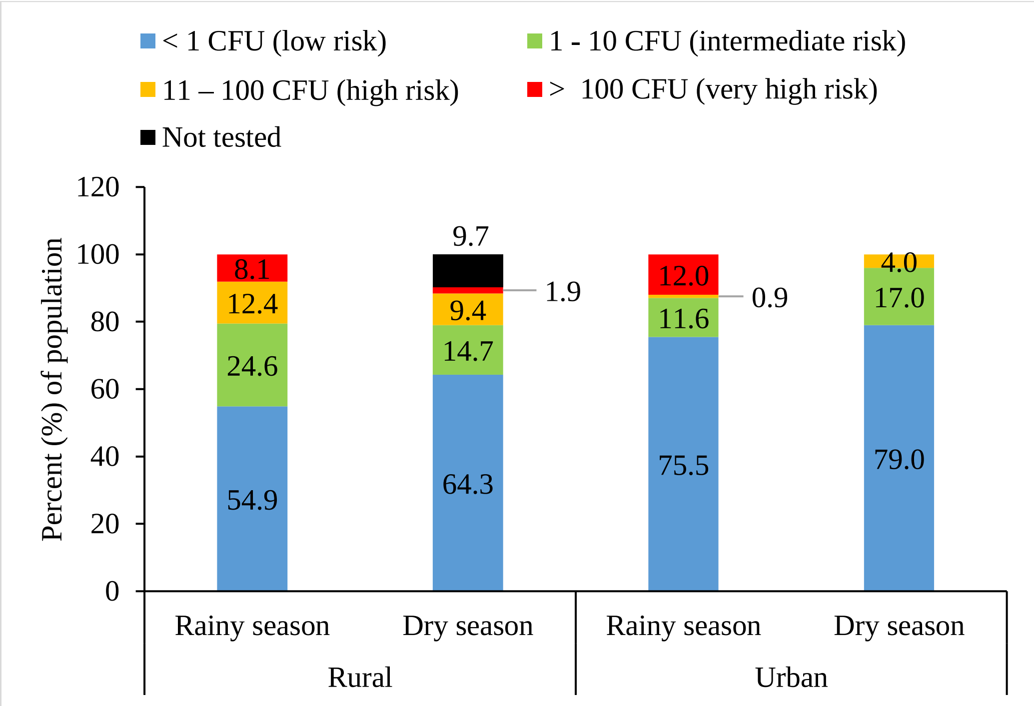


Figure 7.4: Rural-urban population exposure to faecal coliforms in drinking water

7.2.5 Risk assessment of faecal contamination of improved drinking water sources

According to the WHO (2011), the most effective way of providing safe drinking water is through comprehensive risk assessment and management of water supply systems from catchment to consumer. The WHO in its 4th edition of drinking water quality guidelines, refers to this approach of safeguarding water supply systems as Water Safety Plans (WSP). WSP has three interrelated phases, involving system assessment, effective operational monitoring, management, and communication (WHO 2011). The primary objective of a WSP is to prevent or minimise contamination of drinking water from source to the point of consumption (WHO, 2011). In this study, a qualitative risk assessment was conducted to help identify risk factors that could cause faecal contamination of drinking water sources, to inform the design and implementation of control measures in the study area. Risk factors were identified through site observation[28] of water sources, FGDs with men, women and water committees, and expert interviews with staff of Community Water and Sanitation Agency (CWSA).

[28] Site observation of water sources was carried out with guidelines from Howard et al. (2012) - *Rapid assessment of drinking-water quality implementation handbook*, World Health Organisation

The study identified **poor sanitation practices** as the main risk factor in faecal contamination of improved water sources in the study area. It manifests in two main ways;

- First, limited containment of faeces increases vulnerability of water sources, including improved sources to contamination. It was common to see human and animal excreta littered around the environment in the study area. This is largely due to widespread open defecation by households. Moreover, septic tanks of the few KVIP, WC, pit latrines in the study area were poorly lined, leading to ingress of faeces underground. Also, in both Municipalities, faeces are not treated nor do they have an engineered land fill site. When a toilet facility is full, households empty faecal sludge and dump it in the open or abandon their facility, and construct a new one. The presence of faeces on the environment is further exacerbated by the extensive system of animal rearing.

- Second, inappropriate methods of waste disposal also expose water sources to faecal contamination. Household waste often contains children's and animal faeces, and thus need to be disposed of properly. However, the common method of waste disposal in the study area is dumping into open spaces.

Poor management of water sources also emerged strongly as a potential risk factor in faecal contamination of water sources. In line with best practice in water resource management, most water resources in Ghana, especially communal water resources, have management committees. These committees among others are to protect water sources from contamination. All improved water sources surveyed had management committees. However, the findings show that they are ineffective, resulting in poor protection of water sources against contamination.

- First of all, site observation of standpipes, boreholes and protected wells reveals that they are not sufficiently protected against animals. It appears to be a norm by water users to allow animals to drink wastewater from troughs,

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and International Water Association (2009) - *Water Safety Plan Manual*, WHO (2011a) – *Guidelines for drinking water quality (4th edition)* and Bartram et al. (2001) - *Water quality guidelines, standards and health.*

especially at borehole sites (Figure 7.5). Consequently, animals defecate around water points. This observation was affirmed by a Hydro-Geologist of CWSA in Kassena Nankana Municipal as follows;

> *"the immediate surroundings of water infrastructure are not well maintained. Our boreholes are not protected. Animals go to drink water from the troughs and even defecate in them. Meanwhile, the troughs are not cemented. When it rains, faecal matter littered around the environment liquefies and seeps underground. The risk of faecal contamination is very high when so much water seeps underground" (*Hydrologist Geologist - CWSA, Kassena Nankana Municipal*, 01.02.2018)*

Figure 7.5: Cows drinking from a borehole in Atosaale

- Also, water infrastructure (especially boreholes) was noted to be poorly maintained. An in-depth interview with the Hydro-Geologist of CWSA in Kassena Nankana Municipal revealed that boreholes are supposed to be re-developed every 10 years to clear algae, worms and blockages inside wells. However, communities do not do redevelopment because it is very expensive. Considering the high cost involved in redevelopment of wells, the CWSA encourages low-cost maintenance practices such as routine disinfection of wells and cleaning of pipes. These are also rarely done. Water users only carry out disinfection when they see worms coming out from well. Also, cleaning of pipes is only done when a borehole is under repair. The Hydrologists of CWSA in Kessana Nankana Municipal intimated as follows;

> *In line with best practice, communities are supposed to disinfect their water sources quarterly. This is also rarely done. Water users will only disinfect if there are noticeable quality problems like worms. We also encourage redevelopment of wells every 10 years but I must be honest with you that it is not done. Re-development is necessary because with time, algae will develop around the aquifers or the pipes at the base of the well. Other disease-causing organisms and worms may also develop in the well or within the pipes. The redevelopment cleans and*

> *opens up wells. In the case of a borehole, three hours of constant discharge with the Rig will be ok. The re-development also opens up the well by bringing out any dirt or material that might have blocked any aquifer. But this isn't done because is very expensive doing re-development of wells, and communities are unable to meet the cost. We [CWSA] also advise Water and Sanitation (WATSAN) members to clean borehole pipes on monthly basis to reduce the risk of contamination but many committees are reluctant and not doing it. Until a borehole completely fails to produce water, they do not see the essence to clean pipes.*

- Furthermore, leaks and cracks increase risks of water source contamination. From observation, some boreholes and protected hand dug wells were found to have openings around them in the form of cracks and loosened nuts, serving as possible routes for ingress of faecal matter into wells. Similarly, network water infrastructure were characterised by cracks, loose joints and pinholes (Figure 6.6). This coupled with intermittent water supply exposes water to risk of faecal contamination. Some verbal quotations that point to irregular supply of pipe water are as follows;

> *we are unable to supply water continuously to those currently connected on the system resulting in water rationing – each household gets water thrice in a week for a maximum of 4-5 hours at a time* (Jirapa System Manager, 14.03.2018).

> *In the rainy season, pipes flow better than the dry season. For the past three days, our section didn't get water until today. In the months of February and November last year (2017), we never got water from the pipes* (Male discussant, FGD with Men, Saboro, Kassena Nankana Municipal, 01.02.2018).

> *We don't ration water. If for some reason a household doesn't get water in a particular day, by close of the following day, the problem would be resolved for water to continue flowing. For instance, when the water level goes down in the reservoirs, some households don't get water due to low pressure, especially those in highland areas. Also, when we are pumping from the wells into the reservoirs, we close the main lines temporarily* (Manager, GWCL, Kessena Nankana Municipal, 31.01.2018).

Figure 7.6: Staff of GWCL, repairing leak pipe in Navrongo

The third group of risk factors relate to **poor siting/ construction of drinking water infrastructure.** The Hydro-Geologists of CWSA argue that not every aquifer is suitable for the location of a water infrastructure. They stated that before a well is drilled, site feasibility studies, including risk assessment of hazardous events that may compromise water quality must be conducted. However, they lamented that many boreholes, standpipes and protected wells have been constructed by private individuals, politicians and NGOs without following due process. They intimated that where CWSA is not involved in the construction of a water source, the site feasibility study is likely to be compromised. Consequently, boreholes, standpipes and protected wells are wrongly sited in swampy areas, close to surface water bodies and toilets, exposing them to faecal contamination. This assertion of the Hydro-Geologist was confirmed by field observation (Figure 7.7).

Borehole sited close to a dam in Kologu, 01.02.2018

Borehole sited close to a toilet in Piiyiri, 21.11.2017

Figure 7.7: Poorly sited boreholes exposed to hazards

On poorly constructed water sources, the Hydro-Geologists of the CWSA lamented that some improved water sources, especially protected hand-dug wells, are very shallow, exposing them to faecal contamination through seepage of polluted water. From field observation and discussions held with water committees, the depth of most protected hand-dug wells is about 10 metres. This depth, the Hygro-Geologists argue is low, and does not allow for adequate filtration of polluted water seeping underground.

In addition to the above human related risk factors, **rainfall,** a natural risk factor**,** was also identified as an important driver in faecal contamination of water sources. As a driver, it does not act alone but in conjunction with other risk factors, especially poor sanitation. According to the Hydrogeologists of CWSA, when it rains, faecal matter in the environment liquefies and seeps underground to pollute water. Some is also carried as runoff into surface water bodies, with the potential of polluting near-by improved water sources. Consequently, the risk of faecal contamination of water sources is higher in the rainy season compared to the dry season.

7.3 Fluoride Concentration in Drinking Water Sources

A review of literature reveals that there is no global standard for fluoride concentration in drinking water. What exists is a health-based guideline value of at most 1.5mg of fluoride per litre of drinking water, set by the World Health Organisation (WHO, 2011a). Based on this guideline value, countries are encouraged to set national standards taking into account local environmental, social, economic and cultural conditions (WHO, 2011a). Consequently, national standards of fluoride vary markedly across the world; ranging from 0.7 mg/L in Jordan to 8.0 mg/L in Tanzania (Aliev et al., 2010; Properzi, 2010; Smedley et al., 2002; UNICEF & WHO, 2010). In Ghana, the World Health Organisation guideline value of 1.5mg/l has been adopted as the national standard (Government of Ghana, 2015b; Smedley et al., 2002).

The findings of this section have been published in the Journal of Groundwater for Sustainable Development (JGSD), Elsevier. The title page and abstract of the article (Dongzagla et al., 2019) are attached as appendix VII.

7.3.1 Level of fluoride concentration

Fluoride concentration for all sources ranged from 0.6 – 2 mg/l with the average being 1mg/l. From Table 7.6, modest disparities exist in fluoride concentration among source types. For instance, average concentrations ranged from a low of 0.7mg/l for pipe borne to 1mg/l for standpipes, boreholes and dugouts/dams. Also, the minimum concentration values for standpipes (1mg/l) and dugouts/dams (0.8mg/l) are slightly higher than all other sources (0.6mg/l). Moreover, the maximum concentration value for boreholes (2mg/l) is 0.8mg/l higher than the maximum values recorded for pipe borne, standpipes and dugouts/dam and 0.6mg/l higher than the maximum values for protected and unprotected wells.

Table 7.6: Descriptive statistics in fluoride concentration

	Min.	Max	Average	SD	No. of samples
Pipe-borne	0.6	1.2	0.7	0.2	10
Public tap/standpipe	1	1.2	1	0.1	5
Borehole	0.6	2	1.0	0.3	109
Protected well	0.6	1.4	0.9	0.3	8
Unprotected well	0.6	1.4	1.0	0.4	7
Dugouts/Dam	0.8	1.2	1	0.3	2
Improved sources	0.6	2	1	0.3	132
Unimproved sources	0.6	1.4	1	0.3	9
All sources	0.6	2	1.0	0.3	141

Slight differences also exist in fluoride concentration between Jirapa and Kassena Nankana Municipals (Table 7.7). Though both Municipalities have the same minimum concentration value (0.6mg/l), the maximum concentration value in Kassena Nankana Municipal (2mg/l) is 0.5mg/l higher than in Jirapa Municipal (1.5mg/l). However, the average fluoride concentration for all samples in Jirapa Municipal (1.1mg/l) is 0.2mg/l higher than in Kassena Nankana Municipal (0.9mg/l). The descriptive statistics for improved water samples at Municipal level is not very different from that for all samples (Table 7.7).

Table 7.7: Descriptive statistics of fluoride concentration in water sources by Municipalities

Source types	Municipalities	Min.	Max	Average	SD	No. of samples
Improved sources	Jirapa	0.6	1.5	1.1	0.3	59
	Kassena Nankana	0.6	2	1	0.3	73
Unimproved sources	Jirapa	1	1.4	1.2	1.7	5
	Kassena Nankana	0.6	0.8	0.7	0.1	4
All sources	Jirapa	0.6	1.5	1.1	0.3	64
	Kassena Nankana	0.6	2	0.9	0.3	77

From Table 7.8, modest disparities exists in fluoride concentration between urban and rural areas. For all sources, the maximum and average concentrations in rural areas are 2mg/l and 1mg/l, respectively, compared to a maximum value of 1.2mg/l and an average of 0.8mg/l in urban areas. The results for improved water sources are the same for all sources.

Table 7.8: Descriptive statistics of fluoride concentration in water sources by rural-urban

Source types	Areas	Min.	Max.	Average	SD	No. of samples
Improved sources	Rural	0.6	2	1	0.3	107
	Urban	0.6	1.2	0.8	0.2	25
Unimproved sources	Rural	0.6	1.4	1	0.3	8
	Urban	0.6	0.6	0.6	0.6	1
All sources	Rural	0.6	2	1	0.3	115
	Urban	0.6	1.2	0.8	0.2	26

7.3.2 Risk level of fluoride concentration in drinking water by source types and population

This section examines the level of compliance/risk-to-health of water sources and population in the study area based on fluoride concentrations in drinking water. Fluoride data are commonly classified into two groups – compliance and non-compliance with either the WHO guideline value or national standard or both (Aliev et al., 2010; Pelig-ba et al., 2004; Properzi, 2010; Smedley et al., 2002). This study however adopts a more detailed classification system provided by Smedley et al. (2002) in their assessment of fluoride concentration in the Upper East Region of Ghana and parts of central Tanzania. They classified fluoride concentration in drinking water into four levels as follows; <0.7mg/l (low), 0.7 -1.5mg/l (moderate), 1.6-2mg/l (high) and >2mg/l (very high). Besides being detailed, this classification system conforms with both the WHO guideline value and Ghana's standard . Also, considering the similarity in study areas, the use of this classification system makes it easier for comparison of findings.

From Figure 7.8, the levels of fluoride concentration in drinking water for all sources in the study area ranged from low (< 0.7mg/l) to high (1.6 - 2mg/l) with a majority (74.5%) being moderate (0.7 – 1.5mg/l). High fluoride concentrations were recorded in only boreholes. Of the 109 borehole samples, two samples (1.8%) had high fluoride concentrations. With the exception of boreholes, all other water sources are within the WHO and Ghana's maximum permissible limit of 1.5mg/l. Overall, 98.6% of water sources complied with the WHO guideline values and the Ghana standard value.

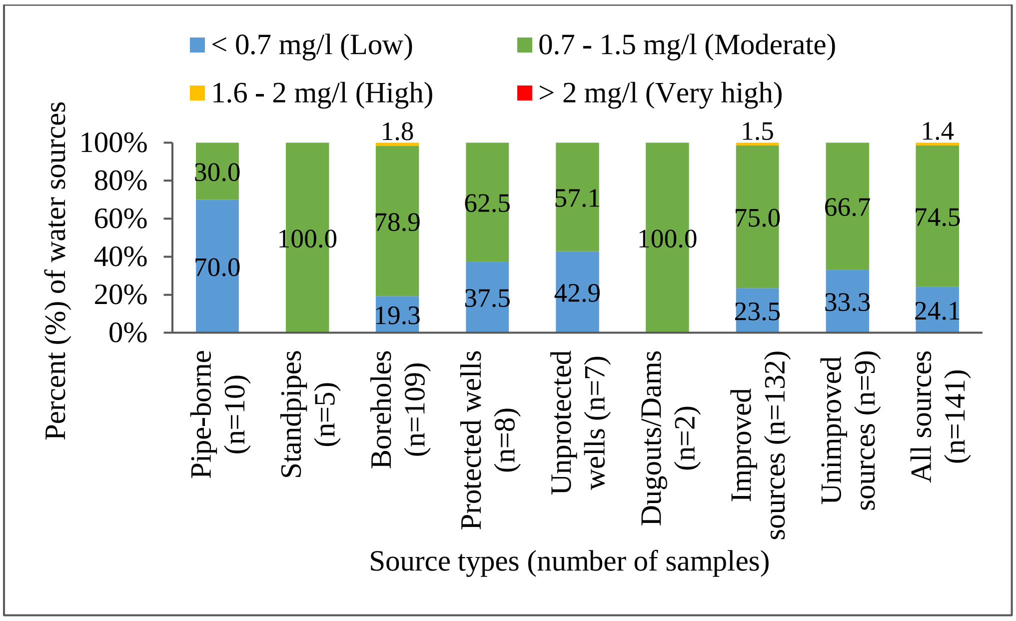

Figure 7.8: Level of fluoride concentration in drinking water by source types

Slight disparities exist in the level of fluoride concentration between Jirapa and Kassena Nankana Municipals. For instance, in Jirapa Municipal, all samples have low to medium concentrations, whereas in Kassena Nankana Municipal, concentration levels range from low to high. Consequently, Jirapa Municipal has 100% fluoride concentration compliance with the WHO guideline value and Ghana standard (1.5mg/l) as against 97.4% in Kassena Nankana Municipal. Similarly, in terms of improved water sources, compliance levels in Jirapa Municipal are 100% as against 97.3% in Kassena Nankana Municipal (Table 7.9).

Table 7.9: Levels of fluoride concentration in water sources by Municipalities

Source types	Municipalities	< 0.7 mg/l (Low)	0.7 - 1.5 mg/l (Moderate)	1.6 - 2 mg/l (High)	> 2 mg/l (Very high)	No. of samples
Improved Water Sources	Jirapa	13.6%	86.4%	0.0%	0.0%	59
	Kassena Nankana	31.5%	65.8%	2.7%	0.0%	73
Unimproved Water Sources	Jirapa	0.0%	100.0%	0.0%	0.0%	5
	Kassena Nankana	75.0%	25.0%	0.0%	0.0%	4
All sources	Jirapa	12.5%	87.5%	0.0%	0.0%	64
	Kassena Nankana	33.8%	63.6%	2.6%	0.0%	77

Analysis by rural and urban areas reveals that the level of fluoride concentration in the former is higher than the latter. For instance, 1.7% of water sources in rural areas have high fluoride concentrations compared to none in urban areas (Table 7.10). Moreover, 81.7% of water sources in rural areas have moderate fluoride concentrations compared to 42.3% in urban areas (Table 6.14). The proportion of water sources in compliance with the WHO guideline value and Ghana standard in rural areas is 98.3%. In urban areas, compliance is 100%. Similarly, in terms of improved water sources, compliance to both the WHO guideline value and Ghana standard value (1.5mg/l) in rural areas is 98.1% as against 100% in urban areas (Table 7.10).

Table 7.10: Levels of fluoride concentration in water sources by area

Source types	Areas	< 0.7 mg/l (Low)	0.7 - 1.5 mg/l (Moderate)	1.6 - 2 mg/l (High)	> 2 mg/l (Very high)	No. of samples
Improved sources	Rural	15.9%	82.2%	1.9%	0.0%	107
	Urban	56.0%	44.0%	0.0%	0.0%	25
Unimproved sources	Rural	25.0%	75.0%	0.0%	0.0%	8
	Urban	100.0%	0.0%	0.0%	0.0%	1
All sources	Rural	16.5%	81.7%	1.7%	0.0%	115
	Urban	57.7%	42.3%	0.0%	0.0%	26

A crosstab of fluoride concentration levels with household size reveals that a majority (80.4%) of the population drink water with moderate fluoride concentration (Figure 7.9). 98.5% of the population's drinking water complies with both the WHO guideline and national standard maximum permissible value of 1.5mg/l (Figure 7.9). Of the 97.4% sampled population that use improved water, 1.5% drink from sources with fluoride concentration above the WHO guideline and Ghana standard value (Figure 7.9).

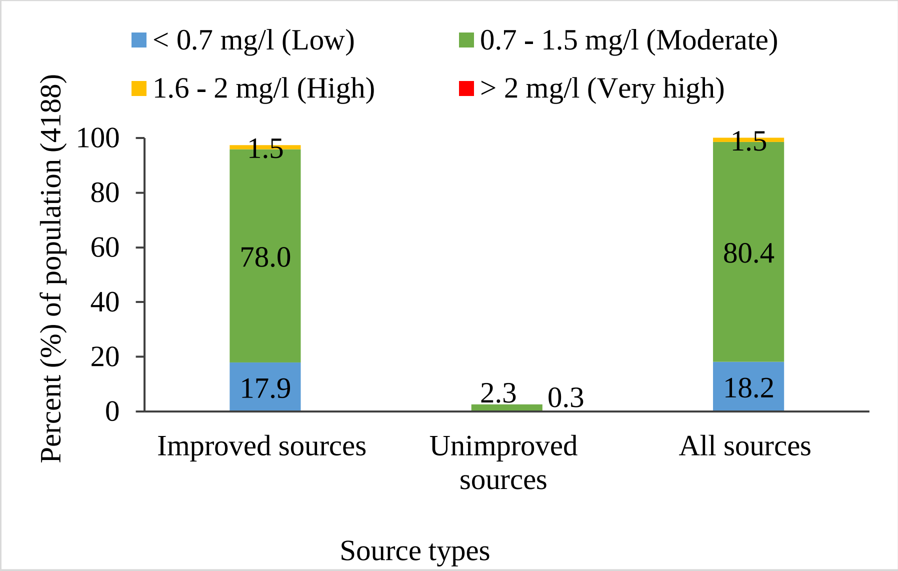

Figure 7.9: Level of fluoride concentration in drinking water by population

From Figure 7.10, a slight disparity exists in population exposure to fluoride in Jirapa and Kassena Nankana Municipals. Whereas all population in Jirapa Municipal drinks from sources within the WHO guideline and Ghana standard value, in Kassena Nankana Municipal 3% do not. In other words, 3% of the population in Kassena Nankana Municipality are exposed to excessive (>1.5mg/l) fluoride in drinking water. Also, a modest disparity exists in population exposure to excessive fluoride in drinking water between urban and rural areas (Fig. 7.11). All of the sample population in urban areas drink from sources within the WHO/GSA permissible limits. In rural areas, however, 1.8% of population were exposed to excessive fluoride in drinking water.

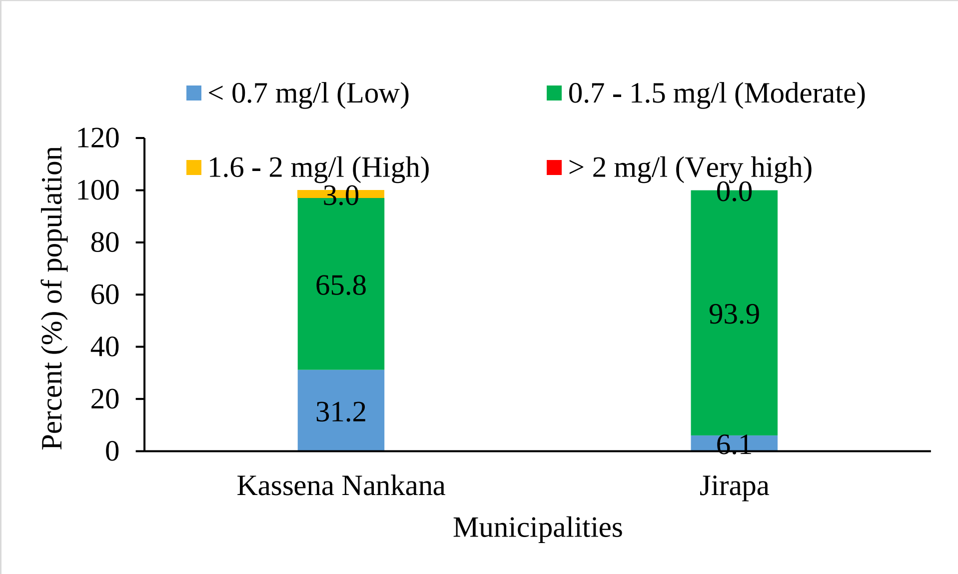

Figure 7.10: Population exposure to fluoride in drinking water by Municipality

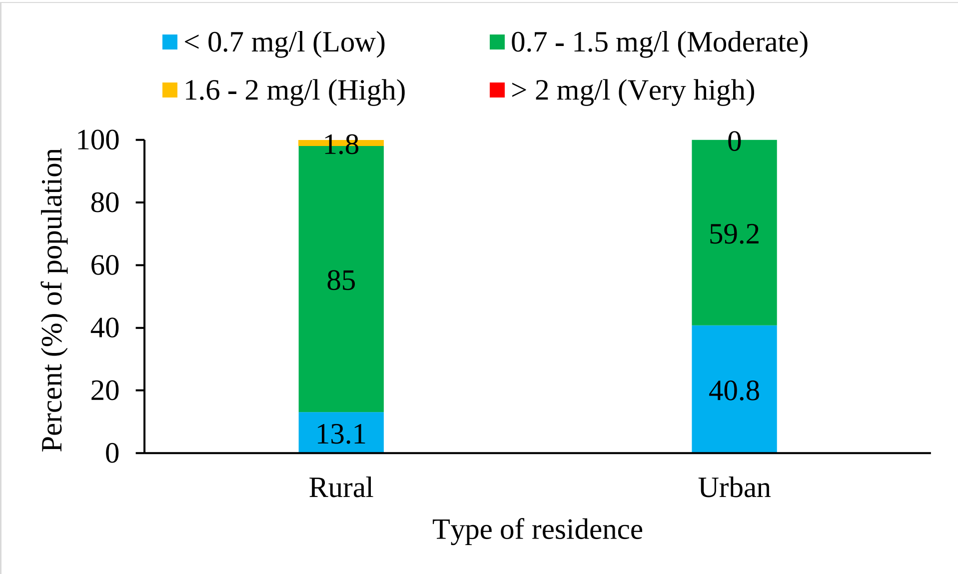

Figure 7.11: Population exposure to drinking water in fluoride by rural-urban

7.3.3 Analysis of variations in fluoride concentration by source types and geology

This section addresses two empirical research questions;

I. Does Fluoride concentration differ significantly by source types?

II. Does fluoride concentration in groundwater sources differ significantly by geological types?

I. Does Fluoride concentration differ significantly by source types?

Analysis of descriptive statistics (minimum, maximum and mean) in section 7.3.1 reveals a slight disparity in fluoride concentrations between source types (Figure). In this section, a statistical test was conducted to ascertain if the observed disparity is significant or otherwise. A Kruskal-Wallis test was found to be appropriate because it is suitable for examining differences of non-normally distributed data between two or groups[29] (Field, 2013). The normality of the data was verified based on K-S and Shapiro Wilk SPSS test statistics (Appendix II).

Like the descriptive statistics, the Kruskal-Wallis mean ranks also reveal a slight disparity in fluoride concentration between source types (Table 7.11). However, from the test statistics, observed differences are not significant ($P>0.05$) (Table 7.12). In other words, there exist no variations in fluoride concentration between source types, and also between improved and unimproved sources (Table 7.11).

[29] NB: Source types were six in number

Table 7.11: Kruskal-Wallis test Mean ranks of variations in Fluoride concentration between water sources

Test groups	Water sources	Number of samples	Mean Ranks
Between source types	Pipe-borne	10	34.9
	Public tap/standpipe	5	78.1
	Borehole	109	75.2
	Protected well	8	58.5
	Unprotected well	7	67.1
	Dugout/Pond/Lake/Dam	2	68.8
	Total	141	
Between improved & unimproved sources	Improve sources	132	71.2
	Unimproved sources	9	67.4
	Total	141	

Source: Field survey, 2017

Table 7.12: Kruskal-Wallis Test statistics of variations in Fluoride concentration between water sources

Test groups	Chi-Square	df	P-value	Effect size (r)
Between source types	10.683	5	0.058	
Between improved & unimproved sources	0.078	1	0.780	

Source: Field survey, 2017

II. *Does fluoride concentration in groundwater sources differ by geological types?*

With geology being the source of fluoride in groundwater, this section sought to find out if fluoride concentrations in groundwater sources vary by geological types. Pipe-borne water samples (10) were excluded from the analysis because water from pipes do not come directly from the ground but from a centralised system. This reduces the number of samples from 141 to 131. A spatial overlay of the 131 water points with geological data reveals that samples were drawn from three different geological systems - alluvium, granite and quartz-sericite schists. The number of samples from alluvium, granite and quartz-sericite schists are 71, 59 and 1, respectively. The one sample from quartz-sericite schists was excluded in the analysis because it was considered insignificant for a meaningful statistical analysis.

Analysis of descriptive statistics reveals mixed findings on the association between geological systems and fluoride concentrations in groundwater sources for all samples (Table 7.13). The maximum value recorded in alluvium formation (2.0 mg/l) was higher than in granite. However, the mean concentration in granite (1.1 mg/l) is slightly higher than in alluvium (1.0 mg/l). The minimum concentration value recorded in both geological systems was the same (0.6 mg/l).

Table 7.13: Descriptive statistics of fluoride concentration (mg/l) in aquifers by geological types

	Geological types	Min	Max	Mean	No. of samples
All sources	Alluvium	0.6	2.0	1.0	71
	Granite	0.6	1.5	1.1	59
Jirapa	Alluvium	1	1.4	1.2	11
	Granite	0.6	1.5	1.2	48
Kassena	Alluvium	0.6	2.0	1	60
Nankana	Granite	0.6	1.2	0.7	11

At the Municipal level, the descriptive statistics also reveal mixed findings on the association between fluoride concentrations in groundwater sources and geological systems in Jirapa Municipality (Table 7.13). The mean fluoride concentration in both alluvium and granite formations is the same (1.2 mg/l). However, granite recorded much lower and higher concentration values compared to alluvium. From Figure 7.13, all four low concentration samples were associated with granite. In Kassena Nankana Municipality, the mean and maximum fluoride concentrations between the two geological systems are slightly higher in alluvium samples than in granite samples. From Fig. 7.12, the two-recorded high fluoride are both associated with alluvium formation in the Kassena Nankana Municipality.

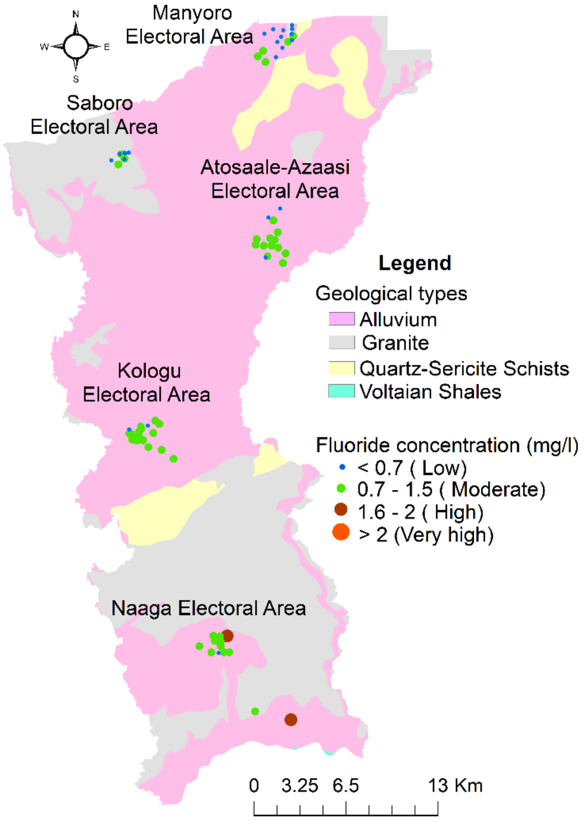

Figure 7.12: Distribution of fluoride concentration by geological types in Kassena Nankana Municipal

Source: Author's construct (2018), with geological data from PPD, Ghana (2015)

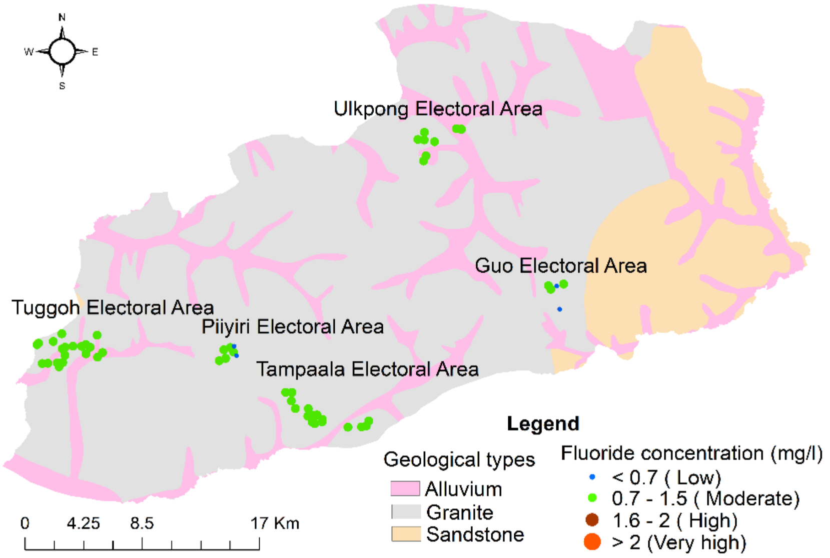

Figure 7.13: Distribution of fluoride concentration by geological types in Jirapa Municipal

Source: Author's construct (2018), with geological data from PPD, Ghana (2015)

A Mann-Whitney U test was employed to ascertain if the findings from the descriptive statistics are significant. Although the descriptive statistics reveal no clear association between fluoride concentration in groundwater sources and geological systems for all samples, the Mann-Whitney U test shows otherwise. The test reveals significant differences ($p<0.05$) in fluoride concentration between alluvium and granite water samples (Table 7.15). From the mean ranks, fluoride concentration in granite is generally higher than in alluvium (Table 7.14).

At the Municipal level, the findings are contrasting. The test statistics in Table 7.15 reveal significant variations in fluoride concentration by geological systems in Kassena Nankana Municipality ($P<0.05$) and otherwise for Jirapa Municipality ($P>0.05$). Analysis of the Mann-Whitney U mean ranks for alluvium and granite samples in Kassena Nankana Municipality reveal that fluoride concentration in the former is significantly higher than the latter (Table 7.14). This is not surprising because the two recorded high fluoride concentration values in Kassena Nankana Municipality are both associated with alluvium formation (Figure 7.13)

Table 7.14: Mann-Whitney Mean Ranks of fluoride concentration by geological types

Test groups	Water sources	Number of samples	Mean Ranks
All samples	Alluvium	71	57.2
	Granite	59	75.5
Jirapa Municipal	Alluvium	11	25.7
	Granite	48	31.0
Kassena Nankana Municipal	Alluvium	60	38.5
	Granite	11	22.6

Table 7.15: Mann-Whitney test statistics of fluoride concentration by geological types

Water sources	N	Z- score	P value (2-tailed)
All samples	130	-2.864	0.004
Jirapa Municipal	59	-0.956	0.339
Kassena Nankana Municipal	71	-2.517	0.012

7.4 Arsenic Concentration in Drinking Water Sources

As mentioned in section 4.5.1, the arsenic colour chart against which test samples were compared and read ranges from 0-500ug/l, comprising of 10 different levels. All 141 drinking water samples have arsenic concentration between 0 and 9 ug/l, the lowest level of the arsenic colour chart. The results, if compared to arsenic standards, reveal that all drinking water sources in the study area are in compliance with both the WHO and Ghana maximum arsenic concentration limit of 10ug/l. In terms of variability, it can be concluded that arsenic concentration in the study area does not vary by source types, geological types, rural-urban and Municipalities.

7.5 Overall Access to Safe Water Sources

A combined water quality analysis based on the WHO/GSA permissible limit for arsenic, fluoride and faecal coliforms concentrations in drinking water revealed that 55.8% of households have access to safe drinking water. From Table 7.16, significant variations exist in access to safe water in space. Households' access to safe water in Jirapa Municipality (66.4%) was 20.1 percentage points higher than in Kassena Nankana Municipality (46.3%). Between urban and rural areas, households' access to safe water in urban areas (75.0%) was significantly higher than in rural areas (51.1%).

Table 7.16: Combined access to safe water sources by households (n= 568)

	Safe water: source has < 1 CFU/ml, ≤ 1.5 mg/l and ≤10ug/l		**Unsafe water**: source has ≥ 1 CFU/ml or > 1.5 mg/l or > 10ug/l		
	Improved Source	Unimproved source	Improved source	Unimproved source	Total
All households	55.8%	0.0%	41.4%	2.8%	100%
Municipality					
Jirapa	66.4%	0.0%	29.9%	3.7%	100%
Kassena Nankana	46.3%	0.0%	51.7%	2.0%	100%
Area					
Rural	51.1%	0.0%	45.4%	3.5%	100%
Urban	75.0%	0.0%	25.0%	0.0%	100%

In terms of population, 58.5% have access to safe drinking water while the remaining do not (Table 7.17). At the Municipal level, the population with access to safe water in Jirapa Municipality (68.5%) was higher than in Kassena Nankana Municipality (47.6%). The proportion of population with access to safe water in urban areas (75.4%) was 20.6 percentage points higher than in rural areas.

Table 7.17: Access to safe water sources by population

	Safe water: source has < 1 CFU/ml, ≤ 1.5 mg/l and ≤10ug/l		**Unsafe water**: source has ≥ 1 CFU/ml or > 1.5 mg/l or > 10ug/l		
	Improved Source	Unimproved source	Improved source	Unimproved source	Total
Total	58.5%	0.0%	38.9%	2.6%	100%
Municipality					
Jirapa	68.5%	0.0%	28.1%	3.4%	100%
Kassena Nankana	47.6%	0.0%	50.7%	1.7%	100%
Area					
Rural	54.8%	0.0%	42.0%	3.1%	100%
Urban	75.4%	0.0%	24.6%	0.0%	100%

7.6 Households Perception of Drinking Water Quality and Treatment Practices

Although a majority (97.2%) of households use improved water sources, reports of drinking water quality problems were widespread in the study area. Of the 568 households surveyed, 39.1% of household respondents said their household's main source of drinking water have quality problems, 53.5% said otherwise while 7.4% couldn't tell the state of their water quality. Respondents who were indecisive of their water quality argue that the human senses are limited in assessing water quality, and hence cannot be categorical. For instance, they stated that it is not possible for the eye to see pathogens in water. Water quality problems reported by respondents include suspended materials (34.5%), unattractive colour (9%), worms (7.7%), unpleasant taste (5.5%) and odour (4%) (Figure 7.14).

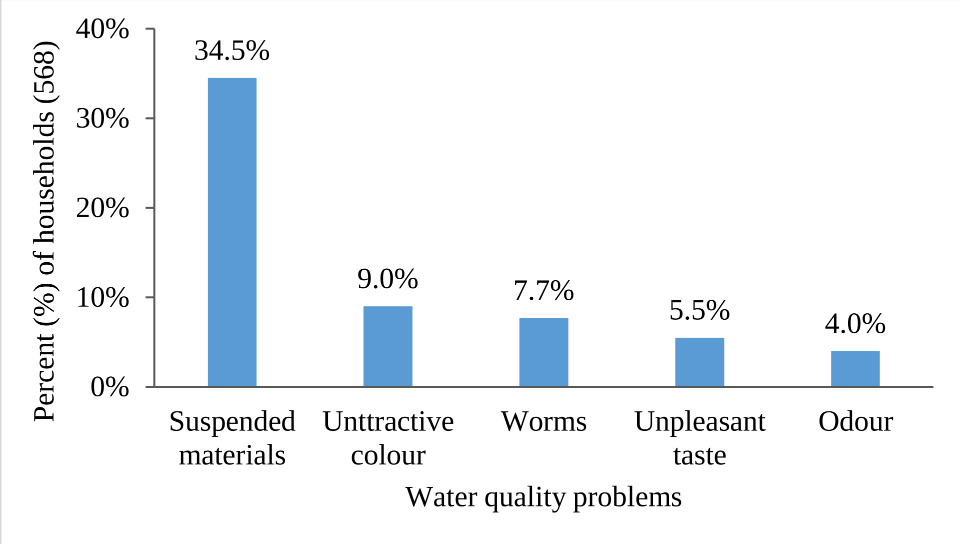

Figure 7.14: Water quality problems

The findings from the qualitative study were consistent with the survey. Focus Group Discussions (FGDs) held with water committees, men, women, girls and boys reveal that some improved water sources, occasionally have suspended materials (mainly black and sand particles), unattractive colour (milky and brownish), odour, worms and salty taste. Verbal responses from some discussants are presented below;

> *In the rainy season, our section borehole water is not good. It looks milky, and there are always some worms inside the water* (Female Discussant, FGD with Women at Kolugu in the Kassena Nankana Municipality, 2.11.2017)

> *Our borehole water is not good. There are times we see black materials and worms in the water…ours occasionally turns brown like river water* (Female Discussants, FGD with Women at Akrugudaboo in the Kassena Nankana Municipality, 2.11.2017). .

> *With the exception of one borehole in which the water is milky, all our boreholes water is good* (Female discussant, FGD with Women at Tampaala in the Jirapa Municipality, 21.11.2017).

> *The pipe borne water sometimes smells. I don't know if it is overdose of disinfectant. Anytime I detect that scent, I cannot drink it, if I dare, I will vomit…..as for colour, is ok. There is only colour problem after they have worked on a broken pipe or if a pipe is leaking* (Male Discussant, FGD with Men at Saboro in the Kassena Nankana Municipality, 01.02.2018).

Figure 7.15: Milky borehole water in Akrugudaboo, Kassena Nankana Municipal

Source: Field survey, 2017

Water quality problems were pronounced in rural areas compared to urban areas. From the survey, 46.5% of rural households reported that their main drinking water source had quality problems compared to 8.9% in urban areas. The leading water quality problem in both rural and urban areas is suspended materials (Figure 7.16).

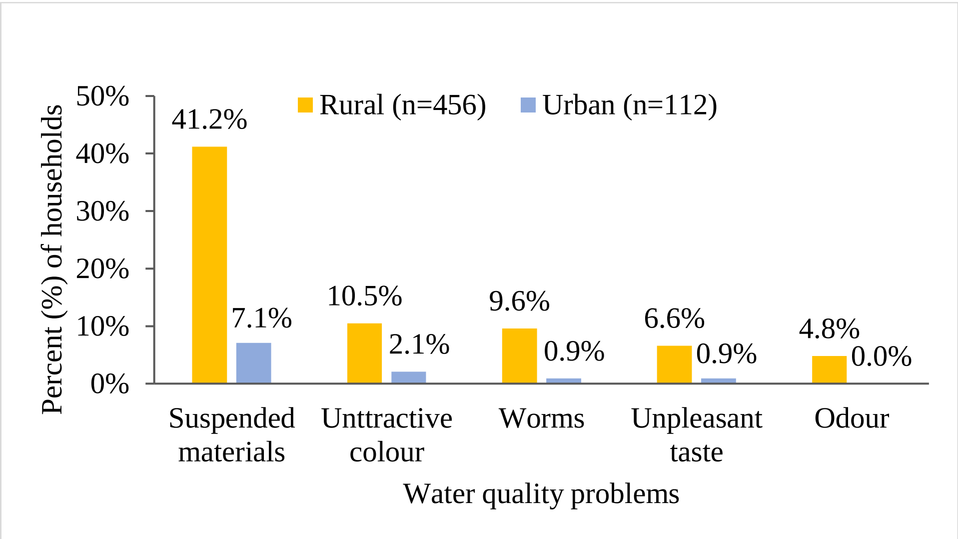

Figure 7.16: Water quality problems by rural and urban areas

At the Municipal level, water quality problems are more widespread in Kassena Nankana Municipal than in Jirapa Municipal. From the survey, 48.7% of households in Kassena Nankana Municipal reported of water problems with their drinking water compared to 28.8% in Jirapa Municipal (Figure 7.17). The principal problem is suspended materials in water (Figure 7.17).

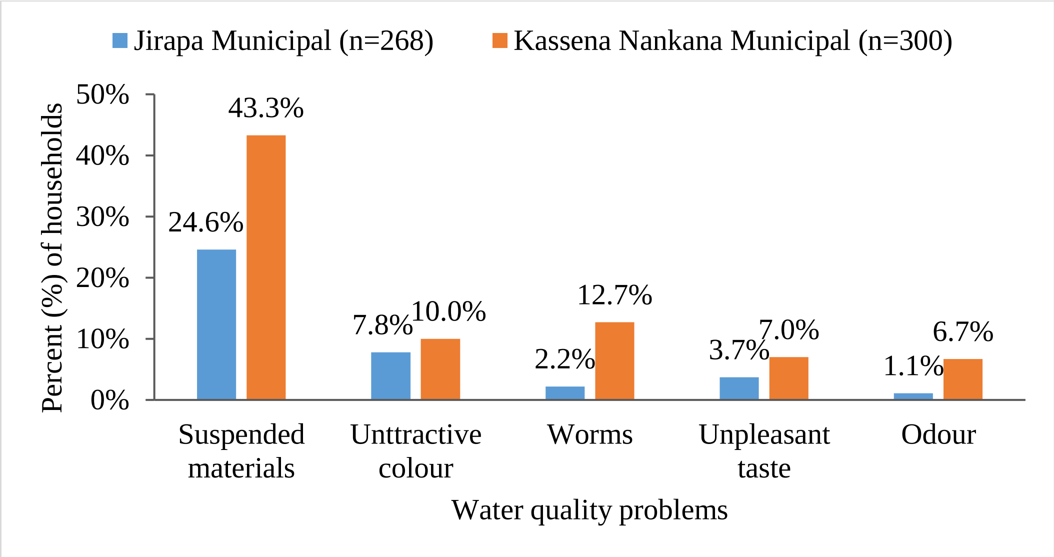

Figure 7.17: Water quality problems by Municipalities

7.7 Household Water Treatment Practices

Of the 222 households that reported water quality problems, 64.4% treat water before drinking. The remaining (35.6%) do nothing to their drinking water. In rural areas, 65.1% (n=212) of households with water quality problems treat their water while in urban areas, 50% (n=10) treat water. At the Municipal level, more households in Kassena Nankana Municipal (81.5%, n=146) treat water than in Jirapa Municipal (31.6%, n=76).

A range of water treatment methods are employed by households. However, inappropriate water treatment methods, particularly addition of camphor/naphthalene in water are commonly practised. Recommended water treatment methods such as boiling, solar disinfection, filtering and chlorination are rarely or not practised (Figure 7.18). Boiling, though cost effective was not widely practise because water collectors feel it is time and fuel consuming.

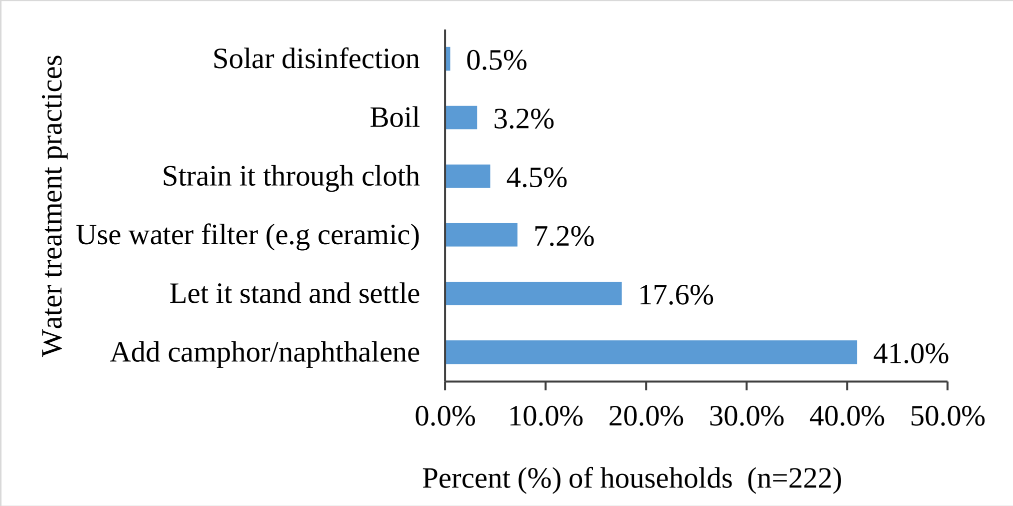

Figure 7.18: Water treatment practices of households with water quality problems

7.8 Consequences of Poor Water Quality on Livelihoods

Data on this subject was gathered through a combination of household surveys with homemakers and Focus Group Discussions (FGDs) with men, women, girls and boys. In both methods, the question on consequences of poor water quality for livelihoods was limited to only participants who reported of water quality problems. The rationale was to gather valid and reliable data based on people's experiences.

The study identified five different consequences of poor water quality problems on livelihoods. Of the 222 homemakers who reported water quality problems in the household survey, 35% intimated that household members get stomach upsets (pains, dysentery, diarrhoea and cholera) from consuming contaminated water. Secondly, 30% indicated that, odour, awful taste, unattractive colour and suspended materials make them drink less water. Thirdly, 27% cited loss of productive time in treating contaminated water. Furthermore, 11% mentioned psychological stress, stemming from fear of receiving a visitor or fear of falling sick from consuming contaminated water. Lastly, 2% stated that buying tabs/materials to purify water is expensive and a drain on household income.

The findings from the FGDs held with women, men, boys and girls are consistent with the household survey. A majority of discussants alluded to the consumption of infected water being the main cause of cholera, and sometimes death of children in the study area. Extracts of verbal reports from women discussants in Kolugu and Naagah are captured below;

> *There are times you fetch water from a pot to drink, and you need no Doctor to tell you that the water isn't good. You may think your borehole water is clean and well stored but within a day or two, you find worms or some particles inside the water….Consumption of contaminated water gives us sicknesses… Many a time, we know the water is contaminated but we don't have a choice than to drink. Is only God that is taking care of us….* (Female Discussants, FGD with Women at Kolugu in the Kassena Nankana Municipality, 02.11.2017).
>
> *Anytime the borehole water is salty, we do not drink much water to out satisfaction. There are times you take it to your mouth and loses appetite (*Female Discussant, FGD with Women at Naagah in the Kassena Nankana Municipality, 03.11.2017).

Finally, from field observation, few cases of dental fluorosis (caused by excessive fluoride) were observed in Kassena Nankana Municipality. In terms of age, the incidence appears to be high among adults than children.

7.9 Discussion

The portable test kits used to test for faecal coliform[30], fluoride[31] and arsenic[32] concentration in drinking water sources were easy to use, less expensive and produce rapid results compared to traditional laboratory test (Centre for Affordable Water and Sanitation Technology, 2013). Therefore, in resource poor regions like Ghana, access to portable water quality test kits will promote periodic risk assessment of drinking water quality, and also in tracking target 6.1 of the SDGs. Access to potable test kits will also "allow microbial water quality testing to move out of the domain of scientist-specific knowledge and into the practitioner field skill set"(Grady et al., 2014, p. 5).

Faecal coliforms concentration in drinking water sources vary by seasons. Concentration in the rainy season was significantly ($P<0.05$) higher than in the dry

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[30] 3M Petrifilm Coliform Count Plates
[31] Palintest visual standard comparator kits
[32] Palintest Visual Arsenic Detection Kit

season. This finding agrees with the with work of Kostyla et al. (2015) and Kumpel et al. (2017). Due to poor sanitation practice, faecal matter on the environment easily liquefies in the rainy season and pollute water sources. This perhaps explains why diarrhoea diseases in developing countries are high in the rainy season compared to the dry season (Ahmed et al., 2008; Anyorikeya et al., 2016). Therefore, monitoring of faecal matter in drinking water sources in the dry season may result in underestimating of population at risk.

Over half of drinking water sources in the rainy season and close to a third of water sources in the dry season were contaminated with faecal matter. In both seasons, faecal contamination was significantly ($P<0.05$) lower in improved water samples compared to unimproved water samples. This is because improved water sources are better protected than unimproved water sources (Agensi et al., 2019). This suggests that adequate protection of drinking water sources can reduce the level of faecal contamination at source. In terms of source types, concentration was significantly ($P<0.05$) lower in pipe-borne samples, followed by borehole, standpipe, protected well, unprotected well and surface water. This finding agrees largely with many previous studies (Ghana Statistical Service et al., 2015; Kirby et al., 2016; Kumpel et al., 2017; Smiley, 2017).

Close to a third of drinking water sources in the dry season failed to comply with the WHO/GSA guideline of source free faecal coliforms. In the rainy season, non-compliance of drinking water sources was more than half of samples tested. All unimproved water samples, regardless of season failed to comply with the guideline. For improved water sources, compliance was highest for pipe-borne, followed by borehole, standpipe and lastly protected hand-dug well in both seasons. The findings are close to results of the 2014 Ghana Demographic Health Survey (Ghana Statistical Service et al., 2015). The survey revealed E-coli compliance level of 56.5% for all drinking water sources with significant difference between improved (51.2%) and unimproved (29.2%) water sources. In the same DHS survey, compliance was highest for sachet/bottled water samples (89.2%), followed by pipe-borne (70%), standpipe (52.8%), borehole (47%), protected hand-dug well (31%), surface water (29.1%) and unprotected hand-dug well (9.9%). But unlike the DHS survey, all samples from protected hand-dug wells, surface water and unprotected hand-dug wells in this study failed to comply. The findings differ significantly from the work of Arnold et al. (2013)

in the Ashanti Region of Ghana. For all borehole samples, they did not detect E. coli, whereas in this study faecal coliforms were detected in 44% and 21% of borehole samples in the rainy and dry seasons, respectively. Furthermore, Arnold et al. (2013) in their study found that 72%, 33% and 20% of samples from dug wells, rivers and shallow wells were free from E.coli, respectively, whereas in this study all dug wells and surface water were contaminated with Faecal Coliforms.

Based on the WHO and Ghana Standard Authority faecal coliforms guideline, approximately six out of every 10 persons in the Upper Regions of Ghana have access to safe water. The remaining four persons were drinking water contaminated with faeces. The proportion of population exposed to faecal contaminated water is two percentage points lower than the finding of the 2014 DHS. Paradoxically, almost all of the population whose drinking water was contaminated drink from improved water sources - sources which are supposed to be free from faecal contamination (WHO/UNICEF Joint Monitoring Programme, 2015b).

The study revealed a range of risk factors that might account for the high faecal contamination of drinking water sources. Firstly, poor sanitation practice increased risk of water source contamination (Kirby et al., 2016; Mkwate et al., 2016). The study area is characterised by high levels of open defecation, which, combined with open dumping of waste and extensive systems of animal rearing resulted in the presence of human and animal excreta in the environment. From the 2010 Population and Housing Census, 81.3% of households in Jirapa Municipal and 83.7% of households in Kassena Nankana Municipal have no toilet facilities, and thus practise open defecation in the bush/field (Ghana Statistical Service, 2014a, 2014b). Also, 71.6% of households in Jirapa Municipal and 83.2% of households in Kassena Nankana Municipal are into livestock rearing, mainly fowls, goats, sheep, pigs and cows (Ghana Statistical Service, 2014a, 2014b). Animals are usually not caged, and hence they defecate openly. The situation is further compounded by inappropriate methods of waste disposal. From the 2010 Population and Housing Census, 79.3% of households in Jirapa Municipal dispose of solid waste by dumping into open space (Ghana Statistical Service, 2014a). In Kassena Nankana Municipality, 66% of households were reported to engage in similar unhealthy practices (Ghana Statistical Service, 2014b). Open dumping of refuse implies that children's and animal faeces collected by households find their way back into the environment.

In addition to poor sanitation, poor management of water sources was also identified as a risk factor in faecal contamination of drinking water. It includes a lack of protection of water points against animals, a lack of re-development of boreholes, infrequent disinfection, leakages and cracks of water pipes. In the case of network water supply, leakages and cracks of pipes coupled with intermittent water supply increases the risk of water pollution. According to the WHO (2011a, p. 57), “intermittent water supply allows the ingress of contaminated water into the system through breaks, cracks, joints and pinholes during periods of low pressure.... The risks may be elevated seasonally as soil moisture conditions increase the likelihood of a pressure gradient developing from the soil to the pipe”. In Yemen, Klasen et al. (2012) found that more than half of E-coli recorded in household taps came from leaking pipes and water rationing. Another human related risk factor was poor construction/siting of water infrastructure. This comprises of shallow wells and inadequate feasibility studies in locating water points away from pollutants.

Aside from the above three human factors, rainfall was identified as a catalyst in faecal contamination of drinking water sources. When it rains, faecal matter in the environment – mainly from poor sanitation practices - liquefies and seeps underground to pollute drinking water or is conveyed into surface water bodies. This finding is consistent with Kirby et al. (2016). In their study in Rwanda, they found an association between risk of bacteriological contamination of water sources and continuous rainfall in the past seven days before a water quality test was conducted. The rain factor explains why faecal contamination of water sources in the rainy season in higher than in the dry season.

The second contaminant tested in household drinking water sources was fluoride, a naturally occurring chemical in aquifers. Fluoride concentration in granite samples was significantly ($P<0.05$) higher than in alluvium samples. However, the two samples above the WHO recommended limit of 1.5mg/l were clearly associated with alluvium. The maximum concentration value recorded in granite suites (1.5mg/l) was significantly lower compared to the findings of Smedley et al. (1995) in the Upper Regions of Ghana. They recorded a maximum value of 3.8mg/l in the Bongo granitic suite in the Upper East Region. It therefore appears that the Bongo granite has a higher fluoride concentration than the alluvium and granitic suites in the Jirapa and Kassena Nankana Municipalities. According to Smedley et al. (1995), granite in the Bongo district is rich in F-bearing minerals of hornblende, biotite, apatite and sphene with up to 0.3% weight of fluoride.

Whereas the Kruskal-Wallis tests revealed significant differences in fluoride concentration by geological systems, it was not significant by source type. However, analysis of averages suggest that fluoride concentration varies slightly by source type. Borehole and standpipe recorded the highest average concentration value (1.1mg/l), followed by protected hand-dug wells, unprotected hand-dug wells, dugout/dams (1.0 mg/l) and lastly pipe-borne sources (0.7 mg/l). Smedley et al (1995) made a similar observation in the Bongo area in the Upper East Region. They observed that, "for samples with concentration above the WHO maximum concentration of 1.5mg/l for drinking water, fluoride concentration increases considerably with borehole/well depth in samples collected from the Bongo granite" (Smedley et al., 1995, p.65). They further observed that, "although the maximum fluoride concentration in deep wells was 3.8mg/l, that of shallow wells in the granite suite was 0.37mg/l" (Smedley et al., 1995, p.65). Therefore, the high fluoride concentration recorded in standpipes and boreholes in this study can be attributed to strong interaction of water with the underlying bedrock. Conversely, the low concentrations recorded in hand-dug wells and dugout/dams compared to standpipes and boreholes is because they are shallow (less than 10 m deep), resulting in little water-rock interaction. Alfredo et al. (2014) and Smedley et al. (2002) in their studies found that although the Vea dam in the Upper East Region is located within the Bongo granite, a notable high fluoride area, fluoride concentration was low, due to little water-rock interaction. According to Edmunds and Smedley (2005), water at such shallow depth recirculate within the superficial weathered overburden layer rather than fractured rocks at deep depth. Although shallow wells and surface water appear to have low fluoride concentrations, the risk of bacteriological contamination is high, and hence unsafe for drinking (Smedley et al., 1995). The low fluoride concentration rerecorded in pipe-borne water could reflect treatment effects.

Compliance of drinking water sources to the WHO/GSA fluoride guideline of 1.5m/l was very high (98.6%) with little variation between urban and rural areas. Only two (1.4%) samples – both from boreholes – exceeded the guideline value. This implies that, not all boreholes are safe for drinking. In line with the WHO/GSA guideline value, 98.5% of the population have access to safe drinking water. However, results of fluoride levels showed that 1.5% and 18.2% of the population are exposed to excessive (>1.5mg/l) and low (<0.7mg/l) fluorides in drinking water, respectively, and thus at risk of diseases. Excessive fluoride ingestion into the human body can result in dental fluorosis and in extreme case skeletal fluorosis while low fluoride concentrations can also give rise to dental caries (Farewell et al. 2006; Farewell and Nieuwenhuijsen, 2003; Smedley et al., 2002). Low fluoride concentration was high in pipe-borne samples (70%), followed by unprotected hand-dug wells (42.9%), protected hand-dug wells (37.5%) and boreholes (19.3%). No sample from standpipes and dugouts had low fluoride concentration.

The third but last contaminant tested was arsenic, a natural occurring chemical in groundwater. It is known to cause human cancer following exposure in drinking water (Kumi et al., 2015). In Ghana, waterborne arsenic is a known human carcinogen since the 1990s (Ghana Statistical Service, 2014c). The WHO maximum permissible value of arsenic concentration in drinking water is 0.01mg/l or 10µg/l (WHO, 2011). This benchmark according to WHO is “provisional because calculated guideline value is below the achievable quantification level” and also “below level that can be achieved through practical treatment method” (WHO, 2011, p. 178). The Ghana Standard Authority (GSA) standard on arsenic level in drinking water is not different from the WHO recommended value (Ghana Statistical Service, 2014c).

In this study, all water samples, regardless of source type and location complied with the WHO/GSA arsenic guideline value of 10ug/l. The findings suggest that the alluvium, granite and quartz-sericite schists geological systems in which samples were drawn from have low arsenic concentrations. Therefore, population in the study area whose drinking water points are located in the aforementioned geological systems have a low risk of arsenic ingestion into their body.

The level of arsenic concentration recorded in this study differ slightly from previous studies (BGS, 2000; GSS et al., 2014). Of 118 water samples analysed by the BGS in 2000 in the Upper East Region, compliance to the WHO guideline was 98% (BGS, 200) – 2 percentage points lower than the 100 recorded in this study. Similarly, the GSS in the 2014 Living Standard Survey reported very high compliance of 95.7% for drinking water sources in the Upper Regions and 91.4% nationally. National disaggregated data by source type in the 2014 Ghana Living Standard Survey (GLSS) revealed 100% compliance for pipe-borne sources on yard/into dwelling, 95.8% for protected hand-dug wells, 94.7% for sachet/botteled water, 94.4% for boreholes, 94% for standpipes, 79.1% for unprotected hand-dug wells and 70.4% for surface water. In terms of improved/unimproved sources, the GLSS revealed higher compliance for improved water sources (95.4%) compared to unimproved sources (93.6%).

A combined water quality analysis of arsenic, fluoride and faecal coliform concentrations in drinking water sources revealed that only 58.5% of the population have access to safe water, with significant disparities between urban (75.4%) and rural areas (54.8%). Of the 41.5% sampled population whose water source was unsafe, a majority (38.9%) used improved water. Results of the combined access to safe water is not very different from access to safe water based on only faecal coliform. This underscored the robustness of faecal coliform as an indicator for monitoring access to safe water in a resource poor region like Ghana.

Despite high faecal contamination of drinking water sources and risk of diseases, a majority (75%) of households do not treat water before consumption. Even among the few (25%) households that treat water, the methods were largely inappropriate comprising of the addition of camphor, letting it stand and settle and water straining through cloth. Less than 2% of households use appropriate treatment methods[33] (boil or disinfection). The findings on water treatment are not very different from the findings of the GSS in the 2014 DHS. From the 2014 Ghana DHS, 93.3% of households don't treat their drinking water, with no major difference between urban and rural households. Of the few households that treat water, only 4.2% use appropriate treatment methods.

Poor water quality was reported to have adverse consequences on health, economic productivity, income and emotions of water collectors and their households. The main health issue reported by households was disease infection, notably diarrhoea, cholera and dysentery due to the consumption of contaminated water. The link between diarrhoea and faecal contamination of drinking water is well established in the works of Hunter (2003) and Escamilla et al. (2013). Since 2002, diarrhoea has been among the top five outpatient morbidities in Ghana with significant under five mortalities (Ghana Health Service, 2018). According to the WHO (2018b), 85,175 cases of under

[33] Appropriate water treatment methods include boiling, bleaching, filtering, solar disinfection, and purification tablets.

five diarrhoea mortalities were recorded within the period 2015 – 17 in Ghana. The kind of diseases reported by respondents suggests that the causative agent is bacteria, and thus reflects the high faecal contamination of drinking water in the study area. Another effect that came up was the consumption of less water due to odour, awful taste, unattractive colour and suspended materials. This can lead to dehydration and other potential fatal health complications (Crohn's and Colitis UK, 2017). Furthermore, household members especially women, suffer emotional stress when household water is of poor quality. The stress comes from fear of receiving a visitor or fear of falling sick. Traditionally, visitors are given water on arrival. Hence, the dignity of a woman is lowered if she fails to provide a visitor with clean water.

A few cases of dental fluorosis were observed in Kassena Nankana Municipality. This condition imposes a lot of stigma on affected persons, resulting in low self-esteem and lack of socialisation (Nasirudeen, 2015; STAAC-Ghana, 2013). School children with dental fluorosis who cannot withstand ridicule from peers drop out of school (Nasirudeen, 2015). Previous studies (Edmunds & Smedley, 2005; Firempong et al., 2013; Smedley et al., 2002) reported high prevalence of dental fluorosis in neighbouring Districts of the Kassena Nankana Municipality. Firempong et al. (2013) reported the prevalence of dental fluorosis among schoolchildren in the Bongo Township of the Upper East Region to be 63% and 10% outside the Bongo Township. Similarly, Smedley et al. (2002) estimated the prevalence of dental fluorosis among school children in Tarongo in the Upper East Region to be between 20 to 50%. In addition to health, poor water quality was reported to affect households' economic productivity and income through loss of productive time for water treatment and purchase of water treatment equipment/materials. Furthermore, individuals lose income by spending money to treat themselves when they drink contaminated water and fall sick (Jonah et al., 2015).

7.10 Conclusion

Contrary to the WHO and GSA guideline that no drinking water should contain microbial, about 27.3% of drinking water sources in the dry season and 51.8% in the rainy season had faecal coliforms. They were present in all source types, including improved water sources. Approximately 33 – 42% of population in the Upper Regions are exposed to faecal contaminated water, and thus at risk of infectious diseases. Widespread open defecation and open waste disposal in the study area are largely responsible for faecal contamination of drinking water sources. In addition to faecal contamination, a few (1.4%) drinking water sources, all boreholes, were found to contain fluoride above the WHO/GSA recommended limit of 1.5 mg/l. All drinking water sources complied with the WHO/GSA arsenic permissible limit of 10ug/l.

8 RELIABILITY OF DRINKING WATER SOURCES

8.1 Introduction

Reliability of a drinking water source influences the volume and quality of water collected for household use (WHO, 2011a). For this reason, the human right to water in part states that water supply for each person must be continuous for personal and domestic uses. The JMP recognised this important aspect of the right to water in its operationalisation of 'safely managed water', the ultimate target of the SDGs in terms of drinking water supply. A 'safely managed water' service in the words of the JMP is "an improved water source, which is located on premises, *available when needed* and free from faecal and priority chemical contamination" (WHO & UNICEF, 2016, p. 12). The phrase '*available when needed'* implies that a household is said to have access to 'safely managed water' service if drinking water source flows continuously.

This chapter examined the level of reliability of drinking water sources in the Upper Regions of Ghana (objective 3). Water supply reliability was measured by eliciting water users' perceptions on the frequency of water availability from source, using a five point likert scale; continuous, very often, occasionally, rarely and not at all. The methods of data collection were household surveys with housekeepers and focus group discussions with men, women and water committees. Reliability of water sources was assessed separately for both rainy and dry seasons. In the rainy season in which data was collected, water users perceived reliability of systems was in reference to the past month preceding the survey whereas reliability in the dry season was in reference to the immediate past dry season. The results are presented around the following four questions;

i. *What is the perception of water users on the nature of reliability of their drinking water sources?*
ii. *Is there significant seasonal variation in households' access to reliable water sources?*
iii. *What is the proportion of population whose water sources are (un) reliable?*
iv. *How does unreliable water supply affect households?*

8.2 Water Users Perception on the Reliability of Water Sources

With the exception of households that depend on standpipes, not all households that rely on boreholes, pipe borne sources, hand-dug wells and surface water have year round water supply from main source (Table 8.1). Of the 523 households that depend mainly on boreholes, 89.5% stated that they have continuous water supply in the rainy season while the remaining stated otherwise (Table 8.1). In the dry season, the proportion of borehole dependent households with continuous water supply dropped to 76.7% (Table 8.1). In the household survey, delays in the repair of boreholes was reported as the main cause of irregular supply of water from boreholes. Almost half (43.4%) of housekeepers stated that the last time their boreholes broke down, it took the water committee more than a week to fix it. It was also revealed in the focus group sessions that irregular water supply from boreholes and other ground water sources is partly due to limited availability of improved water sources leading to pressure on water sources, which in turn causes frequent breakdowns and low yield. Low yield of boreholes in particular was widely reported in the focus group sessions (Text Box 8.1) and by over a third (36%) of housekeepers in the household survey. Due to pressure on boreholes, those with low yield in their wells easily run out of water in the dry season.

Table 8.1: Responses from household survey on regularity of water availability from main sources

		Reliability of water supply						
Source type	Season	Continuously	Very often	Occasionally	Rarely	Not at all	Don't know	Total HH
Pipe borne	Rainy	46.2%	0.0%	23.0%	30.8%	0.0%	0.0%	13
	Dry	30.8%	0.0%	15.4%	53.8%	0.0%	0.0%	
Standpipes	Rainy	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7
	Dry	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
Boreholes	Rainy	89.5%	5.5%	2.3%	2.1%	0.6%	0.0%	532
	Dry	76.7%	10.2%	5.0%	6.7%	0.8%	0.6%	
Protected hand-dug wells	Rainy	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	9
	Dry	33.4%	22.2%	33.3%	11.1%	0.0%	0.0%	
Unprotected hand-dug wells	Rainy	77.8%	0.0%	0.0%	22.2%	0.0%	0.0%	9
	Dry	11.1%	0.0%	11.1%	55.6%	11.1%	11.1%	
Dams/dugouts	Rainy	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7
	Dry	57.1%	0.0%	0.0%	0.0%	42.9%	0.0%	

Source: Field survey, 2017

Box 8.1: Some responses from focus group sessions on regularity of water availability from source

All boreholes in this community [Nagaah] flow continuously in the rainy season. The hand dug wells and dugouts have plenty water in the rainy season…In the dry season, some boreholes don't flow well. For instance, Afedayire borehole in the dry season sometimes runout of water after several hours of continuous pumping. Anytime it happens like that women have to wait for a while for the well to recharge (FGD with men at Naaga in the Kassena Nankana Municipality, 03.11.2017).

Those of us living at Tinnuolee are really suffering over water. We have a borehole but it doesn't flow well. In the morning, yield is generally Ok but after pumping for about two hours, yield goes down. Anytime the water level in the well goes down, the pump handle becomes harder and water do not flow. If you even pump with force, water won't come out. We usually leave it for about 30 minutes before water will flow from it again. Even after waiting for 30 minutes, we may not even collect up to five basins and the water will stop flowing again…. We are suffering over water…, one can spend over four hours at the borehole and haven't got water (FGD with Women in Ulkpong in the Jirapa Municipality, 17.01.2018).

In this section [Sooreyir] of Tampaala, we only have one borehole but it is not dependable. The yield of the borehole is generally low and worse in the dry season. When pumping, the water at a point stops flowing, and you have to wait for 20 minutes or more before you can pump and get water. We don't know what exactly the problem is. Maybe there is no enough water in the well. It could also be due to pressure on the borehole. The entire Sooreyir community is well over 700 people but we are all depending on this borehole. When is too crowded, some women walk all the way [about 3 km] to Kabari to collect water (FGD with water committee in Tampalaa in the Jirapa Municipality, 21.01.2018].

All boreholes in this community [kologu] have good yield and flow well in the rainy season. The hand dug wells too always have water in the rainy season but many dry up in the dry season, especially between December and April. So in the dry season, we depend solely on the boreholes for water…with the exception of one or two boreholes, I can say that our boreholes in Kologu have good yields even in the dry season. [FGD with Women in Kologu in the Kassena Nankana Municipality, 02.11.2017].

From Table 8.1, all nine households that depend on protected hand-dug wells reported that they have continuous water supply in the rainy season. In the dry season, however, only three households have continuous supply from source. The remaining six households complained of infrequent water supply. Also, of the nine households that depend on unprotected hand-dug wells, seven stated that they have continuous water supply in the rainy season. In the dry season, however, the number of households with continuous supply reduces to one.

The Hydro-geologists of Community Water and Sanitation in the Upper West Region and Kassena Nankana Municipality attested to the unreliability of ground water sources (boreholes, standpipes, protected wells and unprotected wells) in the study area. Although they acknowledged the impact of low rainfall on groundwater availability, they cited poor construction of boreholes and bad maintenance culture as the main causes of irregular water supply from boreholes and hand-dug wells. They intimated that many private drillers do not undertake proper hydrological[34] surveys before drilling boreholes. Consequently, boreholes are sited in poor aquifers. Furthermore, they indicated that where regoliths have poor yield or are leaking, it is advised to screen borehole on the bedrock, otherwise yield is likely to be low. In addition, deep drilling of over 100m is required to reach large cracks within bedrock, which often have good yields. However, private drillers are sometimes unwilling to drill deep due to cost and possible breakdown of equipment. The Regional Hydro-geologist in the Upper West Region revealed that sometimes donor supported borehole projects are awarded based on borehole design, including well depth, and hence contractors are often unwilling to go beyond the agreed depth if even they have not reached water.

Like ground water sources, the frequency of water availability of pipe borne water systems in the study area leaves much to be desired. Of the 13 households that reported in the survey that their main source of water is pipe borne, only six have a regular water supply in the rainy season while the remaining do not (Table 8.1). In the dry season, only four households reported that they have a regular supply of water (Table 8.1). Although 30 – 46% of households who depended on piped water systems claimed

[34] The geological type of the area is that of the precambrian basement rocks of the West African Craton, and are partially covered by late Proterozoic to early Palaeozoic sedimentary rocks

that they have continuous water supply in both rainy and dry seasons, it was gathered through the focus group and in-depth interviews that no household gets continuous water supply 24/7. The Manager of Jirapa Town Water supply system admitted that water demand from his clientele far outstripped supply, and thus resulted in water rationing. According to him, every neighbourhood and for that matter client gets water thrice a week for a period of 1-3 hours. But this assertion, in part, was refuted by residents. A customer stated as follows;

> *Our main source of water is a borehole. Even those with pipes still depend heavily on the boreholes. The pipes don't flow regularly. The rainy season is better, it can flow like thrice a week, but in the dry season, it can take a week without you seeing a drop of water from the tap* (Female discussant, FGD with women in Piiyiri in the Jirapa Municipality, 03.11.2017)

The Manager of Jirapa pipe borne water system attributed the irregular water supply to inadequate revenue for operations. For instance, he lamented that it is not economically feasible for him to buy sufficient power to operate the system in a manner that would ensure continuous water supply. This is because water tariffs vis a vis operational costs are low. The revenue base of the system is further exacerbated by huge uncollected bills. The Manager also cited illegal tapping of water as another factor that obstructs water supply. According to him, some control valves and pipes are exposed resulting in illegal tapping and diversion of water.

In Kassena Nankana Municipality, a majority of focus group discussants in Navrongo Town asserted that pipe borne water flows very often. According to residents, they are supplied with water 4 – 5 times a week, lasting about three hours at a time. In both Jirapa and Kassena Nankana Municipalities, households cope through water storage and/or collection of water from more reliable sources such as private vendors and boreholes. In both Municipalities, customers of pipe borne water systems expressed dissatisfaction over the lack of a reliable water-rationing timetable. As a result, households monitor water supply by opening taps periodically. It was widely reported in both Municipalities that sometimes the water flows in the night, making it difficult for households to collect water. In an interaction with the Manager of the Ghana Water Company Limited in Navrongo, he reported that they don't ration water although they occasionally encounter some operational challenges resulting in intermittent supply. He avers as follows;

We don't ration water. Our lines are opened always for water to flow to our customers. If for some reason a household does not get water in a particular day, by close of the following day, the problem would be resolved for water to continue flowing. For instance, when the water level goes down in the reservoirs, some households don't get water due to low pressure, especially those in highland areas. Also, when we are pumping from the wells into the reservoirs, we close the main lines temporarily. After filling the reservoirs, some areas with big lines may not get water immediately because it will take some time for distribution pipes to be charged (Manager, GWCL, Kessena Nankana Municipal, 31.01.2018)

8.3 Seasonal Variation in Households' Access to Reliable Water Sources

Responses of housekeepers on the frequency of water availability from main source in the rainy and dry seasons revealed marked differences (Table 8.2). Overall, 88.8% of households indicated that in the rainy season water supply from source is continuous. This drops to 74% in the dry season. In other words, water supply from the main source for 11.2% and 26% of households in the rainy and dry seasons are irregular.

Table 8.2: Crosstabulation of households' responses on regularity of water availability from main source in the rainy and dry seasons

		Rainy season (n=568)					
	Degree of water supply regularity	Continuous	Very often	Sometimes	Rarely	Not at all	Total
Dry season (n=568)	Continuous	73.8%	0.2%	0.0%	0.0%	0.0%	74.0%
	Very often	6.9%	2.0%	0.5%	0.4%	0.0%	9.8%
	Occasionally	0.9%	2.8%	1.6%	0.4%	0.0%	5.7%
	Rarely	5.8%	0.0%	0.5%	2.1%	0.0%	8.4%
	Not at all	0.7%	0.0%	0.0%	0.2%	0.5%	1.4%
	Don't know	0.7%	0.0%	0.0%	0.0%	0.0%	0.7%
	Total	88.8%	5.0%	2.6%	3.1%	0.5%	100.0%

Source: Field survey, 2017

A McNemar[35] test was conducted to assess the significance of seasonal differences in regularity of water supply reported by households. In so doing, the five levels of regularity of water supply were categorised into two – regular (for continuous supply) and irregular (ranging from very often to not at all in water supply). The test was guided by the following null and alternate hypotheses;

- Null hypothesis (H_0): The difference (13.2%) in the proportion of households with regular water supply in the rainy and dry seasons is not statistically significant
- Alternate hypothesis (H_u): The difference (13.2%) in the proportions of households with regular water supply in the rainy and dry seasons is statistically significant

The result ($P<0.05$) of the McNemar's test rejects the null hypothesis and accepts the alternate hypothesis. This implies that the percentage change in the proportion of households with regular water supply between the rainy and dry seasons is statistically significant. A test for only households (552) that use improved water sources reveals a similar pattern. From Table 8.2, it can be seen that more households have a regular water supply in the rainy season (88.8%) compared to the dry season (75.2%). A McNemar test reveals that the 13.6 percentage point drop in households' access to regular water supply in the dry season compared to the rainy season is statistically significant ($P<0.05$).

[35] Most appropriate because the variables are nominal, paired (repeated measures), dichotomous (regular and irregular supply) and each cell has at least 5 responses (Field, 2013).

Table 8.3: Regularity of household water supply from main source in the rainy and dry seasons for improved water users only

		Rainy season (n=552)					
	Degree of water supply reliability	Continuous	Very often	Sometimes	Rarely	Not at all	Total
Dry season (n=552)	Continuous	75.0%	0.2%	0.0%	0.0%	0.0%	75.2%
	Very often	7.1%	2.2%	0.5%	0.4%	0.0%	10.2%
	Occasionally	0.9%	2.9%	1.6%	0.2%	0.0%	5.6%
	Rarely	5.1%	0.0%	0.5%	2.2%	0.0%	7.8%
	Not at all	0.2%	0.0%	0.0%	0.0%	0.5%	0.7%
	Don't know	0.5%	0.0%	0.0%	0.0%	0.0%	0.5%
	Total	88.8%	5.3%	2.6%	2.8%	0.5%	100.0%

Source: Field survey, 2017

8.4 Population with/without Reliable Water Sources

The study reveals that not all persons have access to reliable water supply. The situation is worse in the dry season compared to the rainy season (Table 7.4). Overall, 88.5% of the population have a regular water supply from their main source in the rainy season. In the dry season, the population with access to regular water supply drops to 74.3%. Of the 97.6% of population that mainly use improved water, only 86.2% and 73.5% have a regular water supply in the rainy and dry seasons respectively. In other words, the study reveals a 11.4 percentage point drop in improved water coverage in the rainy season and 24.1 percentage point drop in the dry season if the population without regular water supply is discounted. Statistics on year round water supply is not different from that of the dry season. This implies that a household with a continuous water supply in the dry season is guaranteed the same in the rainy season.

Table 8.4: Distribution of population by reliability of main drinking water source

Water sources	Degree of regularity	Rainy season	Dry season/ All-year
Improved sources	Continuous	86.2%	73.5%
	Very often	5.6%	10.1%
	Occasionally	2.4%	5.5%
	Rarely	2.7%	7.5%
	Not at all	0.5%	0.5%
	Don't know	0.0%	0.3%
Unimproved sources	Continuous	2.3%	0.8%
	Very often	0.0%	0.0%
	Occasionally	0.0%	0.2%
	Rarely	0.3%	1.0%
	Not at all	0.0%	0.5%
	Don't know	0.0%	0.1%
	Total	100.0%	100.0%

Source: Field survey, 2017

8.5 Effects of Unreliable Water sources on Livelihoods

From Figure 8.1, it can be seen that an unreliable water supply from households' main water sources has three main negative livelihood outcomes. They include poor health, low income and food insecurity. On poor health, it was reported by homemakers in the survey that unreliable water sources lead to insufficient or an absence of water at home (9.5%), which in turns undermines hygiene practices, consumption of water and food preparation (4.6%). Similar pronouncements were made in the focus group discussions held with men, women, children and water committee members. Participants stated that when their boreholes break down and are unrepaired for many days, activities such as cooking, bathing, washing and cleaning are usually compromised. This they say exposes them to dehydration and infections. Also, in the focus group sessions, it was revealed that when households' main water sources (mostly those closer to their homes) break down or fail to produce water, they walk further to collect water resulting in body pains (neck, spinal and joints). Body pains arising from water collection was affirmed by 11.1% of housekeepers in the survey.

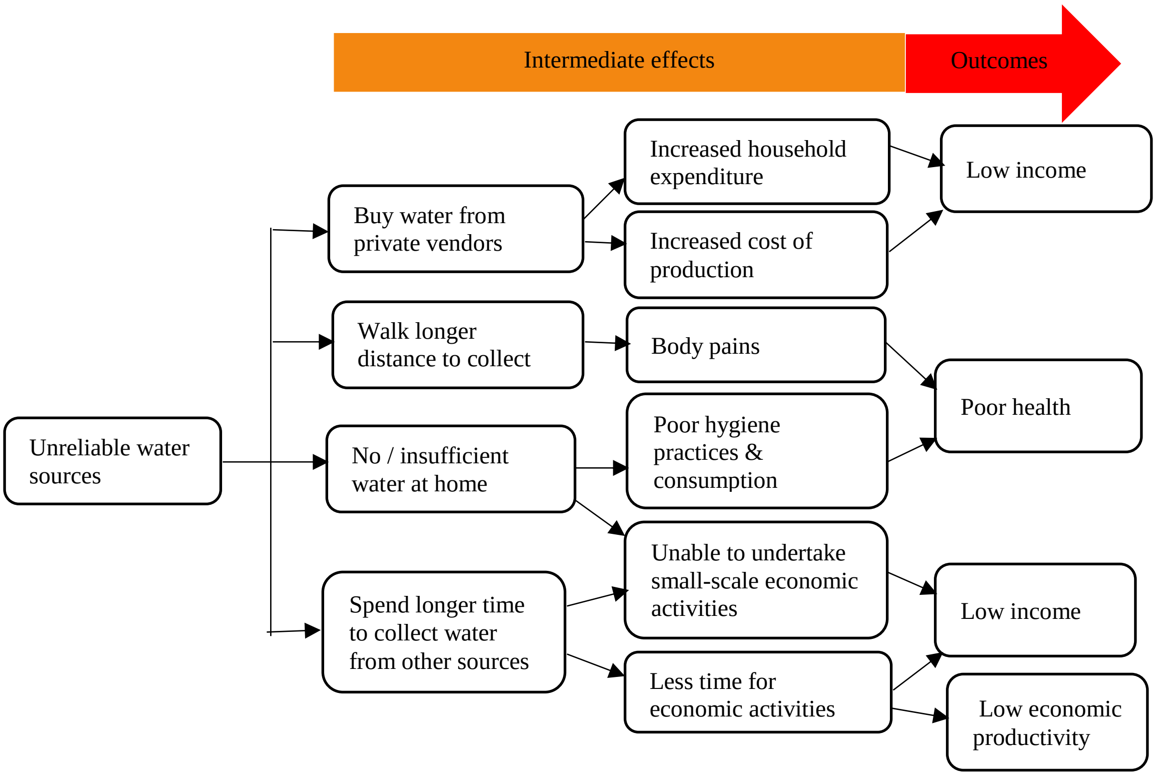

Figure 8.1: Effects of unreliable water supply on livelihoods

Secondly, analysis of responses also reveals that unreliable water sources have multiple effects on household earnings and income. In the FGDs, participants lamented that when there is not enough water at home, women are unable to engage in small scale economic activities such as pito, dawadawa and shea butter production, which are their main sources of income. In urban settings, it was reported that some households especially pito brewers, buy water from private vendors to brew pito when their main water sources are not flowing. This coping mechanism, however, impacts negatively on profits. Where purchased water from private vendors is used solely for consumption, it increases household expenditure.

Furthermore, irregular water supply also obstructs productivity of households. As mentioned earlier, households cope with irregular water supply by collecting water from other reliable sources. These other sources in most cases are far and/or crowded, increasing water collection time. This limits the amount of time households spend on economic activities such as farming, shea butter production, dawadawa production and pito brewing. In the end, many households are unable to produce enough for consumption to talk of selling for income.

8.6 Access to 'Safely Managed Water'

As mentioned earlier, a 'safely managed water' is the indicator for monitoring target 6.1 of the SDG, which focuses on universal and equitable access to safe and affordable drinking water for all by 2030 (United Nations, 2015b). In the words of the JMP, a 'safely managed water' source is a drinking water source, which is located on premises, available when needed and free from faecal and priority chemical contamination (United Nations Children's Fund (UNICEF) and World Health Organization, 2018; WHO & UNICEF, 2017).

A cross tabulation of households with water on premises, reliable water supply and safe water (i.e. faecal, fluoride and arsenic contamination within permissible limits) revealed low access to 'safely managed water', with marginal variations across seasons (Figure 8.2). In the dry season, only 1% of population had 'safely managed water'. It dropped to 0.1% in the rainy season due to poor water quality.

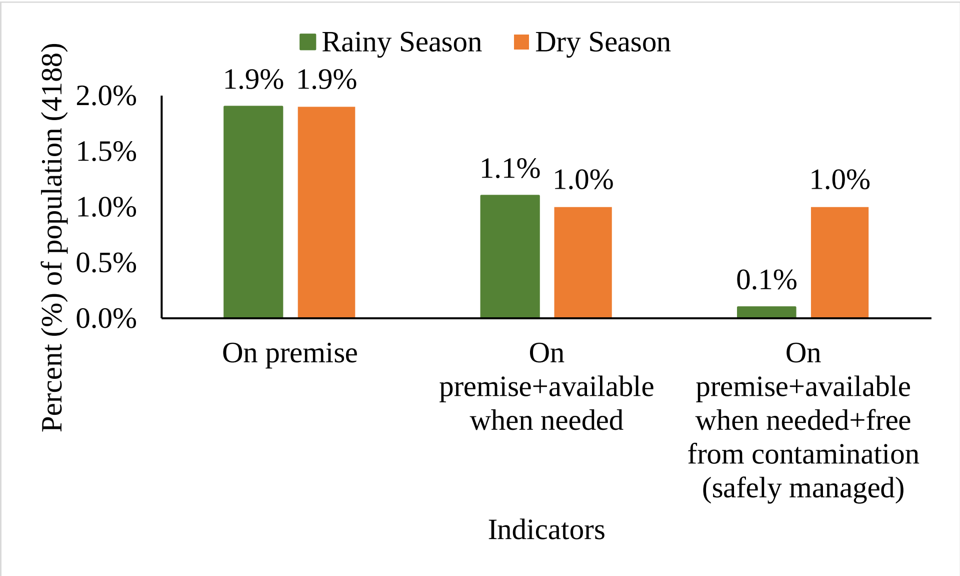

Figure 8.2: Seasonal variations in access to 'safely managed water'

8.7 Discussion

The study revealed significant differences ($P<0.05$) in household access to reliable water sources between seasons. The proportion of households with access to continuous water supply in the rainy season was higher than in the dry season (88.8% as against 74%). In terms of population, 88.5% have access to reliable water sources in the rainy season. This dropped to 74.3% in the dry season, and the same for year round. The findings suggest that water sources in the rainy season are more reliable than in the dry season.

Furthermore, the results of the study show that the use of an improved water source does not guarantee continuous water supply from source throughout a day. Unreliability of water sources was reported for piped water systems, boreholes, standpipes and protected wells. Similarly, a survey conducted by the CWSA in 2014 revealed that 9% and 14% of handpumps in the Upper East and Upper West Regions respectively were unreliable (CWSA, 2015a, 2015b). In the same survey, 8% of small town water piped schemes in the Upper West region and 20% in the Upper East Regions were unreliable (CWSA, 2015a). Piped water systems were found to be characterised with high levels of intermittency. The duration of water supply by the Ghana Water Company limited was however found to be better than the Small Town water supply systems operated by the CWSA. In the rainy season, customers of the Small Town water supply systems are supplied with water thrice a week with each session lasting for 1-3 hrs. In the dry season however, supply is unpredictable. It can take more than a week without water flowing through the pipes. Even though clients of the Ghana Water company claimed that water flows often, they are served 4-5 times a week with each session lasting about three hours. The finding disagreed with the work of Kumpel and Nelson (2016) that the GWCL supplies water continuously for 24 hrs to its clients.

Of the 97.4% of population that drinking mainly from improved water sources, only 86.2% and 73.5% have access to reliable water in the rainy and dry seasons, respectively. The difference in access to reliable improved water sources between seasons was significant at $P < 0.05$. A small proportion of the population (0.8%) has access to year round water from unimproved water sources. However, the risk of contamination is high and thus unsafe for consumption. The population with uninterrupted water supply in the dry season equally has interrupted water supply in the rainy season.

The proportion of households with access to uninterrupted water supply varies by source types. In the rainy season, all households that depended on standpipes, protected wells and dugouts have an uninterrupted water supply. Of the remaining sources, access was high among households that depended on boreholes, followed by unprotected wells and lastly pipe borne sources. Similarly, in the dry season, access to reliable water was high among households that depended on standpipes, followed by boreholes, dams/dugouts, protected wells, pipe borne and unprotected wells. The results implies that surface and shallow ground water sources are more reliable in the rainy season than deep groundwater sources (borehole and standpipes) and pipe borne water. Conversely, in the dry season, surface and shallow groundwater sources are less reliable compared to deep groundwater sources and pipe borne.

Households cope with intermittent water supply through stacking of water sources. The findings of the study showed that over 50% of households depend on two or more water facilities (section 5.8). In cities, formal and informal private vendors are the main providers of water to households when main source, mostly a piped connection, is not flowing (Osumanu et al., 2010). Formal vendors collect water from their own standpipes whereas informal vendors usually collect water from the Ghana Water Company Limited or from private standpipes. Because vendors supply water at a fee, not all households are able to patronise their service.

A range of factors affects the reliability of water sources. Surface and shallow groundwater sources such as (un)protected hand-dug wells are highly dependent on rains. Hence in the dry season, most of them dry up. In addition to seasonal rainfall, unreliability of boreholes and standpipes can be attributed to pressure on water infrastructure, infrequent maintenance, long repair periods and poor construction of water infrastructure. The results suggest that boreholes in the study area are inadequate resulting in increased pressure from the population. This leads to frequent breakdowns and low yields, especially boreholes constructed in poor aquifers. The risk of low yield is also high in the dry season due to a lack of recharge from rainwater. The findings in part reflect a survey conducted by the Community Water and Sanitation Agency (CWSA) in 2014 (CWSA, 2015a, 2015c). In the survey, the period of borehole repair was found to be more than six days for almost half of households surveyed. The survey further revealed that 52% of boreholes in the Upper West Region and 54% in the Upper East Region are repaired within three (3) days after breakage. This raises critical doubts about the capacity of water committees in borehole management. Harvey (2004) also reported poor construction of water infrastructure in Ghana resulting in borehole failure especially in the dry season. He found that the likelihood of a borehole failure in Ghana increased by a factor of six when drilled in the rainy season due to limited knowledge of the hydrogeological conditions by operating staff, inadequate equipment and lack of effective government regulation and supervision of drillers; largely private contractors and NGOs.

With regards to pipe water systems, the main cause of intermittent supply has to do with inadequate revenue/funds to purchase power and undertake repairs. Both the Ghana Water Company Limited and CWSA relies largely on revenue from sale of water for their operations (Kumasi, 2018). However, low revenues arising from low tariffs and uncollected revenues undermine operations and maintenance (Kumasi, 2018; Nedjoh & Esseku, 2016). Due to high poverty levels in Ghana (Ghana Statistical Service, 2018), management of water supply systems and regulators deliberately keep tariffs low to motivate households to use improved water in order to reduce exposure to water borne diseases (Kumasi, 2018).

Unreliability of drinking water sources have dire consequences on households' access to sufficient and safe water (Arnold et al., 2013; Howard and Bartram, 2003). When the main water sources are not flowing, households are most likely not to have sufficient quantities of water for use. Risk of collecting water from unsafe water sources is high if the main source is not flowing (Vedachalam et al., 2016). Also, intermittent water supply may result in a build-up of pollution in water pipes (Klasen et al., 2012) leading to water borne diseases and deaths. It was reported that unreliable water supply impacts negatively on health, economic productivity and income of women and their households. This finding largely agrees with the work of Truelove (2011, p. 6) in Delhi, India;

> *"Due to the infrequency of tanker water deliveries, girls are often kept out of school to stay home and help with either procuring tanker water or watching the youngest children while older women leave on water outings. This further*

jeopardizes these women's available hours for paid employment, as well as time for other domestic responsibilities. The curtailment of opportunities (from income to education) due to water and sanitation activities reinforces a further level of physical insecurity and emotional violence, as some women become locked in a feedback cycle that brings them into distinct spaces and networks in order to access water and sanitation".

A cross tabulation of population with access to reliable and safe water sources on their premises revealed three important findings about access to 'safely managed water' in the study area. Firstly, the study revealed seasonal variations in access to 'safely managed water'. The proportion of population with access to 'safely managed water' in the dry season was marginally higher than in the rainy season. This finding reflects seasonal differences in faecal contamination and reliability of drinking water sources. The JMP therefore risk overestimating 'safely managed water' coverage if seasonality in faecal contamination and reliability of drinking water sources are not monitored. Secondly, the proportion of population with access to 'safely managed water' was very low; 0.1% in the rainy season and 1% in the dry season. This compared to the JMP estimate of about 25% 'safely managed water' coverage in Ghana as at 2015 (WHO & UNICEF, 2017) revealed widespread disparities in access to 'safely managed water'. The findings support Nhamo et al. (2019) assertion that 2030 is too soon for African countries to attain SDG 6. They found that 40 (out of the 54) countries in Africa have a WASH index score of less than 70/100 points as at 2015. Thirdly, the results on 'safely managed water' coverage showed that the use of improved water sources (including piped water supply) does not guarantee access to 'safely managed water'. Of the 97.4% sampled population that use improved water, only a few have access to 'safely managed water'.

8.8 Conclusion

In summary, significant variations exist in the reliability of drinking water sources by season and types. Drinking water sources in the rainy season were more reliable than in the dry season. The proportion of households with continuous water supply from source in the rainy season was 88.8%. It dropped to 74% in the dry season. The most dependable source of water is borehole, followed by standpipes, pipe water systems, hand dug wells and lastly dams/dugouts. The results of the study also showed that not all improved water sources are reliable. Of the 97.4% sampled population whose main source of drinking water was improved, 9.2% and 23.9% in the rainy and dry seasons respectively experienced varied degrees of intermittent water supply. The socio-economic effects of irregularity of water supply include low income, low economic productivity and poor health.

9 CONCLUSION

9.1 Introduction

The aim of the study was to explore the nature of accessibility, quality and reliability of drinking water sources in the Upper Regions of Ghana to inform monitoring and the provision of ‘safely managed water’ for all as envisioned by target 6.1 of the SDG. The study was guided by the following three specific objectives;

1. To examine the extent of accessibility of drinking water sources in the Upper Regions.

2. To assess the quality of drinking water sources in the Upper Regions.

3. To examine the level of reliability of drinking water sources in the Upper Regions.

The results of the study have been presented and discussed in chapters 6, 7 and 8. This chapter concludes the study by first re-stating the major findings. Next, the chapter highlights some possible limitations of the study by reflecting on the entire research process. Finally, the chapter put forwards recommendations for improving monitoring of and access to ‘safely managed water’ service as well as areas for future research.

9.2 Summary of Major Findings

The major findings of the study are structured around five broad themes, comprising of drinking water sources, accessibility to drinking water sources, quality of drinking water sources, reliability of drinking water sources and finally access to ‘safely managed water’ in the Upper Regions of Ghana.

9.2.1 Drinking water sources

The results of the study showed that households in the Upper Regions of Ghana depend on diverse sources of drinking water. They include boreholes, piped water on compound, public taps/standpipes, protected hand dug wells, rainwater (improved sources), unprotected hand dug wells and surface water (unimproved sources). About

97.4% of the population main source of drinking water was found to be improved. The remaining 2.6%, all in rural areas, were found to be using unimproved water sources. Improved water coverage in the study area compared to extrapolated average for the two Upper Regions based on the 2014 DHS is 17.3% higher (Ghana Statistical Service et al., 2015).

Boreholes were identified as the main source of water for over 90% of the population in the study area with slight disparities between rural and urban areas. The high dependence on boreholes in Ghana had earlier been reported in the 2010 PHC and 2014 DHS (Ghana Statistical Service, 2013b, 2013c; Ghana Statistical Service et al., 2015). Boreholes are communally owned and hence not located on the premises of households. This implies that over 90% of the population access water outside their compounds. Pipe borne water supply, the only source of water accessible on compound, was depended on by less than 2% of the population in the study area, all in urban areas. This is three (3) percentage points lower than the findings of the Ghana Statistical Service et al. (2015) in the 2014 Ghana DHS for the two Upper Regions. The generally low access to water sources on compound in Ghana implies that the country is at risk of missing target 6.1 of the SDG, which places emphasis on access to drinking water sources on premises.

The study revealed stacking of water sources in more than half of sampled households. This echoes the findings of Jewitt et al. (2018) on the use of multiple sanitation facilities by households in India and also Masera et al. (2000) on multiple cooking fuel use in Mexico. Although stacking of water sources is a coping strategy to improving drinking water supply, it leads to backsliding of households from the consumption of improved water to unimproved water, and thus increases the risk of water borne infections. Consequently, water and health surveillance bodies like the DHS, MICS and LSMS are at risk of underestimating access to ‘safely managed water’ if they continue to collect information on only household main source of drinking water.

9.2.2 Accessibility to drinking water sources

The first objective of the study examined the extent of accessibility of drinking water sources in the Upper Regions of Ghana. Data were collected through a combination of household survey with housekeepers and focus group discussions with men, women and children. Accessibility was measured in terms of distance to water sources and roundtrip water collection time. The major findings are presented below.

The study revealed gender disparities in water collection responsibility. Water collection in the study area was reported to be the responsibility of women with support from girls. This is a traditional practice in Africa founded on a gendered division of labour (Graham et al., 2016; Oxfam, 2017). Women are usually responsible for household chores and caring of children while men are involved in productive activities like farming to feed the family (Oxfam, 2017). Whereas women and girls walk to collect water on their heads home with containers, a majority of men and boys use bicycles to collect water. The ascribed domestic role of women do not allow them to earn much income to buy bicycles to aid in water collection like their male counterparts. Consequently, women and girls bear a disproportionate share of the burden involved in water collection.

The average distance to drinking water sources from dwelling units was 363 meters. This is far lower than the 1000 metres (1km) recommended by the WHO for obtaining basic access to drinking water. However, 5.6% of households constituting 5.9% of the population were above the WHO 1km threshold for basic access. In terms of water collection time, the average was 42 minutes per roundtrip. This is higher than the 30 minutes roundtrip water collection time recommended by the WHO for obtaining at least basic access to drinking water. Almost half of households (47.2%) and population (48.6%) spend more than 30 minutes on a roundtrip of water with a third spending more than one hour. The proportion of households that spend more than 30 minutes on a roundtrip of water is higher than the national average of 7.4% recorded in the 2014 Demographic Health Survey (Ghana Statistical Service et al., 2015). The population with basic access to water by collection time (51.4%) was 42.7 percentage points lower than the distance measure (94.1%). This implies that a distance of 1km to a source does not guarantee collection time within 30 minutes. Consequently, analysis of basic access to water based on only distance to water source can lead to overestimation of population/households with access to drinking water in Ghana and other developing countries where waiting time at source is high.

The results showed that inaccessibility of water sources have a wide range of socio-economic effects on water collectors and their households. In addition to poor health, low educational attainments, low income and low economic productivity which have been reported in previous studies (Fisher, 2008; Geere et al., 2018; Jonah et al., 2015; Nygren et al., 2016; Osumanu et al., 2010), inaccessibility of drinking water sources is also a driver of marriage instabilities, poor sexual lives of women and teenage pregnancies. The socio-economic effects of inaccessibility of drinking water sources are not entirely negatives. Water collection outside home was said to be a form of exercise, a means of accessing information from peers and an opportunity for children to play.

Furthermore, inaccessibility of water sources in the study area have emotional outcomes on the lives of water collectors. They include psychological stress, tiredness, pains and sadness arising from long distances to water sources, high water collection times and conflicts over water. This reflects the findings of Sultana (2011) in Bangladesh, an arsenic endemic country. She observed that women undergo a lot of emotional pain, struggles, hardship and tensions in an attempt to provide their households with uncontaminated arsenic water. Such embodied emotions affect the position of women in society and also re-enforce gendered and classed social differences (Truelove, 2011).

9.2.3 Quality of drinking water sources

The second objective of the study assessed the quality of drinking water sources in the Upper Regions of Ghana. The main source of data was water quality testing of households' drinking water sources, focusing on three priority contaminants - faecal coliforms, arsenic and fluoride. This was complemented by a household survey with principal housekeepers and focus group discussions with men, women, boys and girls on perceived water quality. The key findings are summarised below.

Faecal coliform concentrations in drinking water sources vary by seasons and source types. Concentration in the rainy season was significantly ($P<0.05$) higher than in the dry season. This is consistent with the works of Kostyla et al. (2015) and Kumpel et al. (2017). In both rainy and dry seasons, concentrations were significantly ($P<0.05$)

lower in pipe-borne samples, followed by boreholes, standpipes, protected hand dug wells, unprotected hand dug wells and lastly surface water. This finding agrees largely with many previous studies (Agensi et al., 2019; Ghana Statistical Service et al., 2015; Kirby et al., 2016; Kumpel et al., 2017; Smiley, 2017). Between improved and unimproved water sources, FC concentration in the latter was significantly ($P<0.05$) higher than in the former. This underscored the need for adequate protection of drinking water sources.

The level of compliance of drinking water sources to the WHO/GSA guideline of source free faecal coliform was significantly higher in the dry season than in the rainy season. For all sources, compliance dropped from 72.7% in the dry season to 48.2% in the rainy season. Some improved water sources were equally contaminated. Meanwhile, they are generally perceived to deliver safe water. Non-compliance of improved water samples to the WHO/GSA faecal guideline increased from 26.2% in the dry season to 48.5% in the rainy season. Faecal coliforms were detected in all improved water source types – piped borne water, standpipes, boreholes and protected hand dug wells. Therefore, the use of an improved water source does not guarantee good water quality (e.g.Bain et al., 2014; Boateng et al., 2013; Cobbina et al., 2012; Kostyla et al., 2015; Mkwate et al., 2016; Onda et al., 2012; WHO/UNICEF Joint Monitoring Programme, 2011). All unimproved water samples, regardless of season failed to comply with the guideline.

In line with the WHO/GSA faecal coliform guideline, only 58.5% of the population in the study area have access to safe water in the rainy season. It increased slightly to 66.9% in the dry season. In other words, 41.5% and 33.1% of the population in the rainy and dry seasons, respectively, drink faecal contaminated water. Of the 97.4% sampled population who drink from improved water sources, only 66.9% in the dry season and 58.5% in the rainy season drink from sources that complied with the WHO/GSA faecal coliform guideline. Thus, a reduction of about 31 to 39 percentage points in improved water coverage. This reduction is two times higher than that recorded by the JMP in Nicaragua and three times higher than that reported for Ethiopia, Nigeria and Tajikistan (WHO/UNICEF Joint Monitoring Programme, 2011). A number of human and natural factors were identified as potential risk factors in faecal contamination of drinking water sources. They broadly include poor sanitation practice, poor management of water sources, poor construction/siting of water infrastructure and rainfall. These factors have earlier been reported by Escamilla et al. (2013), Kirby et al. (2016), Mkwate et al. (2016), Grady et al. (2014) and WHO (2011a).

The second contaminant tested in households' drinking water sources was fluoride, a naturally occurring chemical in aquifers. Concentrations ranged from 0.6 – 2 mg/l with the average being 1mg/l. The values were found to be within the range (0.01 to 3.80 mg/l) reported in previous studies in the Upper West and Upper East Regions of Ghana (Apambire, 2001; Atipoka, 2009; Smedley et al., 1995; Smedley et al., 2002). Fluoride concentration in granite samples was significantly higher than in alluvium samples. This reflects the findings of Smedley et al. (1995) and Smedley et al. (2002). However, two samples which exceeded the WHO recommended limit of 1.5mg/l were clearly associated with alluvium.

Fluoride concentration varies slightly by source types. Boreholes and standpipes recorded the highest average concentration value (1.1mg/l), followed by protected hand-dug wells, unprotected hand-dug wells, dugouts/dams (1.0 mg/l) and lastly pipe-borne (0.7 mg/l). This finding largely agrees with the work of Smedley et al. (1995) and Smedley et al. (2002) who reported high fluoride concentrations in deep underground water sources like boreholes and standpipes than in surface water sources. Compliance of drinking water sources to the WHO/GSA fluoride guideline of 1.5m/l was very high (98.6%) with little variation between urban and rural areas. Only two (1.4%) samples – both from boreholes – exceeded the guideline value. Thus, as high as 98.5% of the population drinking water was within the WHO/GSA guideline value of 1.5 mg/l.

The third but last contaminant tested was arsenic, a naturally occurring chemical in groundwater. In this study, all water samples, regardless of source type and location complied with the WHO/GSA arsenic guideline value of 10ug/l. The findings suggest that the alluvium, granite and quartz-sericite schist geological systems in which samples were drawn from have low arsenic concentrations. Therefore, populations in the study area whose drinking water facilities are located in the aforementioned geological systems have a low risk of arsenic ingestion into their body.

A combined water quality analysis of arsenic, fluoride and faecal coliform concentrations in drinking water sources revealed that only 58.5% of the population have access to safe water, with significant disparities between urban (75.4%) and rural areas (54.8%). Of the 41.5% sampled population whose water source was unsafe, a majority (38.9%) used improved water. Poor water quality in the study area was said to affect health, economic productivity and income. In addition to these effects reported in previous studies (Escamilla et al., 2013; Firempong et al., 2013; Hunter, 2003; Jonah et al., 2015), poor water quality at home has emotional outcome. Women suffer from psychological stress of being disgraced when a visitor is served with contaminated water or fear of household members falling sick for consuming contaminated water.

9.2.4 Reliability of drinking water sources

Objective three of the study examined the level of reliability of drinking water sources in the Upper Regions of Ghana. Water supply reliability was measured by eliciting water users' perceptions on the frequency of water availability from source, using a five point likert scale; continuous, very often, occasionally, rarely and not at all. The methods of data collection were household surveys with housekeepers and focus group discussions with men, women and water committees. Reliability of water sources was assessed separately for both rainy and dry seasons. The main findings are summarized below.

Seasonal variations exist in the reliability of households' drinking water sources. Households' access to continuous water supply was significantly higher in the rainy season (88.8%) than in the dry season (74%). All 74% of households that have continuous water supply in the dry season equally have continuous water supply in the rainy season. In other words, 74% of households have year-round access to reliable water. In terms of population, 88.5% have access to reliable water sources in the rainy season. This dropped to 74.3% in the dry season. The findings suggest that water sources in the rainy season are more reliable than in the dry season.

The results of the study revealed that not all improved water sources are reliable. Of the 97.4% sampled population that drinking mainly from improved water sources, only 86.2% and 73.5% have access to reliable water in the rainy and dry seasons, respectively. The difference in access to reliable improved water sources between seasons was significant at $P < 0.05$. A few of the sampled population (0.8%) have access to year round water from unimproved water sources. However, the risk of contamination is high and the water is thus unsafe for consumption.

Significant variations exist in the reliability of drinking water sources. Surface water and hand-dug wells (mostly 10 metres deep) are only available in the rainy season (May – August) and early part of the dry season (September-November). By the middle of the dry season (December), a majority of them dry up, and thus not accessible. This implies that households that depend on surface and hand dug wells switch to other water sources in the latter part of the dry season. Boreholes and standpipes were identified as the most dependable sources of water in the study area although they were reported to be characterised with low yield or irregular supplies in the dry season. Comparatively, piped water systems were more unreliable than boreholes and standpipes. Of the two piped water systems investigated, the GWCL system was more dependable than the CWSA system. The GWCL piped water system supplies households with water four-five times a week with each session lasting for about three hours. In the case of the CWSA piped water system, management supplies water to households three times a week with each session lasting one to three hours in the rainy season. In the dry season, however, it takes more than a week for households to be supplied with water. The findings of the study contradicts the work of Kumpel and Nelson (2016) that the GWCL supplies water continuously for 24 hrs to its clients.

A range of factors affects the reliability of water sources. Surface and hand-dug wells are highly dependent on rains, and hence dry up in the dry season. In addition to low rainfall, the reliability of boreholes and standpipes is affected by long repair periods, pressure on limited water infrastructure, poorly constructed water infrastructure and infrequent maintenance. Similarly, Harvey (2004) linked rampant dry season borehole failures in Ghana to poor construction due to limited knowledge of the hydrogeological conditions by operating staff, inadequate equipment and lack of effective government regulation and supervision of drillers. The CWSA in 2014 also identified long repair period of boreholes as a factor affecting water supply in the Upper Regions of Ghana (CWSA, 2015a, 2015c). The factors accounting for the unreliability of pipe borne water systems were management related. They include inadequate collected revenue to sustain operations, lack of routine maintenance and illegal tapping of water. The findings, in part, agree with the works of Kumasi (2018) and Nedjoh and Esseku

(2016) who identified low revenue as the main cause of intermittent water supply of piped water systems in Ghana.

Unreliability of drinking water sources was reported to undermine health, economic productivity, income and educational attainments of households, especially women and girls. These outcomes are consistent with the findings of Truelove (2011) in Delhi. She observed that in periods of infrequent tanker water supplies, women spend longer hours to collect water from other sources, a situation which affects their engagement in economic activities, income levels and domestic activities.

9.2.5 Access to 'safely managed water'

As mentioned earlier a 'safely managed water' is the indicator for monitoring target 6.1 of the SDG (United Nations, 2015b). It represents the proportion of population with improved water sources on premises, available when needed and free from faecal and priority chemical contamination (WHO/UNICEF Joint Monitoring Programme, 2015e). By 2030, the United Nations seeks to achieve universal access to 'safely managed water'. Ghana as a member of the United Nations has subscribed to this global vision.

The study revealed seasonal variations in access to 'safely managed water'. Access to 'safely managed water' in the dry season was marginally higher than in the rainy season. This finding reflects high faecal contamination of drinking water sources in the rainy season. Consequently, monitoring of 'safely managed water' in the dry season can lead to overestimation of the population at risk. In both rainy and dry seasons, access to 'safely managed water' was low (0.1% vs 1%). Ghana therefore risks missing target 6.1 of the SDG. However, it is somewhat brighter for universal basic[36] access, which currently stands at 49.2%.

[36] Proportion of population that collect water from an improved water source within 30 minutes per roundtrip

9.3 Limitations of the Study

- Firstly, the proportion of population/households with access to safe water maybe overestimated in this study. This is because, of the over 100 possible contaminants of drinking water, only three contaminants were assessed in the study. Furthermore, water quality testing was conducted at source while, previous studies (Agensi et al., 2019; Clasen & Bastable, 2003a; Lavanya & Ravichandran, 2013) have shown that water can also be contaminated during transportation and storage.

- There is also the likelihood of underestimating the proportion of the population exposed to moderate, high and very high risk of faecal matter in drinking water. This is because the WHO *E.coli*-risk to health framework adapted to classify faecal coliforms into levels is based on sampling 100mL volumes of water but the 3M Petrifilm method used in this study utilised a sample volume of 1mL. However, this might not have significant impact on the findings because previous studies (Schraft & Watterworth, 2005; Vail et al., 2003) have shown that 3M Petrifilms yield reliable and consistent results when compared with other methods of microbial water quality analysis.

- The low levels of arsenic and fluoride concentrations in groundwater may be limited by two factors. First, all samples were tested in the rainy season, and hence chemical concentrations in aquifers might have experienced dilution, resulting in low values. Secondly, samples were collected in three out of the seven geological systems in the Upper Regions. The remaining four systems could possibly have rich fluoride and arsenic bearing minerals.

- Lastly, due to limited resources, the study could not explore the quality, reliability and accessibility of households' secondary water sources. With evidence of over 50% of households engaged in stacking of water sources, the proportion of population with 'safely managed water' risks being overestimated.

9.4 Recommendations

The recommendations of the study are broadly categorised into three themes. The first set of recommendations are aimed at improving monitoring of 'safely managed water' service while the second set is geared towards improving access to 'safely managed water' in Ghana and developing countries at large. The third part presents recommendations for future studies.

9.4.1 Improving monitoring of 'safely managed water'

The findings of the study show that the measures used in global surveys (DHS, MIC, LSMS) as well as the JMP core questions for monitoring 'safely managed water' in the SDG era are limited and may lead to the generation of inaccurate statistics, especially in developing regions. The 'safely managed water' indicator and its accompanying statistics would be more useful if the following are considered;

1. *Monitoring of drinking water source quality, accessibility and reliability should go beyond main sources to include secondary sources*. At present, global surveys like DHS, LSMS and MICS position all their questions on drinking water in relation to households' main water source. This is also true for the JMP core questions used to monitor access to 'safely managed water' in the SDG era. However, evidence of water facility stacking by over 50% of households implies that monitoring only the main water source will lead to overestimation of the population with accessible, safe, continuous and 'safely managed water' supply in Ghana and other developing countries. The study therefore calls for monitoring of both main and secondary water sources as opposed to only the former.

2. *Monitoring of seasonal variations in population exposure to faecal contamination*. Although the JMP and its surveying bodies (DHS, LMSS, MIC) monitor faecal contamination of drinking water sources, it is cross-sectional. With evidence of significant seasonal variations in population exposure to faecal contamination in the study area, the JMP risks over-estimating the population with access to safe water in Ghana and Africa at

large. To address this, the study recommends seasonal monitoring of population exposure to faecal matter through drinking water. However, in the light of limited resources, monitoring of faecal contamination is most appropriate in the rainy season, when the risk of contamination is high.

3. *Monitoring of seasonality in the reliability of drinking water sources and sufficiency of drinking water in homes.* The findings of the study showed that the reliability of households' drinking water sources was significantly higher in the rainy season compared to the dry season. This implies that cross-sectional surveys (including the DHS, MICS and LSMS) risk overestimating the population with reliable/sufficient quantities of water, especially in regions with varied rainfall regimes. The study therefore recommends the monitoring of seasonality in the reliability of drinking water sources and sufficiency of drinking water in homes.

4. *Monitoring of contaminants in drinking water should include priority chemicals*. Although the 'safely managed water' indicator in part emphasized monitoring of faecal and priority chemicals, the JMP and major global surveys (e.g DHS, MICS and LSMS) monitor only faecal contamination. With evidence of excessive fluoride contamination in the study area, the JMP risks overestimating the population with access to 'safely managed water' by monitoring only faecal contamination. In this regard, the study calls for monitoring of chemicals with significant health impacts, particularly fluoride and arsenic. However, in Ghana and other poor sanitation countries, priority should be placed on faecal contamination because of its deleterious health impact and widespread exposure. Having said that, we need to be mindful that faecal matter may not be a priority contaminant in all regions and countries. For instance, the water quality problem in Bangladesh is related more to arsenic than faecal contamination. Therefore, the choice of priority contaminant for monitoring should be based on its prevalence and health impacts at the national scale rather than at the global scale.

5. *Measures of basic access to water should go beyond water collection time to include distance*. Although the findings suggest that the WHO distance

threshold of 1km is a poor measure of basic access to water compared to the 30 minutes round trip water collection time, the study found distance to be an important indicator in understanding accessibility to water sources and livelihoods. It sheds light on the socio-economic impacts of water collection on water collectors (mainly women and girls) and their households. Therefore, monitoring of only water collection time by the JMP (Figure 2.3) will conceal the distances women and girls walk to collect water in developing countries and its associated impact on livelihoods. Considering the fact that SDG 10 is solely devoted to bridging inequalities, the study recommends the inclusion of distance as one of the measures of basic water supply.

6. *Data disaggregation below national scale.* The study revealed inequalities in the quality, accessibility and reliability of drinking water sources between urban and rural areas, and between administrative districts. Meanwhile, the national scale remains the lowest spatial scale in which the JMP provides statistics on 'safely managed water' coverages (WHO & UNICEF, 2017). This masks significant disparities within countries, and thus limits area-based targeting by governments aimed at bridging inequalities. This underscored the need for data disaggregation by administrative regions and also by rural-urban classifications.

9.4.2 Improving access to 'safely managed water' and livelihoods

Based on the findings of the study, the following measures are recommended for improving access to 'safely managed water' and livelihoods in Ghana, and developing countries at large.

1. *Increase commitment in drinking water supply.* The study has shown that access to 'safely managed water' in the study area is low, and its achievement by 2030 looks gloomy. However, I am of the firm belief that access to 'safely managed water' for all in Ghana by 2030 can still be met with increased commitment to drinking water supply from all stakeholders in the water sector.

Specifically, it may require increased budgetary allocations and aggressive mobilisation of resources in the delivery of water services.

2. *Periodic risk assessment and management of water quality*. The study revealed widespread contamination of drinking water sources, especially with faecal matter yet a 'safely managed water' source must be free from faecal contamination and other priority chemicals. The study therefore calls for periodic water quality testing and management of facilities with unacceptable risks, particularly microbial. The risk management strategies should include risk prevention such as promotion of behaviour change in sanitation practices, location of water facilities away from hazards, regular maintenance of facilities, periodic disinfection of wells and water networks.

3. *Expand access to piped borne water on compound in both rural and urban areas*. One of the elements of the 'safely managed water' metric for tracking target 6.1 of the SDG is access to drinking water sources on premises. This can be achieved through network water supply via pipes on compound. However, from the study, access to pipe borne water is low and is restricted to only urban areas. To achieve target 6.1 of the SDG, the study recommends for improvement in piped water coverage in both rural and urban areas. Due to erratic hydro-power supply, pipe borne water supply systems should be powered by solar energy to improve reliability of water. The use of solar energy will also reduce operational costs. To minimise problems of pipe leakages and illegal tapping, modern technology and equipment should be employed in pipe borne water supply.

4. *Construction of solar mechanised standpipes with multiple outlets*. The findings of the study show that almost half of households spend more than 30 minutes on a roundtrip of water, limiting access to basic water. Boreholes, the main source of water in the study area, usually have one outlet and water drawn manually. This increases water collection time at source, especially when the serviced population is high. To improve access to basic water, the study

recommends a shift away from the present manual-one-outlet boreholes to solar mechanised standpipes with multiple outlets. Existing boreholes should be rehabilitated in line with the proposed design. A solar mechanised standpipe with multiple outlets will not only reduce water collection time by households but also the drudgery of pumping boreholes.

5. *Improved hydrogeological assessment in the location of boreholes*.

   The findings of the study showed that the unreliability of boreholes - the main source of water in the study area – was partly due to poor hydrogeological assessment in the location of boreholes. Consequently, some boreholes are sited in poor aquifers resulting in low yield or failure, especially in the dry season. To enhance the reliability of boreholes, drilling companies are encourage to do a thorough hydrogeological assessment and site boreholes in rich aquifers. Companies without expertise in hydrogeological assessment should collaborate with the CWSA for technical advice in siting boreholes.

6. *Harvesting of rainwater.* Despite the potential of rainwater in enhancing households' access to sufficient and reliable water, the findings of the study showed that, it not widely practised. No households in this study depended on rainwater as a major source of water. Even as a secondary source, only 4.5% of households depended on it. To improve reliability of water supply, especially in the dry season, households/communities should be supported to harvest and treat rainwater for use.

7. *Increase education on water source management and water treatment practices in developing countries*. This intervention should be targeted at improving sanitation practices around water sources, protecting water sources and routine maintenance by water and sanitation committees. In addition, households should be encouraged to treat surface and underground water before drinking. Boiling of water is a low cost appropriate treatment practice that can be promoted to reduce risk of exposure to microbes through water. This method though cost effective was rarely practice because households feel it is time and fuel consuming.

9.4.3 Future research

The recommendations for future research outlined here, if conducted, will help shed light on key limitations of the study outline in section 9.3.

- Firstly, future studies on water quality should go beyond the three contaminants (faecal matter, fluoride and arsenic) examined in this study to include other major contaminants like chlorine, copper, iodine, lead, mercury, nitrate, pH and zinc. A combined analysis of many contaminants will provide a better understanding of population with/without safe drinking water.

- Unlike this study, future studies that seek to estimate population with access to safe water should account for contamination of drinking water at home, especially faecal contamination, as water can be contaminated through poor handling (Clasen & Bastable, 2003b; Lavanya & Ravichandran, 2013).

- Future studies on water quality should undertake a comparative study on access to safe water for different contaminants (including faecal matter) in developing and developed countries. Such a study will contribute to knowledge about the utility or otherwise of monitoring faecal contamination worldwide.

- Future studies on fluoride and arsenic contamination of drinking water sources in arid and semi-arid countries like Ghana should explore seasonal variation in contamination. Knowledge on seasonality of arsenic and fluoride concentration in drinking water sources will help inform timing of water quality studies.

- Finally, future studies on water in the Upper Regions of Ghana should examine in detail the impact of water quality, accessibility and reliability on livelihoods and embodied emotions. These were recurring themes from the qualitative work but time and resources did not permit me to undertake a thorough investigation of the different aspects of livelihoods and emotions that are affected. Therefore, there is significant scope for future work on these topics.

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APPENDICES

I. Normality Tests Statistics of FC Concentration in Drinking Water Sources

Variables	Kolmogorov-Smirnova[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
FC in rainy season	0.38	128	0.000	0.368	128	0.000
FC in dry season	0.419	128	0.000	0.204	128	0.000
FC in improved water (rainy season)	0.383	126	0.000	0.329	126	0.000
FC in improved water (dry season)	0.425	126	0.000	0.183	126	0.000
FC in unimproved water (rainy season)	0.26	2	.			
FC in unimproved water (dry season)	0.26	2	.			
FC in pipe-borne (rainy season)	0.38	10	0.000	0.516	10	0
FC in pipe-borne (dry season)	0.478	10	0.000	0.539	10	0
FC in public tap/standpipe (rainy season)	0.31	4	.	0.833	4	0.177
FC in public tap/standpipe (dry season)	0.432	4	.	0.644	4	0.002
FC in borehole (rainy season)	0.397	105	0.000	0.287	105	0
FC in borehole (dry season)	0.428	105	0.000	0.173	105	0
FC in protected well (rainy season)	0.198	7	.200*	0.889	7	0.268
FC in protected well (dry season)	0.346	7	0.011	0.674	7	0.002
FC in unprotected wells (rainy season)	0.26	2	.			
FC in unprotected wells (dry season)	0.26	2	.			

a. Lilliefors Significance Correction. * This is a lower bound of the true significance. FC = Faecal Coliforms

II. Normality Tests statistics of Fluoride Concentration in Water Sources

Variables	Kolmogorov-Smirnova[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Fluoride concentration (all sources)	.207	141	0.000	.887	141	0.00
Fluoride concentration in improved water	.216	132	0.000	.885	132	0.000
Fluoride concentration in unimproved water	.201	9	0.200	.860	9	0.096
Fluoride concentration in pipe-borne	.427	10	0.000	.652	10	0.000
Fluoride concentration in public tap/standpipe	.367	5	0..026	.684	5	0.006
Fluoride concentration in borehole	.213	109	0.000	.893	109	0.000
Fluoride concentration in protected well	.235	8	0.200*	.871	8	0.156
Fluoride concentration in unprotected wells	.269	7	0.136	.817	7	0.060
Fluoride concentration in Dugout/dam	.260	2	0.000			

* This is a lower bound of the true significance

III. Household Questionnaire

PhD Research

School of Geography

University of Nottingham, UK

Aim: The study seeks to investigate the quality, accessibility and reliability of improved water sources, and their effects on access to domestic water and livelihood in Northern Ghana.

Introduction:

The household questionnaire is divided into four broad modules;
1. Metadata,
2. Access to drinking water
3. Access to water for other domestic uses (cooking, washing and personal hygiene).
4. Socio-demographic characteristics,

NB: All notes and questions form this point forward will be uploaded in the surveyCTO platform and accessible to surveyors via its android supported data collection app.

INFORMED CONSENT

> Before you proceed, first introduce yourself to respondent. Secondly, read out loudly all statements on participant information sheet and consent form to respondent in a language that he/she understands. If he/she agrees to participate in the study, kindly co-sign duplicate copies of the consent form with respondent and leave a copy with him/her. Before signing, make sure that respondent checks either yes or no for all consent statements.

A. METADATA/IDENTIFICATION

Question	Response Options	Notes/Skip Patterns
A1. Surveyor Initials (text)	………………………..	
A2. Date of interview (DD/MM/YYYY)	………………………….	
A3. Interview start time (hr:mm) NB: 24hrs	……………………	
A4. Region (select_one)	1. Upper East Region 2. Upper West Region	
A5. District (select_one)	1. Kassena Nankana Municipal 2. Jirapa District	

A6. Electoral Area Name (text)		
A7. Community Name (text)		
A8. Compound name (text)		
A9. Name of household head (text)		
A10. Household ID (numeric)	……………………	Restricted to three numbers
A11. Type of Residence (select_one)	1. Urban 2. Rural	

B – J: ACCESS TO DRINKING WATER

Notes to read to respondent I am now coming to ***learn*** from you about your **household sources of drinking water**. We shall first discuss your major drinking water source in relation to the following; water collection time, water collection responsibility, means of water collection, reliability of drinking water source, quantity of drinking water collected in a day, sufficiency of drinking water and quality of your drinking water. We will also discuss other sources of drinking water aside your main source, if any. **Remind respondent of consent statements** **Any question before I proceed?** Record queries and responses in the *Notes Box* provided in the consent form

B. Major drinking water source

Question	**Response Options**	**Notes/Skip Patterns** **>> means skip to**
B1. Is your major source of drinking water different from your major source for other domestic uses (cooking, washing & personal hygiene) (select_one)	1. Yes 2. No	
B2. What is the main source of drinking water	1. Pipe-borne inside dwelling	

supply for your household? (select_one)	2. Pipe-borne outside dwelling but on compound 3. Pipe-borne outside dwelling but from Neighbour's house 4. Public tap/standpipe **5.** Borehole/Pump/Tube well 6. Protected well 7. Rain water 8. Protected spring 9. Bottled water 10. Sachet water 11. Tanker supply/Vendor provided 12. Unprotected well 13. Unprotected spring 14. River/Stream 15. Dugout/Pond/Lake/Dam/Canal. 16. Other (specify)	
B3. Record main drinking water source ID		

C. Accessibility to drinking water source, water collection and consequences on livelihood

Question	**Response Options**	
C1. Who has the main responsibility for collecting drinking water in your household? (select_one)	1. Adult woman ………………. 2. Adult man ………………. 3. Boys (under 15 years)… 4. Girls (under 15 years)… 5. All of the above 6. Other *(specify)*______	
C2. Which other members of your household support in drinking water collection? (multiple_choice)	1. Adults woman 2. Adults man 3. Boys in the household (under 15 years) 4. Girls in the household (under 15 years) 5. None 888. Don't know	
C3. How many adult women, adult men, boys and girls of your household are involved in the collection of drinking water? (numeric)	1. Adult women ………………. 2. Adult men ………………. 3. Boys in the household (under 15 years)… 4. Girls in the household (under 15 yea rs)… 5. Total…………	

C4. On average, how many round trips of water does an adult woman, adult man, boy or girl of your household collects from main drinking water source in a week? (numeric) NB: Strike average for each group	1. Adult woman ……………… 2. Adult man ……………… 3. Boy in the household (under 15 years)… 5. Girl in the household (under 15 years)	
C5. In the past week, how many buckets of drinking water had your household collected in total from your main drinking water source? (numeric)	888. Don't know	
C6. What is the main means of collecting drinking water from source in your household by adult women? (select_one)	1. Head loading 2. on a bicycle 3. on a motor bike 4. with a hand pulled cart 5. with a horse/donkey drawn cart 6. in a car/truck 7. Other [specify] 888. Do not know 999. Not Applicable	
C7. What is the main means of collecting drinking water from source in your household by adult men? (multiple_choice)	1. Head loading 2. on a bicycle 3. on a motor bike 4. with a hand pulled cart 5. with a horse/donkey drawn cart 6. in a car/truck 7. Other [specify] 888. Do not know 999. Not Applicable	
C8. What is the main means of collecting drinking water from source in your household by girls under 15 years ? (multiple_choice)	1. Head loading 2. on a bicycle 3. on a motor bike 4. with a hand pulled cart 5. with a horse/donkey drawn cart 6. in a car/truck 7. Other [specify] 888. Do not know 999. Not Applicable	

C9. What is the main means of collecting drinking water from source in your household by boys under 15 years? (multiple_choice)		
C10. What time of the day does your household usually collect drinking water? (Multiple_choice)	1. Dawn 2. Morning 3. Afternoon 4. Evening 5. Night 6. Anytime source is flowing 7. Other (Specify)…… 888. Don't know 999. Not Applicable	
C11. How far (meters) is your household major source of drinking water from dwelling? (numeric)		
C12. How would you rate the distance to your major drinking water source from dwelling?	1. Very far 2. Far 3. Average 4. Near 5. Very near 6. Within premises 888. Don't know	
C13. How long (in minutes) does it take you to go to your major drinking water source, get water, and come back? (numeric)	……………………… 888. Don't know	
C14. How would you rate the time it takes to go to your major drinking water source , get water, and come back?	1. Very long 2. Long 3. Average 4. Short 5. Very short 6. Within premises 888. Don't know	
C15. Are there positive effects associated with long distance to water source /long water collection time to members of your household??	1. Yes 2. No 888. Don't know 999. Not Applicable	Relevance: If options 1/2 in C12 or C14

C16. What are the positive effects associated with long distance to water source /long water collection time?? (multiple_choice)	1. Water collectors have private discussions 2. Children are sent away to collect water outside homes to allow adults have private discussions 3. Make friends/socialise at water source 4. Get to hear information from others 5. Water collection outside home is a way of child training 6. Get exercise 7. Other (Specify)……….	If option 1 in C15
C17. Are there negative effects associated with long distance to water source /long water collection time to members of your household?	1. Yes 2. No 888. Don't Know 999. Not applicable	Relevance: If options 1 or2 in C12 or C14
C18. What are the negative effects associated with long distance to water source /long water collection time? (multiple_choice)	1. Neck/spinal/head pains due to head loading of water 2. Fatigue due to carrying of water 3. Spinal deformities due to head loading of water 4. Musculoskeletal damage/early degenerative bone damage/soft tissue damage 5. Early arthritis 6. Loss of productive time due to long distance to water source / high water collection time 7. Quarrels with neighbours over water 8. Insufficient drinking water 9. Reptile bites	If option 1 in C17

	10. Lateness of children to school 11. Children are unable to concentrate in class due to fatigue of carrying water 12. Limited time for household chores 13. Stunted growth of children due to head carrying of water 14. Contamination of water during transportation 15. Risk of attack 16. Other (Specify)….	

D. Sufficiency of household drinking water and consequences on livelihood

D1.Approximately, what quantity of drinking water doesn't your household need in a day (using 24 litres size bucket as the unit of measurement)?? (numeric)	888. Don’t know	
D2. In the past month, has your household had sufficient drinking water at home from your major drinking water source for the use of all members at all times? (select_one)	1. Yes 2. No 888. Don’t Know	This question seeks to measure rainy season water sufficiency at home from source
D3. In the last dry season, has your household had sufficient drinking water at home from your major drinking water source for the use of all members at all times? (select_one)	1. Yes 2. No 888. Don’t know	
D4. How does insufficient drinking water at home from your major source affect household members? (multiple_choice)	1. Drink less water 2. Fall sick by drinking from other less preferred sources 3. Spend more time to access water from other sources 4. Spend (Nygren et al.) money to access water from other sources	*Relevance:* if option 2 in D3 and D3

	5. Collect drinking water from a distant source (s) 6. Other (specify)………..	

E. Reliability of drinking water source and consequences on livelihood

Question	Response Options	Notes/Skip Patterns
E1. In the past month, how regular is the supply of your household drinking water from main source? (select_one)	1. Continuous 2. Several hours per day[37] 3. A few times a week[38] 4. Less frequently[39] 5. Not at all 888. Don't know 999. Not applicable	*Measures regularity of water source in rainy season because survey will take place in rainy season*
E2. In the last dry season, how regular was the supply of your drinking water from the major source? (select_one)	1. Continuously 2. Several hours per day 3. A few times a week 4. Less frequently 5. Not at all 888. Don't know 999. Not applicable	
E3. Does the irregular supply of drinking water by your major source negatively affect your household? (Multiple_choice)	1. Yes 2. No	*Relevance:* If options 2/3/4/5 in E1 or E2
E4. How does the irregular supply of water by your drinking water source negatively affect your household? (Multiple-choice)	1. Long waiting time at source 2. Drink less water 3. Spend more time in search of water from other sources 4. Insufficient /lack of drinking water at home 5. Collect drinking water from distant sources 6. Quarrels with neighbours over water 7. others	Relevance If 1 in E3 above

[37] Almost continuously
[38] Occasionally
[39] Almost not at all.

E5. How would you rate the flow/yield of water of your major drinking water source in the past month? (select_one)	1. Very high 2. High 3. Average 4. Low 5. Very low 6. Not at all 888. Don't know 999. Not applicable	*Measures yield level of water source in rainy season because survey will take place in rainy season*
E6. How would you rate the flow/yield of water of your drinking water from the major source in the last dry season? (select_one)	1. Very high 2. High 3. Average 4. Low 5. Very low 6. Not at all 888. Don't know 999. Not applicable	
E7. Does the low yield/flow of your drinking water from the main source negatively affect your household?	1. yes 2. No 888. Don't know	*Relevance:* If 4/5/6 in either E5 or E6
E8. How does the low yield/flow of your main drinking water source negatively affect your household? (multiple_choice)	1. Long waiting time at source 2. Collect insufficient drinking water 3. Spend more time in search of water from other sources 4. long duration of drawing to fill container e.g pumping of borehole 5. Quarrels with neighbours over water 6. Collect drinking water from other distant sources 7. Other	If 2 in E6
E9. When was the last time your major drinking water facility broke down? (select_one)	1. During last week 2. One month ago 3. Three months ago 4. More than 3 months ago 5. Never broke down 888. Don't know 999. Not applicable	5 >>F1 888>> F1 999>> F1

E10. The last time your main water facility broke down, how long did it take to have it fixed and working again? (select_one)	1. Immediately/Few days 2. One week 3. During the same month 4. More than one month 5. Not fixed yet	

F. Quality of drinking water and consequences on livelihood

Question	Response Options	Notes/Skip Patterns
F1. Record amount of faecal coliforms (colonies/ml) in household major source of drinking water (numeric) NB: Faecal coliforms test to be conducted using Palintest 3M Petrifilm.	…………………….	Before household survey in each Electoral Area, household drinking water sources would be surveyed and tested for faecal coliforms, fluoride and arsenic. Surveyor task at this stage is to refer to drinking water source of household and input data appropriately. Where water source hasn't been tested, surveyor will collect water sample for testing immediately after field on that day.
F2. Record amount of fluoride (mg/l) in household major source of drinking water (numeric) NB: Flouride test will be carried out using Palintest contour colour comparator.	……………………….	
F3. Record amount of arsenic (ug/l) in household major source of drinking water (numeric) NB: Arsenic test will be done using Palintest visual arsenic detection kit.	…………………………	
F4. Do you think your main drinking water	1. Yes 2. No 888. Don't know	2 >>G1

source has any quality problems? (select_one)		
F5. What kind of quality problems (multiple_choice)	1. Odour 2. Poor Taste 3. Unattractive Colour 4. Suspended Materials 5. Other (Specify)	
F6. How does the poor quality of your main drinking water source negatively affect members of your household? (multiple_choice)	1. Always lack/ have insufficient safe drinking water 2. Drinking less water due to odour, taste, colour, suspended materials 3. High financial cost in buying treatment tabs/materials 4. Loss of productive time in treating water 5. Stomach upset (pains, nausea, diarrhoea and cholera) 6. Brownish teeth 7. Other specify 888. Don't know	
F7. Do you treat your main drinking water in any way to make it safer to drink? (select_one)	1. Yes 2. No	2 >> G1
F8. What do you usually do to make the water safer to drink? (multiple_choice)	1. Boil 2. Add bleach / chlorine 3. Strain it through a cloth 4. Use water filter (ceramic, sand, composite, etc.) 5. Solar disinfection 6. Let it stand and settle 7. Add camphor/naphthalene 8. Add water tablet 9. Other	

G. Other sources of drinking water

G1. Aside from your main drinking water source, did your household drink water	1. Yes 2. No	2>>K1

from other sources in the past year?		
G2. How many are these other sources?	1. One 2. two 3. Three 4. Four 5. Five or more	
H. Second Major source		**Relevance** **If options 1, 2, 3 or 4 in G2**
H1. In the past year, what was your household second major source of drinking water?	1. Pipe-borne inside dwelling 2. Pipe-borne outside dwelling but on compound 3. Pipe-borne outside dwelling but from Neighbour's house 4. Public tap/standpipe 5. Borehole/Pump/Tube well 6. Protected well 7. Rain water 8. Protected spring 9. Bottled water 10. Sachet water 11. Tanker supply/Vendor provided 12. Unprotected well 13. Unprotected spring 14. River/Stream 15. Dugout/Pond/Lake/Dam/Canal. 16. Other (specify)	
H2. In the past year, how frequently did your household drink water from this source	1. Once a while 2. Few weeks 3. Few months 4. Half of the year 5. More than half of the year 6. Throughout the year	
H3. Why did your household drink from this source but not your main source?	1. Water from main source not available at home 2. Main water source broke down/stopped flowing 3. Water quality better than main source 4. Long distance to main water source 5. Long water collection time at main water source 6. Other	

I. Third major source		Relevance If options 1 or 2 in G2
I1. In the past year, what was your household third major source of drinking water?	1. Pipe-borne inside dwelling 2. Pipe-borne outside dwelling but on compound 3. Pipe-borne outside dwelling but from Neighbour's house 4. Public tap/standpipe 5. Borehole/Pump/Tube well 6. Protected well 7. Rain water 8. Protected spring 9. Bottled water 10. Sachet water 11. Tanker supply/Vendor provided 12. Unprotected well 13. Unprotected spring 14. River/Stream 15. Dugout/Pond/Lake/Dam/Canal. 16. Other (specify)	
I2. In the past year, how frequently did your household drink water from this source	1. Once a while 2. Few weeks 3. Few months 4. Half of the year 5. More than half of the year 6. Throughout the year	
I3. Why did your household drink from this source but not 1st or 2nd maijor sources?	1. Water from first/ second major sources not available at home 2. First /second major water sources broke down/not flowing 3. Water quality of third major source better than first/ second major sources 4. Long distance to first/second major water sources 5. Long water collection time at first/second major water sources 6. Other	

J– R: ACCESS TO WATER FOR OTHER DOMESTIC USES

Notes to read to respondent

I am now coming to ***learn*** from you about your ***household*** sources ***of water for other domestic uses – cooking, washing and personal hygiene.*** We shall first discuss your household major source of water for other domestic uses in relation to water collection time, water collection responsibility, means of water collection, reliability of water source, quantity of water household collects in a day, sufficiency of water and quality of water. We will also discuss alternative sources of water for other domestic uses aside the main source. **Remind respondent of consent statements** **Any question before I proceed?** Record queries and responses in the *Notes Box* provided in the consent form

J. Major source of water for cooking, washing and personal hygiene

Question	**Response Options**	**Notes/Skip Patterns**
J1. What is your household's main source of water supply used for cooking, washing and personal hygiene? (select_one)	1. Pipe-borne inside dwelling 2. Pipe-borne outside dwelling but on compound 3. Pipe-borne outside dwelling but from Neighbour's house 4. Public tap/standpipe **5.** Borehole/Pump/Tube well 6. Protected well 7. Rain water 8. Protected spring 9. Bottled water 10. Sachet water 11. Tanker supply/Vendor provided 12. Unprotected well 13. Unprotected spring 14. River/Stream 15. Dugout/Pond/Lake/Dam/Canal. 16. Other (specify)	
J2. Record ID of main water source for cooking, washing and personal hygiene		

K. Accessibility to drinking water source, water collection and consequences on livelihood

Question	Response Options	
K1. Who has the main responsibility of collecting water for cooking, washing and personal hygiene in your household? (Select_one)	1. Adult women 2. Adult men 3. Boys in the household (under 15 years) 4. Girls in the household (under 15 years) 5. Other	
K2. Which other members of your household support in the collection of water for cooking, washing and personal hygiene? (multiple_choice)	1. Adult women 2. Adult men 3. Boys in the household (under 15 years) 4. Girls in the household (under 15 years) 5. None 6. Don't know	
K3. How many adult women, adult men, boys and girls of your household are involved in the collection of water cooking, washing and personal hygiene? (numeric)	1. Adult women ……………… 2. Adult men ……………… 3. Boys in the household (under 15 years)… 4. Girls in the household (under 15 years)… 5. Total…………	
K4. On average, how many round trips of water does an adult woman, adult man, boy or girl collect in a week for cooking, washing and personal hygiene ? (numeric)	1. Adult woman ……………… 2. Adult man ……………… 3. Boy in the household (under 15 years)… 4. Girl in the household (under 15 years)…	
K5. In the past week, how many buckets of water has your household collected in total from main source for cooking, washing and personal hygiene? (numeric)	888. Don't know	
K6. What is the main means of collecting water from source for cooking, washing and personal hygiene in your household by adult women? (select_one)	1. Head loading 2. on a bicycle 3. on a motor bike 4. with a hand pulled cart 5. with a horse/donkey drawn cart 6. in a car/truck 7. Other [specify] 888. Do not know 999. Not applicable	

K7. What is the main means of collecting water from source for cooking, washing and personal hygiene in your household by adult men? (select_one)	1. Head loading 2. on a bicycle 3. on a motor bike 4. with a hand pulled cart 5. with a horse/donkey drawn cart 6. in a car/truck 7. Other [specify] 888. Do not know 999. Not applicable	
K8. What is the main means of collecting water from source for cooking, washing and personal hygiene in your household by children? (select_one)	1. Head loading 2. on a bicycle 3. on a motor bike 4. with a hand pulled cart 5. with a horse/donkey drawn cart 6. in a car/truck 7. Other [specify] 888. Do not know 999. Not applicable	
K9. What is the main means of collecting water from source for cooking, washing and personal hygiene in your household by children? (select_one)	1. Head loading 2. on a bicycle 3. on a motor bike 4. with a hand pulled cart 5. with a horse/donkey drawn cart 6. in a car/truck 7. Other [specify] 888. Do not know 999. Not applicable	
K10. What time of the day does your household mostly collects water from source for cooking, washing and personal hygiene? (Multiple_choice)	1. Dawn 2. Morning 3. Afternoon 4. Evening 5. Night 6. Anytime source is flowing 7. Other (Specify)…… 888. Don't know 999. Not applicable	
K11. How far (meters) is this major source of water for cooking, washing and personal hygiene from your dwelling? (numeric)		
K12. How would you rate the distance to your major source of water for cooking,	1. Very far 2. Far 3. Average	

washing and personal hygiene from your dwelling?	4. Near 5. Very near 6. Within premises 888. Don't know	
K13. How long (in minutes) does it take you to go to your major source of water for cooking, washing and personal hygiene, get water, and come back? (numeric)		
K14. How would you rate the time it takes to go to this water source, get water, and come back?	1. Very long 2. Long 3. Average 4. Short 5. Very short 6. Within premises 888. Don't know	
K15. Are there any positive effects associated with long distance to your major water source for cooking, washing and personal hygiene or high water collection time?	1. Yes 2. No 888. Don't know 999. Not applicable	Relevance: If options 1/2 in k12 or k14
K16. What are the positive effects associated with long distance to your major water source for cooking, washing and personal hygiene or high water collection time of this source? (multiple_choice)	1. Water collectors have private discussions 2. Children are sent away to collect water outside homes to allow adults have private discussions 3. Make friends/socialise at water source 4. Get to hear information from others 5. Water collection outside home is a way of child training 6. Is a form of exercise 7. Other (Specify)……….	
K17. Are there negative effects associated with long distance to your major water source for cooking, washing and personal hygiene or high water collection time of this source?	1. Yes 2. No 888. Don't know 999. Not applicable	Relevance: If options 1/2 in K12 or options 1/2 in K14

K18. What are the negative effects associated with long distance to your major water source for cooking, washing and personal hygiene or high water collection time of this source? (multiple_choice)	1. Neck/spinal/head pains due to carrying of water 2. Fatigue due to carrying of water 3. Spinal deformities due to carrying of water 4. Musculoskeletal damage/early degenerative bone damage/soft tissue damage 5. Early arthritis 6. Loss of productive time due to long distance to water source / high water collection time 7. Quarrels with neighbours over water 8. Insufficient water at home 9. Reptile bites 10. Lateness of children to school 11. Children are unable to concentrate in class due to fatigue of carrying water 12. Limited time for household chores 13. Stunted growth of children due to head carrying of water 14. Contamination of water during transportation 15. Risk of attack 16. Other (Specify)….	If option 1 in K17

L. Sufficiency of household water for cooking, washing and personal hygiene, and consequences on livelihood

L1. On average, how many medium size basins of water does your household use for cooking, washing and personal hygiene in a day?	888. Don't know	
L2. In the past month, has your household had sufficient water at home from main source for cooking, washing and	1. Yes 2. No 888. Don't know	This question measures sufficiency of household water in rainy season

personal hygiene at all times? (select_one)		because survey will take place in raining
L3. In last dry season, has your household had sufficient water at home from main source for cooking, washing and personal hygiene at all times? (select_one)	1. Yes 2. No 888. Don't know	
L4. How does insufficient water at home from main source for cooking, washing and personal hygiene affects household members? (multiple_choice)	1. No/insufficient water to cook 2. No/insufficient water to bath 3. No/insufficient water to wash 4. Cooking utensils/bowls often not cleaned 5. Spend more time to access water from other sources 6. Collect water from other sources at a longer distance 7. Other (specify)………..	Condition: If option 2 is selected in either l2 or L3

M. Reliability of water source for cooking, washing & personal hygiene, and consequences on livelihood

Question	**Response Options**	**Notes/Skip Patterns**
M1. In the past month, how regular is the supply of your main water source for cooking, washing and personal hygiene? (select_one)	1. Continuous 2. Several hours per day 3. A few times a week 4. Less frequently 5. Not at all 888. Don't know 999. Not applicable	*This question measures regularity of water source in rainy season because survey will take place in rainy season*
M2. In the last dry season, how regular was the supply of water from your main source for cooking, washing and personal hygiene? (select_one)	1. Continuous 2. Several hours per day 3. A few times a week 4. Less frequently 5. Not at all 888. Don't know	

	999. Not applicable	
M3. Does the irregular supply of water from your main source for cooking, washing and personal hygiene negatively affect your household? (select_one)	1. Yes 2. No	*Relevance:* If options 2/3/4/5 in N1 or N2
M4. How does the irregular supply of water from source for cooking, washing and personal hygiene negatively affect your household? (Multiple_choice)	1. Insufficient/lack of water at home for cooking , washing & personal hygiene 2. Less cooking/less washing/limited personal hygiene 3. Collect water from distant water sources 4. Spend more time to collect water 5. Quarrels with neighbours over water 6. Long waiting time at water source 7. Other	*If 1 in N3*
M5. How would you rate the flow/yield of water of your main water source for cooking, washing and personal hygiene in the past month? (select_one)	1. Very high 2. High 3. Average 4. Low 5. Very low 6. Not at all 888. Don't know 999. Not applicable	*Measures yield level of water source in rainy season because survey will take place in rainy season*
M6. How would you rate the flow/yield of water of your main water source used for cooking, washing and personal hygiene in the last dry season? (select_one)	1. Very high 2. High 3. Average 4. Low 5. Very low 6. Not at all 888. Don't know 999. Not applicable	
M7. Does the low yield/flow of your main water source for cooking, washing and personal hygiene negatively affect	1. Yes 2. No	*If 4/5/6 in N5 or N6*

your household? (select_one)		
M8. How does the low yield/flow of your water source for cooking, washing and personal hygiene negatively affect your household? (multiple_choice)	1. Long waiting time at source 2. No/insufficient water for cooking/washing/personal hygiene 3. Spend long time to collect water from other sources 4. Long duration of drawing water to fill container e.g time spend in pumping borehole 5. Quarrels with neighbours over water 6. Spend more time to get water 7. Other	*Relevance:* If 1 in N7
M9. When was the last time your water source for cooking, washing and personal hygiene broke down? (select_one)	1. During last week 2. One month ago 3. Three months ago 4. More than 3 months ago 5. Never broke down 888. Don't know 999. Not Applicable	35>>O1 888>> O1 999>>O1
M10. Last time the water facility broke down, how long did it take to have it fixed and working again? (select_one)	1. Immediately/Few days 2. One week 3. During the same month 4. More than one month 5. Not fixed yet	

N. Quality of water for cooking, washing and personal hygiene and consequences on livelihood

Question	**Response Options**	**Notes/Skip Patterns**
N1. Record amount of faecal coliforms (colonies/ml) in household major source of water for cooking, washing and personal hygiene (numeric)	……………………	Same approach to be adopted as in the case of

NB: Faecal coliforms test to be conducted using Palintest 3M Petrifilm.		household drinking water
N2. Record amount of fluoride (mg/l) in household major source of water for cooking, washing and personal hygiene (numeric) NB: Fluoride test will be carried out using Palintest contour colour comparator.	………………………	
N3. Record amount of arsenic (ug/l) in household major source of water for cooking, washing and personal hygiene (numeric) NB: Arsenic test will be done using Palintest visual arsenic detection kit.	…………………………	
N4. Do you think your major source of water for cooking, washing and personal hygiene has any quality problems? (select_one)	1. Yes 2. No	2 >>record time and end of survey
N5. What kind of quality problems (multiple_choice)	1. Odour 2. Bad Taste 3. Unattractive Colour 4. Suspended Materials 5. Other (Specify)	
N6. How does the poor quality of your main water source for cooking, washing and personal hygiene negatively affect members of your household? (multiple_choice)	1. Always lack/ have insufficient water for cooking, washing and personal hygiene 2. Use less water due to odour, taste, colour, suspended materials 3. High financial cost in buying treatment tabs/materials 4. Loss of productive time in treating water	

	5. Stomach upset (pains, nausea, diarrhoea and cholera) 6. Brownish teeth 7. Other specify	
N7. Do you treat your water in any way to make it safer for cooking, washing and personal hygiene? (select_one)	1. Yes 2. No	2 >> record time and end survey
N8. What do you usually do to make the water safer for cooking, washing and personal hygiene? (multiple_choice)	1. Boil 2. Add bleach / chlorine 3. Strain it through a cloth 4. Use water filter (ceramic, sand, composite, etc.) 5. Solar disinfection 6. Let it stand and settle 7. Add camphor/naphthalene 8. Add water tablet 9. Other	

O . Alternative sources of water for cooking, washing and personal hygiene aside main source

O1. Aside your main source of water for cooking, washing and personal hygiene, did your household use water from other sources for the same purpose in the past year?	1. Yes 2. No	2>>K1
O2. How many are these other sources?	1. One 2. two 3. Three 4. Four 5. Five or more	
P. Second major source of water for cooking, washing and personal hygiene		**Relevance** **If options 1, 2, 3 or 4 in G2**
P1. In the past year, what was your household second major source of	1. Pipe-borne inside dwelling 2. Pipe-borne outside dwelling but on compound	

water for cooking, washing and personal hygiene?	3. Pipe-borne outside dwelling but from Neighbour's house 4. Public tap/standpipe 5. Borehole/Pump/Tube well 6. Protected well 7. Rain water 8. Protected spring 9. Bottled water 10. Sachet water 11. Tanker supply/Vendor provided 12. Unprotected well 13. Unprotected spring 14. River/Stream 15. Dugout/Pond/Lake/Dam/Canal. 16. Other (specify)	
P2. In the past year, how frequently did you use water from this source for cooking, washing and personal hygiene ?	1. Once a while 2. Few weeks 3. Few months 4. Half of the year 5. More than half of the year 6. Throughout the year	
P3. Why did your household use this source for cooking, washing and personal hygiene but not first major source?	1. Water from main source for cooking, washing and personal hygiene not available at home 2. Main water source for cooking, washing and personal hygiene broke down/stopped flowing 3. Water quality better than main source for cooking, washing and personal hygiene 4. Long distance to main water source 5. Long water collection time at main water source 6. Other	
Q. Third major source of water for cooking, washing and personal hygiene		Relevance If options 1 or 2 in G2
Q1. In the past year, what was your household third major source of water for	1. Pipe-borne inside dwelling 2. Pipe-borne outside dwelling but on compound	

cooking, washing and personal hygiene?	3. Pipe-borne outside dwelling but from Neighbour's house 4. Public tap/standpipe 5. Borehole/Pump/Tube well 6. Protected well 7. Rain water 8. Protected spring 9. Bottled water 10. Sachet water 11. Tanker supply/Vendor provided 12. Unprotected well 13. Unprotected spring 14. River/Stream 15. Dugout/Pond/Lake/Dam/Canal. 16. Other (specify)	
Q2. In the past year, how frequently did you use water from this source for cooking, washing and personal hygiene ?	1. Once a while 2. Few weeks 3. Few months 4. Half of the year 5. More than half of the year 6. Throughout the year	
Q3. Why did your household use this source for cooking, washing and personal hygiene but not first or second major sources source?	1. Water from first /second major sources not available at home 2. First/second major water sources broke down/not flowing 3. Water quality of third major source better than first/ second major sources 4. Long distance to first/second major sources 5. Long water collection time at first/ second major water sources 5. Other	

R. SOCIO-DEMOGRAPHIC PROFILE OF RESPONDENTS

Question	**Response Options**	**Notes/Skip Patterns**
R1. Name of respondent (text)		

R2. Sex of respondent (select_one)	1. Male 2. Female	
R3. Age of respondent in completed years (numeric)	……………….	
R4. Highest formal educational level respondent has completed (select_one)	1. No formal education 2. Nursery/Kindergarten 3. Primary 4. Middle School/JSS/JHS 5. SSS/SHS 6. Voc/technical school 7. Post-secondary certificate/diploma 8. Bachelor degree 9. Post graduate (Cert., Diploma, Masters, PHD, etc)	
R5. Primary work respondent does for a living (select_one)	1. Agriculture /fishery work 2. Trade/business 3. Casual work 4. Artisan 5. Community development worker 6. Educational professional 7. Health professional 8. Banking/financial work 9. Clerical support 10. Service/sale work 11. No employment 12. Dependant 13. None	
R6. Secondary work respondent does for a living (select_one)	1. Agriculture /fishery work 2. Trade/business 3. Casual work 4. Artisan 5. Community development work 6. Educational professional 7. Health professional 8. Banking/financial work 9. Clerical support 10. Service/sale work 11. No employment 12. Dependant 13. None	
R7. Position of respondent in housekeeping (select_one)	1. Principal housekeeper 2. Assistant housekeeper 3. Not housekeeper 4. Others (Specify)…….	

R8. Relationship of respondent to head of household (select_one)	1. Head 2. Wife or husband 3. Son/daughter 4. Son-in-law/daughter-in-law 5. Grandchild 6. Parent 7. Parent-in-law 8. Brother/sister 9. Adopted/foster child 10. Other relative 11. Not related 12. Don't know	
R9. Sex of household head (select_one)	Male Female	
R10. Age of household head in completed years (numeric)	…………………..	
R11. Highest educational level of household head has completed (select_one)	1. No formal education 2. Nursery/Kindergarten 3. Primary 4. Middle School/JSS/JHS 5. SSS/SHS 6. Voc/technical school 7. Post-secondary certificate/diploma 8. Bachelor degree 9. Post graduate (Cert., Diploma, Masters, PHD, etc)	
R12. Primary work household head does for living (select_one)	1. Agriculture /fishery work 2. Trade/business 3. Casual work 4. Artisan 5. Community development worker 6. Educational professional 7. Health professional 8. Banking/financial work 9. Clerical support 10. Service/sale work 11. No employment 12. Dependant 13. None	
R13. Secondary work household head does for a living (select_one)	1. Agriculture/fishery work 2. Trade/business 3. Casual work	

	4. Artisan 5. Community development worker 6. Educational professional 7. Health professional 8. Banking/financial work 9. Clerical support 10. Service/sale work 11. No employment 12. Dependant 13. None	
R14. Monthly net income (GHC) of household head in the past month (including remittances)	………………….	
R15. How many adult males, adult females, boys under 15 years and girls under 15 years usually lives in this household, excluding visitors – de jure household members (numeric)	Adult Males…… Adult Females…… Boys under 15 years….. Girls under 15 years…….. Total ………..	
R16. How many adult males, adult females, boys under 15 years and girls under 15 years slept in this household last night, including visitors – De facto members (numeric)	Adult Males…… Adult Females…… Boys under 15 years….. Girls under 15 years…….. Total ………..	
R17. GPS coordinates of household	Press "Record Location" *once* and the phone will search for a signal, with increasing accuracy. GPS coordinates set within 10 meters of accuracy.	

IV. Interview Guide with Managers of Piped Water Supply Institutions

PhD Research
School of Geography
University of Nottingham, UK

Aim of Study: The study seeks to investigate the quality, accessibility and reliability of improved water sources, and their effects on access to water and livelihood in Northern Ghana.

Before the discussion starts, remember to do the following;

- Make available participant information sheet to discussants
- Seek consent of participants

1, Background of participants

a. District
b. Name
c. Contact
d. Organization
e. Position

2. Where do you get water from for your customers?

3. What does a prospective customer needs to do to be connected to your water supply system?

4. How many households do you supply water to? And how many aren't connected? What are your expansion plans and targets?

5. How frequent do your customers get water? Probe on continuous supply, rationing etc

6. Are you able to repair and maintain your systems regularly as desired? Probe for frequency of maintenance/checking for leakages

7. Do you treat your water? What kind of treatment?

8. Are there concerns of water quality from your clients? If yes, what are they? And how are they been addressed?

9. Target 6.1 of the SDG 6 is aimed at achieving **universal** and **equitable** access to **safe** and **affordable** drinking water for **all** by 2030. What is your outfit doing towards the attainment of this target as a country?

(a) What measures has your agency/organization undertaken/is taking to ensure that you supply safe water to clients?

V. Focus Group Discussion Guide with Men, Women, Children and Water Comittees

PhD Research
School of Geography
University of Nottingham, UK

Aim of Study: The study seeks to investigate the quality, accessibility and reliability of improved water sources, and their effects on access to water and livelihood in Northern Ghana.

1. For Women/Men Groups

Before the discussion starts, remember to do the following;

- Read out loudly participant information sheet to discussants in a language they understand
- Seek consent of each participant (NB: make sure they thumb print/sign informed consent forms)
- Record Date, EA, Community, Venue and Category/Number of Participants

1. Mention the types of water sources you know of, and draw each on the cards provided to you with the aid of a marker

2. Rank in order of preference, the types of water sources you will prefer your households to have for each of the following uses and why?

   a. Drinking
   b. Cooking
   c. Bathing
   d. Washing

3. What is your household major source of water for domestic uses?

   a. In the rainy season. Probe for drinking and other domestic uses

   b. In the dry season. Probe for drinking and other domestic uses

Accessibility to water sources, water collection and consequences on livelihood

4. Who has the main responsibility for collecting water in your household and why?

   a. Probe on whether it is adult women, adult men, girls or boys.
   b. Probe further on why men and boys hardly collect water as revealed in the survey
   c. Probe why children are involve in water collection

5. How would you rate the distance to your major water sources from dwelling?

- Probe on whether it is very far, far, average, near, very near or within premises

6. How long (in minutes) does it take you to go to your major water source, get water, and come back?

7. How would you rate the time it takes to go to your water source, get water, and come back?

- Probe on whether it is very long, long, average, short or very short

8. Are there negative effects associated with long distance to water source /long water collection time to members of your household? If yes, what are they?

   a. Probe for specific adverse effects on children

9. Are there positive effects associated with long distance to water source /long water collection time to members of your household? If yes, what are they?

Sufficiency of household water and consequences on livelihood

10. In this rainy season, has your household had sufficient water at home *from your major water source* for the use of all members at all times? If no, why?

11. In the last dry season, has your household had sufficient water at home *from your major water source* for the use of all members at all times? If no why?

12. How does insufficient water at home *from your major source* affect household members?

13. In this rainy season, how regular is the supply/flow of water from main source?

- Probe on whether it is continuous, several hours per day, few times a week or less frequently

14. In the last dry season, how regular was the supply/flow of water from the major source?

- Probe on whether it is continuous, several hours per day, few times a week or less frequently

15. Does the irregular supply of water by your major source negatively affect your household? If yes, how?

16. How would you rate the flow/yield of water of your major water source in this rainy season?

- Probe on whether it is very high, high, average, low, very low or not at al

17. How would you rate the flow/yield of water of your major water source in the last dry season?

- Probe on whether it is very high, high, average, low, very low or not at al

18. Does the low yield/flow of water from the main source negatively affect your household? If yes, how?

Quality of water and consequences on livelihood

19. Do you think your main water source has any quality problems? If yes, what kind of quality problems?

20. How does the poor quality of your main water source negatively affect members of your household?

21. Aside from your main water source, did your household use water from other sources in the past year? If yes, probe on the following;

- How many other sources
- What are they?
- Why not from main source?

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2. For Boys and Girls Groups

Before the discussion starts, remember to do the following;

- Read out loudly participant information sheet to discussants in a language they understand
- Seek consent of each child (NB: make sure they thumb print/sign informed consent forms)
- Make sure that 1 or 2 adults are present during session
- Record Date, EA, Community, Venue and Category/Number of Participants

1. What are your names and ages?

2. Are you attending school? If yes, mention your classes and career choices If no, why aren't you going to school (Encourage them to go to school. Follow up to discuss with parents).

3. Mention your favourite subject and teacher

4. Where do your households get water for the following?

a. Drinking
b. Other domestic uses [cooking, bathing & washing]

5. In your various households, who usually collects water for domestic use?

Probe on the following population groups

a. Adult women
b. Adult men
c. Boys/girls

6. Who has the main responsibility for collecting water in your household?

a. Probe on whether it is adult women, adult men, girls or boys.
b. Probe further on why boys hardly collect water as revealed in the survey

7. By what means do you go to collect the water. Probe if by head loading, bicycle, hand pull cart, donkey pull cart, etc

8. What container do you usually use to collect the water? Probe if medium size basins, bucket, gallon etc

9. What time of the day do you usually go to collect water from source?

10. How many trips of water do you collect in a day?

11. How would you rate the distance to your water sources from dwelling?

- Probe on whether it is very far, far, average, near, very near or within premises

12. How long (in minutes) does it take you to go to your major water source, get water, and come back?

13. How would you rate the time it takes to go to your water source, get water, and come back?

- Probe on whether it is very long, long, average, short or very short

14. Are there negative effects associated with long distance to water source /long water collection time on you? If yes, what are they?

- Probe on health, leisure/sleeping, education etc

15. Are there positive effects associated with long distance to water source /long water collection time on you? If yes, what are they?

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3. For Water Committees

Before the discussion starts, remember to do the following;

- Read out loudly participant information sheet to discussants in a language they understand
- Seek consent of each participant (NB: make sure they thumb print/sign informed consent forms)
- Record Date, EA, Community, Venue and Category/Number of Participants

1. What are your roles and responsibilities as WATSAN members?

2. Mention the type of water sources you manage?

3. Have you received any training on maintenance and repair of the various water sources you are managing? From who? Do you have the tools?

4 In this rainy season, how regular is the supply/flow of water from source?

- Probe on whether it is continuous, several hours per day, few times a week or less frequently

5. In the last dry season, how regular was the supply/flow of water from source?

- Probe on whether it is continuous, several hours per day, few times a week or less frequently

6. How would you rate the flow/yield of your water sources in this rainy season?

- Probe on whether it is very high, high, average, low, very low or not at al

7. How would you rate the flow/yield of your water sources in the last dry season?

- Probe on whether it is very high, high, average, low, very low or not at al

8. How many pipes have been inserted in your boreholes? [NB: find out the length of each casing pipe]

9. How often do you remove the casing pipes to clean, look for breakages etc

- Probe if they have any broken pipe inside the well?

10. When was the last time your water source broke down? How long did it take you to repair?

12. Do you think your water sources have quality problems? If yes, what kind of quality problems?

VII. Title Page and Abstract of Published Article in Journal of Groundwater for Sustainable Development, Elsevier, Vol. 9.

(a). Title Page

Assessment of Fluoride Concentrations in Drinking Water Sources in the Jirapa and Kassena-Nankana Municipalities of Ghana

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(b). Abstract

Fluoride is an important chemical for human health. However, its deficiency or excess in the human body poses health problems. In Ghana, the geological formation in the Upper Regions exposes groundwater, the main source of drinking water to risk of excessive fluoride. The risk of population exposure to high fluoride is further increased by the consumption of large volumes of water due to the hot climate of the area. Based on a Risk Assessment and Risk Management (RARM) model to safe drinking water supply, this study assesses the extent of fluoride concentrations in drinking water sources in the Jirapa and Kassena-Nankana Municipalities of Ghana. A concurrent nested mixed method design, which emphasized quantitative data was adopted for the study. Data were gathered through household surveys with housekeepers, testing of fluoride levels in households' drinking water sources and in-depth interviews with hydrogeologists from the Community Water and Sanitation Agency (CWSA). From the results, fluoride concentrations in drinking water sources is generally moderate (0.7 – 1.5 mg/L). Only a few (1.4%) water samples, all from boreholes, exceeded the World Health Organisation (WHO)/Ghana Standard Authority permissible limit of 1.5 mg/L. This implies that boreholes classified as improved water sources do not necessarily deliver safe water. In the Sustainable Development Goal (SDG) era where access to 'safely managed water' is central to the achievement of target 6.1, we call on stakeholders in the water sector to assess and manage improved water sources with high fluoride levels.

Keywords: Risk Assessment; Fluoride; Improved Water Sources; Borehole; safely managed water; Ghana.