Perception, Quality And Consumption Health Risk Of Water In Manyoro-Gworie, Ghana

Noel Bakobie, Bismark Adoah, Samuel J. Cobbina, Wilhemina Asare, Abudu B. Duwiejuah

Abstract: The study was to assess household perception of water quality and its associated health consequences. Nine water samples were collected from three water sources and transported to the Water Research Institute, laboratory for analysis and 120 questionnaires were randomly administered. The physico-chemical values were within the Ghana Standard Board and World Health Organization maximum limits for potability except turbidity and nitrate concentrations. Nitrate concentrations ranged from 1.19 to 46.97 mg/l with a general mean value of 14.11 mg/l. Generally, there was a significant difference ($P < 0.05$) in some physico-chemical parameters values and E. coli count for the three water sources. The microbial count exceeded GSB and WHO limits for potability except Escherichia coli making the water unwholesome for drinking purpose. The community's perception of water quality did not reflect much in the laboratory analysis. It is recommended that, proper treatment should be done at the household level to prevent health implications.

Keywords: Household water, microbial count, perception, water quality, Ghana

◆

1 Introduction

The main sources of drinking water are surface and groundwater and access to these fresh water sources can lead to development and reduction in disease burden in communities, and nations at large. However, these sources stand the risk of contamination with chemicals and microbes through natural or anthropogenic means that threatens human lives. Water treatment for domestic use by households in rural sub-Saharan Africa is not a common practice. Instead, many people are often guided by their perception of water quality and not physico-chemical and bacteriological qualities that are often the most important parameters for measuring access to improved water sources (WHO 2004). By depending on perceptions, consumers hold different views about the aesthetic values of water quality (Doria 2010). Consequently, it is prudent that, consumer perceptions and aesthetic criteria should be considered when assessing drinking water supplies, though they may have no adverse effect on human health (WHO 2004). This would definitely play an important role when trying to undertake preventive measures against water-related diseases. It has been reported that poor perception of water quality can prevent people from taking any water quality treatment measure before drinking and this could be deleterious to human health (Cairncross and Valdmanis 2006). Levallois et al. (1999) have corroborated this with similar findings. It has also been suggested that people's income and education can also influence their risk perception. According to Larson and Gnedenko (1999) an educated person can perceive colour, taste, smell, or turbidity in drinking water and adapt a preventive measure such as boiling or filtration. The level of household income could determine their water quality and the decision for choosing their source of drinking water. Successful interventions for ensuring water quality depended on the understanding of the socio-cultural context of current household water management decisions (Sobsey 2002). Hence, household water management could be influenced by a variety of factors that included knowledge of water treatment practices prior to distribution, perceptions of water quality at the tap, and socio-demographic characteristics of the decision-maker (Sabau and Haghiri 2008; Gartin et al. 2010; Fielding et al. 2012). It has been established that households are more likely to treat their tap water when they believe that government or community treatment facilities are ineffective (Katuwal and Bohara 2011), or when they believe that water quality was low at the tap (Hu et al. 2011). Although there has been considerable improvement in access to safe water, most of rural Ghana still suffers from lack of access to potable water from improved sources, with sanitation being a worst performer (JMP 2016). The lack of access to water also limits good sanitation and hygiene practices in many households because of the priority given to drinking and cooking purposes (WHO2000). The major sources of water for the inhabitants of rural and semi-urban area in most African counties are boreholes, wells, streams and rivers. The majority of the people from Kassena-Nankana Municipality in Ghana depends solely on groundwater and open-well sources for domestic water supply (KNMAP 2013). Some studies on water quality have been carried out in different areas of Ghana but they failed to take into account the perception of household consumers. Hence, this study was to assess water quality and household perception of water quality and its associated health consequences in Manyoro-Gworie in Kasena-Nankana Municipality.

2 Materials and methods

2.1 Study area

This study was conducted in Manyoro-Gworie, one of the ninety-seven (97) communities in the Kasena-Nankana Municipality. Temperatures here are usually high with recordings of around 42 °C (especially in February and March) and night temperatures as low as 18 °C (KNMAP 2013). The community experiences the tropical maritime air mass between May and October and this result in rainfall averaging 950 mm per annum. The community is covered

---

- *Noel Bakobie, Bismark Adoah, Samuel J. Cobbina, Wilhemina Asare, Abudu B. Duwiejuah*
- *Department of Ecotourism and Environmental Management, Faculty of Renewable Natural Resources, University for Development Studies*
- *Department of Biotechnology, Faculty of Agriculture, University for Development Studies*
- *Email: abalu096@gmail.com*

mainly by the Sahel and Sudan-savannah types of vegetation and characterised by open savannah with fire-swept grassland and deciduous trees. Some of the most densely vegetated parts of the community can be found along river basins and forest reserves (KNMAP 2013). The two main types of soils present within the community are namely; the savannah ochrosols and groundwater laterite. The savannah ochrosols are porous, well drained, loamy, and mildly acidic and are interspersed with patches of black or dark-grey clay soils (KNMA 2013). The population of the community is estimated to be 1,200 out of which 586 are males representing 48.8% and 614 are females representing 51.2% (KNMAP 2013). The mainstay and predominant work is agriculture, out of which majority are subsistence farmers. Most of the farmers engage in crop farming and rearing of livestock. The main system of farming is bush fallowing and inter-cropping and every location in the community is a potential farming area. It is estimated that about 82% of the working population are engaged in this sector, which constitutes the main source of household income in the community. Craft works and related trades in the community are also sources of income for their livelihood (KNMAP 2013).

2.2 Sampling, data collection and analysis

Structured questionnaires were administered and open-ended discussions with stakeholders and some members of the community. The questionnaire developed addressed areas such as household water use practices, water quality perceptions, socio-economic factors, water utilization characteristics and household determinants of collecting water from improved and unimproved water sources. A total of 120 questionnaires were randomly administered in Manyoro Gworie. Water samples were collected from three different sources of water; a hand-dug well, a borehole and a dam in the community. A total of nine (9) water samples were collected from the three water sources in March and May 2015 and conveyed to the Council for Industrial and Scientific Research (CSIR) - Water Research Institute (WRI), Tamale laboratory for analysis. Sampling bottles (750 ml sterilised bottles) were rinsed thoroughly, at least three times, with the water to be sampled before sample collection. The collected samples were stored in an ice chest containing ice cubes (4 ºC) and transported to the Water Research Institute laboratory in Tamale for the analysis. All samples were collected from the surface and sub-surface. The bottles were open to fill and closed below the water (APHA 1998). Water samples for microbiological examination were taken aseptically from the dam by holding the bottle near its base in the hand and plunging its neck downward below the surface. The bottle was turned until the neck pointed slightly upward and the mouth directed towards the current. This was done to ensure the sample containers were filled to the brim and making sure that no air was trapped in the sample. The hand-dug wells were all open and hence samples were collected at a depth of about 1 meter below the surface of water. The distances covered between these sources ranged from 50 meters to 1000 meters. Water quality analyses of the sampled water were analysed using American Public Health Association (APHA) analytical methods (APHA 1995). Physico-chemical and microbial parameters of the water samples were analysed within 24 hours after collection. The pH, turbidity and total dissolved solids of the different water samples were determined using a pH-meter, a turbidity meter and electrical conductivity meter, respectively. Total alkalinity, total hardness**,** calcium, magnesium and chloride concentrations in the sampled water were deter-mined using titrimetric methods. Nitrate, phosphate, fluoride and sulphate were determined with a UV/Visible spectrophotometer in accordance with APHA 4500. Potassium and sodium were analysed with flame atomic absorption spectrophotometer (FAAS) in accordance with APHA 20th edition 31113. Samples were analysed by direct aspiration in an air/acetylene flame at specified wavelengths for both potassium and sodium. The membrane filtration technique was used to determine total and faecal coliforms, Escherichia coli and Salmonella spp in accordance with APHA 9222B, 9222D, 9260F and 9215B. Hundred (100) ml of each of the water samples was separately filtered through 0.45 µm pore size membrane filters. Determination of Total coliform, E. coli, Salmonella spp. and Faecal coliform were done by incubating on poured M-endo media, Hicrome (Difco) media, SS agar and M-FC and in Petri dishes at 37 °C ± 0.5 °C and 44 °C for 16-24 hours, respectively. Total heterotrophic bacterium resolve by the pour plate technique and incubated at 37 °C ± 0.5 °C for forty eight hours. Colonies were counted with a colony counter. Means, standard deviations, minimum, maximum values and comparative analysis were calculated using SPSS (version 16.0). One way ANOVA was used to test for significance between the observed parameters of the different water sources.

3. Results and discussion

3.1 Socio-economic characteristics of respondents

The socio-economic characteristics of the respondents are presented in table 1. The study recorded an average household size of 7 and this is attributable to the extended family system practiced in the community. This inevitably puts pressure on available water resources for domestic needs. The age of respondents ranged from 1-15, which represented 8%, 16-30 represented 37%, 31-45 represented 35% and 20% represented age range of 46 and above with an average age of 38 years (see Table 1). The study revealed a wide range of age distribution that was helpful in assessing the water consumption behaviour pattern and perceived quality. The survey also revealed that about 49% of the respondents could read and write whilst 51% of the respondents had no form of formal education (Table 1). Thus, most of the respondents were illiterates, but this did not have an effect on their perception and understanding of their water sources and the related consequences. Studies have shown that variations in household water management are usually influenced by a variety of factors which include knowledge of water treatment practices prior to distribution, perceptions of water quality at the tap and socio-demographic characteristics of the decision-maker (Sabau and Haghiri 2008; Gartin et al. 2010; Fielding et al. 2012). Majority of the respondents' household income came from petty trade and farming representing 38% and 44% respectively (Table 1). However, few of the respondents' farmed and traded at the same time which represented 18%. The study also revealed that, the respondents were predominantly peasant farmers hence will have lower income that influences the risk perception. Household income in developing countries like Ghana can influence the risk perception. Income of households determines the quality of their drinking water and decision related to sources of drinking water (Larson and Gnedenko 1999).

Table 1: *Socio-economic characteristics of respondents*

Gender	Frequency	Percentage
Male	48	40%
Female	72	60%
Total	120	100%
Age	Frequency	Percentage
1-15 years	9	8%
16-30 years	44	37%
31-45 years	43	35%
46 years and above	24	20%
Total	120	100%
Educational Background	Frequency	Percentage
Illiterate	61	51%
Primary and Junior High School	48	40%
Senior High/ Middle School	10	8%
College and University	1	0.8%
Total	120	100%
Household Income Source	Frequency	Percentage
Farming	53	44%
Petty Trade	45	38%
Farming and Petty Trade	22	18%
Total	120	100%

3.2 Household water consumption

The difference in household water management is usually influenced by multiple factors. The study determined the household water consumption behaviour by looking at the primary and secondary or alternative water supply sources. From the study, 18%, 24% and 58% of the respondents used dam, hand dug well and borehole water respectively. Thus 18% of the respondents depended solely on unimproved water sources against 82% for hand dug well and borehole water. The study revealed that rivers and streams were also in the community aside the three sources but were dried up. The perception of their water consumption sources was much distinct in the dry seasons where longer queuing times was common (Admasu et al. 2002). However, the few that used the boreholes still resorted to the hand dug wells and the dam water to meet their water needs. This makes them susceptible to water-borne diseases as they use polluted drinking water sources. The study revealed that children (18%) and women (72%) were mainly responsible for fetching water in the community. Similarly, Ademun (2009) reported that the issue of water fetching was a general problem for both the urban and the rural population and that women and children bear the greatest burden because of their social gender roles. Consequently, these women and children, mostly suffer from water related diseases; have limited participation in education, less income generating activities and less engagement in cultural and political issues (Ademun 2009). A similar study by Addisie (2012) in Simada Woreda in the Amhara region of Ethiopia also revealed that women and children are mostly burdened in terms of fetching water. The frequency of water collection per day on average was 3 times and 5 times from improved and unimproved sources respectively. Consequently, longer waiting time (queuing time) and distance were the main factors that influenced most households in their choice of water source. The study showed that an average of 35 minutes of time and a distance of 1,100 m (1.1 km) was covered for collecting water. As a result, the per capita water consumption of 15 litres and an average household water consumption of 38 litres per day were recorded. However, these findings did not meet the WHO (2006) threshold of at least 20 litres of drinking water per day per person, a distance of not more than 1 km and a maximum time taken to collect water round trip of 30 minutes. The total average time spent by a person per week was 4.85 hours. The perception about distance was not quite convenient as only about 33% accepted distance was convenient and very convenient whilst the remaining 67% saw the distance as not at all and somewhat convenient. As a result of this, people are compelled to resort to other alternative water sources especially nearby unimproved sources. This could lead to household water insecurity in rural areas especially for those households for which the demand was higher due to large family size (Collick 2008). However, the per capita water consumption of 15 litres recorded in the study area exceeded the 10 litres (2.6 gallons) a day as stated by ADF (2005) and 13 litres per day per person in urban areas and 11 litres per day per person from rural areas in Simada, Ethiopia (Addisie 2012). Comparatively, the average time spent per week in collecting water in the study area was similar to that of Roy et al. (2005) who reported water collection times in Kenya to be more than four hours in dry seasons and two hours in wet seasons. Moreover, four to six hours were necessary to collect water in Burkina Faso, Botswana and Cote D'Ivoire (Roy et al. 2005). The majority of the respondents (about 84%) were mostly not satisfied collecting their daily water, but 16% were satisfied or over satisfied collecting their daily water sometimes. The water was mainly used for building and filling cattle troughs (78%) and 22% of respondents used the water for cooking, drinking and bathing. The study showed that the factors that accounted for the use of unimproved water sources were; income (2.5%), quality (3.3%), presence of alternative sources (4.2%), interest (12.5%), distance (25.8%), waiting time (50.0%), and others (1.7%). The study revealed that 75% of the respondents paid for their water use whilst 25% did not pay for water use. The payments were basically for maintenance and repair of the borehole and sometimes as contribution towards the construction of a new borehole. It was also observed that only about 40% of the respondents were willing to pay for improved water use whilst the remaining 60% expressed their unwillingness to pay for improved water use. The study revealed that majority of the respondents who understood water quality was poor were willing to pay for quality water. Sara and Katz (1997) reported that, when communities perceive their water have been significantly improved they will be more willing to pay for quality water.

3.3 Water Quality Perception

About 70% of the respondents said water of good quality should "quenche taste" whilst the remaining 30% said as long as there was "no dirt". Along with that, about 29.2%, 23.3%, 20.0%, 25.8% and 1.7% chose taste, colour, odour, disease attack and others as the major indicators of water quality respectively. However, about 70.0% of them believed the taste, colour and odour of both the improved sources and unimproved sources were the same whilst only 30% believed and accepted the difference in taste of these water sources. The respondents used aesthetic factors such as taste, odour, and colour to determine their drinking water quality. Hence, they would rather go for water that was of a good taste, odourless and void of colour which probably could be of poor quality to water which do not meet these aesthetic characteristics but of good quality and safe for consumption (Doria 2010). Water user communities' perceptions of quality also carry countless weight in their drinking water safety (Doria 2010). Therefore, depending on their perception on taste, odour and appearance of the water, this could lead to different views about the aesthetic values of water quality (Doria 2010). It is important for consumer perceptions and aesthetic criteria to be considered when assessing drinking water supplies though they have no adverse effect on human health (WHO 2004). Consequently, about 14.2% of the respondents said the water consumed was "not safe at all", 9.2% said "somewhat safe", 25% said "partially safe", 45.0% of them said the water they consume was "safe" with 6.6% agreeing that their water was 'highly safe" for consumption (Table 2). About 69% of the respondents believed floods contributed to poor water quality, animal waste (21.7%), human waste (9.2%) and others (0.8%). The study revealed that, the few who used borehole water believed, that once it was from an improved source, there was no problem or risk.

Table 2: *Respondents' perception of water quality*

Water Quality	Frequency	Percentage
Not at all	17	14.2%
Somewhat safe	11	9.2%
Partially safe	30	25%
Safe	54	45%
Highly safe	8	6.6%
Total	120	100%

3.4 Sanitation and hygiene

The study revealed that only a single respondent (1%) had a latrine whilst 99% of the households had no latrines of their own and therefore resorted to open defecation. This is an addition to the global 2.6 billion people without access to improved sanitation (WHO/UNICEF 2010). Water supply conditions without sanitation and hygiene behaviour is nothing (Water Aid 2009). The community's awareness toward sanitation (about 97%) seemed good. The practice of open defecation could worsen the drinking water quality during the rainy seasons. This could render the water unwholesome and its consumption without treatment could cause health risks (Oyelude et al. 2013). Majority of the respondents (97%) washed their hands after defecation especially women who were responsible for housework. However, only a few of them washed their hands with soap. The study revealed that 16.7%, 6.7%, 50.0%, 24.2% and 2.5% of the total water sources, including both improved and unimproved sources had not been clean at all, somewhat clean, partially clean, clean and very clean respectively (Table 3). The poor sanitation problem in the study area could be attributed to lack of additional facilities such as cattle trough, fences among others. This led to the littering of the water source with animal waste and this invariably affected the surrounding cleanliness which was already not encouraging. The most common measures the community took as an initiative to protect their water sources from pollution was sweeping the surroundings and occasional scrubbing of the cemented part of the borehole and covering of some of the wells by the beneficiaries.

Table 3: *Surrounding cleanliness of water sources*

Surrounding cleanliness	Frequency	Percentage
Not at all	20	16.7%
Somewhat clean	8	6.7%
Partially clean	60	50.0%
Clean	29	24.2%
Very clean	3	2.5%
Total	120	100%

3.5 Physico-chemical and microbial quality of water

The results of the physico-chemical and microbial characteristics of the water sampled from selected borehole, hand-dug well and dam is presented in Table 4 and 6 respectively.

3.5.1 Physico-chemical quality of water

The study revealed a significant difference ($P<0.05$) in the conductivity values in terms of water sources signifying their level of pollution differ (Table 6**)**. Conductivity indirectly measures the presence of dissolved solids and can be used as an indicator of water pollution. The present study recorded conductivity values that fell within the conductivity range of 314.11 to 562.09 μS/cm for borehole samples but a bit lower than the conductivity of 383.21 to 723.14 μS/cm for hand-dug wells in the Kasena-Nankana Municipality (Oyelude et al. 2013). The study recorded TDS values that fell within GSB (2006) and WHO (2011) limit for potability (Table 4). Hence, the water sources were not heavily polluted with salts as TDS is an indication of the level of salts present in water (Ahmad and Bajahlan 2009). TDS in drinking water up to 600 mg/l is generally considered to be good and when greater than 1000 mg/l is objectionable (WHO 2004). The sampled water from the community was therefore classified as good on the basis of TDS. There was a significant difference ($P<0.05$) in the TDS concentration of the different water sources signifying their level of pollution differed (Table 6). The turbidity values from the hand dug well and dam exceeded GSB (2006) and WHO (2011) limit of 5 NTU for drinking water (Table 4**)**. This finding agrees with Oyelude et al. (2013) who reported that one out of every four wells sampled in the Kasena-Nankana Municipality recorded turbidity levels higher than 5 NTU, especially during the dry season from December to May. Activities such as farming, sewage disposal, regular fetching of the water for molding bricks and blocks and mixing of mortar for building might have accounted for the higher turbidity levels. Elevated levels of turbidity usually pose treatment challenges as this could harbour pathogens. It has been reported that high levels of turbidity could protect microorganisms from the effect of disinfection and this could stimulate bacterial regrowth (WHO 2008). The pH values recorded were within the GSB (2006) and WHO (2011) limits of 6.5-8.5 pH unit for potability (Table 4), and this signifies that the water resources were of good quality in terms of physical characteristics (WHO 2006). The pH values were within a similar range when compared to a previous study by Oyelude et al. (2013), who reported pH values that ranged from 6.70 to 7.21 pH-unit for borehole and 7.08 to 7.92 pH-unit for well water in the Kasena-Nankana Municipality. Some nitrate concentrations exceeded the limit of 10 mg/l (GSB 2006; WHO 2011) especially with all hand dug well samples and some samples from the borehole (Table 4). The presence of high levels of nitrate in hand dug wells could be attributed to the use of manure and fertilizer for agricultural activities and indiscriminate disposal of human and animal excreta (WHO 2011). Nitrate is one of the most ubiquitous chemical constituents or contaminants of water bodies worldwide as it is derived from human activities, particularly from the disposal of human and animal wastes and the use of nitrogenous fertilisers in agriculture. The intensification of farming practices, for example, has increased nitrate levels in many groundwater resources (Howard et al. 2003; WHO 2004). Intake of water containing excessive nitrate ions may lead to health challenges, especially in pregnant women and infants. At elevated concentrations, nitrate ion is known to cause digestive disturbance (Quagraine et al. 2010). Sulphate ion concentrations were within acceptable concentrations favourable for consumers except for one of the dam water sample that was extremely high. The presence of the anion in drinking-water at levels in excess of 500 mg/l may affect the acceptability of water (WHO 2011). Fluoride values were within the GSB (2006) and WHO (2011) limits for potability (Table 5). Fluoride in drinking water could be beneficial or detrimental depending on its concentration and total amount ingested. It is beneficial, particularly to infants and young children younger than 8 years for calcification of dental enamel when present within the permissible range of 0.5 to 1.5 mg/l, as the maximum acceptable level in drinking water is 1.5 mg/l (WHO 2011). The fluoride concentrations recorded in the study area were not higher than those reported by other researchers in the catchment. Hence, this finding is consistent with Oyelude et al (2013) who reported fluoride concentrations ranges of 0.01 to 0.37 mg/l for borehole and 0.05 to 0.81 mg/l for hand dug well in Kassena-Nankana Municipality. Total hardness, magnesium and calcium concentrations were all within the GSB (2006) and WHO (2011) limits for potability regardless of the water source (Table 4). However, there was a significant difference (P<0.05) in the calcium and magnesium concentrations for the three different water sources (Table 6). In terms of total hardness the water from the three sources can be classified as hard. As water hardness may be classified as; soft (0 to 50 mg $CaCO_3$/l), moderate soft (50 to 100 mg $CaCO_3$/l, slightly hard (100 to 150 mg $CaCO_3$/l), moderate hard (150 to 200 mg $CaCO_3$/l), hard (200 to 300 mg $CaCO_3$/l) and very hard (over 300 mg $CaCO_3$/l) (WHO 1984). Studies suggested that the intake of soft water is associated with increased morbidity and mortality from cardiovascular diseases (CVDs) compared to hard water as well as water high in magnesium (Donato et al. 2003). According to Rubenowitz et al. (2000), only a few months exposure may be sufficient consumption time effects of water that is low in magnesium and/ or calcium. Potassium concentrations were within the GSB (2006) and WHO (2011) limit for potability. In the present study potassium concentrations were t lower 14.33 to 27.77 mg/l and 12.87 to 32.45 mg/l in borehole and well water samples respectively in the Kasena-Nankana Municipality (Oyelude et al. 2013). Potassium is an essential element in human nutrition. According to WHO (2011), potassium may cause some health challenges in susceptible persons. The consumption of water with these low levels of potassium in the community will have adverse effects on health. Manganese and total iron concentrations ranged from 0.14 to 1.40 mg/l and 0.01 to 20.44 mg/l respectively (Table 4). There was a significant difference (P<0.05) in manganese and total iron with respect to the various water sources (Table 6). Dam water samples generally recorded very high total iron concentrations that exceeded GSB (2006) and WHO (2011) stipulated limit of 0.3 mg/l whilst borehole and well water recorded very minimum values below 0.3 mg/l. Hence, the elevated concentrations of total iron in the drinking water makes their drinking not risk free. Total iron is an important trace metal in human nutrition. Total iron in water up to the concentration of 2 mg/l may be consumed without causing any negative impact on health. However, the taste and colour in water with total iron concentration greater than 0.3 mg/l may make it objectionable to consumers (WHO 2011).

Table 4: *Physico-chemical water quality results from sampled water points*

Parameter	Min	Max	Mean	SD	GSB L*	WHO L*
Conductivity (µs/cm)	1.37×10^2	3.78×10^2	2.79×10^2	9.93×10^1	-	-
Turbidity (NTU)	1	2.27×10^2	4.60×10^2	8.27×10^2	5	5
pH (pH units)	7.26	7.67	7.45	0.14	6.5-8.5	6.5-8.5
TDS (mg/l)	8.47×10^1	2.34×10^2	1.72×10^2	6.12×10^1	1000	1000
Nitrate (mg/l)	1.19	4.70×10^1	1.41×10^1	1.54×10^1	-	10
Phosphate (mg/l)	0.07	1.28	0.42	0.48	-	2.5
Sulphate (mg/l)	4.72	3.28×10^2	9.02×10^1	1.13×10^2	250	250
Fluoride (mg/l)	0.01	0.91	0.53	0.33	1.5	1.5
Total Alkalinity (mg/l)	8.0×10^1	1.74×10^2	1.34×10^2	3.96×10^1	-	-
Calcium (mg/l)	1.12×10^1	4.73×10^1	3.20×10^1	1.36×10^1	-	200
Magnesium (mg/l)	1.26×10^1	1.94×10^1	1.50×10^1	2.6	-	150
Potassium (mg/l)	3.3	1.44×10^1	6.93	4.39	-	30
Total Hardness (mg/l)	8.0×10^1	2.75×10^2	1.71×10^2	5.81×10^1	500	500
Manganese (mg/l)	0.139	1.404	0.52	0.49	-	0.4
Total Iron (mg/l)	0.014	2.04×10^2	5.53	8.05	0.3	0.3

Note: *GSB/GWC L*; Ghana Standard Board Stipulated limits (2006); WHO L*; World Health Organisation Stipulated limits (2011).*

3.5.2 Microbial quality of water

The importance of microbial quality of drinking-water cannot be over-emphasized in relation to water borne diseases (Oyelude and Ahenkorah 2012). Microbial counts in the dam water samples for Escherichia coli, total coliform, faecal coliform and Salmonella spp. exceeded GSB (2006) and WHO (2011) limits for potability. Some of the water samples from both borehole and hand dug wells also recorded total coliform, faecal coliform and Salmonella spp. that ranged from 3 to 3.90 × 10^2 cfu/100 ml (Table 5**)**. The level of coliforms in water is generally used as an indicator of cleanliness and effectiveness of disinfection. It is absolutely important that drinking-water must never contain any faecal indicator organism (WHO 2011). It is obvious that underground and surface water in Manyoro-Gworie community possessed poor microbial characteristics and this was worse in the hand-dug well than borehole water. The level of sanitation in Manyoro was poor since open defecation was very common. Also, the large population of livestock reared on the free range basis could contribute to the poor microbial characteristics of water in the community. Dirty surroundings could also be a major factor of water contamination at the water sources. As reported by Ologe (1989), where basic sanitation is lacking, there is more likelihood of indicator bacteria from faeces being introduced into the water bodies. Consequently, it is always impossible to isolate the sanitation and hygiene practices from the water quality perspective (Water Aid 2009).

Table 5: *Microbial water quality results from sampled water points*

Parameter	Min	Max	Mean	SD	GSB L*	WHO L*
TC (cfu/100ml)	6.4×10^1	3.1×10^4	9.77×10^3	1.19×10^2	0	0
FC (cfu/100ml)	0	7.4×10^4	2.13×10^4	2.0×10^1	0	0
E. coli (cfu/100ml)	0	4.4×10^4	1.22×10^2	0	0	0
SS (cfu/100ml)	0	2.1×10^4	7.00×10^3	3.9	0	0
THB (cfu/1ml)	3.70×10^2	1.88×10^3	8.45×10^2	4.98×10^2	500	500

Note: *GSB/GWC L*; Ghana Standard Board Stipulated limits; WHO L*; World Health Organisation Stipulated limits.*

Table 6: *Comparative analysis of water source*

Parameter	Water sources	Df	Mean Square	F	Sig.
Conductivity	Between Groups	2	29346.41	183.83	0.001
	Within Groups	3	159.64		
TDS	Between Groups	2	11159.47	181.09	0.001
	Within Groups	3	61.62		
Alkalinity	Between Groups	2	4632.67	106.91	0.002
	Within Groups	3	43.33		
Calcium	Between Groups	2	510.70	17.67	0.022
	Within Groups	3	28.90		
Magnesium	Between Groups	2	18.30	13.76	0.031
	Within Groups	3	1.33		
Potassium	Between Groups	2	55.71	37.64	0.008
	Within Groups	3	1.48		
Bicarbonate	Between Groups	2	6888.72	110.25	0.002
	Within Groups	3	62.48		
Manganese	Between Groups	2	0.66	17.38	0.022
	Within Groups	3	0.04		
Total Iron	Between Groups	2	178.53	16.73	0.024
	Within Groups	3	10.67		
E. coli	Between Groups	2	8.88	23.68	0.015
	Within Groups	3	0.38		

4 Conclusion

The study revealed issues related to water supply, water quality and sanitation behaviour in the study area. The study revealed women and children as the main household members responsible for water collection besides the workload of women doing the house activities and even field works with men. Queuing time, distance and interest were the main factors that influenced households' reluctance to collect water from improved sources in the study area. This could leave them vulnerable to water borne diseases. Most of the physico-chemical parameters were within the Ghana Standard Board (GSB) and World Health Organization (WHO) limits for potability except turbidity and nitrate concentrations. The dam water concentrations of heavy metals such as total iron and manganese exceeded the GSB and WHO limits for potability. The microbial count of the sampled water exceeded GSB and WHO limits for potability except Escherichia coli count from borehole and hand dugout well water. The present study revealed that underground and surface water in Manyoro community has poor microbial characteristics and cannot be risk free if consumed without proper treatment. Generally, there was a significant difference ($P<0.05$) in the physico-chemical, heavy metal and microbial parameters for the three different water sources. The community's perception of water quality did not reflect much in the laboratory analysis. Based on the findings of this study, it is therefore recommended that proper treatment should be done at the household level before usage to prevent water related diseases.

Authors' contributions

NB, BA, and SJC have contributed in the study conception and design, data acquisition, and analysis and interpretation of data. WA and ABD participated in the intellectual helping in different stages of the study. NB, BA and ABD participated in drafting of manuscript and preparation of the final version. All Authors have read the manuscript and have agreed to submit it in its current form for consideration for publication. All have read and approved the final manuscript.

Acknowledgements

We are grateful to the staff of the CSIR-Water Research Institute (Tamale, Ghana), especially Mr. Emmanuel Bekoe and Mrs. Millicent E. Adu-Boakye for their support and ensuring the analysis was timely and accurate.

Conflict of interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

REFERENCES

[1] Addisie BM (2012) Assessment of drinking water quality and determinants of household potable water consumption in Simada District, Ethiopia. Master of Professional Studies (MPS). Faculty of the Graduate School of Cornell University. Pages 1-76.

[2] Ademun RS (2009) Domestic water supply: an evaluation of the impacts, challenges and prospect on women in rural household in Uganda. MSc. (Environmental studies and Sustainability Science). LUMES, Lund University International Master's Programme in Environmental studies and Sustainability Sci., Pages 15-17.

[3] Admasu M, Kumie A, Fentahun M (2002) Sustainability of drinking water supply projects in rural of North Gondar, Ethiopia, Ethiopian. J. Health Dev, 3: 221-229.

[4] African Development Fund (ADF) (2005) Ethiopian rural water supply and Sanitation Programme. Appraisal report. Infrastructure department north, east and south Onin. June 2005, Ethiopia. Pages 38.

[5] Ahmad M, Bajahlan AS (2009) Quality comparison of tap water vs. bottled water in the industrial city of Yanbu (Saudi Arabia). Environ. Monit. Assess, 159 (1-4): 1-14.

[6] American Public Health Association (APHA) (1998) Standard methods for the examination of water and waste Water. (20th Ed). American Public Health Association, Washington. Pages 135-170.

[7] APHA, AWWA, WEF (1995) Standard Methods for the Examination of Water and Waste Water, 19th Edition, 1: 1294.

[8] Cairncross S. Valdmanis V (2006) Water supply, sanitation and hygiene promotion, in Disease Control Priorities in Developing Countries, 2nd Edn., Editors D.T. Jamison, J.G. Breman, A.R. Measham, G. Alleyne, M. Claeson, D.B. Evans, P. Jha, A. Mills, P. Musgrove. Oxford University Press and the World Ban.

[9] Collick AS (2008) Community water use in the Yeku watershed and hydrological modelling in watersheds of the upper Nile basin, northern Ethiopia.

[10] Donato F, Monarca S, Premi S. and Gelatti U. (2003) Drinking water hardness and chronic degenerative diseases. Part III. Tumors, Urolithiasis, Fetal Malformations, Deterioration of the Cognitive Function in the Aged and Ato- pic Eczema. Annali di Igiene, 15(1): 57-70.

[11] Doria MD (2010) Factors influencing public perception of drinking water quality. Water Policy, 1-19.

[12] Fielding KS, Russell S, Spinks A, Mankad A (2012) Determinants of household water conservation: The role of demographic, infrastructure, behaviour, and psychosocial variables. Water Resour Res 48.

[13] Gartin M, Crona B, Wutich A, Westerhoff P (2010) Urban ethnohydrology: cultural knowledge of water quality and water management in a desert city. Ecology and Society 15: 36.

[14] Ghana Standard Board (GSB) (2006) Drinking water quality guideline. GSB, Accra, p. 6.

[15] Howard G, Ince M, Smith M (2003) Rapid assessment of drinking-water quality: a handbook for implementation (draft). Geneva and New York: World Health Organization and United Nations Children's Fund.

[16] Hu Z, Morton LW, Mahler RL (2011). Bottled water: United States consumers and their perceptions of water quality. Int J Env Res Pub Health 8: 565–578.

[17] JMP (2016) Technical task force meeting on monitoring drinking-water quality. Retrieved from http://www.wssinfo.org/fileadmin/user_upload/resources/JMP-Task-Force-Meeting-on-Monitoring-Drinking-water-Quality.pdf. [Accessed on 21st May, 2016].

[18] Kassena Nankana Municipal Assembly Profile (KNMAP) (2013) Kassena-Nankana Municipal profile, Navrongo. Secondary data, Pages 1-69.

[19] KassenaNankana Municipal Assembly Profile (KNMAP) (2013) Kassena-Nankana Municipal Profile, Navrongo. Secondary data, pp. 1-69.

[20] Katuwal H, Bohara AK (2011) Coping with poor water supplies: empirical evidence from Kathmandu, Nepal. J Water Health 9: 143–158.

[21] Larson BA, Gnedenko ED (1999) Avoiding health risks from drinking water in Moscow: An empirical analysis. Environ. Dev. Econ. 4: 565-581.

[22] Levallois P, Grondin J, Gingras S (1999) Evaluation of consumer attitudes on taste and tap water alternatives in Quebec. Water Sci. Technol. 40: 135-139.

[23] Ologe JO (1989) Household water in rural Kwara, Water, Engineering and Development in Africa. Proceedings of the 15th Water, Engineering and Development Centre, Conference. WEDC, Loughborough, 15: 96–99.

[24] Oyelude OE, Densu AE, Yankey E (2013) Quality of groundwater in Kassena-Nankana district, Ghana and its health implications. Advances in Applied Science Research 4(4): 442-448.

[25] Oyelude, EO, Ahenkorah S. (2012) Quality of sachet water and bottled water in Bolgatanga Municipality of Ghana. Research Journal of Applied Sciences, Engineering and Technology, 4(9): 1094-1098.

[26] Quagraine EK, Adokoh CK (2010) Assessment of dry season surface, ground, and treated water quality in the Cape Coast municipality of Ghana. Environmental Monitoring and Assessment, 160 (1-4), 521.

[27] Roy JL, Crow B, Swallow B (2005) Getting access to adequate water: community organizing, women and social change in western Kenya. International workshop on 'African Water Laws: Plural Legislative Frameworks for Rural Water Management in Africa', 26-28 January 2005, Johannesburg, South Africa. Pages 1-11.

[28] Rubenowitz E, Molin I, Axelesson R. (2000) Magnesium level in drinking water in relation to morbidity and mortality from acute myocardial infarction. Epidemiology, 11(4): 416-421.

[29] Sabau G, Haghiri M (2008) Household willingness-to-engage in water quality projects in western New found land and Labrador: a demand-side management approach. Water and Environment Journal 22: 168–176.

[30] Sara J, Katz T. (1997) Making the rural water supply sustainable: Report on the impact of project rules. UNDP World Bank water and sanitation program: Washington D.C. pp. 1-87.

[31] Sobsey M D (2002) Managing water in the home: accelerated health gains from improved water supply. World Health Organization.

[32] Water Aid (2009) Water, sanitation and hygiene for development. Advocacy for change. Water Aid's Global strategy 2009–2015. pp. 1-28.

[33] WHO (2000) Iron in drinking-water. Background document for development of WHO Guidelines for drinking-water quality. Geneva, World Health Organization. pp. 1-9.

[34] WHO (2006) Guidelines for Drinking-Water Quality. 3rd Edn, Incorporating First Addendum, pp. 121-493. Retrieved from: http://www.who.int/wateranitationhealth/dwq/gdwq3rev/en. [Accessed on: July 13, 2016].

[35] WHO (2008) Guidelines for drinking-water quality, 3rd edition. Incorporating 1st and 2nd Addenda. 1: 251-409.

[36] WHO (2011) Guidelines for drinking-water quality, 4th edition. Pages 117-409.

[37] WHO/UNICEF (2010) Progress on sanitation and drinking water, 2010 update. Pages 6-10.

[38] World Health Organisation (WHO) (1984) Guidelines of drinking water quality. Vol. 1, Recommendations, WHO Geneva, pp. 19-115.

[39] World Health Organisation (WHO), (2004) Guidelines for drinking-water quality, 3rd edition. Vol. 1 Recommendations. World Health Organisation, Geneva. pp 210-229.