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RESEARCH ARTICLE

ELUCIDATING MICROBIAL POLLUTION MARKERS OF DRINKING WATER IN APPIADU WITHIN THE ASHANTI REGION OF GHANA

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ABSTRACT

Access to safe drinking water a major challenge affecting many countries in the world especially developing countries. The main objective of this study was to assess the quality of water supplied by Appiadu community water system; in Appiadu, a suburb in the Kumasi metropolis, Ghana. Parameters analysed included pH, temperature, electrical conductivity, total dissolved solids, turbidity, total hardness, total coliform, faecal coliform, faecal enterococci, total viable count, Escherichia coli and salmonella. In this study, a total of 60 water samples were collected from the main reservoir (tank) and 5 households in Appiadu from April to June, 2013. Assessment of the microbiological properties of the water samples showed that the mean figures for total coliform, faecal coliform, total viable count and faecal enterococci exceeded the permissible limits of the World Health Organization/Ghana Standard Authority for drinking water. *E. coli* and *Salmonella* were however absent in all the samples. The study also showed that the concentrations of all physico-chemical parameters in the drinking water samples were within the permissible limits of the WHO)/GSA. The presence of indicator organism in the water samples was an indication of a possible faecal contamination, which could pose a public health risk for consumers.

INTRODUCTION

Deterioration of drinking-water quality during storage or in distribution systems remains one of the major challenges experienced by potable drinking water suppliers and pathogenic. Toxigenic microbiological agents in drinking water have long been known to cause diseases and to some extent death in consumers (Craun, 1986). It is therefore not surprising that, many waterborne outbreaks are as a result of contamination of this distribution system (Hunter, 1997). A study conducted by Shrestha *et al*. (2009), reported the occurrence of *Salmonella* species in drinking water samples of urban water supply system of Kathmandu, Nepal. According to WHO, 88% of diarrheal diseases is attributed to unsafe water supply, inadequate sanitation and hygiene resulting in 1.8 million deaths (WHO, 2007), of which 1.5 million are children under the age of 5. Although Ghana is naturally endowed with many water resources, access to safe drinking water supply by the populace still remains a gloomy one. In addition, there are so many water and sanitation diseases prevalence in Ghana, ranking the country the second worst affected guinea worm cases in the world (WaterAid Ghana, 2013). Research has shown that, groundwater remains one of the major sources of water supply to many rural and urban communities in Ghana. This according to their study, habours a lot of excellent natural qualities as compared to surface water, where poor distribution systems could make groundwater susceptible to microbial contamination (Gyau-Boakye and Dapaah-Siakwan, 2000). Most community drinking water distribution systems involve a complex network of pipes, tanks and reservoirs that delivers finished water products to consumers (Jonah, 2003). But then, as water travels through the distribution system, a variety of physical, chemical and biological transformations could ensue and cause an adverse change in the quality of water (Umar, 2012). It ought to be noted that, the purpose of a water supply distribution system is to deliver to each consumer safe drinking water which is also adequate not only in quantity and acceptable but also in terms of taste, odour and appearance (Karikari and Ampofo, 2013). The integrity of reservoirs for community water storage and mains in the distribution network is therefore crucial for the safety of the drinking water with respect to the apparent health of its unsuspecting consumers (Van Lieverloo *et al.*, 2006).

Water quality indicators which include physical, chemical and biological measurements are mostly employed to describe the condition of a water source (McCaffrey, 2010). We have

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reported previously, that, the Appiadu community water system draws groundwater from borehole which is pumped to a series of overhead tanks (Bosompem *et al.*, 2014). In this regard, the water is distributed through a network of pipelines to individual homes within the community. Most of these pipelines run through the main drainage system, and since the distributed water undergoes no treatment process prior to public consumption, there is the likelihood of contamination from these drainage channels. A study conducted by Egwari and Aboaba (2002) to assess the impact of town planning, infrastructure, sanitation and rainfall on the bacteriological quality of domestic water supplies in Lagos, Nigeria, revealed that water samples collected from points of leak were more frequently contaminated with *E. coli* or other coliforms.

It is therefore not out of place to state that, microbial contamination has the potential to cause large outbreaks of waterborne diseases especially within community drinking-water supplies than in larger drinking-water supplies (WHO, 2008). Furthermore, due to the health risk that a potential contamination could pose, it has become very imparative to investigate the physico-chemical and microbial quality of water reaching the tap at homes as well as water in the storage tank. In this present study, we sought to investigate the physico-chemical and microbial quality of water supplied by Appiadu community water system and its potential impacts on the health of its consumers.

Study Area

This study was conducted at Appiadu, a peri-urban community within Kumasi, the capital of Ashanti Region of Ghana. Kumasi covers an area of about 245 km^2 and is located in the transitional forest zone and is about 270 km north of the national capital, Accra. It is between latitude 6.35°- 6.40°and longitude 1.30°- 1.35° and lies within the wet semi-equatorial zone marked by double maximum rainfall ranging between 1 150 and 1 1750 mm per annum. The major rainfall season is from April to July and the minor season is between September and Mid-November.

MATERIALS AND METHODS

With the help of GPS, the main storage tank (reservoir) and 5 different households which receive water from the community water system was recorded. Water for drinking and for other domestic purposes were collected from this main reservoir (tank) and the 5 other household taps in Appiadu (study community) from April to June, 2013. Physico-chemical and microbiological analysis were conducted for each water sample collected from each of the sampling points. The five households were selected using judgmental sampling from seven households that had their pipelines running through the main drains. These distribution mains were exposed above the ground resulting in frequent leaks and bursts thereby making them possible points of contamination.

MAP OF KUMASI

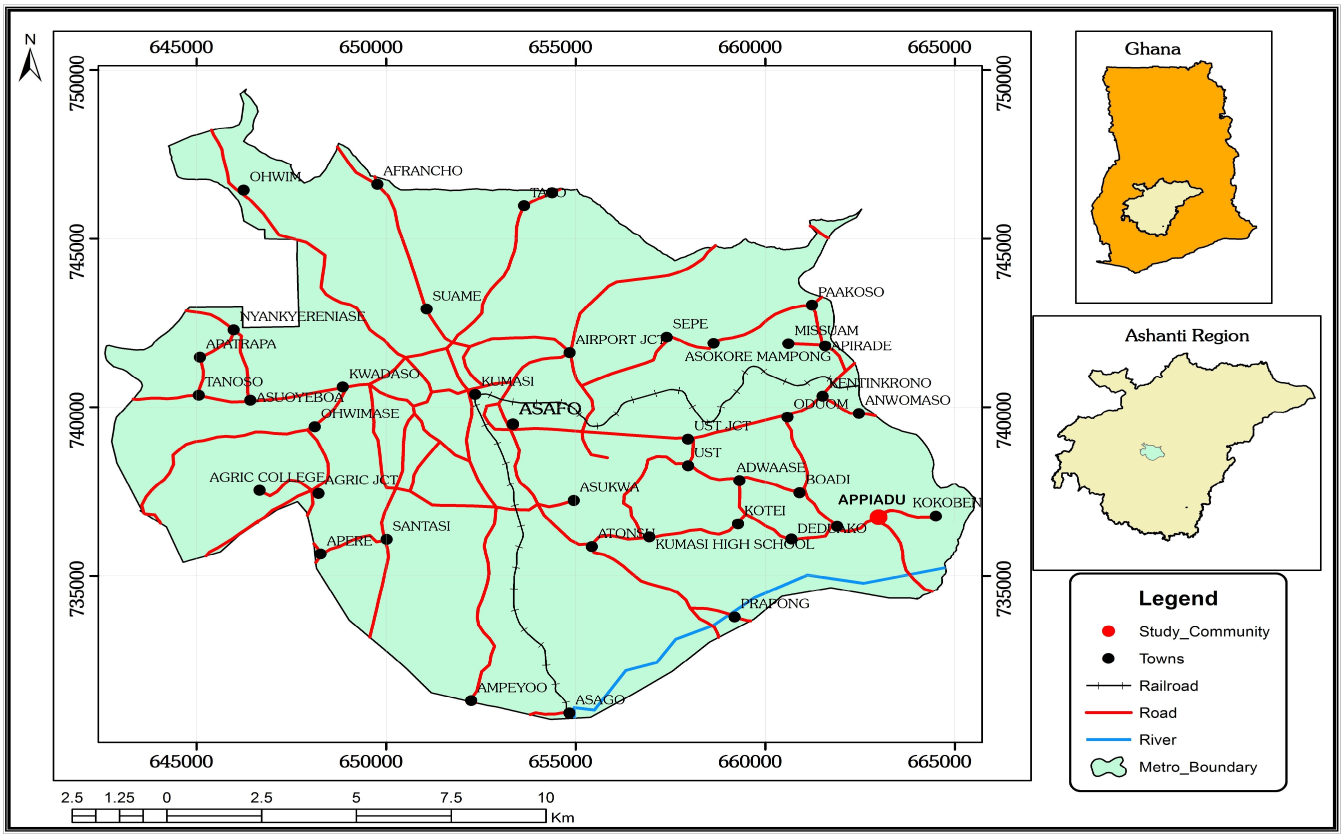

Figure 1. A Map of Kumasi (left) showing the Study area Appiadu (circled red) and the transportation networking linking the

Physico-chemical analysis of the water samples were carried out by instrument and non-instrumental method. Temperature, pH, TDS and electric conductivity (EC) were determined on-site using the PC 300 Waterproof Handheld pH/Conductivity/TDS/Temperature meter whilst turbidity and total hardness were analysed using the standard procedure mentioned in APHA (1995). Microbiological parameters determined included total/faecal coliform, total viable count, faecal enterococci, *E. coli* and *Salmonella*. Samples were collected on-site in sterilised 500 ml litre plastic bottles and preserved in an ice chest at 4°C and taken to the laboratory for immediate analysis. The Most Probable Number (MPN) method was used to determine total and faecal coliforms in the sample.

RESULTS

Results from the study have shown that, with respect to physicochemical parameters based on pH, water from Appiadu community was generally acidic with the main distribution tank (APT) recording the lowest pH (5.1) with a standard deviation of 0.361 as shown in Table 1. All pH values recorded for the study however was outside the range set by the WHO and GSA recommendations for drinking water (6.5-8.5). Mean temperature of all the water samples collected during the study ranged from 28.60 ± 0.94 to 30.78 ± 4.35°C as shown in table 3. Household 3, code named AP3 recorded the lowest mean temperature 28.7 and this was similar to the rest of the other households (Table 1). Household 5, code named AP5 also recorded a mean temperature of water samples (30.7) over the study period.

The study also sought to assess electrical conductivity of the drinking water at Appiadu and analysis of results during the study showed that, the mean conductivity values observed ranged from 304.4 ± 7.96 to 308.8 ± 4.15 µS/cm. Conductivity analysis of water samples collected from Appiadu community based on household type comparison also showed that, the household code named AP5 recorded the highest mean conductivity (308.8 µS/cm) with standard deviation 4.147 as shown in Table 1. This figure fell far below the WHO/GSA recommendations for drinking water 1000 µS/cm (Table 1). Physico-chemical quality analysis of water samples collected from the study community was investigated with respect to total dissolved Solids (TDS) as part of the study. Analysis of the results showed that, all water samples collected had low TDS figures, that is <155 mgL^{-1}, This figure fell within the WHO and GSA recommendations for drinking water as shown in Table 1 below. The study also showed that, none of the water samples collected from the Appiadu community had a mean Turbidity figure <1NTU. This was also seen with total hardness as all values recorded during the study fell below the WHO/GSA recommendations for drinking water (Table 1).

Microbial quality based analysis was carried out for all the water samples collected from the main distribution tank, code named (APT) as well as those of the different households coded named AP1-AP5. Results of the study with respect to total coliform count of the samples showed that, household code named AP1 was the most polluted (log of mean 6.5cfu/100ml, whiles household AP4 showed the least polluted (mean of log 4.2 cfu/100ml). All of these however exceeded the WHO and GSA guidelines for drinking water as shown in Figure 2.

Table 1. Some Physico-chemical parameters of water from the main storage tank and selected Households in the Appiadu

	Main Tank	AP1	AP2	AP3	AP4	AP5	WHO/GSA
Parameter	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Guidelines
pH	5.1±0.361	5.6±0.5639	5.4±0.1508	5.3±0.387	5.2±0.4237	5.3±0.3493	6.5-8.5
Temperature ^{O}C	28.7±0.965	28.7±0.8503	28.7±0.9138	28.6±0.943	28.6±0.8849	30.7±4.349	-
Conductivity µS/cm	306.8±5.450	306.0±4.416	304.4±7.925	304.8±4.494	307.4±1.817	308.8±4.147	1000
TDS mg/L	153.6±2.702	153.2±2.168	152.6±3.847	152.8±2.28	154±0.707	154.4±2.074	1000
Turbidity (NTU)	0.616±0.715	0.694±0.4318	0.588±0.4012	0.37±4.604	0.38±0.1606	0.426±0.2392	5
Total Hardness	88.8±8.556	81.6±9.206	86.8±8.319	88.8±4.604	83.2±6.261	87.2±8.672	500

Note: N=5, SD refers to standard Deviation, WHO: World Health Organization, GSA: Ghana Standard Authority. All figures preceded by (±) refers to the respective Standard Deviation, Main Tank: The main distribution water system in the community, AP1, AP2, AP3, AP4 and AP5 also refers to the 5 systematically selected households within the community where water samples were taken from.

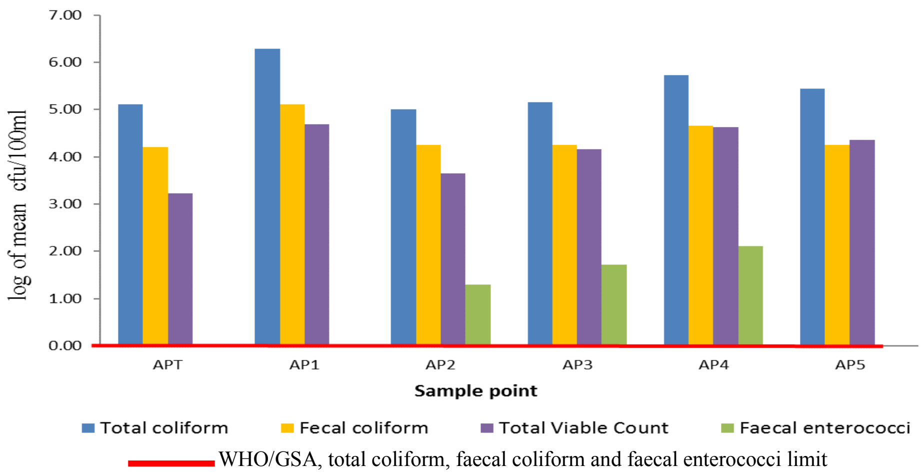

Figure 2. Log of mean number of total/faecal coliform, faecal enterococci and total viable count (cfu/100ml) of water samples from APT, AP1, AP2, AP3 and AP4

NOTE: N=5, WHO refers to World Health Organization, GSA: Ghana Standard Authority. APT: The main distribution water system in the community, AP1, AP2, AP3, APT4 and AP5 also refers to the 5 systematically selected households within the community where water samples were taken from.

Faecal coliform was employed as microbial pollution markers for all the water samples collected during the study. Analysis of the results showed that, none of the source of these drinking water was wholesome for consumption with respect to the WHO/GSA permissible guidelines for drinking water (Figure 2). Water samples collected during the study revealed that, water samples collected from APT (the main distribution system) was the least polluted with respect to faecal coliform numbers (mean log of 4.20 cfu/100ml) as shown in Figure 2 below. The study sought to assess the level of pollution of water from all sampling point with respect to total viable count and analysis of the results showed that, these were all polluted. Total coliform numbers ranged from mean log 5.00 - 6.29 cfu/100ml, exceeding the WHO/GSA permissible guideline for drinking water (Figure 2).

Water samples collected from all sampling points were cultured for faecal enterococci and the results of this study showed that, 50% of the sampling sites were free from contamination that is APT, AP1 and AP5. Water collected from AP4 was the most polluted with respect to faecal enterococci (mean log 2.11 cfu/100ml) with AP2 being the least contaminated (mean log 1.30 cfu/100m). These values exceeded the WHO/GSA permissible guidelines for drinking water as shown in Figure 2.

Figure 2. Mean values of total/faecal coliform, total viable count and faecal enterococci in the water samples at the

DISCUSSION

This is the first time both physico-chemical and microbial analysis based study is being carried out for groundwater collected in a main reservoir and distributed to nearby households in the Appiadu community. The mean pH levels falling below the WHO/GSA optimum limits of between 6.5 and 8.5 implied the water from the various sample points was mildly acidic. The slightly acidic nature of the water can be attributed to the source water: which is groundwater. The acidity may be due to the presence of CO_2 within the soil zone and other natural biogeochemical processes (Yankey *et al.,* 2011). Amfo-Otu *et al.* (2012), in assessing the physico-chemical quality of groundwater sources in Ga East Municipality of Ghana observed that the pH (5.2±0.5, 5.3±0.4 and 5.1±0.2) of all the three boreholes sampled were below WHO recommended levels which made the water acidic and aggressive.

Electrical Conductivity is affected by the presence of inorganic dissolved salts in water and therefore with a higher conductivity, it is an indication that a higher salt concentration of the water (Hach, 2000) and may cause water to taste salty. The lower turbidity levels observed for the samples were expected, considering the fact that the source of water supply is groundwater. Groundwater is not under the direct influence of surface water, thus is considered less vulnerable to contamination and therefore turbidity could generally be below 1.0 NTU (Strestha *et al.,* 2009). According to Langmuir (1997), total hardness is usually categorised as follows: soft water has a hardness concentration of 0 to 60 mgL^{-1}; moderately hard water has a hardness concentration of 61 to 120 mgL^{-1}; hard water has a hardness concentration of 121 to 180 mgL^{-1}; and very hard water has a hardness concentration greater than 180 mgL^{-1}. The recorded levels of total hardness for the water samples imply that the water supply is moderately hard. Hardness of water is mainly due to the presence of salts of calcium and magnesium and this reduces lather formation and also increases the boiling point of the water (Murhekar, 2011).

The mean figures observed for total coliform, faecal coliform and faecal enterococci in this study far exceeded the WHO and GSA recommended guideline for drinking water. Ideally, indicator organism should not be detectable in any 100 ml sample for drinking water (WHO, 1996) and therefore the presence of indicator organism in drinking water is a very powerful indication of faecal contamination which poses a public health risk (Van Lieverloo *et al.* 2006). The occurrence of indicator organism in drinking water is a common phenomenon all over the world. From this study, the presence of total coliform, faecal coliform, faecal enterococci and total viable count in the water samples collected at the 5 households could be attributed to leaks in the distribution pipelines, causing a breach in the distribution system's integrity by allowing leakage of contaminated environmental water into the distribution lines carrying water to the houses. Waste water from the drains in the study community is the primary possible source of the contaminated environmental water.

The observed trend of total coliform, faecal coliform, faecal enterococci and total viable count presence in the water samples was lower at APT as compared to the households (AP1, AP2, AP3, AP4 and AP5). It could then be deduced from this observation that the microbial load increased as water travelled from the APT through the distribution system to the individual household. A number of studies have reported a statistically significant deterioration in the microbiological quality of water between the source and point of use in the home (Simango *et al.,* 1992). The observations made in this study is consistent with a study conducted by Umar in 2012, in assessing water quality deterioration in piped water observed that microbial quality of water sample deteriorated as water travelled through the distribution network to homes (Umar, 2012).

Earlier work in environmental impact on the bacteriological quality of domestic water supplies in Lagos, Nigeria (Egwari and Aboaba, 2002) concluded that leakages in pipelines increases the rate of contamination and wastewater from drains was the main source of contamination of pipe-borne water. The incidents of indicator organism in the tank could also be due to biofilm formation and build-up in the tank. This assertion was consistent with a study by Batinas (2002) where the results of indicators of faecal contamination and opportunistic pathogenic bacteria monitored in biofilms associated with drinking water indicated that coliform populations prevailed in surface attached consortia. Biofilms can serve as a hosting platform for bacteria and other microbes and can allow the growth of bacteria to reach a level that interferes with total coliform compliance testing or support the growth of coliform organisms to a level that jeopardizes the microbial quality of drinking water (Seo, 2010).

Water leaving the tank was relatively lower in microbial load and the upsurge in microbial loads in the 5 houses occurred as water travelled through the pipelines; which served as a source of further microbial contamination. The data clearly shows that the levels of total coliform, faecal coliform, faecal enterococci and total viable count in the water samples far exceed the recommended WHO/GSA permissible levels. Presence of faecal coliforms in water may not necessarily indicate the presence of faeces; however it does indicate an increased likelihood of harmful pathogens in the water supply (Umar, 2012). This situation represents a major health concern and the continuous consumption of the water supply by the community could increase the risks of water-related diseases especially in children.

All samples showed negative results for the presence of *E. coli* and *Salmonella*. The presence of *E. coli* and *Salmonella* in the water samples would have been a strong indication of recent sewage or animal waste contamination. Although the other samples tested positive for faecal coliform and faecal enterococci which may also indicate a possible faecal contamination, *E. coli* has been credited to be a more specific indicator of faecal contamination than the more general test for faecal-coliform bacteria (Dufour, 1984).

Conclusion

Results from the study has shown that, water from all sampling points were polluted with some microbial indicators of pollution i.e total coliform and faecal enterococci which far exceeded the WHO and GSA recommended guideline for drinking water. The presence of coliform bacteria in the water samples from the tank and the households is a very powerful indication of faecal contamination which poses a health risk to consumers. All the water samples however were negative for *E. coli* and *Salmonella*. The incident of coliform bacteria in their drinking water should be addressed urgently to avoid incidences of water related diseases within the community

Conflict of Interest

The author(s) declare that they have no competing interests.

Authors Contribution

MOD: Contributed in study design of this work, collected data from the field, carried out physicochemical analysis and other parameters in the laboratory, carried out microbial analysis, assisted in data analysis and interpretation of analysed data, assisted in writing of this manuscript.

EAA: Made substantial contributions to conception and design of the study, assisted in statistical analysis, involved in drafting the manuscript and revising the manuscript critically for intellectual content approval prior to submission, gave the final approval for the publication of this manuscript.

SFG: Made substantial contributions to conception and design of the study, assisted in statistical analysis and interpretation of analysed data, editing of the manuscripts. He also agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work was appropriately investigated and resolved.

All 3 authors read and gave final approval for submission of this manuscripts.

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