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Water Quality and Handling Behaviour of Households in Peri-Urban Area of Kumasi, Ghana

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ABSTRACT

This study was conducted to assess household water quality and the effect of water storage and handling behaviors in Kumasi, Ghana. The changes in the physical, chemical and bacteriological quality of water at primary water sources and secondary storage points were assessed. A total of 55 water samples at primary water sources and secondary storage points were collected for water quality analysis. The physical, bacteriological and chemical quality of water samples were determined using standard procedures. It was observed that residents in Kotei use water from urban water, hand dug wells and mechanized boreholes as their domestic water supply. The physical and chemical quality of water at primary and secondary storage were within the World Health Organization (WHO) and Ghana guideline values except total suspended solids (TSS) with an average parametric value of 1.0 ±0.5 mg/l for source and 1.5 ±0.7 mg/l for storage. Total coliform and Escherichia coli numbers were higher in the water storage than the three major water supply sources. Out of the 55 respondents, only one used alum to treat water occasionally. Ninety-four percent (94%) and 92% of the respondents respectively had no knowledge about water treatment and water quality issues. The water was stored in storage containers without lid. The frequency of cleaning primary and secondary storage tanks above one month impacted negatively on the bacteriological quality of water. The community should be educated on household water supply hygienic practices.

1. INTRODUCTION

In developing nations, precisely Ghana, majority of the population are inhabitants of peri-urban and rural communities where piped water is not always readily available in homes when and where required (Doe, 2007). This is because several homes lack direct connection to pipe-borne urban water and issues such as availability of resources and steady income flow to afford these connections and tariffs attached (Doe, 2007). Many households rely on underground water from hand dug wells and mechanized bore-holes situated near or distance away from home in these communities as major water source. These alternative sources are vulnerable to contaminations.

Storage of water is therefore a necessary obligation in households within these communities. Different storage units are used in storing water. Storage facilities range from overhead tanks, barrels to big and small buckets etc., and are made from materials such as plastic and aluminum (Kausar *et al.,* 2012). The storage facilities may not be safe due to contamination and bad water handling behaviors. The handling of water within household is an important factor in determining the quality of water. Factors such as conditions of the various storage facilities, duration of storage, frequency of cleaning and treatment of storage containers are important in maintaining the quality of water (Wright *et al.*, 2004; Maraj *et al.*, 2006; Doe, 2007; Deshpande *et al.,* 2007; UNICEF, 2010; Rufener *et al.*, 2010; Kausar *et al.*, 2012; Kanda *et al.,* 2013; Lantagne and Clasen, 2013; Zin et al., 2013).

Consumption of unsafe water can cause diseases such as diarrhea, cholera, dysentery and others there by increasing the disease burden of the community. Increase in disease burden affects the productivity of the population within a household, community or country and household water storage and water handling behavior affect water quality (Kausar et al., 2012; Lantagne and Clasen, 2013). The extent to which the activities of consumers affect the quality of water differ due to varying water handling behavior need to be assessed to address the water quality problems (Lantagne and Clasen, 2013).

To be able reduce contamination and recontamination of water at household levels it is necessary to investigate the quality of water from source to storage and the associated effects unsafe handling of water have on its quality (Preez *et al.*, 2008). By so doing, specific water handing behaviors that are responsible for contamination of water can be identified and targeted for appropriate action. In addition, assessing the knowledge water consumers have about water quality will give the policy makers the starting point to carry out education on safe water handling. The combination of the above baseline information will give a better insight to issues with household water quality which will help improve policy, planning and technology development. Improving the water quality within households will contribute to the overall improvement of health in the community and general population at large (Mohsin *et al.,* 2013). Agencies such as Public Utilities Regulatory Commission (PURC), Ghana Water Company Limited (GWCL), Kumasi Metropolitan Assembly (KMA), will benefit from the results of this study. This study thus assessed the effect of water storage and handling behaviors on household water quality. Specifically, the study determined the physico-chemical and bacteriological quality of water sources, assessed the level of contamination from water sources to households' storage and the effect of water storage and handling behaviours on water quality.

2. MATERIALS AND METHODS

2.1. Description of Study Area

The study was conducted in Kotei, a peri-urban community in Kumasi, the Ashanti Regional Capital in Ghana. The community rely on two main water resources and these are ground water and surface water. The groundwater is made available through mechanized boreholes (MBH) and covered hand dug well (CHDW). The new Kotei town is dominated by the middle-class person in the society and its choice the study was necessitated by the fact that most household in the area depended more on shallows wells, with limited urban water supply and mechanized boreholes. Meanwhile the old town depend on pipe borne water which was introduced in 1978, hand dug well by individual household. Treated surface water is supplied to the community by urban water (stand pipe) at a cost and supply is intermittent. Water usage in the community can be categorized into two forms. These are the consumptive and non-consumptive water uses. Consumptive use generally comprises of domestic activities such as drinking, cooking, washing, while the non- consumptive uses include agriculture, and molding of block (building purposes) in the community.

2.2. Sample Collection

The study area was divided into four quadrants to ensure even representation of samples across the study area. The quadrants are Sunshine area, Dansoman, Twumduase, Cemetery area. From each structure, a random selection of household was taken. Interviews were conducted and water samples were collected from the storage container in the household from each quadrant. Sampling points were randomly selected using a Global Positioning System (GPS) to pick coordinates. Along the water consumption chain (i.e., from source to point of consumption), samples were collected from two points. These points are the primary storage tanks and the secondary storage tanks. For the purpose of this study, samples from primary storage tanks refers to those pumped from various sources to storage tanks within the community and at individual homes. Samples from secondary storage, refers to those collected from primary storage and stored in various household containers (as shown in Figure 1).

Figure 1: Map of sampling locations

2.3. Analytical Methods

A total of 55 water samples at primary and secondary storage levels were collected for physical, chemical and bacteriological quality analysis. Water quality parameters to be measured under physical, chemical and biological parameters were conducted on the field and in the laboratory. The electrical conductivity and total dissolved solids were determined with a Wagtech WE30120 conductivity/TDS meter, while turbidity was measured with a WE30140 Potalab turbidity meter, by the procedures used by Ameso *et al.* (2020). The pH, temperature and total suspended solids were measured using PC 300 Waterproof handheld equipment, while the chloride, total hardness, fluoride, iron, magnesium, nitrate and sulphate were determined with palintest automated wavelength equipment. Chromocult coliform agar was used to determine the bacteriological quality of water samples.

2.4. Data Collection

For the household survey, a total of (55) questionnaires were developed and administered to households within the community. Questionnaires were administered in the morning unannounced to each of the participating households. Statistical tools used for analysis were SPSS and Microsoft excel.

3. RESULTS AND DISCUSSION

From Tables 1 and 2, apart from the TSS, the physical and chemical parameters measured for the samples were within the WHO/Ghana Standard (WHO, 2011) for all the three sources under the two storage conditions i.e., primary and secondary storage. TSS values recorded ranged between 1.0-2.0 mg/L (Table 1) as against a standard of zero for both WHO Guideline Value and Ghana Standard. For the physico-chemical quality of water, covered hand dug wells had the best quality with all parametric values within standard at both primary and secondary storage levels. The main reason for this was proximity to environmental contamination. The hand dug well was situated in a more hygienic environment than the mechanized borehole. The result of the study implies that the physical quality of water both at source and storage were within the accepted limits although there were slight increments in turbidity, TDS and TSS values at storage. Several research work from different countries have indicated that it is during this period of collection and storage that physico-chemical quality of water may deteriorate to levels unsafe for human consumption (Maraj et al., 2006; Deshpande et al., 2007; UNICEF, 2010; Rufener et al., 2010). Inadequate cleaning of storage and transport-containers were being described as key cause of increase in TSS levels in drinking-water (Maraj et al., 2006).

High TSS in water although does not have any health implications but does have effect on the aesthetic value of the water. Customer satisfaction with drinking water quality is largely based on the aesthetic quality of water. For customers, water usually termed as "good" means it is colourless, free from suspended particles and has no unpleasant taste odour (WHO, 2011). Thus, water with high TSS can be rejected by customers as it is regarded as unsafe for drinking (WHO, 2011; ADWG, 2011).

Further analysis revealed that there was bacteriological contamination at high levels for all sources of water at primary storage. According to WHO Guideline/Ghana Standard for drinking water quality, there should be no *Escherichia coli* and coliform in drinking water. Comparing results from the three source (Figure 2) shows that the water was contaminated by coliform and *Escherichia coli*. Covered hand dug wells recorded the highest *Escherichia coli*, followed by the urban water (stand pipe) and mechanized borehole as shown in Figure 2. This is mainly due to the degree of protection of the water source as well as the ease of access of *Escherichia coli* from contaminated environment to the water source. Sometimes contaminated containers are indiscriminately thrown into the well. Mechanized boreholes are often very deep and have the least tendency of contamination by *E. coli* than the hand dug wells and urban water.

Table 1: physical quality of water for primary and secondary storage

Parameters (Primary storage)	Mechanized borehole	Covered hand dug well	Urban water (Stand pipe)	WHO/Ghana Standard
pH	7.7	7.66	7.68	6.5-8.5
Turbidity (NTU)	1.95	1.12	1.45	≤ 5
TDS (mg/L)	240	42.1	244	≤ 1000
EC (µs/cm)	480	84.2	488	< 1500
TSS (mg/L)	1	0	1	0
Parameters (Secondary storage)	Mechanized borehole	Covered hand dug well	Urban water (Stand pipe)	WHO/Ghana standard
pH	7.69	7.66	6.68	6.5-8.5
Turbidity (NTU)	1.85	1.42	3.73	≤ 5
TDS (mg/L)	244	46.7	378	≤ 1000
EC (µs/cm)	488	86.4	502	< 1500
TSS (mg/L)	1	0	2	0

Table 2: chemical quality of water for primary and secondary storage

Chemical parameters	Mechanized borehole	Covered hand dug well	Urban water (Stand pipe)	WHO/Ghana standard
(Primary storage units)				
Chloride (mg/L)	29.9	9.8	30	< 250
Total hardness (mg/L)	106	81	144	< 500
Fluoride (mg/L)	0	0	0.27	< 1.5
Iron (mg/L)	0	0	0.02	< 0.3
Magnesium (mg/L)	42	10	65	< 150
Nitrate (mg/L)	2.2	3.4	13	< 50
Sulphate (mg/L)	20	7	10	< 250
Secondary storage units				
Chloride (mg/L)	29	9	29	< 250
Total hardness (mg/L)	105.8	43	116	≤ 500
Fluoride (mg/L)	1.27	0	0.81	< 1.5
Iron (mg/L)	0	0.02	0.02	< 0.3
Magnesium (mg/L)	41	8	80	< 150
Nitrate (mg/L)	1.8	3.6	16.1	< 50
Sulphate (mg/L)	20	7	70	< 250

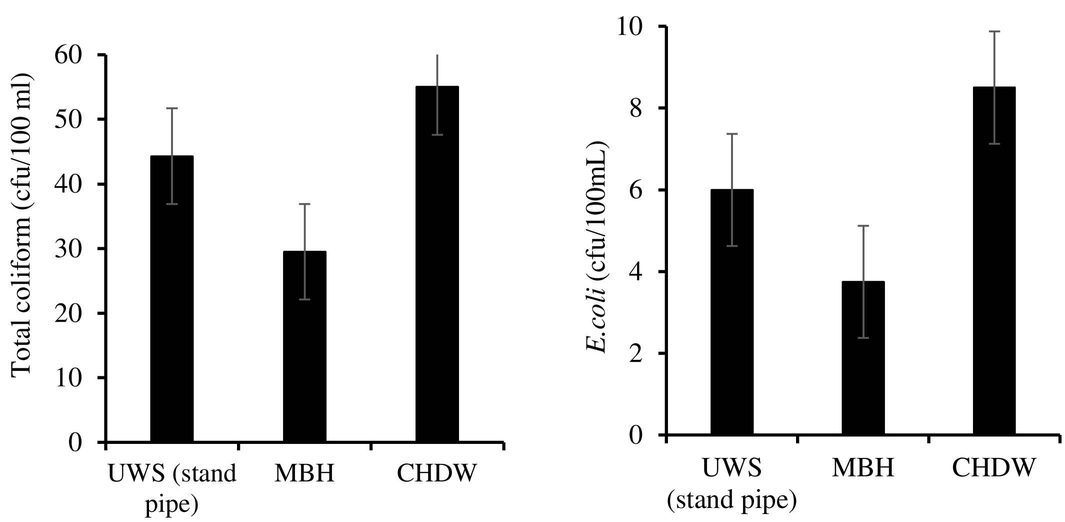

Figure 2: Microbial contamination at primary storage

Figure 3 shows that water transported from the three sources and stored in various household containers (secondary storage) were all contaminated with *Escherichia coli* and coliform with urban water (stand pipe) having a high mean *Escherichia coli* level, followed by MBH and CHDW while for the total coliform, CHDW had the highest mean *Escherichia coli*, followed by MHB and urban water. The total coliform which includes the bacteria found in soil and in water that has been influenced by surface pollution were more dominant in CHDW, being due to shallow depth and water handling process. The *E. coli*, however, are not generally found growing and reproducing in the environment. This result did not conform to the WHO Guideline 2011/Ghana Standard.

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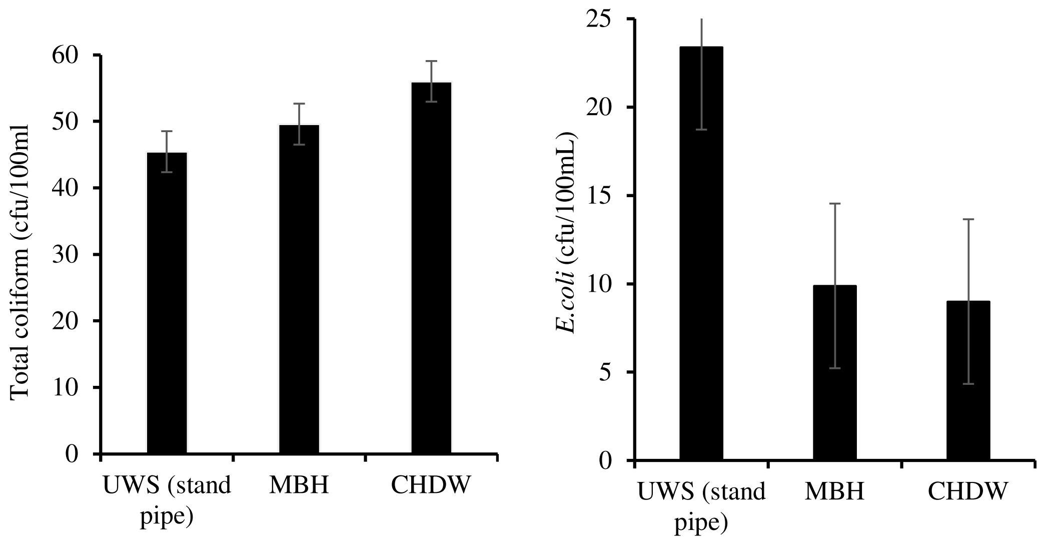

Figure 3: Microbial contamination at secondary storage

In assessing the level of contamination from water sources to households' storage study findings revealed that deterioration of water increased from primary storage to secondary storage. The reasons for the deterioration from the primary storage level to the secondary storages are attributed to the following:

Frequency of cleaning storage tank: residents who cleaned their primary storage tanks monthly, every three months and every six months showed no contamination whereas those who cleaned yearly or did not clean at all recorded *Escherichia coli* contamination. However, the differences in *Escherichia coli* levels as a result of different cleaning frequencies was not significant as the P-value was greater than 0.05. This implies that, the occurrence of *Escherichia coli* in drinking water is not as result of the frequency of cleaning but other factors such as the quality of water source, the mode of water storage and the frequency of disinfection.

Frequency of disinfection: from the study, most residents did not disinfect their water at the primary storage level. Out of the 51 respondents, only 9 residents disinfected their storage tanks with chlorine. With the few people, they had no knowledge about the process since they leave plumbers to do the dosing for them. With this information, it is expected that frequency of disinfection influences the *Escherichia coli* levels at the primary storage. But the results indicated otherwise. Statistically, the differences in *Escherichia coli* levels due to disinfection frequency was insignificant. This implies that, for this study, the *Escherichia coli* levels at primary storage is not as a result of disinfection frequency; the water source quality and storage mode of water are key factors in the buildup of *Escherichia coli*. This was corroborated by Kausar *et al.* (2012) in a study of storage system for drinking water and its health impacts at household levels in Pakistan.

Quality of source: the quality of water from source before being stored at primary level impacts on the quality of water been stored. From the study, urban water source recorded low bacteriological contamination, followed by MBH and CHDW. The trend is seen at the secondary storage levels (Figure 3). For the secondary storage tank, the following reasons was attributed to this occurrence. Water transported in containers with or without handles had *Escherichia coli* contamination. But container without handle recorded the highest *Escherichia coli* contamination. Water transported when covered or not covered had *Escherichia coli* contamination in both cases (Wright *et al.*, (2004).

Mode of storage: there was *Escherichia coli* contamination for both waters stored with or without lid. Statistically, the differences in *Escherichia coli* levels for both scenarios was significant. This suggests that covering of water reduces *Escherichia coli* contamination. In addition, the study revealed that fetching of water from storage containers with different household bowls introduces contamination in the water.

There was bacteriological deterioration of water from primary storage (source) to secondary storage (household level) with counts of total coliform and *Escherichia coli* increasing for all three sources. This conforms to other results from literature as many studies from different countries have reported on microbial contamination during collection and storage (Maraj *et al.*, 2006; Rufener *et al.*, 2010; UNICEF, 2010; Deshpande and Kakkar, 2016). Particularly of concern from these studies is the increase in high levels of *Escherichia coli* at the point of consumption compared to the source (Wright et al., 2004). Some of the reasons associated to this trend are handling water with dirty hands during collection and transportation, mode of storage and frequency of cleaning storage tanks. There were lot of bad water handling practices observed in Kotei. To assess the effect of water storage and handling behaviours on water quality, the knowledge, attitude and practice of study participants were accessed based on the following criteria: washing of hands before handling water, water treatment and water quality. From the survey most residents did not know about water quality issues and treatment options. In the study area, 1 out of 55 respondents said they treat water using Alum while the other do not treat at all at their respective houses as shown in Figure 4.

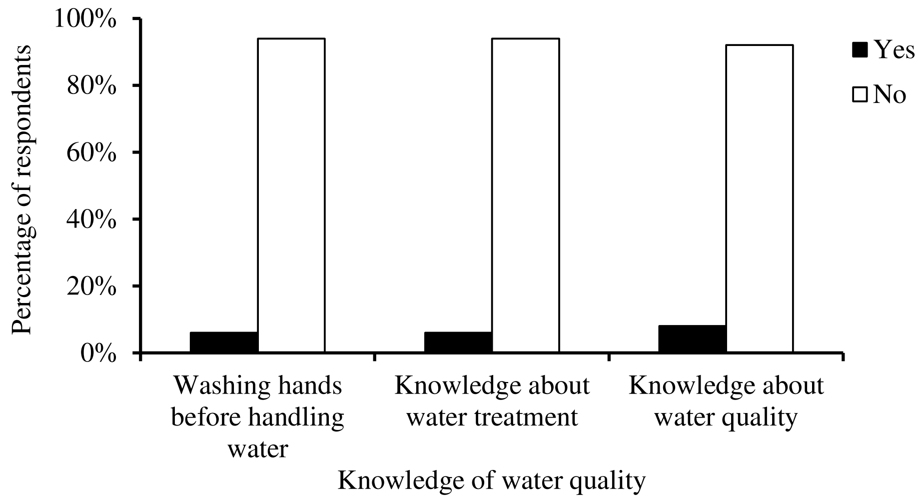

Figure 4: Respondents' response to water quality knowledge

4. CONCLUSION

Physico–chemical quality of water within Kotei is of high quality whereas that of bacteriological quality is poor. The poor bacteriological quality of water can be attributed to the water handling behavior and hygienic practices of the residents. The household survey conducted to determine the knowledge attitude and practices of residents revealed that most of the respondents had little or no knowledge about household water quality issues and safe handling of water to avoid contamination.

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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