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Preliminary Evaluation of Microbial Quality of Water Stored in Earthen Pots in the Tamale Metropolis, Ghana

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Abstract

The study was conducted to evaluate the microbial quality of earthen pot stored water in the Tamale Metropolis. A total of fifteen (15) samples were taken from five selected communities in the Metropolis from March to May 2013. Samples collected were conveyed to Water Research Institute laboratory, Tamale for analysis. Membrane filtration method was used to determine total coliform, faecal coliform and Escherichia coli while pour plate method was used to determine total heterotrophic bacteria (THB). The study obtained bacteria count of the earthen pot stored water that exceeded World Health Organisation and Ghana Standard Board specified limits. Total coliform values ranged from 9 to 5.84 X 10^2 cfu / 100 ml with a mean of 2.47 x 10^2 cfu / 100 ml. Comparative analysis shows that Escherichia coli and faecal coliform from some vending sites are significantly different ($p < 0.05$). The study revealed that earthen pot stored water from the various communities were contaminated due to unhygienic handling practices such as dipping of hands and utensils into the storage earthen pot. It is therefore recommended that water stored in earthen pots should be covered with a well fitting lid after collection and usage in order to meet the Millennium Development Goal 7.

Keywords*:* Tamale Metropolis, *E. coli*, membrane filtration, earthen pot stored water

INTRODUCTION

The quality and quantity of available drinking water in the Tamale municipality during March-April where the temperature is relatively high with low relative humidity are critical factors determining the well-being of the residents. The drinking water supply systems and accessibility in developing countries is a global concern (Cobbina *et al*., 2013). Water is the elixir of life and abounds on earth, but this vast natural resource has been depleted and turned into scarce commodity with increased usage. There is almost a global shortage of water and the world's most urgent and front rank problem today is supply and maintenance of clean drinking water (Agarwal and Rajwar, 2010). Urban places with high population densities may not have access to safe drinking water, and water transported long distances may be of dubious quality and safety (Wright *et al*., 2004). Household socio-economic status measures such as education and occupation may be associated with exposure to, and perceived salience of health education about water quality and sanitary habits. For example, detailed evidence from behavioral studies of water use and quality indicates household storage of water and sanitary habits, such as hand washing, on microbiological contamination of household water supply (Trevett *et al*., 2005).

Water has become a scarce resource in some regions over the last several decades, efforts have generally focused on supplying more water to people, without considering its quality. Although the quantity of water that people receive influences hygiene and promotes public health. Poor quality of water also affects humans and the environment, increasing famine, child mortality, waterborne diseases, environmental deterioration, and social inequalities. The likelihood of being infected by waterborne diseases is not homogeneous among all age groups. The groups most likely to be affected by these diseases are children under five years, the elderly, and people living in poor hygiene conditions (no-running water or proper waste disposal) (World Health Organization (WHO) and United Nations Children's Fund (UNICEF), 2011).

The high prevalence of diarrhoea among children and infants can be traced to the use of unsafe water and unhygienic practices. Therefore, maintaining a safe drinking water remains essential to human health as transient bacterial contamination may have implication well beyond a period of acute-self-limited illness. All living organisms require a wide variety of inorganic compounds for growth, repair, maintenance and reproduction. Water is one of the most important, to living organisms (Tortora *et al*., 2002). Within the cell, water is the medium for most chemical reactions. It makes up at least 5 - 95% of every cell and the average being between 65 - 75%. In addition, water has been traced to be one of the ways by which humans could be infected with various kinds of diseases. Some waterborne diseases include typhoid fever, cholera, bacillary dysentery and so on. In waterborne infections, pathogens are usually spread by water contamination with untreated or poorly treated sewage (Tortora *et al*., 2002).

Microorganisms that cause cholera, severe diarrhoea, and other illness are often present in huge numbers in infected human faeces. If drinking water is contaminated with these dangerous microbes**,** illnesses can result and these illnesses can spread easily to others. Diarrhoea infection spread not only through water supplies but also through contaminated food, utensils and fingers. It is very difficult to control diarrhoea without a reliable supply of safe water to maintain hygiene and this reliable supply of safe water is most often beyond the reach of poor people (Tibetts, 2000). The Millennium Development Goals (MDGs), which is the blueprint for the world to accelerate development and measure progress, contain a set of time-bound measurable goals and targets for combating poverty, hunger, diseases, illiteracy, environmental degradation and discrimination against women. The Goal 7 which aims at ensuring environmental sustainability is of paramount importance in the water supply sector. Two targets of goal 7 are to reduce by halve, the proportion of people without sustainable access to safe drinking water and basic sanitation by 2020 (United Nations, 2006).

Access to safe drinking water has improved over the last decades in almost every part of the world, but approximately one billion people still lack access to safe water and over 2.5 billion lack accesses to adequate sanitation (United Nations, 2008). The high usage of fresh water could create problems such as scarcity, poverty, power and global water crisis (United Nations Development Programme, 2006). The surge in human population coupled with industrialization steadily decreased freshwater supplies. Generally, water for drinking is stored in containers by households with or without treatment after collection from a variety of sources. There is a concern regarding in-house microbial contamination during handling and storage of water in developing countries. The prevalence of water related infectious diseases is now common among people in Ghana especially the northern sector. The objective of this study was to evaluate the microbial quality of water stored in earthen pot in the Tamale Metropolis.

MATERIALS AND METHODS

Study area

The study was conducted in the Tamale metropolis in the northern region of Ghana. Tamale is located in the savannah vegetation zone. Geographically, the metropolis lies between latitude 9º24` 00” N and longitude 0º 50` 00” W. The Metropolis has a population of 537, 986 inhabitants (Ghana Statistical Service (GSS), 2010).

Fig. 1: Map of the Northern Region with Tamale Metropolis

Experimental design and sampling

Stored water samples were collected from five different sites namely; Gunbihini (represented by A), Mooshi Zongo (represented by B), Tishegu (represented by C), Ward ‘K’ (represented by D) and Kalpohin (represented by E). Due to the intermittent and inadequate supply of potable water to the communities, the inhabitants resort to the storage of water from hand dug wells and water supplied by Ghana Water Company Limited in Dalun. A social survey conducted during the study revealed that three households washed their earthen pots weekly prior to water storage. Triplicate samples were collected from the five selected sites making a total of fifteen (15) samples from March to May 2013. Sterilized plastic bottle (500 ml) were used to collect stored water samples. Upon collection, samples were stored at 4ºC in ice chest and transported to the laboratory for analysis.

Microbial analysis of stored water

Laboratory analyses were carried out at the Water Research Institute of Council for Scientific and Industrial Research (CSIR), Tamale. Microbial analysis was done in accordance with the American Public Health Association (APHA) (1998) standard procedures. Membrane filtration technique was used to determine total coliform, faecal coliform and *Escherichia coli* in accordance with APHA 9222B, 9222D and 9260F respectively.

Filtration unit comprising of an Erlenmeyer flask, suction system and porous support were assembled and with the aid of a flame-sterilized forceps, a sterile membrane filter (0.45µm Millipore) was placed on the porous support. The upper funnel was placed in position and secured with appropriate clamps in a Millipore machine. 100 ml of earthen pot stored water sample was aseptically poured into the upper funnel and suction applied to create a vacuum. After the sample was passed through the membrane filter, the filtration unit was taken apart and with the aid of a sterile forceps the membrane filter was placed in the petri dish containing selective media for various parameters: M-Endo for total coliform, M-FC for faecal coliform and Hi-Chrome agar for *E. coli*. Clamps, forceps were usually sterile prior to use for the next sample. All plates were incubated in inverted position at 37±2 ºC (total coliform and *Escherichia coli*) and 44±2 ºC (faecal coliform) for 18-24 hours.

Total heterotrophic bacteria count was determined following the heterotrophic plate count method, using pour plate technique in accordance with APHA 9215. 1ml of the sample was pipetted into a sterilized Petri dish and 10-15 ml of nutrient agar added to it. This was uniformly mixed for a minute and allowed to solidify. It was then incubated at 37ºC for 48 hours. Colony growth on the plate after the incubation period was then counted using a colony counter.

Statistical analysis

The Bacteria counts in the water stored in earthen pots were subjected to Pearson's significant correlation analysis using SPSS version 16 to determine the mutual relationship that exist between the parameters. One-way ANOVA was used to test for significance between bacteria count from the various sampling sites.

RESULTS AND DISCUSSION

Microbial analysis of the earthen pot stored water

The greatest risk of microbes in water is associated with consumption of drinking-water that is contaminated with human and animal excreta, although other sources and routes of exposure may also be significant. The sanitary quality of water stored in earthen pot in the various communities in the metropolis was assessed for its microbial quality. The study observed microbial contamination in earthen pot stored water samples. Total coliform values ranged from 9 to 5.84×10^2 cfu / 100 ml with a mean of 2.47×10^2 cfu / 100 ml (Table1). The minimum value was recorded from sample site D, while maximum was recorded from sample site E**.** Figure 1 shows the mean values of total coliform recorded from the various earthen pot stored water from the communities.

Faecal coliform values ranged from 0 to 2.91×10^2 cfu / 100 ml with a mean of 3.7×10^1 cfu/ 100 ml (Table1). The minimum value was recorded from sample site C, while maximum was recorded from sample site E**.** Figure 2 shows the mean values of faecal coliform recorded from the various earthen pot stored water from the communities. Generally, comparative analysis shows that faecal coliform contamination from the sampling sites A verse E, C verse E and D verse E are significantly different ($p < 0.02$) (Table 3). Unhygienic handling practices such as dipping of hands and utensils into the earthen pots and temperature effect accounting for the contamination in the various communities differ or are intense. Two of the samplings sites where earthen pots are kept were dirty and earthen pots are not regularly clean prior to water storage hence the difference in the microbial contamination.

E. coli values ranged from 0 to 1.40×10^2 cfu / 100 ml with a mean of 2.1×10^1 cfu/ 100 ml (Table 1). The minimum value was recorded from sample site C and B while maximum was recorded from sample site E**.** Figure 3 below shows the mean values of *E. coli* recorded from the various earthen pot stored water from the communities**.** The study observed strong positive correlation between faecal coliform and *E. coli* (0.94) that suggests common source of contamination such as recent sewage or animal faecal contamination (Table 2).The comparative analysis shows that *E. coli* contamination from the sampling site A verse E and C verse E are significantly different ($p < 0.04$) (Table 3).

Total heterotrophic bacteria values ranged from 1.46×10^2 to 1.944×10^3 cfu / 1ml with a mean 5.56×10^2 cfu / 1ml (Table1). The minimum value was recorded from sample site A, while maximum was recorded from sample site B.Figure4 shows the mean values of total heterotrophic bacteria recorded from the various earthen pot stored water from the communities. The study recorded total coliform, faecal coliform, *E. coli* and some total heterotrophic bacteria that exceeded the WHO (2006) stipulated limits for potability. The study obtained elevated counts of bacteria from the various storage earthen pots hence making the water unsuitable for drinking. When drinking water contains coliform bacteria in levels greater than one per 100 ml of water, the water may also contain pathogens that cause acute intestinal illness. Generally, such water can cause a discomfort to health that can be fatal for infants, the elderly and those who are sick. The contamination can be attributed to temperature effect, prolong storage, unhygienic water handling and use of unclean utensils to draw the water from the earthen pots.

The unhygienic water handling that might have accounted for the high contamination of water stored in earthen pot(Akuffo *et al*.,2013). Pinfold

(1990) also reported that the most common route of contamination of stored water is through water handling practice such as dipping. According to Chidavaenzi *et al.* (1998), using uncovered water containers increased water contamination between source and point-of-use as hands are dipped into vessels to scoop a cupful of water. Studies conducted by Sutton and Mubiana (1989) and Sobsey (2002) reported that the geometric design of water storage containers played an important role in ensuring that stored drinking water does not become contaminated by external factors such as dirty hands and utensils.

Improvise mechanisms such as taps at the mouth of storage containers when fetching water either for cooking or for drinking is kept in place. However, this study revealed that earthen pots used to store water were without taps and handles hence utensils and other easily accessible or close container were continually dipped into these earthen pots. Usually, contamination may occur when water is regularly taken by using dippers such as; a metal bowl, a calabash or even a plastic cup in the course of fetching water either for drinking or for cooking.

Transportation of water from the main source to the household water storage earthen pots in these communities after fetching can result in bacterial contamination. Contamination of food, hands, utensils and clothing can also play a role, particularly when domestic sanitation and hygiene are poor. Dirty surrounding is also a major factor of water contamination. As reported by Ologe (1989) that where basic sanitation is lacking, there is more likelihood of indicator bacteria from faeces being introduced into the stored water. The elevated bacterial contamination observed in the earthen pot stored water in these communities is similar to the report by Vanderslice and Briscoe (1993). In their study, higher levels of contamination of bacteria were recorded from earthenware vessels (earthen pots) used for water storage. The presence of microbes in the earthen pot stored water indicates that the residents from these communities are not free from waterborne diseases. According to Mintz *et al*. (1995), the presence of coliform bacteria in stored water for domestic use has health consequences, since consumption of contaminated water affect humans in many ways.

Most rural folks prefer drinking water from these earthen pots because of their ability to cool stored water or to maintain the water temperature. However, the ability to cool or maintain the temperature of water might have accounted for the high prevalence of bacteria in the stored water. This might have created favourable temperature that could activate or aid the growth of microorganisms in the stored water. Temperature plays a role in the activities and survival of microorganisms (Cynthia, 2010). The earthen pot stored water indicate the potential for increased bacteria growth which is a health concern because even low levels of bacteria growth have the potential to cause illness in users.

CONCLUSION

The study revealed that earthen pot stored water from the various communities was contaminated and this could be attributed to unhygienic handling practices such as dipping of hands and utensils into the earthen pot, irregular cleaning of earthen pots, dirty surroundings and temperature effect. Total coliform, faecal coliform, *E. coli* and total heterotrophic bacteria exceeded the WHO and the Ghana Standards Board limits. Comparative analysis shows that *Escherichia coli* and faecal coliform from some sampling sites are significantly different ($p < 0.05$). Filthy surrounding is a major factor in the determination of contamination especially where basic sanitation is lacking. The earthen pot stored water in the various communities in the metropolis was unwholesome since the study recorded elevated levels of bacteria. Based on the findings of this study it is recommended that: stored drinking water should be covered with a well fitting lid after collection before usage by indigenes.

Education and information on basic sanitation, hand washing and washing of the pots regularly in the communities will minimize the level of earthen pot stored water contamination, which may invariably prevent water-borne and other related diseases in order to meet Millennium Development Goal 7.

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Table 1:Microbial loads of water stored in earthen pots

Sample ID	TC (cfu / 100 ml)	FC (cfu / 100 ml)	E. *coli* (cfu / 100 ml)	THB (cfu /1 ml)
A	31	8	4	-
	106	21	2	146
	582	10	13	362
B	92	35	4	-
	485	6	0	386
	388	70	70	1944
C	61	13	7	-
	104	0	0	328
	386	6	1	320
D	9	5	2	-
	194	12	0	384
	291	9	30	296
E	108	37	21	-
	288	291	140	422
	584	29	18	972
Mean	247	37	21	556
Min	9	0	0	146
Max	584	291	140	1944
GSB	0	0	0	500
WHO STD	0	0	0	-

Key: TC; Total coliform; FC; Faecal coliform; THB; Total Heterotrophic Bacteria; A; represent Gunbihini, B; represent Mooshi Zongo, C; represent Tishegu, D; represent Ward 'K'; E; represent Kalpohin and GSB; represent Ghana Standard Board.

Table 2:Correlation matrix of microbial quality of water stored earthen pot

Parameter	TC	FC	*E. coli*	THB
TC	1			
FC	0.09	1		
E. coli	0.20	0.94**	1	
THB	0.33	0.12	0.34	1

** Correlation significant at 0.01 levels

Table 3: Comparative analysis of water stored earthen pot parameters

(I) Community	(J) Community	Mean Diff. (I-J)	Sig.	Mean Diff. (I-J)	Sig.
		Dep. Variable (EC)		Dep. Variable (FC)	
A	B	-18.33	0.53	-24	0.65
	C	3.67	0.9	6.67	0.9
	D	-4.33	0.88	4.33	0.93
	E	-74.17*	0.04	-151.00*	0.03
B	A	18.33	0.53	24	0.65
	C	22	0.46	30.67	0.56
	D	14	0.63	28.33	0.59
	E	-55.83	0.11	-127	0.05
C	A	-3.67	0.9	-6.67	0.9
	B	-22	0.46	-30.67	0.6
	D	-8	0.78	-2.33	1
	E	-77.83*	0.04	157.67*	0.02
D	A	4.33	0.88	-4.33	0.93
	B	-14	0.63	-28.33	0.6
	C	8	0.78	2.33	1
	E	-69.83	0.06	-155.33*	0.02
E	A	74.17*	0.04	151.00*	0.03
	B	55.83	0.11	127	0.05
	C	77.83*	0.04	157.67*	0.02
	D	69.83	0.06	155.33*	0.02

*. The mean difference is significant at the 0.05 level.

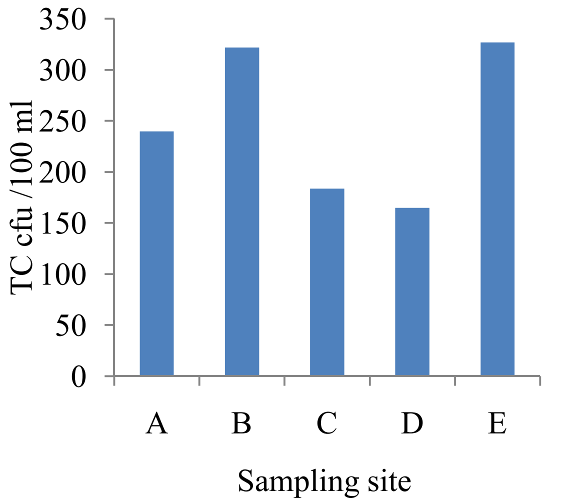

Fig. 1: Mean values of total coliform from the various communities

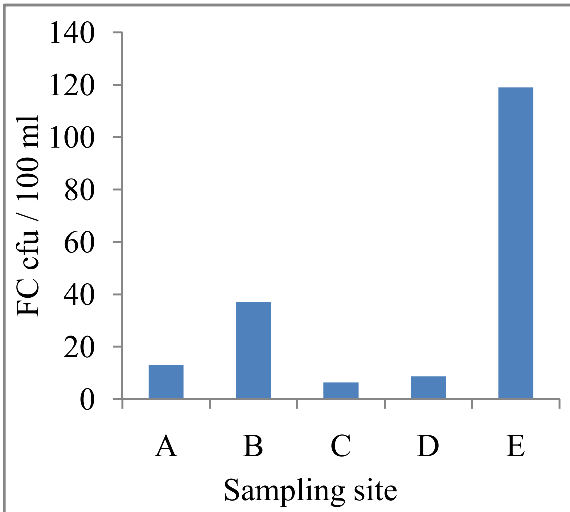

Fig. 2: Mean values of faecal coliform from the various communities

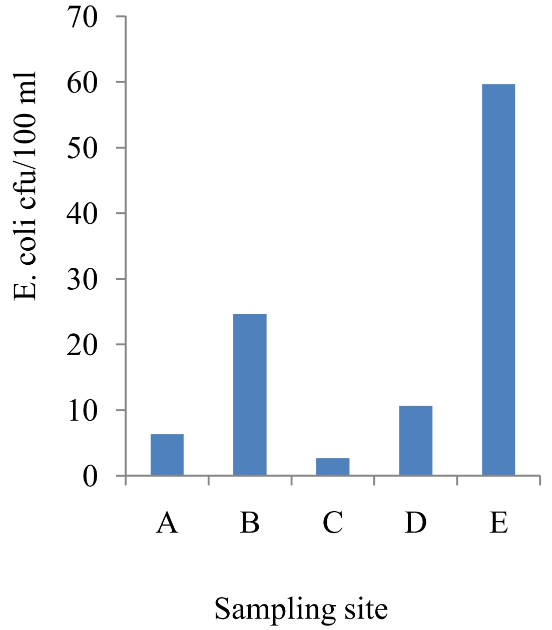

Fig. 3: Mean values of *E.coli* from the various communities

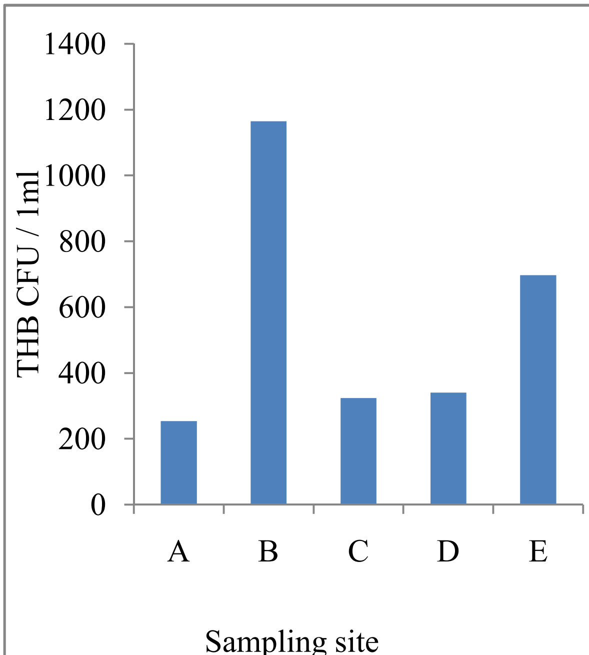

Fig. 4: Mean values of total heterotrophic bacteria from the various communities

Plate 1**:** Water in earthen pot used as drinking water, for cooking and washing utensils