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Microbial Quality of Household Water Sources and Incidence of Diarrhoea in three Peri-Urban Communities In Kumasi, Ghana

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Abstract
The aim of this study was to assess the physicochemical and microbiological quality of the sources of household water supply and the prevalence of diarrhoea in three peri-urban communities in Kumasi, Ghana. Nine water sources, four from hand dug wells and five from boreholes, were identified, sampled and analysed for physicochemical (colour, turbidity, total dissolved solids, conductivity, and acidity) and microbiological characteristics. The total dissolved solids and conductivity values determined were within the WHO limit but the turbidity and colour of two of the water sources exceeded the WHO limits. All the water sources were acidic and did not meet the WHO specification for pH for drinking water. Faecal coliforms and faecal streptococci were consistently present in the water sources at levels signifying human pollution. Diarrhoea cases among children < 5 years reported at the various health facilities within the studied communities increased during periods when high levels of microbial contamination in drinking water sources were recorded. Provision of potable household water should continue to be the priority of governments of developing countries, especially those in sub-Saharan Africa, to reduce the prevalence of water-borne diseases.

Keywords: Coliforms, diarrhoea, groundwater, peri-urban communities, streptococci

INTRODUCTION

About 20 % of the world's population does not have access to safe drinking water [1] and most of these communities are found in Asia and sub-Saharan Africa. Water related diseases such as infectious diarrhoea, microbial dysentery and cholera abound in these communities [2]. Over 1.5 million children below the age of 5 years die every year from water related infectious conditions [3]. Many people in these deprived communities are turning to the use of underground water as their main sources of drinking water supply [4]. This is because underground water is normally available throughout the year. The storage point can be near or directly under the point of use and is immediately available on demand through pumping [5]. The most important point to address for all water intended for drinking purposes is the quality since this has a direct impact on human health [6 – 8]. Variation in groundwater quality has been attributed to pollution from uncontrolled application of fertilizer and manure, changes in climatic conditions, residence time of water with aquifer materials and inputs of soil during water percolation [9 – 11].

The population of Ghana is about 23.8 million with an annual growth rate of 2.1 % (World Bank estimates for 2009). About 79 % of this population has access to improved source of drinking water with 93 % coverage in urban areas and 68 % in the rural communities [6]. The main river systems that drain the country are the Volta river system (Oti, Daka, White and Black Volta, Pru, Sene and Afram rivers), the South Western river system (Bia, Tano, Ankobra and Pra rivers) and the Coastal river system (Ochi-Nakwa, Ochi Amissah, Ayensu, Densu and the Tordzie rivers) [12, 13]. In Ghana, underground water occurs mainly in the Voltaian formation and the Cenozoic and Mesozoic sediments [13] and is usually abstracted from "machine-drilled" boreholes and "hand-dug" wells for most rural communities.

The Kumasi metropolis water supply requirement is estimated at about 225,000 m^3 per day. Barekese and Owabi dams which are the main water sources can only supply just about 50 % of this requirement [14, 15]. This makes it difficult for the regular supply of potable water to most of the peri-urban areas that have sprung up in the metropolis. Residents of Atonsu, Kenyasi, Pankrono, Anloga, Asokore-Mampong and many other peri-urban areas experience persistent water crisis, hence some have resorted to the drilling of wells and boreholes as their main source of water for domestic use. These sources yield water of

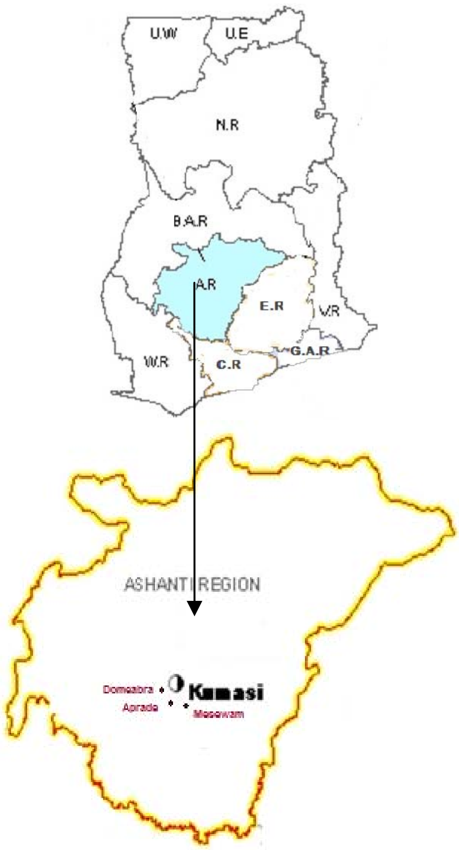

Fig.1: Map of Ashanti Region of Ghana showing the three peri-urban communities in Kumasi

varying physical, chemical and microbiological qualities [16, 17]. We hereby report the results of our study of the quality of drinking water from hand dug wells and machine-drilled boreholes and its relation to recorded diarrhoeal cases in three peri-urban communities in Kumasi, in the Ashanti Region of Ghana.

MATERIALS AND METHODS

Water Sampling Points

Four hand-dug well water sources designated H_1, H_2, H_3 and H_4 and five machine-drilled borehole water sources designated B_1, B_2, B_3, B_4 and B_5 (all being the main sources of household water to Aprade, Domeabra and Mesewam communities in Kumasi,Ghana) were chosen (Fig. 1). The wells were between 1.0 to 1.2 m in diameter and 6.0 to 10.0 m deep with the edges covered with concrete of 0.2 to 0.4 m high. Water is usually drawn from these hand-dug wells by residents of these communities with buckets connected to ropes. The boreholes were fitted with PVC pipes and one of them was connected to an overhead storage tank.

Sampling

The wells were sampled using 1L bottles connected to ropes, both of which were previously disinfected with 70 % alcohol and dried in sterile air. The rope was lowered to immerse the bottle in the water to fill. Once the bottle was full, it was pulled out of the well and corked firmly, ensuring that there was enough air space in the bottle, at least 3cm at the top of the bottle. For the boreholes, the water was pumped and allowed to run for about 3 minutes before collection. All the samples were collected in triplicates, covered with sterilized closures and then transported to the laboratory in a cool box [18 – 20].

Physical Analysis

The collected water samples were analysed for the following physical parameters: pH (WTW pH 323), Turbidity (Nephla EU DR LANGE), Conductivity, Total Dissolved Solids (TDS) and Colour (Nessleriser-2150 Loviband) [18].

Isolation, Identification and Enumeration of isolates

Isolation and enumeration of total coliforms, faecal coliforms and faecal streptococci were carried out by membrane filtration technique as previously described [16, 21] using 100 ml aliquots of the water samples. Results were expressed as the number of colony forming units (CFU) per 100 ml of water. All the recovered isolates were maintained on Brain Heart Infusion (Oxoid) at 4 ^{o}C. These were identified by morphological – biochemical procedures [22], complemented with the API 20E test kit.

Diarrhoea cases in the communities

Statistical data on diarrhoea cases reported between April 1, 2007 and March 31, 2008 were collected from the various healthcare facilities in the three communities and analysed.

RESULTS

The three peri-urban communities of study had a total population of about 6000 inhabitants [23]. These communities have over the years moved from using stream water, (Subin and Akokronari streams) to that of hand-dug wells and machine drilled boreholes. Most of the physical properties of the various water samples were within acceptable limits with the exception of H_1 and H_3 (water from hand dug wells) which had higher values for turbidity and colour (Table 1). All the water sources were found to be contaminated with faecal coliforms whilst majority of the sources were contaminated with faecal streptococci (Table 2). The faecal coliform to faecal streptococci (FC/FS) ratios for the water sources varied widely as follows: October 2007: 9.8 – 49; November 2007: 6.0 – 157; December 2007: 9.6 – 27.6; January 2008: 2.6 – 21; February: 1.9 – 39; March 2008: 3.5 – 12.9. On the whole, water sourced from boreholes was less contaminated with faecal coliforms and faecal streptococci than water from hand dug wells. Other microorganisms such as *Escherichia coli*, *Enterobacter sakazakii*, *Salmonella* species,

Table 1: Mean physical and chemical properties of water sampled from hand-dug wells and bore holes

Water sources	TDS (mg/ml)	Conductivity (μS/cm)	Turbidity(NTU)	Colour(°H)	pH
H_1	172±0.15	176.53±0.76	30.74±0.48	130±0.10	5.15±0.71
H_2	214.25±1.02	218.83±0.92	0.23±0.67	10±0.89	5.26±0.19
H_3	122.50±0.25	124.78±0.77	7.14±0.41	51±1.45	5.22±0.11
H_4	68.25±0.51	70.68±0.06	2.20±0.01	30±1.78	4.64±0.32
B_1	61.25±0.54	63.20±1.03	0.22±0.97	10±1.57	5.05±0.94
B_2	103.73±1.00	106.33±0.22	0.18±0.89	10±0.58	4.86±0.44
B_3	76.75±0.92	78.65±0.61	0.29±0.34	10±0.74	5.21±0.97
B_4	66.13±0.22	68.75±0.36	0.14±1.33	10±0.83	5.39±0.09
B_5	254.25±1.25	258.75±0.41	0.07±1.24	10±0.22	5.11±0.22
WHO standards	**500**	**400**	**5**	**≤ 50**	**6.5-8.5**

Table 2: Mean counts of faecal coliforms (FC) and faecal streptococci (FS) of water samples collected from hand-dug wells and boreholes

Months		Groundwater sources								
		H_1	**H_2**	**H_3**	**H_4**	**B_1**	**B_2**	**B_3**	**B_4**	**B_5**
October 2007	FC	787	147	493	345	156	128	12	54	57
	FS	80	3	37	28	9	6	0	0	3
	FC/FS	9.8	49	13.3	12.3	17.3	21.3	-	-	19
November 2007	FC	853	157	562	255	147	112	6	39	61
	FS	85	1	32	34	10	2	1	0	2
	FC/FS	10	157	17.6	7.5	14.7	56	6	-	30.5
December 2007	FC	721	138	423	435	165	145	6	22	53
	FS	75	5	42	22	7	10	0	0	3
	FC/FS	9.6	27.6	10	19.7	23.5	14.5	-	-	17.7
January 2008	FC	486	72	253	180	26	12	21	84	13
	FS	68	0	17	17	0	0	8	4	0
	FC/FS	7.1	-	14.9	10.6	-	-	2.6	21	-
February 2008	FC	490	47	240	140	24	14	21	78	13
	FS	59	0	15	10	1	1	11	2	0
	FC/FS	8.3	-	16	14	24	14	1.9	39	-
March 2008	FC	488	30	247	116	25	13	21	90	10
	FS	57	0	33	19	0	0	6	7	0
	FC/FS	8.6	-	7.5	6.1	-	-	3.5	12.9	-

Key: ‘-‘ = not determined

Serratia marcescens, *Enterobacter cloacae*, *Citrobacter diverus*, *Candida albicans* and *Staphylococcus aureus* were also found in the water samples. The diarrhoea cases reported among children < 5 years in the 3 communities were very high in some of the months (Fig. 2).
The increase in diarrhoea cases during those months appeared to coincide with periods of high levels of coliform bacteria counts in the communities' sources of water supply.

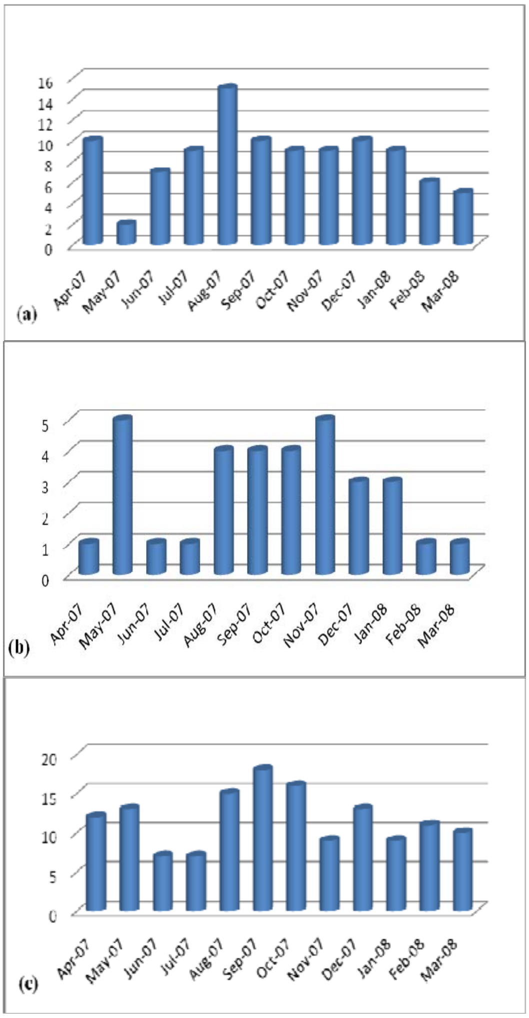

Fig. 2: Diarrhoea cases in children under five years in the communities studied:
(a) Aprade, (b) Mesewam and (c) Domeabra

DISCUSSION

The quality of drinking water in developing countries is of grave concern, especially where there are rapid urban expansions and growth in the country's population [24]. Many of these nations are unable to meet the increased demand for good drinking water by the growing population. In Africa, there is a high incidence of diarrhoeal diseases as a lot of the people resort to the use of unsafe sources of drinking water and this continue to be one of the major causes of morbidity and mortality [25, 26]. It has been reported that many sources of drinking water in Ghana have been contaminated not only with microorganisms of faecal origin but also varied levels of metals, many of which affects the pH of these water sources, posing very serious health risks to the people [16, 17, 27, 28].
In our study, the total dissolved solids (TDS) and conductivity values obtained were within the WHO [29] stipulated limit (Table 1). Two of the hand-dug wells exhibited turbidity and colour values far exceeding the specified limits. Turbidity in water is caused by the presence of suspended materials like clay, silt, and fine particles of organic and inorganic matter. While water of high turbidity may not adversely affect health it may cause the need for additional treatment. The high turbidity values recorded could be attributed to contamination from runoff water flowing into these wells. It could also possibly be the result of the rise of the water table into the topmost layer of the soil profile of the communities [30] since these wells were found to be located in lowlands. It is therefore inadvisable to site wells and boreholes meant for domestic use on lowlands. Studies performed [5], have shown that turbidity of well water due to runoffs can be decreased significantly by fixing a properly designed well-head which rises sufficiently above the ground. The wells must also be constructed with narrow mouths with appropriate covers to prevent wind-blown items from falling in. Colouration of water may be caused by decaying organic materials and leaching of metallic ions and is indicative of inadequate chemical treatment.
All the samples from the water sources tested were acidic (pH 4.6 – 5.4) and did not meet the WHO standard [29]. This water of low pH values when stored in metallic containers could corrode the containers and compound the health risks posed to humans and animals. Water drawn from these sources must be treated

appropriately to the acceptable limits for human and animal use [31, 32]. Within the period of the study, faecal coliforms were consistently recorded in water samples from all the sources tested, with the hand-dug wells recording far higher values than the bore-holes (Table 2). Faecal streptococci were also recovered in most of the water sources sampled, with far higher values from hand dug wells than boreholes. Large amounts of faecal streptococci were consistently recovered from hand dug wells H_1, H_3 and H_4. The faecal coliforms to faecal streptococci ratios (FC/FS) determined in accordance with the reported criteria [33] showed that 96.43 % of the water sources were polluted by human activities. FC/FS values of 0.7- 4.4 indicate human and animal pollution, > 4.4 indicate human pollution and < 0.4 is indicative of poultry and livestock pollution [33].

Some of the microbial pollutants identified in the study through the morphological-biochemical reactions include; *Escherichia coli* and *Salmonella* species which are, respectively, the main etiologic agents of gastroenteritis and salmonellosis. *Enterobacter sakazakii*, *Enterobacter cloacae*, and *Serratia marcescens* were also recovered from the samples. These organisms may not be dangerous in themselves but their presence signified that these household water sources were being contaminated with fresh faecal matter of either human or animal sources or both. This is also an indication that other faeco-orally transmitted organisms including protozoans such as *Balantidium coli, Giardia lamblia, Entamoeba histolytica* and *Cryptosporidium parvum,* in addition to intestinal helminth parasites may be present in these water sources. Diarrhoeal cases reported at the various health centres in the community of study showed a pattern of increase during periods when the water sources were highly contaminated (October – December 2007) and vice versa (January – March 2008). This study has confirmed earlier reports that a direct correlation exists between poor drinking water quality and incidence of diarrhoeal diseases in a community and an improvement in water quality will greatly reduce the occurrence of diarrhoea in any given population [34 – 36].

CONCLUSION

The various sources of ground water in the peri-urban communities in Kumasi were found to be of variable physical, chemical and microbiological quality. While most of the water sources had acceptable physicochemical properties, all the samples were found to be contaminated with either faecal coliforms or faecal streptococci or both and hence did not meet the WHO requirements for human and animal use. Efforts should be made to minimise contamination of groundwater sources which has become a major source of water for domestic use in developing countries.

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