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Original Research

Parasitological evaluation and heavy metal levels of water from boreholes and hand-dug wells in peri-urban centres of Ejisu Juaben Municipality

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ABSTRACT

Aim: The aim of the study is to evaluate the drinking water suitability of hand-dug wells and boreholes through the assessment of parasitic worms and concentrations of iron, manganese, zinc and cadmium in the Ejisu-Juaben municipality of Ashanti Region from 2012-2013. **Method:** Water samples were collected from three boreholes and three hand-dug wells selected randomly from each community and the water samples analyzed using various standard methods. **Results:** Two hand-dug wells at Ejisu and Juaben recorded iron (Fe) levels of 0.6810 and 0.3220 mg/l respectively, all boreholes and hand-dug wells had heavy metal (Fe, Mn, Zn and Cd) levels within the WHO guideline values. The mean iron concentration of boreholes and hand-dug wells across the various sampling locations was highly significant ($p=0.001$). In contrast, mean manganese and iron levels were not significant ($p=0.507$ and $p=0.640$ respectively). A total number of nine helminths were found out of the fifteen hand-dug wells. Six out of the nine helminths encountered were Ascaris species (66.7%), two were Hookworm (22.2%) and one was *Schistosoma haematobium* (11.1%) which were recorded at Ejisu, Juaben, Fumesua and Besease. A brief sanitation survey at each sampling community showed that, most hand-dug wells were sited near pit latrines, refuse dumps, septic tanks, piggeries and in the vicinity of domestic animals with a minimum distance of 5m. The difference between mean distance of boreholes and hand-dug wells to sanitary sites was statistically significant ($p=0.039$). **Conclusion:** By comparism, parasitological quality and metal concentrations of water from the selected boreholes were better than some of the selected hand-dug wells and thus must be treated before use.

KEY WORDS: Helminths; Heavy Metals; Boreholes; Hand-Dug Wells; Parasites.

INTRODUCTION

Water is one of the earth's most precious resources. It is used domestically, in agriculture and in the industries. It is very vital for survival yet most people do not have enough safe water to drink and are forced to use less reliable water sources such as rivers, streams, lakes and springs which are prone to contamination. Those mostly affected are in poverty-stricken towns and villages in peri-urban communities and rural areas of developing countries around the world [1]. According to the [2], contaminated water causes 80% of the health problems throughout the world. The lack of clean drinking water and sanitation systems is a major public concern in Ghana, contributing to 70% of diseases in the country. Consequently, households without access to clean water are forced to use less reliable and hygienic sources of water [3]. The Government of Ghana in conjunction with development partners, Non-Governmental organizations (NGO's), Community Based Organisation (CBO's) and some individuals in an effort to provide safe drinking water to the rural and urban dwellers, have exploited groundwater reserves [4]. Currently, over 95% of water provided to small communities and towns for domestic use in Ghana is extracted from groundwater source, however, the occurrence of high levels of minerals including metal compounds, especially iron and manganese in most of these groundwater sources have been identified as a challenge limiting the extent to which this resource can be exploited [5]. Waterborne diseases are caused by pathogenic microorganisms that most commonly are transmitted in contaminated water. Infection commonly results during bathing, washing, drinking, in the preparation of food, or the consumption of food thus infected. Various forms of waterborne diarrheal disease such as dysentery, cholera and typhoid probably are the most prominent examples, and affect mainly children in developing countries and it is attributable to unsafe water supply, sanitation and hygiene [6]. Helminths are parasitic worms that cause a wide variety of infectious diseases. Populations in the developing world are at particular risk for infestation with helminths due to inadequate water treatment, use of contaminated water for drinking, cooking and irrigation, and walking barefoot [7]. According to [8], *Ascaris* ova have been found in surface water and groundwater and may be a source of waterborne exposure for persons who consume untreated water in areas where sanitation is especially poor. For the past 20 years, Ejisu-Juaben Municipal has been without pipe borne water supply. Until 1984, Ghana Water Company limited (GWCL) was supplying water to some selected areas of the district with water from its head works at Barekese a suburb of Kumasi [9]. The municipality relies on groundwater as their major water sources. These non-treated water sources are being increasingly used as drinking water however; assessing to find out whether the water is of good quality is virtually absent. Also professional consultation was not properly done because most of the boreholes and hand-dug wells are close to pit latrines, refuse dumps, septic tanks, farmlands and piggeries which pose a threat to groundwater quality. It has been established that groundwater contamination often shows a relationship with areas of poor hygiene standards and sanitation [10, 17]. This study examines the drinking water suitability of hand-dug wells and boreholes in some peri-urban centres in Ejisu Juaben Municipality and the extent of their contamination with parasitic worms and concentrations of iron, manganese, zinc and cadmium. The distances of boreholes and hand-dug wells from public utility sites have also been determined.

MATERIALS AND METHODS

Study area

The Municipality is one of the 27 administrative and political districts in the Ashanti Region of Ghana. It lies within latitude 1.15°N and 1.45°N and longitude 6.15°W and 7.00°W. It lies within the semi deciduous forest zone of Ghana, which does not differ much in appearance from the rain forest [11]. The study area is predominantly underlain by crystalline rocks. These rocks belong to the Birimian, Granites formation [12]. The mean annual rainfall is 1200mm with temperatures range between 20°C in August and 32°C in March [13]. The 2010 National Population Census put the population of the Municipality at 143,762 comprising 68,648 males and 75,114 females and the main occupation in the Municipality is farming.

Selection of boreholes and wells

Out of 84 settlements, the municipal has only five (5) urban centres namely: Ejisu, Juaben, Bonwire, Fumesua and Besease. These five towns account for 30.18% of the total population in the district with the municipal capital covering 9.2% [14]. Public boreholes and hand-dug wells were used for the study. All the boreholes in each urban community were used for the study with the exception of Ejisu where simple random sampling was used to select 3 out of the 4 boreholes. Simple random sampling was used to select 3 hand-dug wells from each urban community with the exception of Juaben where purposive sampling was used to select the only hand-dug well at the northern part of the town and random sampling used to select 2 out of the 4 hand-dug wells at the southern part of the town. A total of fifteen boreholes and fifteen hand-dug wells were sampled for the study. A GPS was used to geographically locate all sampling communities (Fig. 1).

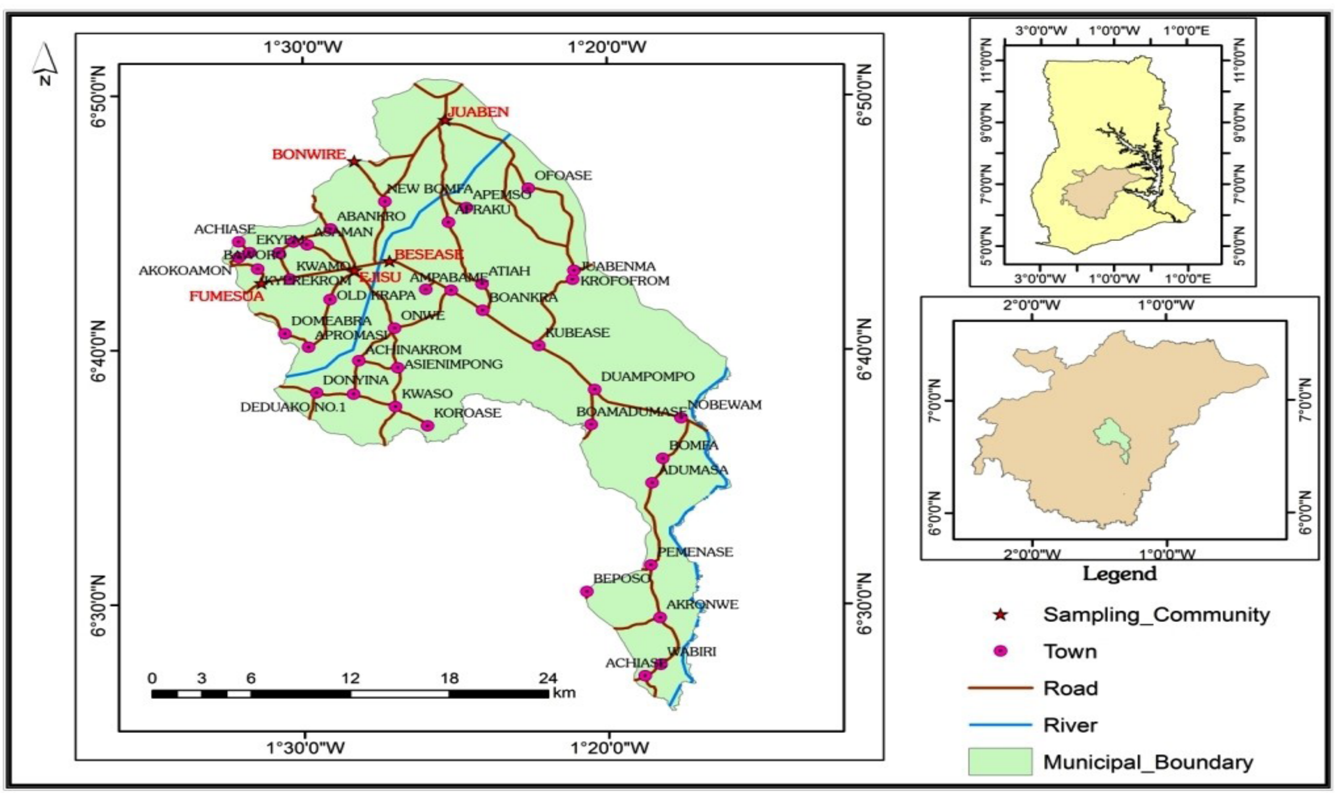

Fig. 1. Map of the Ejisu Juaben area showing the sampling communities (in red print) with an insert of Ghana's map showing Ashanti region in relation to the rest of the country.

Sample collection

Aseptic techniques were used in sample collection. Samples were collected in the early hours of the morning with sterilized plastic bottles. Concentrated nitric acid was immediately added to the water samples for heavy metal analysis reducing the pH to <2. Distances of boreholes and hand-dug wells to unsanitary sites were measured with 100m or 330ft fibre glass measuring tape. Water samples were taken to the laboratory in cool box with ice for analysis.

Laboratory analysis

The levels of iron in water samples were determined by Hach DR/2400 Portable Spectrophotometer (HACH, USA) using Ferro Ver method. The level of heavy metals such as Zinc, Cadmium and Manganese was determined in the water samples by Buck Scientific 210 VGP model (Flame Atomic Absorption Spectroscopy). All samples were quantified for helminths eggs using the modified USEPA methodology [15]. This is a modified US-EPA method, but the same principle of floatation and sedimentation was followed. The eggs were identified on the basis of their shape and size and compared with standard eggs on charts [16].

Statistical analysis

Paired Sample T-Test was used to analyse data using the SPSS (version 16) software for windows (SPSS Inc., Chicago, IL, USA) to examine the apparent differences and means of observed data between the different sampling location of the boreholes and hand-dug wells. Tables and graphs were obtained using the Microsoft Excel Programme (Microsoft Corporation, 2010). The statistical analyses were carried out at $P \leq 0.05$ level of significance.

RESULTS

Analysis of heavy metal concentrations in boreholes and hand-dug wells

Heavy metals concentration analyzed from borehole and hand-dug well water samples were iron, manganese, zinc and cadmium. Iron concentration of water samples from boreholes and hand-dug wells across different locations were within WHO recommended guideline value for drinking water (Table 1 and 2) with the exception of one hand-dug well each at Ejisu and Juaben respectively that recorded values above WHO limits. Mean iron concentration of hand-dug wells was higher than boreholes (Table 3) and the difference was statistically significant ($p=0.001$). Manganese levels of water samples from boreholes and hand-dug wells across different locations were within WHO recommended guideline value for drinking water (Table 1 and 2). Mean Manganese level of hand-dug wells was slightly higher than boreholes (Table 3) but the difference was not statistically significant ($p=0.507$). The concentration of zinc in water samples from boreholes and hand-dug wells across different locations were within WHO recommended guideline value for drinking water (Table 1 and 2). Mean zinc concentration of hand-dug wells was slightly lower than boreholes (Table 3) and the difference was not statistically significant ($p=0.640$). The level of cadmium in all the water samples from different locations of boreholes and hand-dug wells were below detection limit of the equipment (0.01).

Table 1. Mean concentration of heavy metal content of water from boreholes in Ejisu Juaben Municipality.

Towns	Metals			
	Fe (mg/l)	Mn (mg/l)	Zn (mg/l)	Cd (mg/l)
WHO Limits	**0.3**	**0.4**	**3.0**	**0.003**
Ejisu	b/d	**0.0677 ± 0.0013** (0.0660 – 0.0690)	**0.0563 ± 0.0220** (0.0380 – 0.0860)	b/d
Juaben	b/d	**0.0540 ± 0.0117** (0.0430 – 0.0690)	**0.0267 ± 0.0103** (0.0170 – 0.0500)	b/d
Fumesua	**0.2723**	**0.0537 ± 0.0065** (0.0450 – 0.0580)	**0.0252 ± 0.0114** (0.0150 – 0.0360)	b/d
Bonwire	**0.2147**	**0.0817 ± 0.0018** (0.0800 – 0.0840)	**0.0446 ± 0.0191** (0.0200 – 0.0630)	b/d
Besease	b/d	**0.0430 ± 0.0017** (0.0410 – 0.0450)	**0.0217 ± 0.0052** (0.0170 – 0.0270)	b/d

b/d = below detection limit of equipment (0.01).

Table 2. Mean concentration of heavy metal content of water from hand-dug wells in Ejisu Juaben Municipality.

Towns	Metal			
	Fe (mg/l)	Mn (mg/l)	Zn (mg/l)	Cd (mg/l)
WHO Limits	**0.3**	**0.4**	**3.0**	**0.003**
Ejisu	**0.3706±0.2450** (0.1260 – 0.6810)	**0.0630±0.0020** (0.0590 – 0.0640)	**0.0412 ±0.0291** (0.0200 – 0.0800)	b/d
Juaben	**0.3220**	**0.0403 ±0.0013** (0.0390 – 0.0420)	**0.0173**	b/d
Fumesua	b/d	**0.0541±0.0067** (0.0450 – 0.0600)	**0.0639±0.0475** (0.0300 – 0.1400)	b/d
Bonwire	**0.2800**	**0.0799±0.0008** (0.0790 – 0.0810)	**0.0262±0.0004** (0.0260 – 0.0270)	b/d
Besease	**0.1439±0.0586** (0.0970 – 0.2260)	**0.0711±0.0179** (0.0490 – 0.0900)	**0.0104±0.0008** (0.0100 – 0.0110)	b/d

b/d = below detection limit of equipment (0.01).

Table 3. Mean and range values of metal levels of water from selected boreholes and hand-dug wells in Ejisu-Juaben Municipality.

Parameter	Minimum		Maximum		Mean		WHO Guideline value
	BH	HDW	BH	HDW	BH	HDW	
Iron (mg/l)	0.21	0.10	0.27	0.68	[a]0.244	[a]0.268	0.3
Manganese (mg/l)	0.04	0.04	0.08	0.09	0.060	0.061	0.4
Zinc (mg/l)	0.02	0.01	0.09	0.14	0.037	0.036	3.0
Cadmium (mg/l)	bd	bd	bd	bd	bd	bd	0.003
Distance (m)	8.0	5.0	50	35	[a]25.5	[a]12.9	15.24 (USEPA)

BH refers to borehole, HDW refers to hand-dug well, [a] statistically significant means

Parasitological analysis of water samples from boreholes and hand-dug wells

All the boreholes across the different sampling locations recorded zero count for helminths eggs. Some of the water samples from hand-dug wells examined had helminths contamination. Out of the 30 water samples collected and examined, 5 of them had helminths giving an overall prevalence of 16.7% in the study area (Table 4). Hand-dug well water samples were contaminated with 33.3% positivity for helminths (Table 4).

The number of hand-dug wells that recorded positives for helminths eggs were 5 with 9 egg counts representing 26.7% of the total hand-dug wells evaluated in the present study. *Ascaris* species were found in 3 hand-dug wells at Ejisu, Fumesua and Besease out of the 15 hand-dug wells accounting for 20%. Hookworm followed with 13.3% and the least distributed was *Schistosoma haematobium* with 6.7% (Table 5).

Among the helminths, *Ascaris* species had the highest prevalence rate (66.7%) followed by *Hookworm* (22.2%) and *S. haematobium* (11.1%) (Table 6). Chollom *et al.*, (2013) had similar results in that order of prevalence *Ascaris* species (33.9%), *Hookworm* (20.3%) and *Strongyloides spp* (3%).

Table 4. Percentage helminths contamination of water from Ejisu Juaben Municipality

Water source (no.)	Helminths count ($100ml^{-1}$)			Positive	Percentage
	Ascaris eggs	*Hookworm* eggs	*S. haematobium* eggs		
Boreholes (n=15)	0	0	0	0	0.0%
Hand-dug wells (n=15)	6	2	1	5	33.3%
Total n=30	6	2	1	5	16.7%

Table 5. Spread of helminths in all hand-dug wells investigated in Ejisu-Juaben Municipality.

Name of helminths	Locations	Percentage
Ascaris species	3	20.0%
Hookworm	2	13.3%
Schistosoma haematobium	1	6.7%

Table 6. Percentage contamination of water from selected hand-dug wells by helminths types in Ejisu Juaben Municipality.

Name of helminths	Egg count/100 ml	Percentage (%)
Ascaris sp.	6	66.7
Hookworm	2	22.2
Schistosoma haematobium	1	11.1
Total	9	100

Distance between boreholes, hand-dug wells and source of contamination

In some circumstances (33.3%), the distance between the boreholes and sources of contamination was estimated to be less than 15 m (the commonly used guideline is that the distance should be at least 15.24 m or 50 ft.) (Table 7) but in many situations (60%), the distance between the hand-dug wells and sources of contamination was estimated to be less than 15 m (Table 8). Differences in mean distance between boreholes and hand-dug well was statistically significant ($p=0.039$).

Table 7: Distance between sources of contamination and selected boreholes in Ejisu-Juaben Municipality.

Distance (m)	Number of boreholes	Percentage (%)
<15	5	33.3
15-30	6	40.0
>30	4	26.7
Total	15	100

Table 8: Distance between sources of contamination and selected hand-dug wells in Ejisu Juaben Municipality.

Distance (m)	Number of hand-dug wells	Percentage (%)
<15	9	60
15-30	5	33.3
>30	1	6.7
Total	15	100

DISCUSSION

With the exemption of Cadmium which was below detection limit of equipment, all the other heavy metals analyzed (Fe, Mn and Zn) were detected in most of the water samples. The differences in concentrations of metals in individual boreholes and hand-dug wells depends on prevailing factors such as temperature, pH, standing time of water and water hardness [17]. The borehole water samples in the study area were characterized by iron concentrations within the WHO guideline value of 0.3 mg/l which is based on taste and appearance [6]. Observation made at Fumesua showed that, one out of the three boreholes recorded iron in water sample whiles iron levels in all the three hand-dug wells were below the detection limit of equipment. This might be due to corrosion of metallic pipes due to low pH of water samples in the study area because the boreholes are poorly maintained. One hand-dug well each at Ejisu and Juaben respectively had iron levels above the WHO guideline value of 0.3 mg/l. Water with high iron may be due to chemical weathering of the bedrock into lateritic soils and subsequent downward leaching into the shallow aquiferous zones in the area [18]. The iron content of drinking water greater than 0.3mg/l, stains cloths during laundering, stains plumbing fixtures, clogs pipes and incrusts well screens [19]. Manganese levels of water samples from boreholes and hand-dug wells were within the WHO guideline value of 0.4 mg/l. The result is similar to [17] who had the same results from wells and boreholes water in some peri-urban communities in Kumasi, Ghana. Under extreme case, nervous system disorders such as Parkinson's disease may develop [20]. Zinc levels from boreholes and hand-dug well water samples were within the WHO guideline value of 3 mg/l. Acute adverse health effect of drinking water with too much zinc can lead to stomach cramps, vomiting and nausea. Exposure to zinc for longer periods may cause anaemia, nervous system disorders and damage to the pancreas [21]. Water samples from boreholes were found to be free from helminths eggs. This is largely attributed to their make-up; all the boreholes had aprons that carry waste and dirty water away from their immediate surrounding area downstream. Unlike other sources that are open to external contamination, boreholes operate a water system that is closed and fitted with hand pumps to avoid direct contact with animals or humans. Results of this study conform to work by [22] and [23] who recorded zero helminths eggs in boreholes within some parts of Ghana and Nigeria respectively. Helminths eggs were present in 26.7% of the total hand-dug wells evaluated in the present study. [22] and [23] recorded helminths eggs in wells in rural communities in Nigeria and Bawku East District of Ghana respectively. They attributed it to lack of proper toilet facilities, inadequate supply of portable drinking water and poor sewage and waste disposal systems. In this present study it was observed that all wells in these communities do not have windlass and most of them are usually left opened. Some of the wells were close to pit latrines, piggeries, septic tanks and dumps sites. It was also observed that the receptacles used to fetch the water are mostly left in the dirty water around the hand-dug wells and immediately the other person comes, he just uses that same receptacle to fetch the water. This might account for helminths contamination of the hand-dug wells since most of helminths encountered were soil transmitted. Among the helminths, *Ascaris* species had the highest prevalence rate (66.7%) followed by *Hookworm* (22.2%) and *S. haematobium* (11.1%). Chollom *et al.*, (2013) had similar results in that order of prevalence *Ascaris* species (33.9%), *Hookworm* (20.3%) and *Strongyloides spp* (3%). It is reported that *Ascaris* species is the most prevalent and most economically important internal parasite of swine and the eggs can be transported by infested pigs, insects, fomites, blowing dust, pig manure, and effluent [24]. This could account for *Ascaris* species having high prevalence rate in the study area because pigs are mostly raised in semi-intensive system in some of the communities.

CONCLUSION

The study has shown that generally heavy metal (Fe, Mn, Zn, Cd) concentration of groundwater from selected boreholes and hand-dug wells were within acceptable WHO limits for drinking and domestic activities with the exception of few boreholes and hand-dug wells (slightly above recommended range) . Water from few of the selected hand-dug wells is of poor parasitological quality and unsuitable for human consumption without treatment.

RECOMMENDATIONS

Water from the hand-dug wells must be boiled before use. Receptacles for drawing water from open wells should be kept clean and if possible permanently attached to a windlass when not in use. All wells under 15 meters from an adverse source must be closed and the rusted pipes in boreholes must be replaced to reduce the iron content.

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