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ORIGINAL RESEARCH

Assessment of the Quality of Water from Hand-Dug Wells in Ghana

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Abstract: This study focused upon the determination of physicochemical and microbial properties, including metals, selected anions and coliform bacteria in drinking water samples from hand-dug wells in the Kumasi metropolis of the Republic of Ghana. The purpose was to assess the quality of water from these sources. Ten different water samples were taken from different parts of Kumasi, the capital of the Ashanti region of Ghana and analyzed for physicochemical parameters including pH, electrical conductivity, total dissolved solids, alkalinity total hardness and coliform bacteria. Metals and anions analyzed were Ca, Mg, Fe, Mn, NO_3^-, NO_2^-, SO_4^{2-}, PO_4^{2-}, F^- and Cl^-. Bacteria analysed were total coliform and *Escherichia coli.*

The data showed variation of the investigated parameters in samples as follows: pH, 6.30–0.70; conductivity (EC), 46–682 μS/cm; PO_4^{3-}, 0.67–76.00 mg/L; F^-, 0.20–0.80 mg/L; NO_3^-, 0–0.968 mg/L; NO_2^-, 0–0.063 mg/L; SO_4^{2-}, 3.0–07.0 mg/L; Fe, 0–1.2 mg/L; Mn, 0–0.018 mg/L. Total coliform and *Escherichia coli* were below the minimum detection limit (MDL) of 20 MPN per 100 ml in all the samples. The concentrations of most of the investigated parameters in the drinking water samples from Ashanti region were within the permissible limits of the World Health Organization drinking water quality guidelines.

Keywords: hand-dug wells, metals, physiochemical, microbial, coliform

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Introduction

Quality drinking water is essential for life. Unfortunately, in many countries around the world, including Ghana, water has become a scarce commodity[1] as only a small proportion of the populace has access to treated water. Alternative sources of water such as rainwater and ground water have become major sources of drinking water for people living in new settlements and some residents who do not have access to treated water in Ghana. The need to assess the quality of water from some of these alternative sources has become imperative because they have a direct effect on the health of individuals.[2]

Contaminants such as bacteria, viruses, heavy metals, nitrates and salt have polluted water supplies as a result of inadequate treatment and disposal of waste from humans and livestock, industrial discharges, and over-use of limited water resources.[3] Even if no sources of anthropogenic contamination exist there is potential for natural levels of metals and other chemicals to be harmful to human health. This was highlighted in Bangladesh where natural levels of arsenic in groundwater were found to be causing harmful effects on the population.[4] Unfortunately, this problem arose because the groundwater was extracted for drinking without a detailed chemical investigation.

The natural water analyses for physical and chemical properties including trace element contents are very important for public health studies.[5] These studies are also a main part of pollution studies in the environment.

In addition, coliform enters water supplies from the direct disposal of waste into streams or lakes or from runoff from wooded areas, pastures, feedlots, septic tanks, and sewage plants into streams or groundwater. Coliform can also enter an individual house via backflow of water from a contaminated source, carbon filters, or leaking well caps that allow dirt and dead organisms to fall into the water.[6] The presence of *Escherichia (E) coli* in drinking water denotes that the water has been focally contaminated and therefore presents a potential health risk to households that use them untreated.[7]

Research conducted in Ghana[8] indicated that 77% of filtered underground water samples sold as sachet water that were analyzed contained infective stages of pathogenic parasitic organisms. Common pathogens and indicators identified include, *Microsporidia spp*. 14/27 (51.2%), *Cryptosporidium parvum* 17/27 (63.0%), *Cyclospora cayetenens* 16/27 (59.3%), *Sarcocystis* sp. 18/27 (66.7%), Rotifers 5/27 (18.5%), and Charcoat Leyden crystals 12/27 (evidence of allergies or parasitic infection) (44.4%). Ninety-three percent of the samples contained unidentified impurities/artifacts. A total of 29.6% of the samples contained at least one type of parasite, 14.8% contained at least 2 types of parasites, 25.9% contained at least three types of parasites, and 29.6% contained four types of parasites. This has grim public health implications as the organisms identified can cause water related diseases that have serious complications in children and adults particularly immunocompromised individuals.

During this study, some physicochemical properties and biological parameters of untreated water from hand-dug wells were determined and evaluated. The purpose of this study was to assess the quality of water from hand-dug wells in the Kumasi metropolis, Ghana.

Materials and Methods

Sample collection

Two water samples were collected each of ten different hand-dug wells in various residences in Kumasi. The water samples were collected into 1 L pre-washed polyethylene bottles. pH of the water samples was measured on-site with a Suntex® SP-707 (Taipei, Taiwan) portable pH meter. All the water samples were collected in duplicate and stored in ice in the laboratory until analysis were completed within 14 days. The determinations of the other physicochemical properties of the water samples were performed on the same day of sampling. Test on samples for bacteria was conducted within 6 hours of sampling while that for anions was within 14 days.

Chemical analysis

A photometric method was used for the determination of Fe, Mn, NO_3^-, NO_2^-, SO_4^{2-}, PO_4^{2-}, SiO_2 and F^-. Analytical water test tablets prescribed for Palintest® Photometer 5000 (Wagtech, Thatcham. Berkshire, UK) series were used. Each sample was analysed for Fe, Mn, NO_3^-, NO_2^-, SO_4^{2-}, PO_4^{2-}, SiO_2 and F^- using procedures outlined in the Palintest Photometer Method for the examination of water. Other analyses such as the determination of total hardness, Mg and Ca concentrations, were done by complexometric titration using EDTA. The determination of Cl^- concentrations was completed using argentometric titration. Total dissolved solids and electrical conductivity were determined by a means of a multifunctional WTW® cond. 730 series, conductivity meter (Munich, Germany).

Microbial analysis

Standard methods for the determination of total coliform and fecal coliform[9,10] (Brenner et al, 1993 and APHA, 1995) were employed.

All measurements were completed in triplicate.

Results and Discussion

The mean (average) values for pH, conductivity, total dissolved solids, hardness, alkalinity and cations determined in the hand dug well water samples are shown in Table 1.

The mean (average) values of pH of the samples ranged from 6.3 to 7.7. The pH levels were within WHO optimum limits of between 6.5 and 8.5. pH values lower than 6.5 are considered too acidic for human consumption and can cause health problems such as acidosis. The pH values greater than 8.5 are considered to be too alkaline for human consumption.

The WHO permissible limit for electrical conductivity (EC) of water is 300 µS/cm.

Conductivity values of the samples ranged from 46 to 282 µS/cm. These values are below the WHO permissible limit.

Total hardness ranged from 8.0 to 103 mg/L and alkalinity from 20 to 80 mg/L. All the samples had the total hardness and alkalinity concentrations below the WHO permissible limits. The concentrations of trace metals iron and manganese and bulk metal calcium and magnesium ions in the drinking water samples are also presented in Table 1. Iron was below the minimum detection limit of 0.01 mg/L in all the samples except BHD, which generated a result of 1.2 mg/L. This concentration is above the WHO permissible level in drinking Water of 1.0 mg/L. This may have resulted from the materials used in the construction of the well and the type of soil in which the well has been constructed. Manganese (Mn) concentrations in the samples ranged from below detection limit to 0.018 mg/L. Calcium (Ca) and Magnesium (Mg) concentrations ranged from 0.09 to 24.80 and 0.01 to 11.80 respectively. The levels of Iron (Fe) and Manganese (Mn) in most cases were below the limits permitted by WHO in

Table 1. Physicochemical properties and levels of some trace metals in well water samples.

Sample	pH X ± SD	EC µS/cm	TDS mg/L	Alk. mg/L	Tot. hard. mg/L $CaCO_3$	Ca^{2+} mg/L	Mg^{2+} mg/L	Fe mg/L	Mn mg/L
B	7.02 ± 0.05	282 ± 4	64.2 ± 24	80 ± 2	103.0 ± 1	24.8 ± 0.5	11.8 ± 0.15	b/d	0.010 ± 0.0
BB	6.50 ± 0.01	46 ± 3	6.0 ± 16	20 ± 5	8.0 ± 3	0.09 ± 0.7	0.01 ± 0.00	b/d	$0.013 \pm 1.5 \times 10^{-3}$
PM	7.70 ± 0.05	256 ± 6	330 ± 27	55 ± 2	71.0 ± 5	21 ± 8	6.7 ± 0.21	b/d	$0.002 \pm 6.0 \times 10^{-4}$
BHA	7.26 ± 0.05	191 ± 4	134 ± 32	85 ± 3	62.0 ± 5	20.4 ± 1.6	3.14 ± 0.07	b/d	$0.004 \pm 1.0 \times 10^{-3}$
BHB	7.29 ± 0.01	185 ± 5	130 ± 14	77 ± 4	61.0 ± 3	18.8 ± 2.7	4.0 ± 0.58	b/d	$0.007 \pm 2.1 \times 10^{-3}$
BHC	7.16 ± 0.05	176 ± 11	158 ± 15	45 ± 5	56.0 ± 6	18.4 ± 0.9	2.86 ± 0.02	b/d	$0.004 \pm 1.0 \times 10^{-3}$
BHD	6.60 ± 0.09	256 ± 16	230 ± 4	70 ± 8	56.0 ± 4	18.4 ± 1.7	2.86 ± 0.10	1.2 ± 0.1	b/d
BHE	6.61 ± 0.11	94 ± 2	80 ± 5	25 ± 6	28.0 ± 7	9.2 ± 0.7	1.4 ± 0.15	bd	$0.018 \pm 1.0 \times 10^{-3}$
BHF	6.3 ± 0.06	50 ± 5	90 ± 3	32.5 ± 1.8	38.4 ± 6	0.3 ± 1.9	0.1 ± 0.00	bd	$0.018 \pm 2.1 \times 10^{-2}$
CP	7.48 ± 0.13	167 ± 16	29 ± 2	60 ± 3	52 ± 5	0.45 ± 4.7	0.09 ± 0.01	b/d	$0.004 \pm 2.0 \times 10^{-2}$
MDL	0.01	0.9	0.01	0.1	0.1	0.01	0.01	0.001	0.001
WHO Limit	6.50 – 8.50	1500	1000	200	500	N/A	N/A	1.0	0.500

Abbreviations: b/d, below detection; N/A, not applicable; MDL, Minimum detection limit.

drinking water (Table 1) and USEPA.[11,12] Though these trace metals are needed by the body to satisfy its nutritional requirements, only minute quantities are required as high doses lead to health hazards which are sometimes lethal. Calcium (Ca) and Magnesium (Mg) however are needed by the body in much larger quantities and its lack in the human system will lead to adverse health effects.

Levels of anions determined in the water samples are shown in Table 2. The mean (average) values of Cl^- concentration in the water samples ranged from 0.2–29.4 mg/l. These values are below the WHO quality standard for drinking water of 250 mg/L. Phosphate (PO_4^{2-}) ranged from 0.33 to 9.30 mg/L. Fluoride (F^-) varied from 0.20 to 0.80 mg/L. The minimum value (0.20 mg/L) was observed in two samples, BHE and PM among all the samples analyzed. The maximum concentration (0.80 mg/L) of F^- was observed in BB. Permissible limit for F^- concentration is 1.0–1.5 mg/L according to.[12] Fluoride (F^-) has a significant mitigating effect against dental caries if the concentration is approximately1 mg/L. However, continuing consumption of higher concentrations of 4 mg/L or more can cause dental fluorosis and in extreme cases even skeletal fluorosis.[13] Nitrate and nitrite in the investigated samples ranged from below detection (MDL: 0.001) to 0.968 mg and below detection (MDL: 0.001) to 0.063 respectively. NO_3^- and NO_2^- are considered to be non-cumulative toxins.[14] High concentrations of NO_3^- and NO_2^- may give rise to potential health risks such as methmoglobinemia or 'blue-baby-syndrome' particularly in pregnant women and bottle-fed infants respectively,[15] NO_3^- at elevated concentrations is also known to result in cyanosis in infants.

The range of sulfate (SO_4^{2-}) in the samples was 3.0 to 37.0 mg/L, The values recorded for nitrate, nitrite and sulfate were all below the WHO permissible limits as shown in Table 2.

Total coliform and *E. coli* (Table 3) were below detection in all the samples.

Work done on the assessment and comparison of microbial quality of drinking water in Chikwawa, Malawi revealed that though the microbiological analysis of borehole abstracted water did not reveal the presence of either total coliform or *Escherichia coli* at MDL of 20 MPN per 100 ml. The results of all water samples taken from every drinking water storage container from the study area were positive for total.[16]

Table 2. Level of anions in well water samples.

Sample	Cl^- (mg/L)	F^- (mg/L)	NO_2^- (mg/L)	NO_3^- (mg/L)	SO_4^{2-} (mg/L)	SO_2^- (mg/L)	SiO_2^- mg/L	PO_4^{3-} (mg/L)
B	29.4 ± 0.40	0.2 ± 0.10	$0.011 \pm 1.0 \times 10^{-2}$	b/d	36.0 ± 1.0	0.10 ± 0.01	11.2 ± 0.2	2.90 ± 0.2080
BB	5.0 ± 0.12	0.8 ± 0.06	$0.013 \pm 6.0 \times 10^{-4}$	$0.62 \pm 1.5 \times 10^{-2}$	7.0 ± 0.6	0.06 ± 0.005	24.0 ± 2.0	0.67 ± 0.0058
PM	12.0 ± 0.15	0.3 ± 0.00	$0.016 \pm 1.5 \times 10^{-5}$	b/d	37.0 ± 0.6	0.03 ± 0.01	15.0 ± 0.6	4.10 ± 0.0608
BHA	13.4 ± 0.10	0.3 ± 0.10	$0.004 \pm 1.5 \times 10^{-5}$	0.080 ± 0.010	35.0 ± 1.0	0.06 ± 0.0	18.0 ± 1.0	9.90 ± 0.1
BHB	14.2 ± 0.15	0.3 ± 0.10	b/d	0.140 ± 0.010	31.0 ± 2.0	0.07 ± 0.0	18.0 ± 0.6	16.00 ± 1.5275
BHC	28.8 ± 0.06	0.3 ± 0.10	0.001 ± 0.0	0.040 ± 0.010	35.0 ± 1.0	0.08 ± 0.005	18.0 ± 1.0	10.00 ± 2.0
BHD	28.8 ± 0.75	0.3 ± 0.00	$0.027 \pm 1.5 \times 10^{-2}$	0.003 ± 0.010	17.0 ± 1.0	0.08 ± .01	17.0 ± 0.6	15.00 ± 0.577
BHE	0.2 ± 0.12	0.2 ± 0.12	$0.017 \pm 1.5 \times 10^{-3}$	0.320 ± 0.010	3.0 ± 0.0	0.09 ± 0.01	14.8 ± 0.06	12.00 ± 1.0
BHF	12.0 ± 0.15	0.3 ± 0.10	$0.063 \pm 4.2 \times 10^{-3}$	0.968 ± 0.004	3.0 ± 0.6	0.07 ± 0.0	5.9 ± 0.1	4.10 ± 0.1528
CP	18.0 ± 0.10	0.1 ± 0.00	$0.020 \pm 1.0 \times 10^{-2}$	0.090 ± 0.010	22.0 ± 2.0	0.03 ± 0.01	1.3 ± 0.1	4.32 ± 0.0800
WHO Limit	250	1.5	3.000	50.000	500	N/A	30	–

Abbreviation: N/A, No standard available.

Table 3. Levels of total and fecal coliform in water samples.

Sample	Total coliform <20 MPN 100 ml (MDL)	Facal coliform (E-coli) <20 MPN 100 ml (MPN)
AB	b/d	b/d
BB	b/d	b/d
PM	b/d	b/d
BHA	b/d	b/d
BHB	b/d	b/d
BHC	b/d	b/d
BHD	b/d	b/d
BHE	b/d	b/d
BHF	b/d	b/d
CP	b/d	b/d
WHO limit	b/d	b/d

Abbreviations: b/d, Below the MDL of 20 MPN 100 ml.

Groundwater is a relatively safe source of potable water compared with other unprotected water sources e.g. rivers, springs, rainwater. Water samples taken directly from hand-dug wells in this study contained levels of coliform below the MDL of the MPN technique. These results are similar to the findings of a study undertaken in Chikwawa,[16] which found levels of fecal coliform below the MDL of 20 MPN/100 ml in water samples taken from 27 boreholes.

Conclusion

In this study, the concentrations of the investigated anions and trace metal ions in the water samples from hand dug wells from the Kumasi Metropolis in the Ashanti region of Ghana were found to be acceptable according to the guidelines for drinking water provided by the World Health Organization (WHO). The quality of groundwater supplied by the wells was satisfactory with fecal indicator bacteria below the MDL of 20 MPN 100 ml. The water therefore may, according to WHO standards be safely used as drinking water. However since contamination after collection, during transportation and storage is increasingly being recognized as an issue of public health importance,[17,18] it may require treatment such as boiling or treatment with hypochlorite solution since that will kill most microbial parasites before drinking. Further research on other communities in this region for the assessment of the quality of drinking water is required as levels of contaminants may vary due to different soil types, water chemistry and different human activities.

Intensification of education and implementation of regulations on safe drinking water by the Ghana Standards Board, the Ghana EPA and district environmental units and other state enforcements agencies will go along way to reduce incidences of water pollution and the associated water borne diseases.

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Disclosures

This manuscript has been read and approved by all authors. This paper is unique and is not under consideration by any other publication and has not been published elsewhere. The authors and peer reviewers of this paper report no conflicts of interest. The authors confirm that they have permission to reproduce any copyrighted material.

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