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, NO₃⁻, NO₂⁻, SO₄²⁻, PO₄³⁻, 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; PO₄³⁻, 0.67–76.00 mg/L; F⁻, 0.20–0.80 mg/L; NO₃⁻, 0–0.968 mg/L; NO₂⁻, 0–0.063 mg/L; SO₄²⁻, 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 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.

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. 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. 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. 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. 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.

Research conducted in Ghana 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 cayetenes 16/27 (59.3%), Sarcozystis 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...
The levels of Iron (Fe) and 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 mean (average) values for pH, conductivity, total hardness and alkalinity 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.

Conductivity values of the samples ranged from 46 to 282 µS/cm. These values are below the WHO permissible limit. The mean (average) values for 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.

Results and Discussion

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

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 | Ca²⁺ mg/L | Mg²⁺ mg/L | Fe mg/L | Mn mg/L |
|--------|-----------|----------|----------|-----------|----------------|-----------|-----------|---------|---------|
| B      | 7.02 ± 0.05 | 282 ± 4 | 64.2 ± 24 | 80 ± 2    | 103 ± 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 ± 0.3 | 0.09 ± 0.7 | 0.01 ± 0.00 | b/d     | 0.013 ± 1 ± 10³ |
| PM     | 7.70 ± 0.05 | 256 ± 6 | 330 ± 27 | 55 ± 2    | 71.0 ± 5 | 21 ± 8     | 6.7 ± 0.21 | b/d     | 0.002 ± 6.0 ± 10⁴ |
| 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 ± 1 ± 0.0 × 10³ |
| 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 ± 2 ± 10³ |
| 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 ± 1 ± 0.0 × 10³ |
| 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 ± 0.07 | 1.4 ± 0.15 | bd      | 0.018 ± 1 ± 0.0 × 10³ |
| 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 ± 2 ± 10² |
| 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 ± 2 ± 10² |
| 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 | 0.9 | 0.01 | 0.1 | 0.1 | 0.01 | 0.01 | 1.0 | 0.500 |

Abbreviations: b/d, below detection; N/A, not applicable; MDL, Minimum detection limit.
drinking water (Table 1) and USEPA.\textsuperscript{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 standard for drinking water (Table 1) and USEPA.\textsuperscript{11,12} The maximum concentration (0.80 mg/L) of F$^-$(PO$_4^{3-}$) 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.\textsuperscript{12} Fluoride (F$^-$) has a significant mitigating effect against dental caries if the concentration is approximately 1 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.\textsuperscript{13} Nitrate and nitrite in the investigated samples ranged from below detection (MDL: 0.001) to 0.968 mg/L. These values are below the WHO permissible limits as shown in Table 2. 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 \textit{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 \textit{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.\textsuperscript{16}

### Table 2. Level of anions in well water samples.

| Sample | Cl$^-$ (mg/L) | F$^-$ (mg/L) | NO$_3^-$ (mg/L) | SO$_4^{2-}$ (mg/L) | SiO$_2^-$ (mg/L) | PO$_4^{3-}$ (mg/L) |
|--------|---------------|--------------|-----------------|-------------------|----------------|------------------|
| B      | 29.4 ± 0.40   | 0.01% ± 0.06 | 0.01± 1.0 × 10$^{-3}$ | 0.62 ± 1.5 × 10$^{-3}$ | 0.080 ± 0.010 | 0.01 ± 0.001 |
| BB     | 50.0 ± 0.12   | 0.01% ± 0.06 | 0.01 ± 1.0 × 10$^{-3}$ | 0.62 ± 1.5 × 10$^{-3}$ | 0.080 ± 0.010 | 0.01 ± 0.001 |
| PM     | 120.0 ± 0.15  | 0.01% ± 0.06 | 0.01 ± 1.0 × 10$^{-3}$ | 0.62 ± 1.5 × 10$^{-3}$ | 0.080 ± 0.010 | 0.01 ± 0.001 |
| BHA    | 14.2 ± 0.15   | 0.01% ± 0.06 | 0.01 ± 1.0 × 10$^{-3}$ | 0.62 ± 1.5 × 10$^{-3}$ | 0.080 ± 0.010 | 0.01 ± 0.001 |
| BHC    | 28.8 ± 0.06   | 0.01% ± 0.06 | 0.01 ± 1.0 × 10$^{-3}$ | 0.62 ± 1.5 × 10$^{-3}$ | 0.080 ± 0.010 | 0.01 ± 0.001 |
| BHE    | 12.0 ± 0.15   | 0.01% ± 0.06 | 0.01 ± 1.0 × 10$^{-3}$ | 0.62 ± 1.5 × 10$^{-3}$ | 0.080 ± 0.010 | 0.01 ± 0.001 |
| CP     | 18.0 ± 0.10   | 0.01% ± 0.06 | 0.01 ± 1.0 × 10$^{-3}$ | 0.62 ± 1.5 × 10$^{-3}$ | 0.080 ± 0.010 | 0.01 ± 0.001 |
| WHO Limit | 250 ± 0.00 | 0.01% ± 0.06 | 0.01 ± 1.0 × 10$^{-3}$ | 0.62 ± 1.5 × 10$^{-3}$ | 0.080 ± 0.010 | 0.01 ± 0.001 |

**Abbreviation:** N/A, No standard available.
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.

### References

1. IDLO. Water Tenure Reform and Public Access to Water as a Basic Need, International Development Law Organization Voice of Development Jurists Series. 2006.
2. WHO. Guidelines for drinking water quality (2), 231: World Health Organization. 1996.
3. Singh1 S, Mosley LM. Trace metal levels in drinking water on Viti Levu, Fiji Islands. *S Pac J Nat Sci*. 2003;21:31–4.
4. Anawara HM, Akah J, Mostofic KMG, Safiullah S, Tareqf SM. Arsenic poisoning in ground water health risk and geochemical sources in Bangladesh. *Environ Int*. 2002;27:597–604.
5. Kot B, Baranowski R, Rybak A. Analysis of mine waters using X-ray fluorescence spectrometry. *Polish J Environ Stud*. 2000;9:429.
6. National Groundwater Association (NGA). 601 Dempsey Road, Westerville, Ohio. 614-898-7791. http://www.h2O-ngwa.org/pubaff/bacq_a.html, Accessed Feb 11 2008.
7. WHO. Guidelines for drinking water quality. Second Edition. Volume 1: Recommendations. Geneva: World Health Organisation. ISBN 94-4-154503. 1993.
8. Kwakye-Nuako G, Borketey PB, Mensah-Attipoe I, Asmah RH, Ayeh-Kumi PF. Sachet Drinking Water in Accra: The Potential Threats of Transmission of Enteric Pathogenic Protozoan Organisms. *Ghana Med J*. 2007;41(2):62–7.
9. Brenner KP, Rankin CC, Roybal YR, et al. New medium for the simultaneous detection of total coliforms and *Escherichia coli* *Appl Environ Microbiol*. 1993;59:3534–44.
10. American Public Health Association. (APHA). Standard methods for the examination of water and wastewater, 19th ed. American Public Health Association, Washington, D.C. 1995.
11. United States Environmental Protection Agency (USEPA). Chemical contaminants in drinking water: Technical fast sheet on microbes. EPA 816-03-016. 2003.
12. WHO. Guidelines for drinking water quality. Geneva., (WHO/SDE/WSH 03. 04) 2003.
13. Dissanayake CB. The fluoride problem in the groundwater of Sri Lanka—environmental management and health. *Int J Environ Studies*. 1991;19: 195–203.

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

| Sample | Total coliform (<20 MPN 100 ml (MDL)) | Fecal 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.
14. Dallas HF, Day JA. The Effect of Water Quality Variables on River and Ecosystem. Water Research Commission Report No. TT 61/93. South Africa. 1993.

15. Kempster PL, Van Vliet HR, Kuhn A. The Need for Guideline to Bridge the Gap between Ideal Drinking Water Quality and Quality which is ractically Available and Acceptable. Water SA. 1997;23(2):163–7.

16. Jabu GC. Assessment and Comparison of Microbial Quality of Drinking Water in Chikwawa, Malawi. Accessed on the 29th April, 2008. (www.csfp-online.org/news/jabupaper.pdf)

17. Lindskog P, Lindskog U. Bacterial contamination of water in rural areas. An intervention study in Malawi. Journal of Tropical Medicine. 1988; 91:1–7.

18. Genthe B, Strauss N. The effect of type of water supply on water quality in a developing country in South Africa. Water Science Technology. 1997;35 (11–12):35–40.