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Study of the underground water of Monrovia and its environs for potability

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Abstract
Access to potable water, in Monrovia (Liberia) and environ is majorly through hand-pump-fitted boreholes (HPFB). The study to evaluate the potability of these waters with reference to safety involved thirty three communities of Monrovia and its environs from which thirty four samples of drinking water was obtained from hand-pump-fitted boreholes. The samples were stored at 4˚C and later analyzed. Total dissolved solids (TDS), conductivity and pH were three physical parameters analyzed along with the concentration for twelve heavy metals (arsenic, cobalt, cadmium, lead, silver, potassium, manganese, sodium, iron, magnesium, calcium and aluminum) using Atomic Absorption Spectrophotometry. All the samples complied with WHO specification for TDS and pH while 97.05% of the samples complied with conductivity requirement. The values of sodium, potassium, calcium, manganese, silver and cadmium were within the WHO specification for drinking water while 58.83%, 97.05%, and 88.24% of samples complied for magnesium, aluminium and lead respectively. All the samples except two (5.89%) complied with arsenic standard.

Keywords: Arsenic; Water quality; Heavy metals; Monrovia; Liberia.

INTRODUCTION

Water is essential for life and individuals, corporate bodies and national government tries to provide access to drinking water. In Liberia, access to potable water, is through the Government of Liberia (GOL) owned Liberia Water and Sewer Corporation (LWSC) however major (over 95%) access is by boreholes (wells) fitted with hand pumps referred to as " hand-pump-fitted boreholes" (HPFB). The approximately 1.2 million inhabitants of Monrovia and its environs obtain drinking water such sources believing it is safe and free of any form of contaminations.

Heavy metals can be transported to underground water from hazardous site containing waste. Underground water within the gold belt zone of Ghana showed arsenic (As) and manganese (Mn) to be high above the World Health Organization (WHO) guideline values (Buamah *et al.*, 2008). This means that resident of the gold belt face great health risk involving heavy metals. Asante *et al.* (2007) reported contamination by As, Mn, Hg and Pb in drinking water from Tarkwa, Ghana a year before Baumah and others reported similar results of water pollution involving heavy metals. China, Bangladesh, Vietnam, Taiwan, Thailand, Nepal and India are located, seven countries where environmental concerns are arising because large amounts of heavy metals have been found in drinking water. In these countries,

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arsenic is found at high concentration in groundwater, drinking water and surface soil (Chen, 2006).

Heavy metal toxicity have resulted in damaged or reduced mental and central nervous function, lower energy levels, and damage to blood composition, lungs, kidneys, liver, and other vital organs. Long-term exposure may result in slowly progressing physical, muscular, and neurological degenerative processes that mimic Alzheimer's disease, Parkinson's disease, muscular dystrophy, and multiple sclerosis (Magos, 1986, Friberg *et al.* 1986, Staudinger and Roth, 1998, Facts 1998, Chen 2006). Allergies are not uncommon and repeated long-term contact with some metals or their compounds may even cause cancer (Atlanta 1999. International Occupational Safety and Health Information Centre). Approximately 1 in 100 people who drink water containing 0.05 mg arsenic per liter or more for a long period may eventually die from arsenic related cancers (WHO, 2001).

The access to safe drinking water is extremely low in urban as well as rural areas in Liberia. Three out of four Liberians have no access to safe drinking water (Liberia WASH Consortium, 2010, 2011). The purpose of this study is to determine the safety levels associated with various heavy metals (such as arsenic, cobalt, cadmium, lead, silver, potassium, manganese, sodium, iron, magnesium, calcium and aluminum) present in water samples collected from hand-pump-fitted boreholes (HPFB) in Monrovia and it surrounding communities.

EXPERIMENTAL

Samples. Samples of drinking water from hand-pump-fitted boreholes (HPFB) were collected in several communities of Monrovia and its environs. This summed a collection of 34 samples from HPFB throughout Monrovia and its surrounding.

Sample collection sites coded by the serial numbers

1) Medical Campus (Administrative Building)
2) ELWA Community
3) Sinkor AGM Community
4) Dixville Community
5) Upper Cadwell Community
6) Logan Town Community
7) Barclay Mission Community
8) Down Gaye Town Community
9) Medical Campus (Dining Hall Dormitory)
10) Lonestar Community
11) Duport Road Community
12) Bonard's Beach Community
13) Parker Paint Community
14) 24th Street Community
15) Soul Clinic Community
16) Gobachop Community
17) First Gaye Town Mansion Community
18) Police Academy Community
19) Neezoe Community
20) 72nd Community
21) Pipeline Community
22) Bobo Camp Community
23) Omega Community
24) Nancy Doe Market
25) Catholic Beach Community
26) Menyongar Broad Street, Oldroad Community
27) Brewerville Community
28) GSA Community
29) Lakpacee Community
30) Steven Tolbert Estate
31) 17th Street Community
32) Barnersville Estate
33) IPA Community, Oldroad
34) Bonard's Farm Community

Method

Sample collection: A total of thirty four (34) samples of hand-pump-fitted boreholes ground water were collected into a 330 ml plastic bottle each. Each bottle was thoroughly washed and rinsed with water directly from the hand pump from which the sample was collected. The bottles were well labeled with location and date of collection. The samples after collection were refrigerated at 4˚C. Addition of nitric acid to water sample as per recommended standard was ensured.

Analysis of samples. Accusys 211model Atomic Absorption Spectrophotometer and pH meter (with automatic temperature compensation) HANNA instrument. Italy, Total Dissolved Solid meter (with automatic temperature compensation) HANNA instrument. Italy, Conductivity meter (with automatic temperature compensation) HANNA instrument were used.

The concentration of the various metals was determined using Flame Atomic Absorption Spectrophotometry (FAAS) directly. It is based on the phenomenon that the atom in the ground state absorbs the light of wavelengths that are characteristic to each element when light is passed through the atoms in the vapor state. Because this absorption of light depends on the concentration of atoms in the vapor, the concentration of the target element in the water sample is determined from the measured absorbance. The Beer-Lambert law describes the relationship between concentration and absorbance (Gracia and Baez 2012).

The pH and Total Dissolved Solid (TDS) and conductivity were determined using the Hanna ion specific meter. A 10 ml volume of water was placed in a beaker and the meters were dipped inside and readings taken. The results obtained were compared with WHO standards.

RESULTS AND DISCUSSION

The result showed the samples to have a pH range of 6.6 to 9.13. There has been no health-based guideline value proposed for pH, however, pH is one of the most significant water quality parameters in operations. According to the WHO (2011) International Standards for Drinking-water, pH less than 6.5 or greater than 9.2 would clearly spoil the potability of water. All the samples were within the range recommended by WHO for pH in drinking water. The range of pH was 6.6 at a minimal concentration to 9.13 at a maximum concentration in locations of Bonard's Beach and Omega communities respectively.

Table 1-1: Table of aesthetics and physicality parameters pH, Conductivity, TDS, K, Na, Mg, Ca and Fe of the various water samples.

S/N	pH	Cond.	TDS	K 766.490 (mg/L)	Na 582.592 (mg/L)	Mg 285.213 (mg/L)	Ca 317.933 (mg/L)	Fe 238.204 (mg/L)
1	7.52	0.43	0.21	1.109	0.018	0.016	0.012	0.000
2	8.22	128	066	0.152	1.011	0.022	1.030	0.020
3	8.36	033	017	0.013	0.012	0.011	0.025	0.012
4	8.17	052	026	0.018	1.126	0.008	1.009	0.002
5	7.85	023	010	0.002	0.015	0.002	0.026	0.000
6	8.06	095	046	0.008	0.034	0.025	1.110	0.001
7	8.13	120	061	0.11	1.265	0.034	0.000	0.006
8	8.29	0.12	005	0.000	0.009	0.003	0.003	0.000
9	8.98	046	022	1.120	0.013	0.001	0.009	0.005
10	7.06	069	034	1.109	0.006	0.005	0.010	0.011
11	8.89	183	094	1.369	3.689	0.161	1.175	0.013
12	6.66	142	072	1.421	4.051	0.172	1.122	0.009
13	8.25	154	084	1.580	3.126	0.109	1.142	0.004
14	6.71	083	041	0.146	6.222	0.021	0.266	0.002
15	7.68	085	057	0.041	3.629	0.044	0.292	0.007
16	865	15	077	1.117	1.704	0.138	1.321	0.026
17	7.36L	165	083	0.082	5.100	0.188	1.355	0.013
18	8.44L	216	108	1.263	4.202	1.251	3.002	0.005
19	7.10	018	007	1.177	0.008	0.012	0.014	0.000
20	8.12	078	036	1.151	0.004	0.009	1.229	0.010
21	7.90	032	013	1.212	0.013	0.011	0.018	0.001
22	6.82	016	008	1.102	0.002	0.005	0.006	0.000

23	9.13	281	143	1.109	7.191	0.218	6.313	0.030
24	8.01	198	125	1.116	6.131	0.113	3.228	0.021
25	7.82	105	053	1.304	1.826	0.214	4.012	0.025
26	7.18	217	108	1.339	4.000	0.081	5.281	0.042
27	9.10	195	106	1.209	3.429	0.110	1.026	0.016
28	7.51	087	046	0.533	1.202	0.006	1.882	0.009
29	7.26	124	060	0.231	2.150	0.009	1.721	0.022
30	6.91	130	063	0.430	2.009	0.121	0.034	0.018
31	8.60	115	057	0.111	1.911	0.132	0.016	0.003
32	7.88	054	026	1.361	0.261	0.009	1.123	0.001
33	7.55	110	054	1.221	1.104	0.118	4.032	0.004
34	8.17	194	110	1.621	1.106	1.105	5.271	0.016

Table 1-2. Shows concentrations of heavy metals (Ag, Co, Al, Mn, As, Cd and Pb).

S/N	Ag 328.068 (mg/L)	Co 228.616 (mg/L)	Al 396.153 (mg/L)	Mn 257.610 (mg/L)	As 193.696 (mg/L)	Cd 228.8 (mg/L)	Pb 220.353 (mg/L)
1	0	0.002	0.010	0	0.021	0	0.002
2	0	0.000	0.022	0.001	0.061	0	0.005
3	0	0.000	0.011	0	0.024	0	0.001
4	0	0.001	0.019	0	0.058	0	0.007
5	0	0	0.004	0.001	0.040	0	0.001
6	0	0	0.015	0	0.054	0	0.004
7	0	0.001	0.035	0.004	0.065	0	0.006
8	0	0	0.002	0	0.038	0	0.000
9	0	0.000	0.006	0	0.020	0	0.003
10	0	0.00	0.038	0.000	0.046	0	0.006
11	0	0.001	0.066	0.006	0.123	0	0.000
12	0	0.000	0.122	0.003	0.101	0	0.005
13	0	0	0.126	0.001	0.064	0	0.010
14	0	0	0.071	0	0.132	0	0.002
15	0	0.001	0.022	0	0.063	0	0.002
16	0	0.000	0.062	0	0.091	0	0.003
17	0	0.002	0.142	0.000	0.096	0	0.011
18	0	0	0.164	0.004	0.084	0	0.014
19	0	0	0.123	0.000	0.042	0	0.003
20	0	0	0.007	0	0.061	0	0.001
21	0	0.00	0.005	0	0.019	0	0.00
22	0	0.001	0.002	0.180	0.011	0	0.015
23	0	0.002	0.168	0.030	0.104	0.002	0.009
24	0	0.002	0.152	0.010	0.138	0	0.012
25	0	0.000	0.182	0.005	0.145	0	0.008
26	0	0	0.222	0.002	0.131	0.005	0.003
27	0.010	0	0.035	0.001	0.021	0	0.006
28	0	0	0.082	0.004	0.061	0	0.005
29	0	0	0.076	0.005	0.033	0	0.005
30	0	0	0.062	0.000	0.114	0	0.003
31	0	0	0.012	0.006	0.036	0	0.009
32	0	0	0.005	0.015	0.057	0	0.005
33	0	0.000	0.016	0.000	0.042	0	0.008
34	0.145	0.001	0.082	0.015	0.051	0	0.016

The conduction of electric current by water has a relation to the amount of dissolve substances in it. Though water conductivity does not specify which element is present, it suggests the presence of sodium, potassium, chloride or sulphate contaminations (Orebiyi *et al.*, 2010). According to the results obtained, only the sample form Omega community (281 µS/cm) show conduction higher than WHO (2011) maximum admissible limit of 250 µS/cm which make up 2.94% of the total sample. The rest constituting 97.05% of the samples were normal with WHO standard. Samples from Medical Campus (Administrative Building) and Gaye Town community show conductivity lower than 1µS/cm. These results are 0.43 µS/cm and 0.12 µS/cm respectively, therefore allowing a conductivity range from 0.12 µS/cm to 281 µS/cm.

As WHO (2011) maximum admissible limit provides, there is no health limit for TDS but it matters when the taste of drinking water is an issue. The palatability of water at concentration of 500 ppm is considerable. Drinking water becomes unpalatable at TDS levels greater than about 1000 mg/L. TDS greater than 1200 mg/L could cause disapproval to consumers and may have affect on those who are required to limit their daily salt intake e.g. severely hypertensive, diabetic, and renal dialysis patients (London *et al.*, 2005). For the 34 samples analyzed, none of the result showed TDS concentration above 500 ppm. The concentrations ranged from minimum 0.21 ppm at Medical Campus (Administrative Building) to 143 ppm at Omega community.

Although this research focuses on WHO standards, but there are other guidelines for drinking water that have been identify by different international organizations that references will be made to if certain guidelines are absent from WHO standards. These include United States Environmental Agency (USEPA) and European Commission (EU) Commission. All these organization have maximum admissible limits for heavy metals in drinking water. These national and international values were derived based on different experiences and other health factors/indices. Some diseases rampart in Liberia might not be unconnected with high levels and bioaccumulation of some of these metals in the people (Friberg *et al* 1986, Yu 2008). The concentration of heavy metals analyzed in drinking water samples were, As, Co, Pb, Ag, Al, Fe, Mn, Cd, Mg, Ca, Na and. K There are no adequate data with which to derive a health-based guideline value for silver in drinking-water. The only sign of silver overload is argyria, a condition that result when the skin and the hair are heavily damaged by silver in the tissue (WHO, 2011). High level of silver up to 0.1 mg/L could be acceptable in situations where its salts are used to maintain biological quality of drinking water. Only two of the samples showed detection of silver. These were Brewerville community with a concentration of 0.010 mg/L and Bonard's Farm Community with a concentration of 0.145mg/L. WHO guideline for cadmium is 0.03 mg/L. It was detected in two samples, Omega community (0.002 mg/L) and Menyongar Broad Street Community (0.005 mg/L). The rest of the samples show no sign of cadmium. Thus, the results obtained were within the acceptable range. As for lead, there was no detection in three samples. WHO guideline has a 0.01mg/L concentration for lead as standard in drinking water. Four samples had negligible increment ranging from 0.011 mg/L to 0.016 mg/L. The remaining samples had normal concentrations for lead in drinking water. The test for manganese resulted to seventeen sample being below detection levels while the others were within WHO standards for drinking water of 0.4 mg/L.

Arsenic concentrations in most of the samples (94.11%) were equal to or above 0.02 mg/L. Only two samples were within the range of WHO standard guideline (0.01 mg/L). These were the Pipeline sample (0.010 mg/L) and Bobo Camp community sample (0.011 mg/L). All the other samples have values that were above the WHO guidelines ranging from 0.020 mg/L to 0.145 mg/L. In view of the hazardous nature of Arsenic all the samples except two are considered to have failed for potability (not fit for drinking).

Cobalt was detected in only ten of the samples and all conformed with the USEPA standard guideline of 0.1 mg/L since there no guideline for WHO. Similarly there is no guideline for iron with WHO. Using standard from USEPA, the sample from Menyongar Broad Street community (0.042 mg/L) showed concentration above 0.03 mg/L (USEPA standard). Five samples were below detection level while the rest were within line. 41.17% of the samples contained magnesium a little above WHO standard (0.05 mg/L). These concentrations of magnesium ranged from 0.109 mg/L in Parker Paint community, to 1.1241 mg/L in Police Academy community samples. In the case of aluminum, all the samples were within WHO standard. Results ranged from 0.002 mg/L in Bobo Camp community sample to 0.222 mg/L in Menyongar Broad sample. Sodium concentration in all the samples was in accordance with WHO standard of 200 mg/L. Potassium consumption in drinking water is unlikely to produce adverse health effect in healthy individuals. Potassium is rapidly excreted if kidney damage is not a problem. This makes potassium intoxication rare because increase doses often trigger vomiting (Gosselin, Smith and Hodge, 1984). High doses of potassium have been studied and various symptoms identified are vomiting, chest pain, nausea, diarrhea, hyperkalemia, heart failure and shortness of breath. An upper limit for potassium intake has not been considered due to inadequate data (WHO, 2009). Similarly no upper limit for calcium intake in drinking water has been considered up till present but excess calcium intake has been suspected with few health issues.

Conclusion. The focus of this research was to ascertain the level of drinking water safety obtained from 34 hand-pump-fitted boreholes in Monrovia and it surroundings by Atomic Absorption Spectrophotometric analysis. All the samples showed absolute acceptable pH for potable drinking water. No sample showed result greater than 500 ppm for total dissolved solid and 97.05% of the samples were in line with WHO maximum admissible limit of 250 µS/cm. Most of the heavy metals are within the permissible limit of WHO specification. Thirty two (94.11%) of the samples have concentration of Arsenic higher than the WHO specification (WHO 2011).

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