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Original Article

COMMERCIAL DRINKING WATER QUALITY AND SAFETY IN BO CITY, SIERRA LEONE

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ABSTRACT

Background: Many people who lack reliable access to a quality and safe drinking water source in or near the home rely on commercial drinking water products, such as machine-filled sachet water, that may be of variable quality.

Methods: A participatory geographic information system was used in conjunction with distribution point and vendor census in the study area to identify a total of 36 water sources across Bo city that are used for commercial water production. These include 6 water sources and the production facilities for 10 brands of machine-filled factory-produced water sachets as well as the 10 sources and finished samples for 10hand-tied plastic-bagged water producers. Water samples from all 16 water sources and 20 commercial water products purchased from randomly-selected retail outlets and street vendors were tested for microbiological and physicochemical properties. Workers at all of these facilities were also interviewed about their knowledge and practices.

Results: All of the machine-filled sachet waters were free of microbial contamination, but several of the hand-tied water sachets, all filled from unlined local wells, and had coliform bacteria. Both machine-filled sachet water and hand-tied sachet water had pH levels that were below the World Health Organization's recommended range. Water with acidic pH can cause corrosion of the metal pipes used with wells and can release those potentially harmful minerals into drinking water. Water factory workers used a variety of water treatment methods to purify their products; hand-tied sachets generally used only cloth filters to purify the water, and often stored water in open containers.

Conclusions: Improved quality of commercial water products would improve health in Sierra Leone.

Keywords: Geographic information system, physicochemical, pH, water treatment, sachets

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INTRODUCTION

The quality and hence safety of water for human consumption is important to human health and wellbeing. People who do not have access to a reliably safe drinkingwater source in or near the home must rely on commercial drinking water products (Maduka et al., 2014). In Bo, Sierra Leone, only about one in four households has access to improveddrinking water sources (Ansumana et al., 2013; Jacobsen et al., 2012), and the remainder must rely on commercial products. In Bo, and in other places across West Africa, these commercial drinking water products are typically packaged in plastic sachets. The sachets may be machine-sealed sachets or they may be hand-tied (Adegoke et al., 2012; Oludairo and Aiyedun, 2015). The commercial drinking water market is not effectively regulated, so the quality of these products is quite variable,as reported in Ghana (Adetunde et al., 2014; Oyelude and Ahenkorah, 2012), Nigeria (Anyamene and Ojiagu, 2014; Falegan et al., 2014; Isikwue and Chikezie, 2014; Thliza et al.,, 2015), and India (Gangil et al., 2013).

Low-quality water products may have both microbiological contamination and unacceptable levels of physical, chemical, and physicochemical parameters (Anyamene and Ojiagu, 2014; Gangil et al., 2013), so poor-quality drinking water products have the possibility of causing diarrheal disaeses and other adverse health effects. The World Health Organization (WHO, 2011) and other organizations have set parameters for assessing the quality of drinking water in terms of the maximum allowable concentrations of chemical, microbiological, and organic constituents in drinking water that will have no adverse effects on human health. Quality water is colourless, odourless, tasteless, not turbid, and has a pH range of 6.5 to 8.5. The total coliform count as measured in colony forming units (cfu) per 100ml of water is a measure of feacal contamination that is used in microbiological assessments. There should be no detectable coliforms in drinking water. Additionally, chemicals such as iron, nitrates, aluminium, residual chlorine, and fluorine are recommended for routine monitoring to ensure that their levels do not exceed the thresholds for safety established by experts.

In this study, different brands of commercial drinking water in Bo city Sierra Leone were tested for selected microbial, chemical and physicochemical parameters. The objective is to determine the safety of each brand by comparing each quality parameter to the World Health Organization's (WHO) recommended standards for water quality.

METHODS

Description of study area.
This study was conducted in Bo city, Southern Sierra Leone. Bo is the largest city in the country's Southern region. The city is spread over an area of more than 12 km^2, and it has a population ofapproximately 175,000 (SSL Census, 2015). The study protocol was approved by Njala University and the Bo District Health Management Team (DHMT) of the Ministry of Health and Sanitation. Data were collected between February and April 2015.

The number of sachet water manufacturing premises and hand-tied water vendors is not available from official sources since most of them operate illegally. A participatory geographic information system was developed and used in conjunction with distribution point and vendor census in the study area. The key informants were local water workers and commercial water factory operators. These informants identified a total of 36 water sources across Bo that were used for commercial water production. These include the six sources used by the production facilities for ten brands of machine-filled factory-produced water as well as the ten sources used by ten hand-tied plastic-bagged water producers. The ten factories were all registered, and they represent a 100% sample of registered water production facilities in Bo. The hand-tied water sachet producers were not registered as formal businesses, and it is therefore possible that the sample of ten producers did not include all of the informal water product producers in Bo. We received permission from watersource owners and factory managers or owners to collect water samples at each site. There were no identified sites where permission to enter the facility and collect a sample was not granted. A Garmin Global Positioning System (GPS) handheld unit was used to collect the geographical coordinates of these drinking water sources using ArcGIS (Ansumana et al., 2010) (Figure 1).

Sampling

Water samples from all 36 water sources were collected in one litre plastic containers sterilized with 10% nitric acid to prevent reduction or loss of target analytes (Jimmy et al., 2012). Water wells with hand pumps were operated to clear standing water in the water column, and the outlet pipes were sterilized with alcohol prior to sample collection.

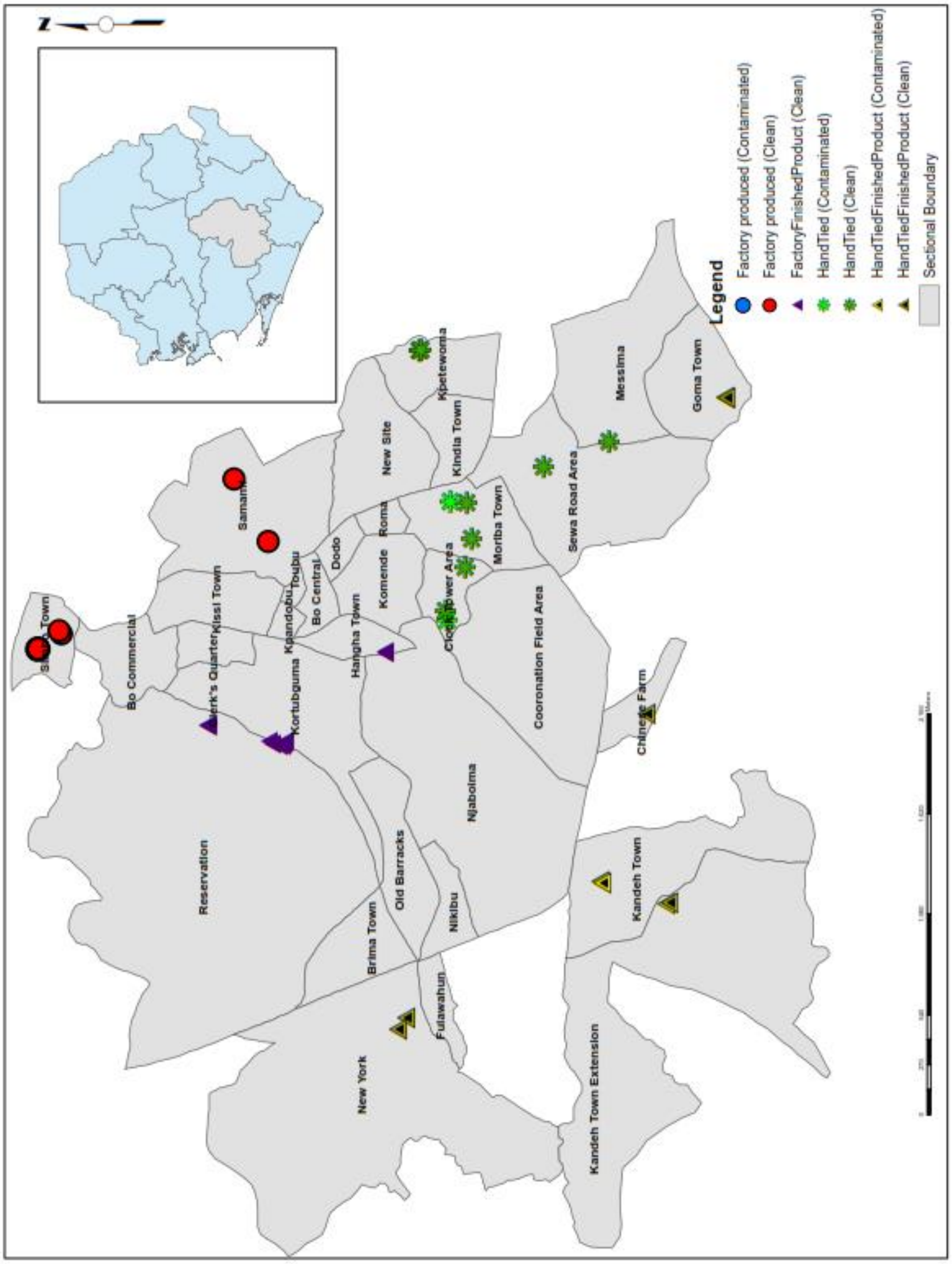

Figure 1: Location of water sampling sites within Bo city, Sierra Leone

A weight of a suitable size was sterilized and attached to sampling tubes with a piece of sterilized string to collect water from water wells without hand pumps. For tap water systems connected to boreholes via a reservoir, the faucet of the tapswere inspected and all forms of water leaks, aerators, strainers, and debris removed, then water was run for approximately 5 minutes before sample collection. Ten commercialwater products from factories and ten hand-tied products were purchased fromrandomly selected retail outlets and street vendors. Samples were preserved immediately upon collection with 10% HNO_3. The preserved samples were kept on ice packs to maintain a temperature of 4°C until analysis at the School of Community Health Sciences Laboratory of Njala University. The pH of the water samples were measured immediately after sampling. All other tests were completed within 5 days of sample collection.

Laboratory analysis.

All 36 samples were tested for faecal coliform and turbidity (NTU). Coliform levels in the water samples were determined by using the membrane-filtration technique with M-Lauryl Sulphate Broth as culture medium, and turbidity determined using a potalab photometer (Wagtech International, UK).Three volumes of water from each sample (10, 20, and 50 ml) were measured and filtered through a membrane filter with pore size 0.45 mm in the pre-sterilized filtration unit assembly to trap any bacteria present. The filters were then placed on top of sterile absorbent pads soaked in membrane-faecal-coliform broth in pre-sterilized petri dishes and incubated for 18 to 24 h at 44°C after a 60-min resuscitation period. The formation of blue colonies on the filters indicated faecal coliforms. These colonies were counted and expressed per 100 ml water sample.

Water conductivity, total dissolved solids (TDS), and pH were determined using a calibrated portable conductivity TDS meter (Model CON11, Wagtech International, UK) and a pH11 meter. Analytical water test tablets prescribed for the Potalab Photometer Wag-WE 10016 (Wagtech International, UK) series were used for analysing the concentration ferrous iron (Fe^{2+}), residual chlorine (Cl^{-}), and nitrite (NO^{2-}) based on the procedures outlined in the potalab Photometer Method. Ferrous iron was measured using the 1,10-phenanthroline method to prevent the oxidation of ferrous iron to ferric iron. The HACHferrous iron reagent powder pillow was added to a 25-ml water sample in the sample cuvette. After a 3 minute reaction time, the concentration of dissolved ion was measured at 255 and 510 nm. The quality of the packaged water samples was determined by comparing it with the national and World Health Organization (WHO) standards for packaged water (WHO, 2011).

Water handling practices. Ten workers at commercial water factories and ten vendors of hand-tied plastic-packaged water vendors were interviewed about their knowledges and practices of water handling.

RESULTS

None of the factory-produced water samples tested positive for coliform, even though all had water sources within 30 meters of the nearest toilet (Table 1). One spring box, a major source for most machine-filled factory-produced water, was found to be contaminated with faecal coliform (2/100ml); this was not only the primary water source for six of the ten factories, but also the only reliable drinking water source for the residential areas near the source, especially during the dry season. The use of sedimentation, coagulation, and filtration at water factories (as per the information provided by key informants as well as our direct observations of the factory facilities) may have been the reason why none of the purchased water products from those factories tested positive for coliform.

Table 1: Bacterial counts for factory-produced sachet water.

Sample or brand name	Type of water source	Distance from water source to packaging location (meters)	Distance from packaging location to nearest toilet (meters)*	Type of toilet	Faecal coliformcolony counts per 100 ml
Water source					
1	Spring box	-	12	Flush/Pit	2
2	Lined hand pump well	-	10	Pit	0
3	Lined hand pump well	-	5	Pit	0
4	Lined hand pump well	-	12	Pit	0
5	Spring box	-	18	Flush/Pit	0
6	Lined bore hole	-	30	Pit	0
Finished product**					
7	Spring box	15	12	Flush/Pit	0
8	Spring box	10	15	Flush/Pit	0
9	Spring box	12	11	Flush/Pit	0
10	Spring box	12	11	Flush/Pit	0
11	Spring box	12	11	Flush/Pit	0
12	Spring box	5	30	Flush/Pit	0
13	Lined hand pump well	3	10	Pit	0
14	Lined hand pump well	4	10	Pit	0
15	Lined hand pump well	7	12	Pit	0
16	Lined hand pump well	8	18	Pit	0

* The World Health Organization recommends a distance of at least 30 meters between a toilet and a water source to minimize the risk of faecal contamination of drinking water [WHO, 2011].
**Sample 7 = "Kuma", Sample 8= "Blue Diamond", Sample 9 = "Jah", Sample 10 = "Savelife", Sample 11 = "Sweetlife", Sample 12 = "National choice", Sample 13 = "Tex", Sample 14 = "Ramzam", Sample 15 = "Goodlife", Sample 16 = "Alkaosar"

Several of the hand-tied plastic-packaged water samples had faecal coliform (Table 2). All of these water sources were unlined wells within a few meters of the nearest toilet. These toilets may have been responsible for contaminating the groundwater sources that were pumpedto the water bagging areas. The coliforms in the purchased samples may have come from the water source or from the production process. Typically, an open-mouthed bucket or bowl is used to fetch tap water for bagging. Polythene films are opened either by rubbing them with bare hands or by blowing air into them by mouth. A cup is used to put the desired volume of water in the polythene film. The film is then sealed by tying a knot at the open end. This production process obviously leaves room for bacterial contamination at several stages. Cloth filters are used by some hand-tied water sachet producers, but this is not a sufficient method of purification.

Table 2: Bacterial counts for hand-tied sachet water.

Sample or brand name	Type of water source	Distance from water source to packaging location (meters)	Distance from packaging location to nearest toilet (meters)*	Type of toilet	Faecal coliform colony counts per 100 ml
Water source					
1	Unlined local well	-	6	Pit	5
2	Unlined local well	-	4	Pit	0
3	Lined hand pump well	-	11	Flush/Pit	0
4	Lined hand pump well	-	11	Flush/Pit	0
5	Lined hand pump well	-	11	Flush/Pit	0
6	Unlined local well	-	12	Pit	2
7	Lined hand pump well	-	20	Pit	0
8	Unlined local well	-	4	Pit	0
9	Unlined local well	-	4	Pit	1
10	Lined hand pump well	-	15	Flush/Pit	0
Finished product					
11	Unlined local well	50	8	Pit	5
12	Unlined local well	20	7	Pit	0
13	Lined hand pump well	100	8	Pit	0
14	Lined hand pump well	250	6	Pit	0
15	Lined hand pump well	130	4	Pit	0
16	Unlined local well	8	10	Pit	2
17	Lined hand pump well	300	6	Pit	0
18	Unlined local well	4	6	Pit	0
19	Unlined local well	120	4	Pit	1
20	Lined hand pump well	1200	6	Pit	0

* The World Health Organization recommends a distance of at least 30 meters between a toilet and a water source to minimize the risk of faecal contamination of drinking water [WHO, 2011].

Levels of nitrate and chlorine for all of the water samples were within the acceptable range, but none of the pH levels was in the acceptable range even though those values were taken immediately after collection. The other results of the water tests are summarized in Tables 3 and 4.

The interviews with commercial drinking water workers and vendors suggested that factory workers had higher levels of knowledge about water purification and better water storage and purification practices than hand-tied water sachet vendors (Table 5).

Table 3: Physicochemical properties of factory-produced sachet water.

Sample or brand name	TDS (mg/l)	Turbidity (NTU)	NO_2^- (mg/l)	Residual chlorine (mg/l)	Fe_2^+ (mg/l)	pH
Recommended levels from WHO [WHO, 2011]	--	<5	<3.0	<5	--	6.5 to 8.5
Water source						
1	105	2	0.07	0.18	0.02	4.79
2	102	4	0.09	0.31	0.00	5.49
3	90.0	0	0.04	0.31	0.01	5.40
4	90.0	0	0.04	0.31	0.01	5.40
5	101	0	0.20	0.08	0.00	4.73
6	24.3	0	0.05	0.20	0.04	5.00
7	24.3	0	0.05	0.17	0.00	4.57
8	63.4	5	0.05	0.17	0.04	4.63
9	84.5	4	0.02	0.16	0.01	3.80
10	28.0	2	0.08	0.20	0.04	5.26
Finished product						
11	160	2	0.07	0.70	0.02	4.79
12	240	4	0.09	0.93	0.00	5.49
13	143	0	0.04	0.81	0.01	5.40
14	158	0	0.05	0.63	0.02	5.30
15	380	0	0.20	0.09	0.00	4.73
16	440	0	0.05	0.94	0.04	5.00
17	370	0	0.05	1.14	0.00	4.57
18	63.4	5	0.05	0.17	0.04	4.63
19	610	4	0.02	1.28	0.01	3.80
20	280	2	0.08	0.90	0.04	5.26

Sample 7 = “Kuma”, Sample 8= “Blue Diamond”, Sample 9 = “Jah”, Sample 10 = “Savelife”, Sample 11 = “Sweetlife”, Sample 12 = “National choice”, Sample 13 = “Tex”, Sample 14 = “Ramzam”, Sample 15 = “Goodlife”, Sample 16 = “Alkaosar”

Table 4: Physicochemical properties of hand-tied sachet water.

Sample or brand name	TDS (mg/l)	Turbidity (NTU)	NO_2^- (mg/l)	Residual chlorine (mg/l)	Fe_2^+ (mg/l)	pH
Recommended levels from WHO [WHO, 2011]	--	<5	<3.0	<5	--	6.5 to 8.5
Water source						
1	44.2	0	0.02	0.23	0.03	4.55
2	26.1	4	0.03	0.26	0.05	4.43
3	26.1	6	0.04	0.60	0.04	4.43
4	63.4	4	0.02	0.36	0.05	4.04
5	17.1	6	0.01	0.25	0.05	4.66
6	47.6	2	0.03	0.05	0.02	4.56
Finished product*						
7	45.3	4	0.02	0.02	0.00	4.56
8	43.3	0	0.02	0.20	0.00	4.36
9	43.1	0	0.18	0.18	0.00	4.35
10	47.6	0	0.04	0.22	0.00	4.29
11	42.4	0	0.03	0.21	0.00	4.54
12	28.0	2	0.08	0.20	0.04	5.26
13	21.7	2	0.06	0.24	0.04	4.11
14	24.8	4	0.01	0.22	0.00	3.91
15	61.4	2	0.05	0.23	0.00	3.99
16	16.5	0	0.03	0.26	0.00	5.33

Sources 3 and 4 are the same location; source 8 and sample 8 are at the same location

DISCUSSION

The results of this study found that factory-produced sachet water in Bo is generally safe but that the quality of hand-tied water sachets is inconsistent. This conclusion was also reached by similar studies in Ghana (Oyelude and Ahenkorah, 2012) and Uganda (Halage et al., 2015), and was the conclusion of a systematic review of the global literature (Williams, 2015) on commercial drinking water safety. The hand-tying process introduces the risk of faecal and non-faecal coliform contamination from water workers (Oludairo, 2015). A study in Ghana examined ten water sachet brands and found that all of them had microbiological contamination (Ngmekpele, 2014).

Although the factory-produced water in our analysis was clean, that is not always the conclusion of water safety studies. Studies in Ghana (Adetunde et al., 2014; Oyelude and Ahenkorah, 2012) and Nigeria (Anyamene and Ojiagu, 2014; Falegan et al., 2014; Isikwue and Chikezie, 2014; Thliza et al., 2015) found that factory-produced water sachets were of poor quality.

Although the pH of water is not considered to be an immediate health issue, the acidity of the water can damage pipes and can release those minerals into wells, potentially causing serious health problems (WHO, 2011).A previous study of the water quality of wells in Bo that are used as residential drinking water sources found levels of acidity very similar to those observed in this study (Jimmy et al., 2012). Acidic water has also been reported from other parts of Africa, including Guinea-Bissau (Bordalo, 2007; Haruna, 2005), Ghana (Adomako, 2008; Fianko, 2010a; Fianko, 2010b), Nigeria (Nduka, 2011; Omezuruike, 2008), South Africa (Zamxaka, 2004), and Tanzania (Shayo, 2007).

One of the factors that may affect the safety and quality of water is the knowledge of water workers. In our study, factory workers had better knowledge than those working at hand-tied water facilities. Occupational health education may be important for protecting the health of the community.

CONCLUSION

In this study, twenty brands of commercial drinking water in Bo city Sierra Leone were tested for selected microbial and physicochemical parameters, and their values compared to the recommendations for quality drinking water from the World Health Organization's (WHO) recommended standards for water quality. In laboratory testing, all of the samples had values for physical parameters that were within the permissible range for turbidity and total dissolved solids. The chemical parameters for nitrate, residual chlorine, and iron were also within the required range in all samples. However, pH concentrations in all of the water samples were too acidic, and several of the hand-tied water products tested positive for microbial contamination. Although this study tested a limited number of water products, the findings are further evidence that hand-tied water sachets are frequently unsafe for human consumption due todue to poor treatment of the drinking waterprior to packaging.

While a low pH is not as immediately damaging to human health as consumption of faecal bacteria, acidic water does contribute to long-term adverse health effects. Acidic water can cause corrosion of the metal pipes used with wells, and when the lead and other minerals from those pipes leach into the water they carry and are then ingested as drinking water, they can cause chronic health issues (WHO, 2011). At present, this may not be a major concern in Bo since most residences are not connected to taps. However, it will be important to factor the acidity of local water into building plans for the future. Appropriatepiping materials will need to be used in water development projects to ensure that city water and sewer infrastructure can withstand the acidity in the water and the pipes in residential and commercial structures are also safe.

Improved monitoring and enforcement of good practices for packaging water sachets would improve health in Sierra Leone. It is also important to raise public awareness about the health risks associated with low-quality water products among water workers and consumers of commercial water products so that reliably safe, high-quality commercial water products can be produced and sold in Bo and other cities.

Table 5: Water handling practices.

	Factory-produced water (n=10)	**Hand-tied sachet water (n=10)**
What type of water storage vessel do you use?	Closed container (10)	Open container (6) Closed container (4)
How long do you store water before packaging?	Less than one day (10)	Less than one day (10)
Do you have any knowledge about why water must be purified before it is consumed?	Yes (10)	Yes (3) No (7)
How do you purify the water before packaging it?	Yes, with a variety of methods (10)	Yes, with cloth filtration (8) No (2)
Do you wash your hands before packaging water?	Yes (10)	Yes (10)

REFERENCES

Adomako D, Nyarko BJ, Dampare SB, Serfor-Armah Y, Osae S, Fianko JR, et al. Determination of toxic elements in waters and sediments from River Subin in the Ashanti Region of Ghana. *Environmental Monitoring and Assessment*. 2008; 141: 165-175.

Adetunde LA, Sackey I, Elvis BB, Afarawoye AE. Bacteriological quality of sachet water produced and sold in the Bolgatanga Municipal in the Upper East Region of Ghana. *International Journal of Modern Social Sciences*. 2014; 3:36-43.

Adegoke OO, BamigbowuEO, Oni ES, Ugbaja KN. Microbiological examination of sachet water sold in Aba, Abia State, Nigeria. *Global Research Journal of Microbiology.* 2012: 62-66.

Anyamene NC, Ojiagu DK. Bacteriological analysis of sachet water sold in Akwa Metropolis, Nigeria. *International Journal of Agriculture and Biosciences*. 2014; 3: 120-122.

Ansumana R, Malanoski AP, Bockarie AS, Sundufu AJ, Jimmy DH, Bangura U, Jacobsen KH, Lin B, StengerDA. Enabling methods for community health mapping in developing countries. *International Journal of Health Geographics*. 2010; 9:56.

Ansumana R, Jacobsen KH, Gbakima AA, Hodges MH, Lamin JM, Leski TA, Malanoski AP, Lin B, Bockarie MJ, Stenger DA. Presumptive self-diagnosis of malaria and other febrile illnesses in Sierra Leone. *Pan African Medical Journal*. 2013; 15: 34.

BordaloAA, Savva-Bordalo J. The quest for safe drinkingwater: an example fromGuinea-Bissau (WestAfrica).*Water Research*. 2007; 41: 2978-2986.

Falegan CR, Odeyemi AT, Ogunjobi LP. Bacteriological and physico-chemicals studies of sachet water in locations at Ado-Ekiti, Ekiti State. *Aquatic Biology*. 2014: 55-61.

Fianko JR, Adomako D, Osae S, Ganyaglo SS, Kortatsi BK, TayCK, et al. The hydrochemistry ofgroundwater in the Densu River Basin, Ghana. *Environmental Monitoring and Assessment* 2010a;167: 663-674.

Fianko JR, NarteyVK, Donkor A. The hydrochemistry of groundwater in rural communities within theTema District, Ghana. *Environmental Monitoring and Assessment* 2010b; 168441-449.

Haruna R, Ejobi F, KabagambeEK. The quality of water from protected springs in Katwe and Kisenyi parishes, Kampala city, Uganda. *African Health Sciences*. 2005; 5: 14-20.

Gangil R, Tripachi R, Patyal A, Dutta P, Mathur KN. Bacteriological evaluation of packaged bottled water sold at Jaipur city and its public health significance. *Veterinary World.* 2013: 6: 27-30.

Halage AA, Ssemugabo C, Ssemwanga DK, Musoke D, MugambeRK, Guwatudde D, Ssempebwa JC. Bacteriological and physical quality of locally packaged drinking water in Kampala, Uganda. *Journal of Environmental and Public Health*. 2015; 2015: 942928.

Isikwue MO, Chikezie A. Quality assessment of various sachet water brands marketed in Bauchi metropolis of Nigeria. *International Journal of Advances in Engineering and Technology*. 2014; 6: 2489-2495.

Jacobsen KH, Ansumana R, Abdirahman HA, Bockarie AS, Bangura U, Meehan KA, Jimmy DH, Malanoski AP, Sundufu AJ, Stenger DA. Considerations in the selection of healthcare providers for mothers and children in Bo, Sierra Leone: reputation, cost, and location. *International Health*. 2012; 4:307-313.

Jimmy DH, Sundufu AJ, Malanoski AP, Jacobsen KH, Ansumana R, Leski TA, Bangura U, Bockarie AS, Tejan E, Lin B, Stenger DA. Water quality associated public health risk in Bo, Sierra Leone. *Environmental Monitoring and Assessment*. 2013; 185:241-251.

Maduka HCC, Chukwu NC, Ugwu CE, Dike CC, Okpogba AN, OguechePN, Maduka AA. Assessment of commercial bottled table and sachet water commonly consumed in Federal University of Technology, Owerri (FUTO), Imo State, Nigeria using microbiological indices. *Journal of Dental and Medical Sciences*. 2014; 13: 86-89.

NdukaJK, Orisakwe OE. Water-quality issues in the Niger Delta of Nigeria: a look at heavy metal levels and some physicochemical properties. *Environmental Science and Pollution Research*. 2011;18: 237-246.

Ngmekpele BS, Hawkins J. Sachet water quality in Obuasi, Ashanti region, Ghana. *Journal of Biology, Agriculture and Healthcare*. 2014; 4: 37-42.

OludairoOO, Aiyedun JO. Contamination of commercially packaged sachet water and the public health implications: an overview. *Bangladesh Journal of Veterinary Medicine*. 2015; 13: 73-81.

Omezuruike OI, Damilola AO, Adeola OT, Fajobi EA, Shittu OB. Microbiological and physicochemical analysis of different water samples used for domestic purposes in Abeokuta and Ojota, Lagos State, Nigeria. *African Journal of Biotechnology*. 2008;7: 617-621.

OyeludeEO, Ahenkorah S. Quality of sachet water and bottled water in Bolgatanga municipality of Ghana. *Research Journal of Applied Sciences, Engineering and Technology*. 2012; 4: 1094-1098.

Shayo NB, ChoveBE, Gidamis AB, Ngoma OB. The quality of water in small community supplies of Kingolwira village, Morogoro, Tanzania. *Tanzania Health Research Bulletin* 2007; 9: 56-60.

Thliza LA, Khan AU, Dangora DB, Yahaya A. Study of some bacterial load of some brands of sachet water sold in Ahmadu Bello University (Main Campus), Zaria, Nigeria. *International Journal of Current Science*. 2015; 14: 91-97.

Williams AR, Bain RES, Fisher MB, Cronk R, Kelly ER, Bartram J. A systematic review and meta-analysis of fecal contamination and inadequate treatment of packaged water. *PLoS ONE*. 2015; 10: e0140899.
World Health Organization (WHO). *Guidelines for drinking water quality* (4th edition). Geneva: WHO; 2011.

Zamxaka M, Pironcheva G, MuyimaNYO. Microbiological and physico-chemical assessment of the quality of domestic water sources in selected rural communities of the Eastern Cape Province, South Africa. *Water SA*. 2004; 30: 333-340.