Research Article

An assessment of the potability of some sachet water brands sold in Cameroon

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ABSTRACT

Analysis of the microbial and physico-chemical qualities of 14 sachet water brands sold in Cameroon was carried out aimed at determining their potability based on World Health Organization (WHO) recommendations. Similar analyses of water samples from the respective sources were used to compare the quality of the water at source and in the sachets in an attempt to identify potential sources of contaminants in each sachet where appropriate. The most probable number method was used to determine the total coliforms in the water while eosine methylene blue (EMB) agar was used for the detection of faecal coliforms and to differentiate *Escherichia coli* from other gram-negative pathogens present in the water samples that showed the presence of coliforms. The physical parameters examined were pH, electrical conductivity (EC), and the total dissolved solids (TDS) using a ++WTW 315i pH meter and a Cond 330i/set, while total suspended solids (TSS) were determined by filtration, and alkalinity determined by titration using hydrochloric acid. The following major ions were determined using ion chromatography: Na^+, K^+, Mg^{2+}, Ca^{2+}, F^-, Cl^-, NO_3^-, PO_4^{3-}, $SO_4^{2-}$and HCO_3^-. The results indicated that the pH, TSS, EC, TDS fell within the WHO limits for potable water. The main water types were Ca-Mg-HCO_3, Na-K-SO_4-Cl and Na-K-HCO_3 with 50% of the samples clustered in the Ca-Mg-HCO_3 zone and the rest in the Na-K-SO_4-Cl (30%) and in the Na-K-HCO_3 (20%) zones. The major ions in all water samples were Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^- and HCO_3^- and their presence was shown to be primarily attributable to the natural geological conditions of the water sources. Although results of the physico-chemical analyses were indicative of acceptable limits for potability, the results of microbial analysis indicated that about 85 % of the brands tested were microbially unsuitable for consumption. The health implications of these results call for further assessment of the policy and management of the sachet water industry in the country.

Key words: sachet water, potability, physico-chemical, microbial, quality.

Résumé

L'analyse des qualités physico-chimiques et bactériologiques de l'eau des différentes marques vendues au Cameroun a été menée avec pour objectif de déterminer la potabilité de cette eau sur la base des recommandations de l'Organisation mondiale de la santé (OMS). Nous avons effectué des analyses similaires des échantillons d'eau issus des différentes sources respectives afin de comparer la qualité de l'eau à la source et dans les sachets en essayant éventuellement d'identifier les sources potentielles de contaminants dans chaque sachet. Nous avons eu recours à la méthode du nombre le plus probable afin d'énumérer les coliformes totaux contenus dans l'eau tandis que la gélose éosine-bleu de méthylène (EMB) a été utilisée pour détecter la présence des coliformes fécaux, et pour différentier l'*Escherichia coli* d'autres agents pathogènes à Gram négatif présents dans les échantillons d'eau, échantillons qui ont montré la présence des coliformes. Les paramètres physiques tels que le pH; la conductivité électrique et les matières dissoutes totales (MDT) ont été examinés à l'aide d'un pH-mètre de type ++WTW 315i et d'un conductimètre de type Cond 330i/set. La quantité de matières solides totales en suspension, quant à elle, a été déterminée par filtration tandis que l'alcalinité a été déterminée par titrage à l'aide d'acide chlorhydrique. Les principaux ions tels que le Na^+, K^+, Mg^{2+}, Ca^{2+}, F^-, Cl^-, NO_3^-, PO_4^{3-}, SO_4^{2-} et le HCO_3^- ont été déterminés à l'aide de la chromatographie ionique. Les résultats ont révélé que les gammes de mesure pH, TSS, CE et de MDT restent conformes aux limites fixées par l'OMS en matière d'eau potable. Les principaux types d'eau étaient le Ca-Mg-HCO_3, Na-K-SO_4-Cl et le Na-K-HCO_3 avec 50% de l'échantillon regroupé dans la zone Ca-Mg-HCO_3 et le reste était regroupé dans les zones Na-K-SO_4-Cl (30%) et Na-K-HCO_3 (20%) respectivement. Les principaux ions dans tous les échantillons d'eau étaient le Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^- et le HCO_3^-. Il a été prouvé que leur présence est due principalement aux conditions géologiques naturelles des sources d'eau. Bien que les résultats de l'analyse physico-chimique étaient révélateurs des limites acceptables en matière de potabilité, les résultats de l'analyse microbiologique ont révélé que les eaux en sachet appartenant à douze marques étaient impropres à la consommation tandis que seules celles de deux (02) marques étaient exemptes de toute contamination bactérienne. Les implications de ces résultats au plan de la santé commandent une évaluation approfondie des politiques de gestion relatives à l'industrie de l'eau en sachet du pays.

Mots clés: Marques d'eau en sachet, potabilité, propriétés physico-chimiques, qualité bactériologique, principaux ions, gélose éosine-bleu de méthylène

Introduction

In recent years, access to safe and reliable water supplies has received increased government attention from around the world. In Cameroon in particular, access to an improved water supply remains a major concern with less than 30 % and 40 % of the population having access to potable water in urban and rural areas respectively (Missions Economiques, 2005; Totouom, 2012). The sale and consumption of packaged water in sachets continues to grow rapidly in most countries of the world and studies of its potability have been found to be uncertain as the water is collected from a range of sources from rainwater to tanker-borne water such as streams, pipe borne water, most of which according to Dibua *et al.*, (2007), are rusty and unwashed.

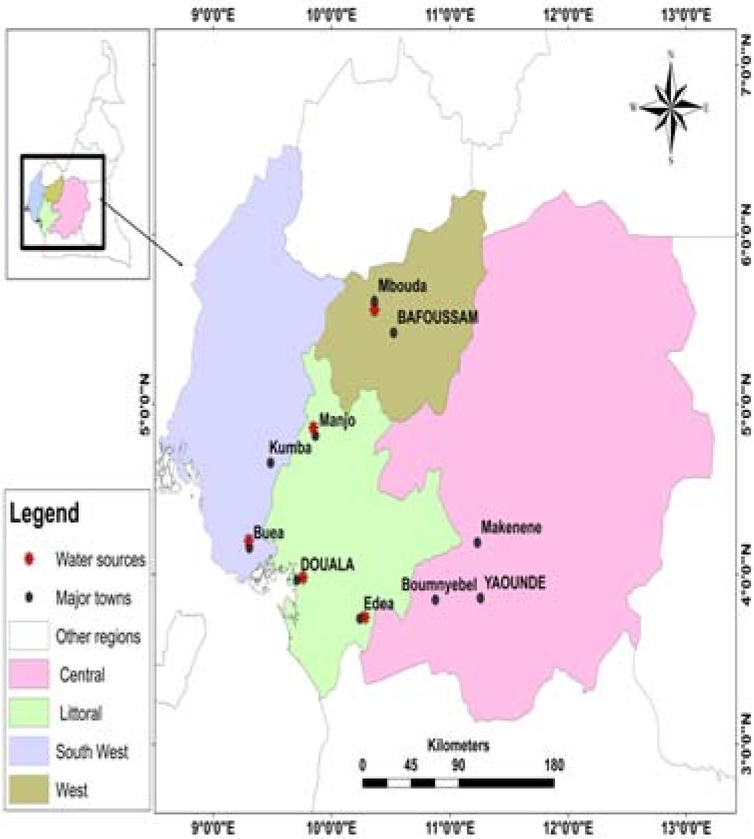
The ever increasing proliferation of sachet and bottle water companies in the country has given rise to all sorts of packaged water products on the market. Most of the water sachet brands are unregistered and not certified by the regulatory agencies. According to Dodoo *et al.* (2006), some producers of sachet water in Ghana even package untreated water into bottles and sachets and sell them labelled as purified water. The continuous increase in the sale and indiscriminate consumption of such sachet water with uncertain quality is accordingly a public health concern. In fact, consumer confidence in the industry which used to be very high is gradually being eroded by the quality mishaps, especially with regards to their health risks (Dodoo *et al.*, 2006).

Research conducted in other countries such as Nigeria and Ghana, showed that most of the sachet water brands fell below WHO drinking water standards and were therefore of doubtful quality (e.g. Egwari *et al.*, 2005, Ezeugwunne *et al.* 2009, Addo *et al.*, 2009; Ackah *et al.*, 2012, Abua *et al.*, 2012) but regrettably, no such work has ever been carried out on any of the more than fourteen sachet water brands which have been sold in Cameroon during the last decades. Oyebog *et al* (2012) investigated the hydro-geochemical characteristics of some Cameroon bottled water but failed to evaluate their microbial quality which is even more important in assessing the potability of water due to the health risks associated with microbial contamination. Furthermore, the sale of bottled water in the country is controlled by regulations while the sachet water industry is not regulated yet and therefore poses a health threat to the population.

It is for these reasons that the present study was carried out to assess the physico-chemical and microbial quality of sachet water produced and sold to the public in nine towns (Buea, Douala, Edea, Mboumyebel, Yaounde, Makenene, Bafoussam, Mbouda, and Manjo) located within the Central Region with metamorphic rocks, South-West and Western Regions with volcanic rocks, and the Littoral Region with sedimentary rocks (figure 1). The selection of these towns was based on the availability of sachet water sold in these localities and elsewhere.

Materials and Methods

Field work was carried in nine (9) towns (figure 1) within the months of March, April and May 2014 during the transition between the dry and rainy seasons. It involved collecting fourteen (14) different water sachet brands from street vendors and sampling the water sources of six (6) of the sachet water brands. This was because barely six of the water sources were identified based on interviews with producers, hawkers, and the indigenes, and also based on the accessibility of the sources. Each of the sachet water brands (e.g. X) was later codified using the subscripts X_1 and X_2 for water from sachet and samples collected directly from the water source respectively. The water sachets for each brand were then emptied directly into sterilised plastic bottles (1500 ml and 500 ml) after thorough rinsing and labelled appropriately for microbial and physico-chemical analyses and the same procedure used for the water collected directly from the sources.



Source: MINEPAT, 2012.

Fig 1: Map of study area showing major towns used in the present study.

Analysis for microbial quality

The most probable number (MPN) technique which involves the use of the Presumptive Test method to see if the water samples contained any lactose fermenting bacteria that produce gas was used to enumerate the coliforms present in the water samples (American Public Health Association, 1985). Eosin methylene blue (EMB) agar plates were streaked with the appropriate bacterial culture collected from the positively tested tubes with the aid of an inoculating loop using the quadrant streak plate method. The petri dishes were then incubated in an inverted manner aerobically at 37 ^{0}C for 48 hours and examined for the appearance of green metallic sheen colonies which, if observed, is an indication of the presence of *Escherichia coli* in the water. EMB agar was used to differentiate *Escherichia coli* from other gram-negative pathogens present in all the water samples that showed the presence of coliforms.

Physico-chemical analysis

Physical parameters analyzed for included the pH, electrical conductivity (EC), and total dissolved solids (TDS) using a ++WTW 315i pH meter and a Cond 330i/set while total suspended solids (TSS) were determined by filtration and weighing as described by ASTM (1999). Alkalinity (in which dissolved bicarbonate and carbonate concentrations are deducted) was determined by titration using hydrochloric acid (U.S. Geological Survey, 2012). The bicarbonate ion in the water samples was determined from alkalinity using the following equation:

$$[HCO3] = (\text{alkalinity} \times 61) \div 1000$$

Major cations (Na^+, K^+, Mg^{2+}, Ca^{2+}) and major anions (Cl^-, F^-, NO_3^-, PO_4^{3-}, SO_4^{2-}) were assayed by ion chromatography (Small *et al.*,1975). The identity of the cations and anions was determined by their retention times while their concentrations were determined by preparing a calibration curve from a standard solution containing known concentrations of all the ions of interest. The devices used were the ICS-90 and ICS-1100 Dionex models which are an isocratic delivery system (Small *et al.*, 1975).

The R-statistical package version 3.0.0 was used for generating the descriptive data and analyzing data in the various statistical relationships between experimental variables. A complete t-test was used to establish variations between sachet water and their sources. A non-parametric Wilcoxon signed rank test was used when conditions for a parametric test (t-test) were not fulfilled.

Results

Microbial quality

The microbial analysis showed that total coliform numbers based on the most probable number (MPN) ranged from 9 to >4800 (per 100 ml) with the highest count occurring in samples A_1, A_2, B_2, E, I and K while the lowest count was recorded in samples $D_1$and G with faecal coliform (*Escherichia coli*) present in most of the water samples as indicated in Table 1 in which the WHO recommended values are also indicated for comparison. Unlike their sources, most brands were seen to be free from contamination with faecal coliforms. It was also noticed that all six (6) water sources investigated contained higher concentrations of total coliforms than in their corresponding sachet water brands (table 1).

Table 1: Results of microbial analysis of the various water samples (WHO limit is 0/100ml)

Sachet brand codes	MPN index per 100ml	95% confidence limit		Presence of *Ecoli*
		Lower limit	Upper limit	
1. A_1	1100	150	4800	Present
2. A_2	>1100	150	>4800	Present
3. B_1	460	71	2400	Present
4. B_2	1100	150	4800	Present
5. C_1	23	4	120	Absent
6. C_2	43	7	210	Present
7. D_1	<3	<0.5	9	Absent
8. D_2	240	36	1300	Absent
9. E_1	1100	150	4800	Absent
10. E_2	93	15	380	Present
11. F_1	4	<0.5	20	Absent
12. F_2	460	71	2400	Present
13. G	<3	<0.5	9	Absent
14. H	240	36	1300	Absent
15. I	>1100	150	>4800	Present
16. J	43	7	210	Absent
17. K	1100	150	4800	Present
18. L	150	30	440	Present
19. Mr	75	14	230	Present
20. N	150	30	440	Present

Table 2: Results of analyses of physico–chemical parameters

Sachet brand codes	pH	Cond	TDS	Alk	TSS	Na^+	K^+	Mg^{2+}	Ca^{2+}	F^-	Cl^-	NO_3^-	PO_4^{3-}	SO_4^{2-}	HC
		µS/cm	*mg/l*	*µEq/ml*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	mg/l	*n*
A_1	7.86	198	113	2064	6.6	10.09	9.79	9.79	18.49	0.06	0.23	0	0.09	0.06	12
A_2	7.21	199.7	114	2046	8.2	10.55	2.86	9.32	18.43	0.07	0.39	0.04	0	0.16	12
B_1	4.53	25	15	0	2.6	2.32	0.3	0.11	0.16	0.05	2	7.49	0	1.5	
B_2	4.88	12.6	7.0	0	18.6	2.39	0.41	0.96	1.36	0.04	3.05	1.04	0	1.98	
C_1	5.51	19.2	11	50	4.2	0.4	0.6	0.09	0.3	0.04	0.51	1.42	0	0.59	3
C_2	6.47	57.8	33	448	4.6	9.54	0.37	0.65	1.63	0.02	0.57	1.26	0	1.74	2
D_1	7.6	99	56	987	6.2	1.81	0.87	2.99	11.78	0.15	0.13	0.05	0.18	0.94	6
D_2	7.14	99.1	56	952	4.2	2.17	1.36	1.21	3.1	0.15	0.15	0	0.05	1.05	5
E_1	7.0	29	16	31	2.9	1.48	1.22	0.76	1.45	0.15	1.44	0.53	0	7.32	
E_2	6.78	24.7	14	41	2	1.48	1.22	0.72	1.27	0.09	1.07	0.73	0	5.36	
F_1	7.51	79.4	45	1044	7.6	3.9	1.03	2.72	7.08	0.07	1.32	1.04	0	0.28	6
F_2	7.25	101	58	498	8	5.58	337	2.73	6.92	0.28	2.59	25.68	0	1.74	3
G	4.53	12.8	7.0	0	6.8	0.4	0.18	0.13	0.2	0.07	0.41	0.25	0	0.14	
H	7.24	125.8	72	502	4	3.68	2.11	1.4	16.27	0.07	0.25	0	0.05	0.12	3
I	7.52	319	182	1768	16.2	21.87	12.45	10.08	21.89	0.07	0.59	0	0.04	0.08	107
J	6.83	260	148	133	4.2	20.2	9.29	1.1	11.69	0.34	9.9	61.14	0	0	
K	5.98	45.2	26	118	1.5	3.59	0.89	1.09	2.49	0.15	0.13	0.05	0.18	0.94	
L	6.16	26	15	123	4.2	1.1	0.43	0.46	2.39	0.05	1.26	5.63	0	0.48	
M	7.05	46.6	27	278	4.6	3.99	0.91	0.9	2.33	0.06	1.3	1.34	0	6.02	
N	7.15	45.3	26	259	3.6	1.91	0.89	3.25	11.32	0.19	3.35	13.1	0	2.65	1

Hydro-geochemical facies of the water

Results of analyses of physico-chemical parameters (Table 2) indicated the main water types of all sachet water brands analyzed being Ca-Mg-HCO_3, Na-K-SO_4-Cl and Na-K-HCO_3 with 50% of the samples clustered in the Ca-Mg-HCO_3 zone and the rest in Na-K-SO_4-Cl (30%) and Na-K-HCO_3 (20%) zones (figure 2). The Ca-Mg-HCO_3 water types express mineral dissolution (probably secondary carbonate and silicate minerals) during time of recharge of freshwater (Garrels and Mackenzie, 1967). The principal water type (Na-K-SO_4-Cl, Ca-Mg-HCO_3 and Na-K-HCO_3) presented in Figure 2 depicts water-rock interaction involving the dissolution of plagioclase and other alumino-silicate minerals (pyroxenes and hornblende) by the recharging groundwater, followed by cation exchange. All the six (6) water sources analysed showed similar water types as seen in their respective sachet brands except for C_1 brand (table 3).

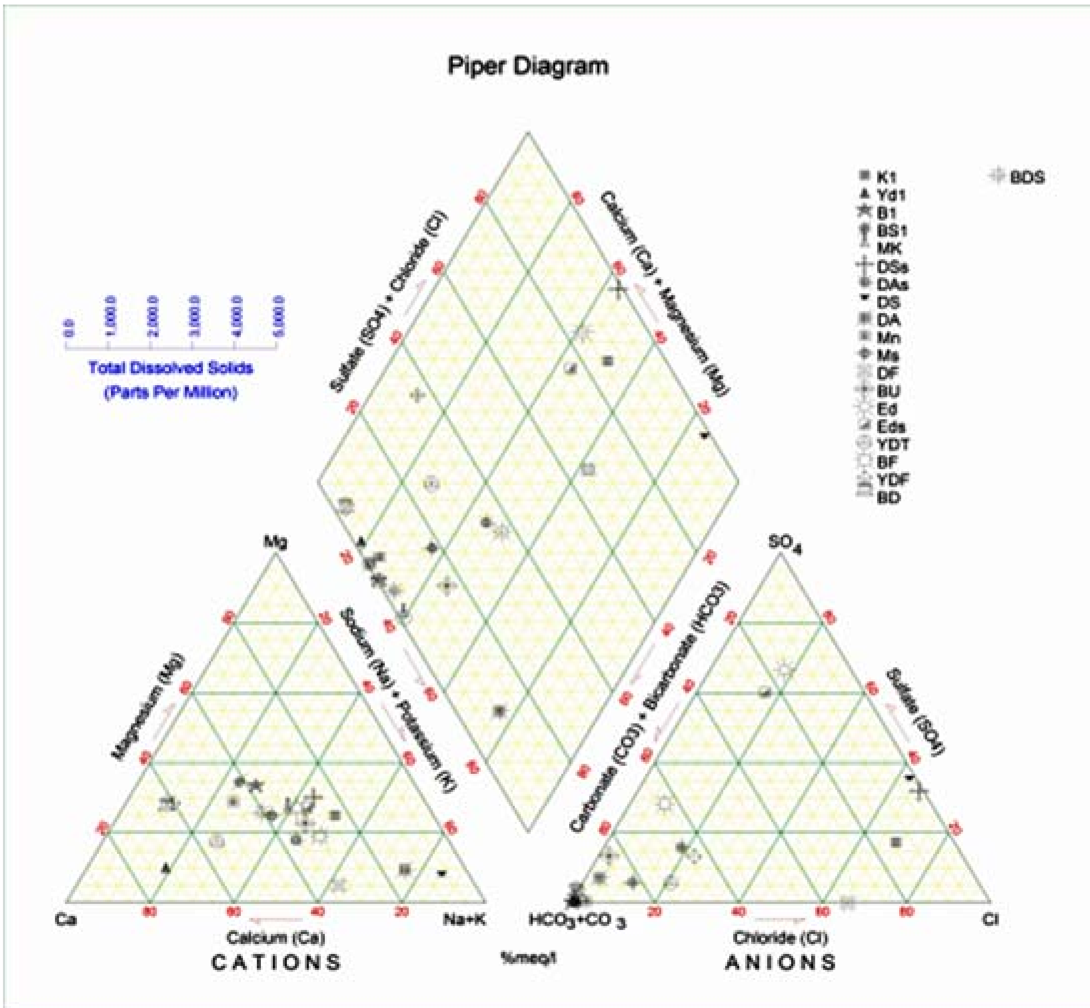


Figure 2: Piper's diagram showing the various water types of all the water samples sampled.

Table 3: Various water types for sachet water brands and of their equivalent sources

Sachet water brands	Sachet water type	Source water type
A_2	$Ca\text{-}Mg\text{-}HCO_3$	$Ca\text{-}Mg\text{-}HCO_3$
B_2	$Na\text{-}K\text{-}Cl\text{-}SO_4$	$Na\text{-}K\text{-}Cl\text{-}SO_4$
C_2	$Na\text{-}K\text{-}HCO_3$	$Ca\text{-}Mg\text{-}HCO_3$
F_2	$Ca\text{-}Mg\text{-}HCO_3$	$Ca\text{-}Mg\text{-}HCO_3$
E_2	$Na\text{-}K\text{-}SO_4\text{-}Cl$	$Na\text{-}K\text{-}SO_4\text{-}Cl$
D_2	$Ca\text{-}Mg\text{-}HCO_3$	$Ca\text{-}Mg\text{-}HCO_3$

Discussion of the results

Although the WHO guidelines recommend the complete absence of microbial indicators in any 100 ml of drinking water, (WHO, 2011) this study recorded very high numbers of total and faecal coliforms (*E.coli*) indicating very high bacterial contamination levels in most of the water samples, hence rendering these sachet water brands unsuitable for drinking. This is similar to results of studies in Nigeria by Adekunle *et al.* (2004) in Ibadan, Ezeugwunne *et al.* (2009) in Nnewi, and by Oladipo *et al.* (2009) in Ogbomoso, who equally found bacteria in sachet water in these localities. Also, Addo *et al.* (2009) in a study of bacteriological quality of sachet water produced and sold in Teshie-Nungua suburbs of Accra, Ghana detected faecal coliforms and *Escherichia coli* which according to them, were attributed to poor treatment and handling methods within the sachet water producing facility.

The presence of these bacteria in most brands of the sachet water in the present study might have been due to contamination of the water from source as equally explained by Okonko *et al.,* (2008) and Taulo *et al.,* (2008). The high concentration of total coliforms in some sachets compared to that of their respective sources could be as a result of improper and unhygienic handling, processing and purification procedures during and after packaging. It may also be attributed to one or more of the following conditions: contamination of water by organisms harbored in connecting tubes to the packaging machines, lack of or poor quality control systems, and poor treatment mechanisms. In fact, Egwari *et al.* (2005) in their study of the bacteriology of sachet water sold in Lagos reported that organisms contained in waste water of defrosted ice in pails and wheelbarrows were inevitably the source of contaminants on the sachet surface. On the other hand, the low concentrations in some water from sachets compared to their respective sources could be due to the fact that the sachet water underwent some form of treatment in order to reduce the microbial load before being packaged as might have been the case with the sachet brand D_1.

The detection of coliform bacteria, subsequently confirmed by the presence of *E.coli,* is a strong indication that some of the sachet water samples had been subjected to faecal contaminations. The possible health hazard of drinking such contaminated or poorly treated water is high, as water related diseases continue to be one of the major health problems globally (Oladipo *et al.*, 2009). In fact, the transmission of water-borne diseases is still a major public health concern despite considerable efforts and modern technology being utilized for the production of safe drinking water (Zamberlan *et al.*, 2008). However, some of the sachet water brands, as in the case of sachet brands G and D_1, are potable. With regards to the physico-chemical properties, the pH of the 20 water samples analyzed was within the range of 6.5 to 8.5 (table 2) which, according to Diawuo (2011); Ackah *et al.* (2012); Taiwo *et al.* (2012) and Devangee *et al.* (2013) falls within the WHO limit for potable water (WHO, 1997). The slight differences in the pH of the various samples may be due to the characteristics of the source waters influenced by both natural (e.g. geology) and anthropogenic factors. Although the pH of drinking water has no direct health effects, its level below and above certain limits could indirectly affect its potability. The levels of TSS which ranged from 2.00 to 18.6 mg/l with the highest value occurring at the B_2 source (Douala), with a value of 18.6 mg/l which was considerably lower than the WHO recommended guideline value of 20 mg/l (WHO, 1997), were generally low in all of the water samples.. Low values or the complete absence of TSS in water is indicative of adequate filtration prior to packaging.

The values of conductivity for the various water samples fell below the WHO guideline limit of 250Us/cm except for the F_2 with a slightly higher conductivity of 260Us/cm (table 2). Conductivity increases as the concentrations of ions in water increases and according to Shalom *et al.*, (2011), it serves as an indication of the TDS in the water whose concentrations were far below the WHO recommended values for drinking water quality (table 2). Ahimah and Ofosu (2012) and Oyebog *et al.* (2012) also observed low TDS concentrations in sachet water samples in Ghana and in bottled water sold in Cameroon respectively. The palatability of water with TDS level of less than 600 mg/l is generally considered to be good, whereas drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l (WHO, 2011).

The alkalinity values ranged from 0.00 to 2064 mg/l when compared to the WHO limit of 500mg/l (table 3). The sachet brands B_1 and G showed alkalinity value of 0.00 mg/l (of $CaCO_3$) while the highest alkalinity values were recorded for sachet water brands A_1, F_1, J, D, and H. The alkalinity values of the water at their sources corresponded with those in their respective sachets except for C_1 with 448mg/l and 50mg/l at source and in the sachet respectively. There is a direct relationship between alkalinity and pH and the alkalinity of water has no WHO recommended health standards although concentrations between 30 to 400 mg/l (of $CaCO_3$) is preferred for potability while excess alkalinity gives unpalatable taste (Goel, 2006; Orewole *et al.*, 2007; Shalom *et al.*, 2011; Ackah *et al.*, 2012).

The concentration of sodium recorded in all the water samples was relatively negligible with a range of 0.400 to 21.87 mg/l. The highest value of 21.87 mg/l occurred for sachet brand I, and then reduced to 0.400 mg/l for both G and C_2. It was also observed that the concentration of sodium at the various sources was higher than that found in their respective sachet water. These values were far below the WHO recommended values of 200mg/l for drinking water. A high concentration of sodium in drinking water has been shown to impact on taste, with the taste threshold dependent on the associated anion and the temperature of the solution. At room temperature, the average taste threshold for sodium is about 200 mg/l (WHO, 2011, Ackah *et al.*, 2012). The concentration of potassium ranged between 0.060 and 12.45 mg/l, with the highest value occurring in sachet brand I and the lowest in C_1. Potassium occurs naturally in the environment and in all natural waters and there has not been any evidence that suggests the need for establishing a health-based guideline value for potassium (WHO, 2011; Ackah *et al.,* 2012).

The concentrations of calcium ranged from 0.16mg/l for sachet brand B_1 to 21.89mg/l for sachet brand I and these values are far below the WHO value of 250mg/l. Generally, a higher concentration of calcium is usually observed for water from sedimentary terrains but in the present study, the values for the B1 source and its sachet brand showed the lowest values. This exceptionally low concentration of calcium but high sodium concentration may be an indication that the source water might have undergone natural softening by cation exchange whereby clays exchange sodium for both calcium and magnesium (Oyelude and Ahenkorah, 2012).

For Magnesium, the highest concentrations were recorded for sachet brand I (10.08 mg/l) and from sachet brand A_1 (9.79 mg/l) although these values are still far below the 150mg/l recommended by the WHO. A high concentration of magnesium is generally observed in water from volcanic terrains due to the presence of magnesium rich minerals such as olivine and pyroxenes. According to Health Canada (2009), the presence of magnesium in natural waters is as a result of weathering of ferromagnesian minerals, igneous rocks, and sedimentary rocks made up of magnesium carbonates.

The fluoride levels in all the samples analyzed were found to be about 0.1 mg/l. This is below the WHO suggested guideline value which ranges from 0.5 mg/l to 1.5 mg/l. Flouride is a recommended essential substance in water for building healthy teeth when up to 1 mg/l. It is beneficial particularly to infants and young children for calcification of dental enamel when present within the WHO (2011) permissible range of 0.5 to 1.5 mg/l (Kumar *et al.*, 2007; Oyelude and Ahenkorah, 2012).

The chloride concentration ranged from 0.13 to 9.90 mg/l which is far below the general threshold taste concentration of about 250 mg/l recommended by the WHO and therefore safe for drinking. According to the WHO (2011), even though the presence of chloride ions has no health based guideline value, higher concentrations (of about 250 mg/l) may give rise to detectable salty taste which may be unpleasant to some consumers.

The highest nitrate concentration of 61.14 mg/l was recorded in sachet brand J while the rest of the sachet water brands indicated concentrations far below the WHO recommended maximum concentration of 50mg/l. This high concentration in Douala may be from anthropogenic sources such as sanitary waste from human and animal sewage or from agricultural run-offs. According to WHO (1998), concentrations above 50mg/l can result in methaemoglobinaemia in infants.

Sulphate concentrations ranged from 0.00 for sachet water brand J to 7.32 for E_1 and this is far below the WHO recommended concentration of 100mg/l. All samples are accordingly safe for drinking especially as sulphate ions, just like chloride ions, are found in almost all natural waters.

With regards to phosphate, its concentration in all samples was negligible ranging from 0.00 to 0.180 mg/l with the highest concentration occurring in D_1 and in K. Health wise, phosphate is non-toxic to both animals and people unless it occurs in very high amount and in such a situation, can result in digestive problems (Kotoski, 1997; Diawuo, 2011). Bicarbonate is the most dominant anion in the water samples (table 2) probably because of the reaction of atmospheric and soil carbon dioxide with water and from carbonate dissolution. It was noticed that some sources contained either higher or lower concentrations of bicarbonate when compared to their equivalent sachet water brands.

It is evident from the known geology of some of the localities which are located within volcanic terrains that the major constituents of the volcanic rocks are calcium, magnesium, potassium and sodium (Dumort, 1986). The dominant water types in these localities were accordingly Ca-Mg-HCO_3 and the dominance of Ca and Mg in the water samples suggests an inverse ion exchange process. The Ca and Mg could have been released from silicate minerals by weathering due to the action of weak carbonic acid and during such a process, Ca from the aquifer matrix will be exchanged by Na from the groundwater.

Thus, the chemical content of sachet water is determined by the composition of the rocks it is abstracted from and similar types of rocks may lead to same types of mineral water and vice-versa. The chemical content depends on the availability of mineralizing agents, such as CO_2 concentration, redox conditions, and the type of adsorption complexes (Birke *et al.*, 2010). The conversion of some of the source water type from Ca-Mg-HCO_3 to Na-K-HCO_3 in the sachet could be a possible result of the addition of additives rich in sodium and potassium at the level of treatment of the water in the factory before packaging.

Conclusions

Results of analysis of physical and chemical properties of water sold in sachets in four Regions of Cameroon are indicative of low values of physical properties thus rendering the water suitable for general domestic use. The results also indicated a strong correlation between the physico-chemical quality of the water at sources and in the sachets and between the geology of the localities of the water sources and their corresponding chemical constituents. However, the results of the microbial quality of the water sources and their corresponding water sachets indicated that twelve of the fourteen sachet water brands do not comply with WHO guidelines for potable water based on their total coliform counts while only two (sachet brand G and D_1) conformed to these guidelines. For any water to conform to international standards, such water must be safe biologically, chemically, and aesthetically. The potential negative effects of water which is contaminated with coliform on health and the environment are issues of major concern and these water brands should not therefore be allowed to be sold in this country without further analytical checks and purification.

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