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Physico-Chemical Analysis of Water Quality of Springs in Bafia-Muyuka, North-Eastern Flank of Mount Cameroon (South West Region, Cameroon Volcanic Line)

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Abstract Bafia-Muyuka is situated at the foot of the North Eastern flank of Mount Cameroon. The rock types of this area are mainly basaltic with minerals such as; pyroxene, olivine, plagioclase and opaque minerals. Samples collected from five (5) different springs during the rainy and dry seasons were analysed. The Physico-chemical analysis for both seasons were compared with WHO (2004) standard and were found to fall within the acceptable limit but for the exception of high temperature values in all the spring waters and NH_4^+ during the rainy season. All the spring waters yielded pH values above 6.5 and were classified as barely acidic to neutral water. Electrical conductivity ranged between 180-302µs/cm. The relative abundance of major ions (mg/l) were as follows; $Ca^{2+} > Mg^{2+} > K^+ > Na^+ > NH_4^+$ for cations and $HCO_3^- > Cl^- > NO_3^- > SO_4^{2-} > HPO_4^{2-}$ for anions. These results suggested an influence of natural processes mainly from rock weathering. The Piper's plot showed that, these springs are characterized by the Calcium-Magnesium Bicarbonate facie (Ca-Mg-HCO_3 water type). The results indicate that the springs are non-polluted chemically and are fairly portable and suitable for domestic purposes.

Keywords: *Bafia, spring waters, Piper's plot, basaltic, WHO standard*

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1. Introduction

Cameroon is the second country in Africa after the Democratic Republic of Congo in terms of quantity of available water resources estimated to be 322 billion m^3 [15]. However, these water resources are not evenly distributed due to variations in the topography, rainfall pattern and climatic changes. Conversely, these water sources are poorly harnessed resulting in acute pipe borne water supply in many localities in the country. Each year 3.6 million people die from water-related disease, 98% of these deaths occur in the developing world [31]. The WHO notes in 2013 that by 2025, half of the world population will be living in water stressed areas. In Bafia there is no pipe borne water supply and the inhabitants consume mainly spring water whose quality is unknown and is poorly managed. In this paper, the geology of the area is studied as well as physico-chemical properties of some springs so as to ascertain their portability and domestic usage.

1.1. Geographic Setting

Bafia-Muyuka is situated in the Southwest Region of Cameroon. It lies between latitude 4°20'N and 4°22'N and longitude 9°18'E and 9°21'E about 15 kilometres from Muyuka town, the Sub-Divisional Head Quarter (Figure 1). The relief of the area is not uniform. It is characterised by steep hills and u-shaped valleys. Part of Bafia lies within the Cameroon Volcanic Spring Line and is well drained. The streams present a parallel drainage network, flowing in the SW - NE direction to the river Yoke (Figure 1). The climate is hot and humid (tropical climate) with dry and rainy season [20]. The rainy season extends from March to November with annual temperatures of 25-30°C and rainfall of 2000-2500mm [1].

2. Methodology

Five different spring water samples (Figure 2) were collected all on basaltic rocks from the study area during the rainy season (September 2015) and during the dry season (February 2016). The sampling points were chosen in relation to their uses by the local population. At the spring sites, careful observations such as; weather conditions, sampling time, sampling method and coordinates were recorded. Clean 1.5liters plastic bottles were used to collect water samples. Each sample was duplicated; one acidified with 2ml of 1M HCl to pre-empt any further acidity prior to analysis. Each plastic bottle was codified and then transported in an ice cool container to the laboratory within 24 hours. The acidified samples were used for the analysis of cations, while the non-acidified samples were used for the analysis of anions.

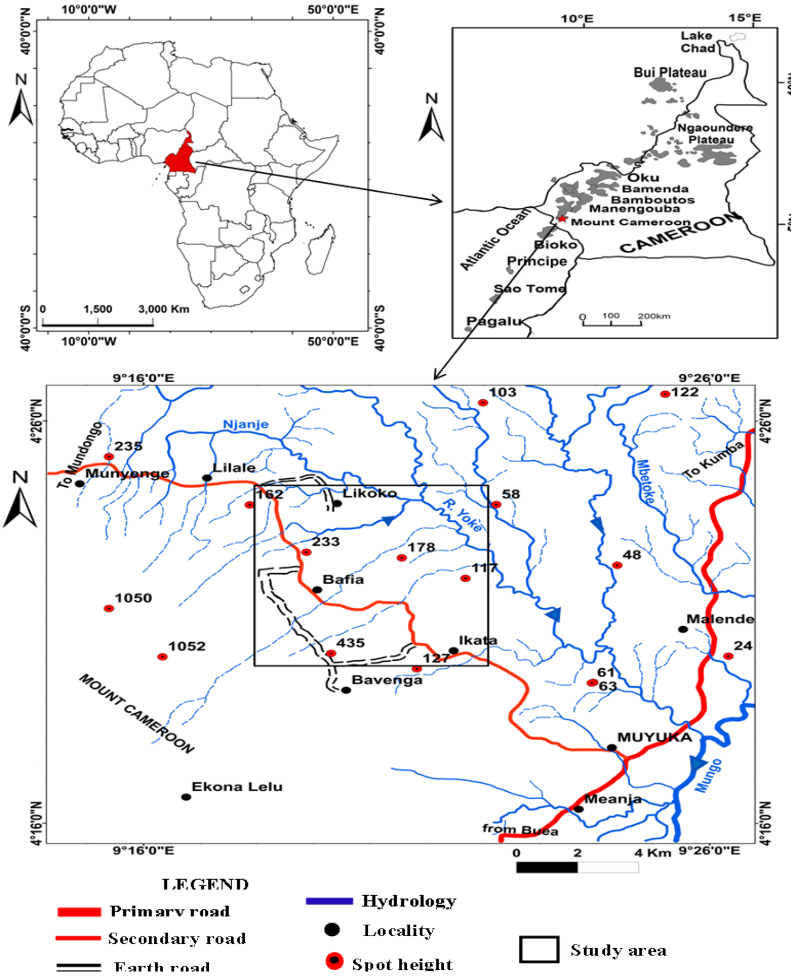

Figure 1. location map of the study area (A) Cameroon in Africa, (B) map of Cameroon showing the CVL [24] (C) Map of study area (black square box) (Source Map of Buea-Douala of scale 1:200000 NB-32-IV)

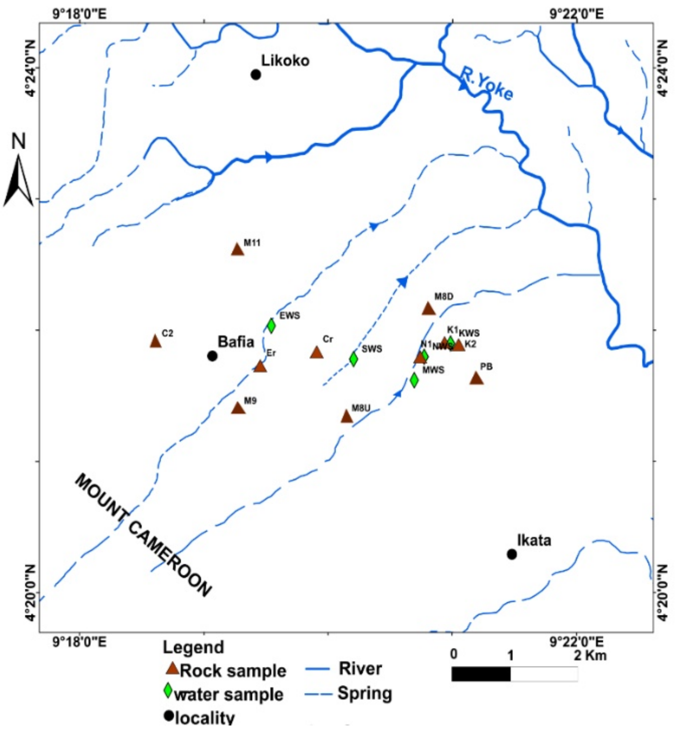

Figure 2. Sampling Map of the study area (Source: Map of Buea – Douala of scale 1:200000 NB)

2.2. Petrographic and Hydrochemical Analyses

Thin sections were prepared in the laboratory of the Institute of Geologic Research and Mining (IGRM) Nkolbisong Yaoundé. The prepared sections were then observed under the light microscope at the HTTC Geology Laboratory of the University of Bamenda. For the spring water samples, physical parameters like colour, odour, taste pH, Electrical Conductivity (EC), and temperature were determined in situ. Taste, odour, colour, and turbidity determined through tasting, smelling and naked eye observation while pH, EC, and temperature were determined using a Hanna pH-EC meter, respectively. The chemical parameters of the sampled waters were determined at the IRAD Ekona Soil Laboratory Centre. Major cations; sodium (Na^+) and potassium (K^+) were determined by flame photometry. The analysis of calcium (Ca^{2+}) and magnesium (Mg^{2+}) was done by titration with 0.02M solution of Ca and Mg- EDTA together with 1ml of TEA and 1ml of 5% KCN. Ammonium (NH_4^+) was analysed using the colorimetric method.Major anions: chloride (Cl^-) was analysed by titration. Nitrates ($NO3^-$) and phosphate (PO_4^{3-}) by colorimetry. Sulphates (SO_4^{2-}) by turbidimetry and Bicarbonates (HCO_3^-) concentrations by titration.

3. Results

3.1. Petrography

The study area is composed mainly of volcanic basaltic rocks which are vesicular, porphyritic and massive. Minerals like olivine, pyroxenes, plagioclases and opaque minerals constitute these rocks. On the microscopic plan, these basalts can be subdivided into: Olivine basalts which outcrop as boulders or blocks with sizes of about 1m to 2m in diameter and cover about 20% of the study area. They present a microlitic with microphenocryst of olivine and some pyroxene. Opaque minerals occur as phenocrysts and also in the groundmass. Plagioclase basalts outcrop as boulders or blocks with sizes of about 1m to 2m and cover about 42% of the study area. Plagioclase are euhedral in shape and make up about 38% of the rock, with sizes ranging from 0.01mm to 2mm. They have polysynthetic twins and are dispersed in a disordered manner within the groundmass. Plagioclases are the main constituents in the groundmass occurring as microlites.

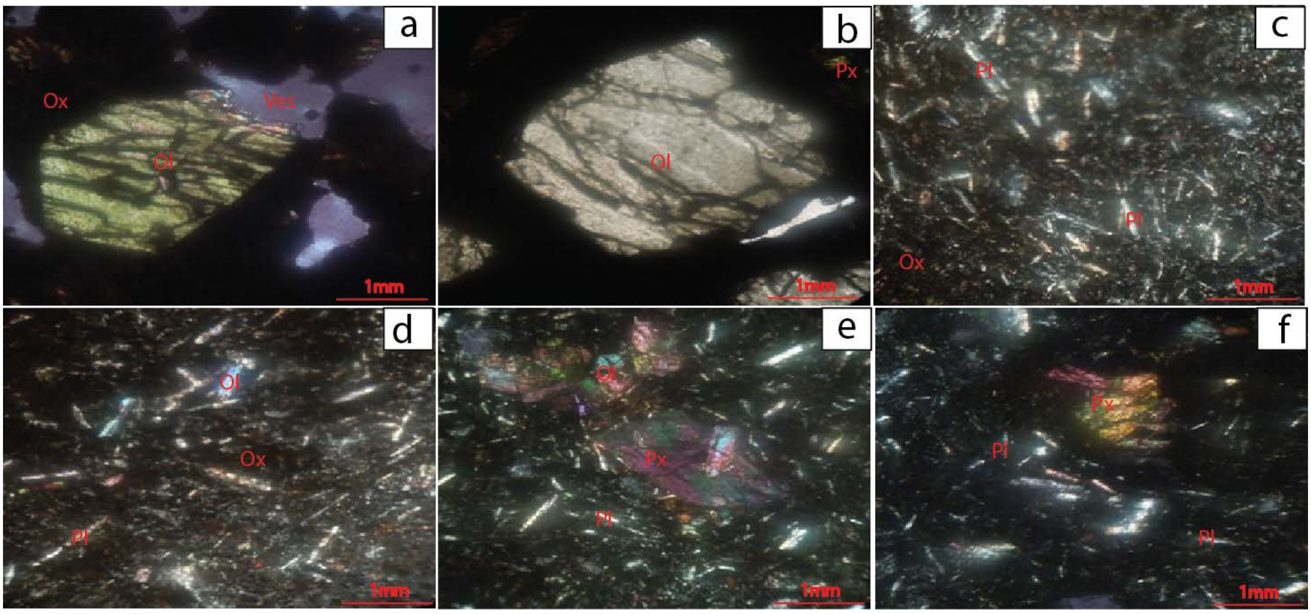

Figure 3. Microphotography of rock thin section from Bafia-Muyuka**: a & b:** Olivine basalt, **c & d:** Plagioclase basalt, **e & f:** Plagioclase-Olivine basalt. **NB**: Ol = Olivine; Pl = Plagioclase; Px = Pyroxene; Ox = Opaque mineral

3.2. Physico-chemical Characteristics of Springs

The physical and chemical parameters of the studied springs in the Bafia-Muyuka area are presented in Table 1.

3.2.1. Physical Parameters

Aesthetics examination such as colour, odour and taste was carried out by sensory method based on human perception of water quality and shows that spring from the studied area were tasteless, odourless and colourless with a clean appearance and little debris. Spring water temperatures were higher during the dry season (average of 27.12°C) and lower in the rainy season (average of 24.4°C) for all springs (Figure 4). The average pH value was higher in the rainy season (7.14) than in the dry season (7.04) as shown in Figure 4, but all spring waters yielded slightly acidic to neutral water (Table 1). The highest pH was recorded in sample MWS (7.82). Their neutrality and acidity is within the range recommended by [30] which is fixed between 6.5 and 8.5. The values for the EC were high regardless of the spring and season but in the dry season the highest value (302µS/cm). was recorded in spring SWS. The average EC value was higher in the dry season (229.4µs) than in the rainy season (219.4µs).

Table 1. Variation of physical Parameters Rainy Season and Dry Season

	T/°C		EC/µs		pH	
Sample code	Rainy season	Dry Season	Rainy season	Dry Season	Rainy season	Dry Season
EWS	24	27.90	234.00	238.00	7.28	7.04
SWS	25.50	28.00	289.00	302.00	7.01	7.00
MWS	23.80	25.70	194.00	212.00	7.14	7.82
KWS	24.90	27.60	180.00	183.00	6.70	6.02
NWS	23.80	26.40	200.00	212.00	7.55	7.32
Average	24.40	27.12	219.40	229.40	7.14	7.04
Mean	25.76		224.40		7.09	

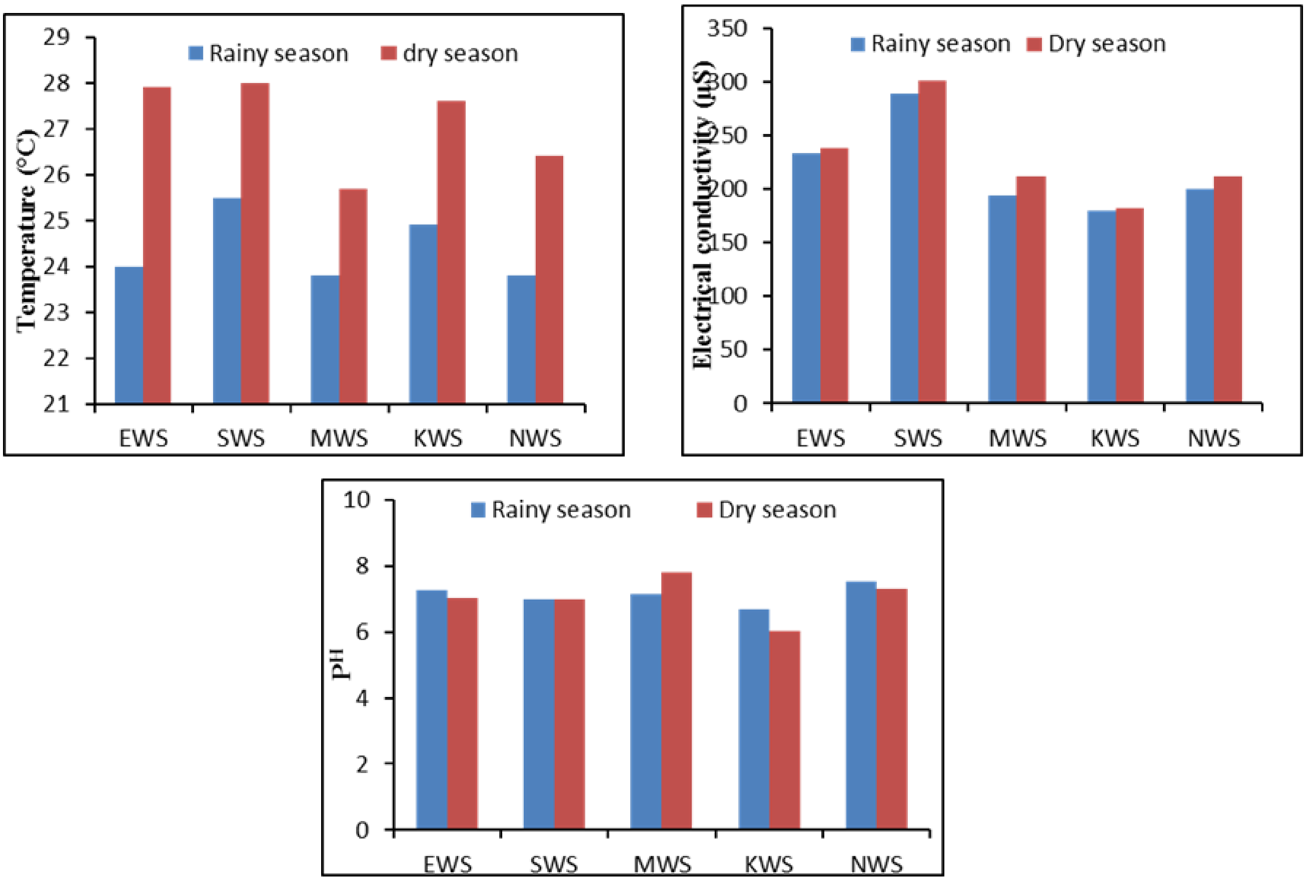

Figure 4. Variation of physical parameters

3.2.2. Chemical Parameters

The average concentration of Na^+ and K^+ were higher in the dry season than in the rainy season. There were no differences for the different water samples but for the sample EWS with high Na^+ concentration in the rainy season and low Na^+ concentration in the dry season. Their respective average values for the rainy season were 0.51mg/l and 4.80mg/l, the values for dry season were 0.58mg/l and 5.79mg/l. The average concentration of Ca^+ in the rainy season shows that it was the most abundant cation with an average value above 20mg/l. The values were higher in rainy season than in the dry season. This stands for all the water samples except NWS water sample where Ca^+ concentration for the dry season was higher than in the rainy season. The second most abundant cation present in the analysed waters was Mg^{2+} with an average concentration of 6.14mg/l in the rainy season and 9.70mg/l in the dry season. Its concentration was higher in the dry season than in the rainy season for all samples (Table 2). NH_4^+ values were higher in the rainy season than in the dry season (Figure 5) with average values of 0.54mg/l in the rainy season and 0.12mg/l in the dry season.

Based on the average concentration of anions, HCO_3^- is the most abundant anion in all the water samples with an exceptional high values during the dry season. Average HCO_3^- values were higher in the dry season (145.67mg/l) than in the rainy season (37.09mg/l). NO_3^- and SO_4^{2-} average concentrations were higher in rainy season than in the dry season as shown in Table 3. Their respective average values for the rainy season were 3.12mg/l and 1.2mg/l while the values for dry season were 2.54mg/l and 0.72mg/l. SO_4^{2-} concentrations are higher in the rainy season than in the dry season for all the water samples. The average concentration of Cl^- was higher in the dry season as compared to the rainy season though with some irregularities on some water samples. HPO_4^{2-} concentration were barely detectable in the rainy and dry season with the average value of 0.01mg/l. HPO_4^{2-} was completely absent in some water samples in both the dry and rainy seasons such as samples KWS and NWS Table 3 and Figure 6.

Table 2. Variation of Cations in the Rainy Season and Dry Season

	Na^+ (mg/l)		K^+ (mg/l)		Ca^{2+} (mg/l)		Mg^{2+} (mg/l)		NH_4^+ (mg/l)	
Sample code	**Rainy Season**	**Dry Season**	**Rainy Season**	**Dry Season**	**Rainy Season**	**Dry Season**	**Rainy Season**	**Dry Season**	**Rainy Season**	**Dry Season**
EWS	0.78	0.71	6.78	7.45	33.68	22.66	4.21	10.77	0.65	0.17
SWS	0.23	0.30	0.77	2.29	11.23	8.50	10.26	12.12	0.63	0.07
MWS	0.60	0.64	6.01	6.31	16.84	16.99	3.33	8.86	0.51	0.15
KWS	0.58	0.62	5.69	6.59	28.07	19.82	10.91	12.84	0.30	0.03
NWS	0.37	0.62	4.77	6.31	11.23	16.99	2.01	3.91	0.61	0.16
Average	**0.51**	**0.58**	**4.80**	**5.79**	**20.21**	**16.99**	**6.14**	**9.70**	**0.54**	**0.12**
Mean	**0.55**		**5.30**		**18.60**		**7.92**		**0.33**	

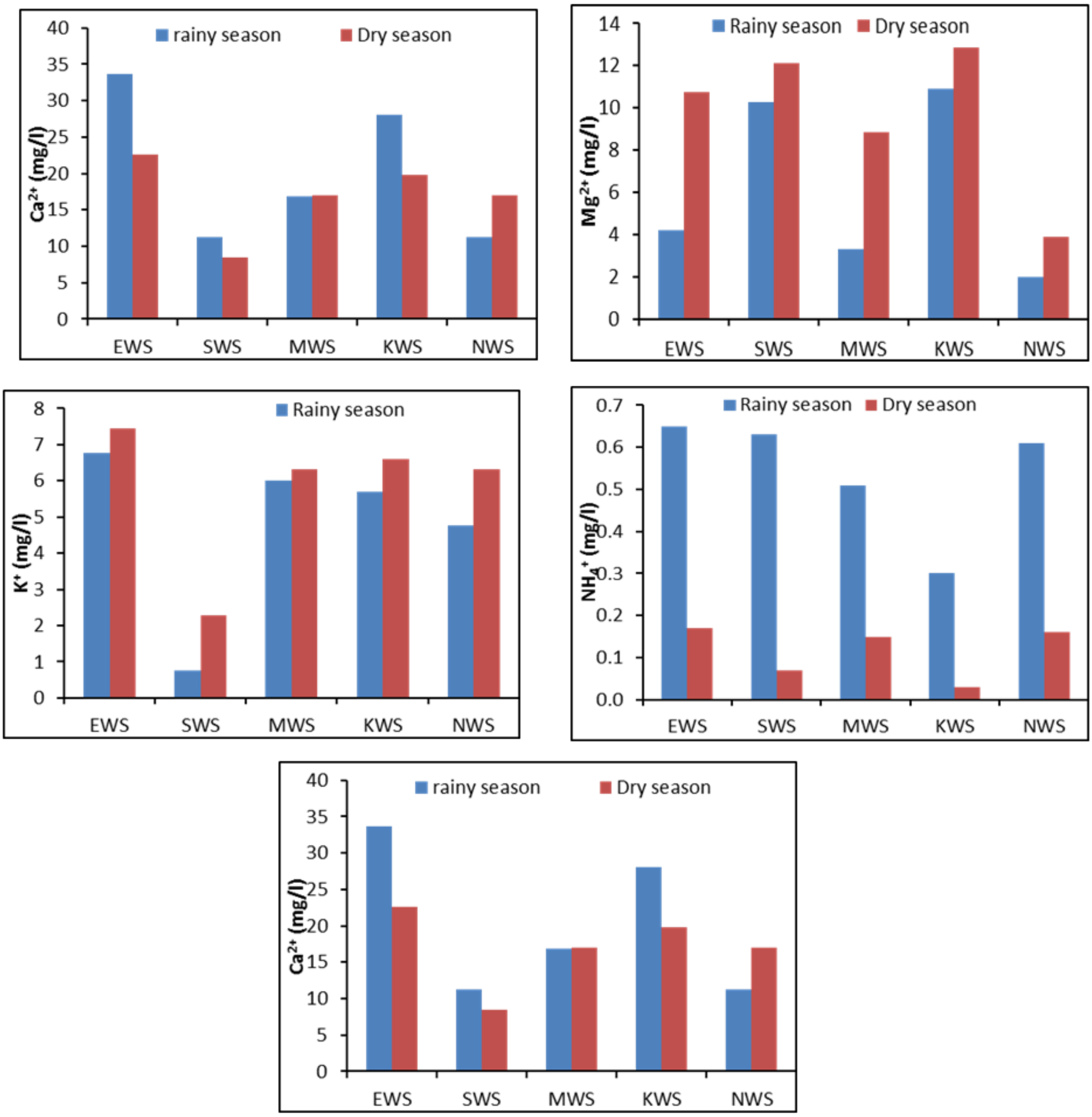

Figure 5. Variation of cations

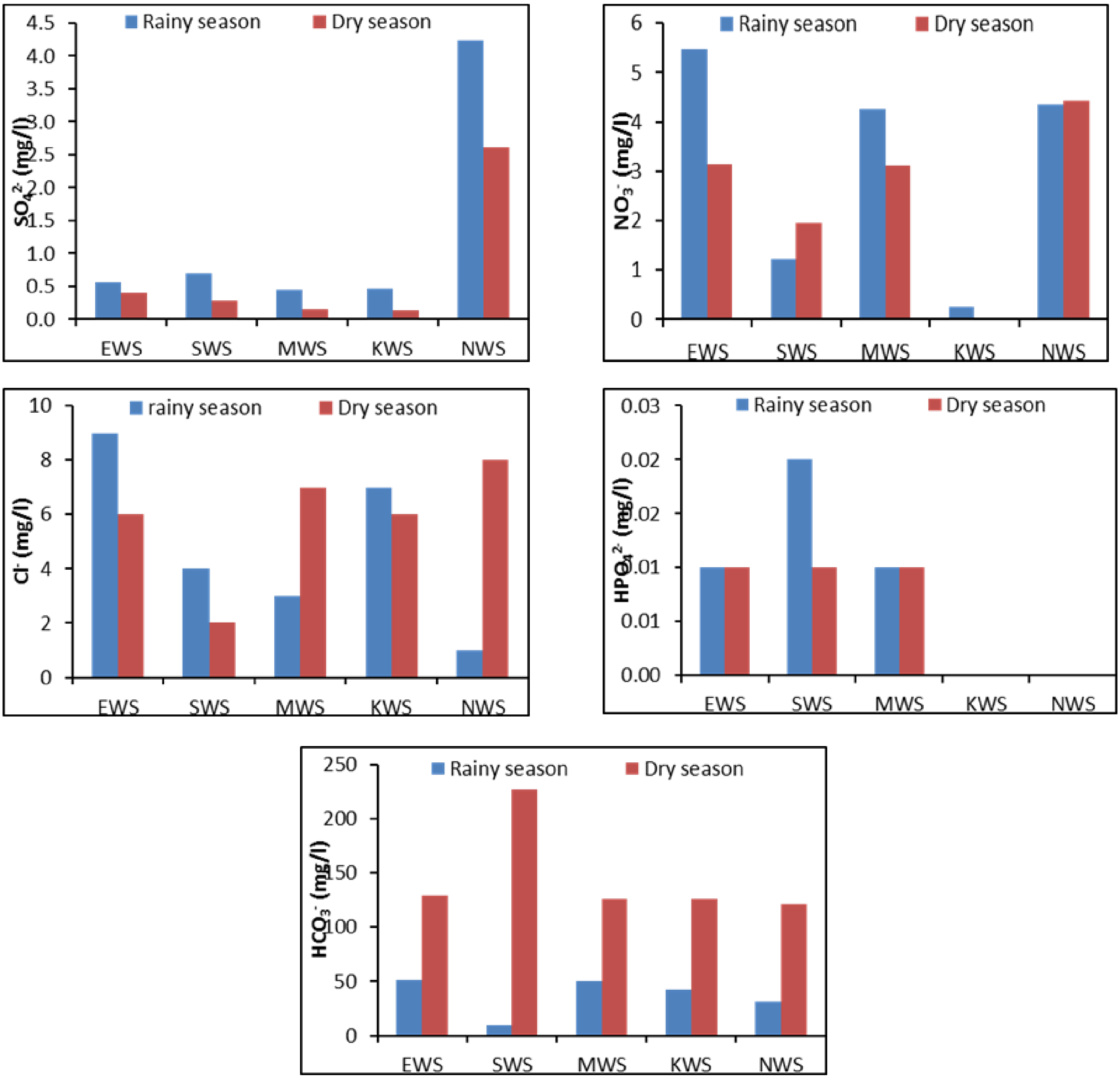

Figure 6. Variation of anions

Table 3. Variation of Anions in the Rainy Season and Dry Season

	HCO_3^- (mg/l)		NO_3^- (mg/l)		SO_4^{2-} (mg/l)		Cl^- (mg/l)		HPO_4^{2-} (mg/l)	
Sample code	**Rainy Season**	**Dry Season**	**Rainy Season**	**Dry Season**	**Rainy Season**	**Dry Season**	**Rainy Season**	**Dry Season**	**Rainy Season**	**Dry Season**
EWS	51.24	129.32	5.48	3.14	0.57	0.40	9.00	6.00	0.01	0.01
SWS	9.76	226.92	1.23	1.96	0.69	0.29	4.00	2.00	0.02	0.01
MWS	50.02	125.66	4.26	3.12	0.45	0.15	3.00	7.00	0.01	0.01
KWS	42.70	125.66	0.26	0.03	0.46	0.14	7.00	6.00	0.00	0.00
NWS	31.72	120.78	4.35	4.44	4.23	2.61	1.00	8.00	0.00	0.00
Average	**37.09**	**145.67**	**3.12**	**2.54**	**1.28**	**0.72**	**4.80**	**5.80**	**0.01**	**0.01**
Mean	**91.38**		**2.83**		**1.00**		**5.30**		**0.01**	

3.2.3. Hydrochemical Facies

The Piper's plots [21] provide information on the different chemical facies of the analysed in the study area. During the rainy season, the major cations from all the water samples are of the calcium-magnesium water type (Ca-Mg type) while the anions presented the bicarbonate water type (HCO_3) and the chloride water type for the lone SWS water sample. This Piper's diagram clearly shows that these springs present a calcium-magnesium-bicarbonate facies (Ca-Mg-HCO_3 type) Figure 7.

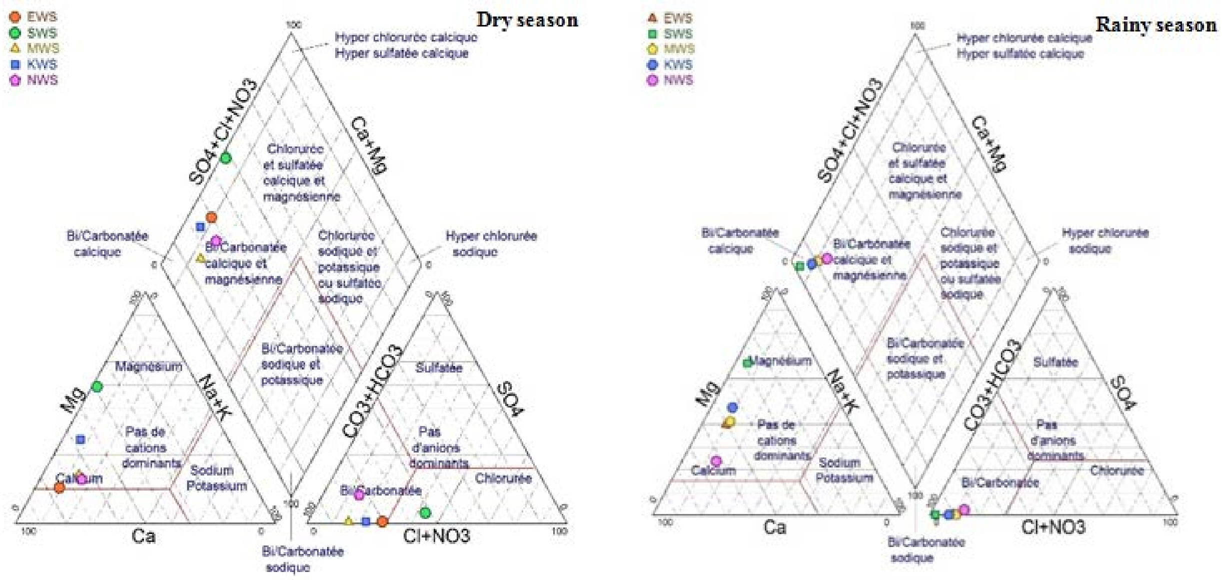

Figure 7. Piper's diagram for water samples in Bafia

4. Discussion

4.1. Water-Rock Interaction

The basaltic rocks were composed of olivine, pyroxene, plagioclase and some opaque minerals. During progressive weathering of these rocks, ions are progressively released. The abundant ions of Ca^{2+} and Mg^{2+} found in all the water samples probably due to the processes of solution of pyroxenes and hydrolysis of olivine and plagioclase.

$$(Mg, Fe, Ca)SiO_3 + 2H^+ + H_2O$$

Pyroxene

$$\rightarrow Mg^{2+} + Fe^{2+} + Ca^{2+} + H_4SiO_4$$

$$(Mg, Fe)_2 SiO_4 + 4H_2O$$

Olivine

$$\rightarrow Mg^{2+} + 2xFe^{2+} + H_4SiO_4 + 4(OH)^-$$

$$CaAl_2Si_2O_8 + 3H_2O + 2CO_2$$

Plagioclase

$$\rightarrow Al_2Si_2O_5(OH)_4 + Ca^{2+} + 2HCO_3^-$$

The occurrence of the bicarbonate ions in all the samples is probably due to the alteration of plagioclase found in basalts.

$$CaAl_2Si_2O_8 + 3H_2O + 2CO_2$$

Plagioclase

$$\rightarrow Al_2Si_2O_5(OH)_4 + Ca^{2+} + 2HCO_3^-$$

Kaolinites

According to [23] if silicate weathering is the possible source of Na^+, then these water sources will have HCO_3^- as the most abundant anion. This is because of the reaction of silicate minerals with carbonic acid in the presence of water, which releases HCO3- [8] as shown below [27].

$$2NaAlSi_3O_8 + 2CO_2 + 11H_2O$$

$$\rightarrow Al_2Si_2O_5(OH)_4 + 2Na^+ + 2HCO_3^- + 4H_4SiO_4$$

This confirms the dominance of HCO3⁻ in the spring sources as a result of weathering reactions on rocks in the study area by percolating ground water.

4.2. Physico-Chemical Parameters of Springs

The current study found that the pH values of drinking water ranged between 6.02 and 7.82. The [30] guidelines for drinking water quality ranged between 6.5 and 8.5. This makes the water very good for drinking. Even though pH has no effect on human health, research has shown that it is closely related to other chemical constituents of water [2].

Generally, the weather in the study area is quite hot; water temperature plays an important factor which influences the chemical and/or bio-chemical characteristics of water body. Cool water is generally more appetizing than warm water. From the field, the maximum temperature of 28°C was recorded during the dry season at SWS point and a minimum of 23.80°C was recorded during the rainy season at NWS point. All the sampled water sources have exceeded the recommended [30] standard of 15°C making them not appetizing to an extent and might favour bacterial growth. The Electrical conductivity values ranged from 180.00 to 289.00 (us/cm^{-1}) in the rainy season and between 183.00 to 302.00 (us/cm^{-1}) in the dry season. It falls within the permissible limits of 750us/cm^{-1} for [30] limit and classed the springs as fresh water type. It has been established that the conductance of water solution increases as temperature rises [28]. This average EC values obviously might be due to their insufficient contact time with the country rock as they flow very fast on the rock couple with the porous nature of the terrain.

4.3. Cations in Springs from Bafia-Muyuka

The relative abundance of the cations was as follows Ca^{2+}> Mg^{2+}> K^+> Na^+> NH_4^+. Among the major cations, Ca^{2+} predominates with average concentrations of (18.60mg/l) followed by Mg^{2+} (7.92mg/l), K^+ (5.30mg/l),

Na^+ (0.55mg/l) and lastly NH_4^+ (0.33mg/l). Portable groundwater should contain less than 75mg/l of Ca^+. according to [30]. The values obtained from this area are within the WHO limit. This makes the water good for human consumption. The high concentration is likely attributed to the presence of plagioclase and pyroxene minerals in the surrounding basaltic rocks which are easily weathered. Mg^{2+} is very soluble in water and in ground water it is usually of lesser concentrations. Mg^+ concentration in water sources of the area ranged from 2.01mg/l to 12.84mg/l which were below the WHO standard. Being a farming area, the major source for K^+ could be due to the application of K^+ rich fertilizers. Ground water should contain less than 25mg/l of K^+ as compared to WHO standard. K^+ values from study area ranged from 0.77mg/l to 7.45mg/l. These concentrations are very low and fall under the ideal acceptable class of [30] drinking water standards. As of now, K^+ has no known effects to the health of humans. Natural water contains small amount of Na^+. A maximum drinking water standard of 100 mg/l has been proposed for the general public [17]. The values for Na^+ in the water of the study area were very low ranging from 0.23mg/l to 0.78mg/l. The most probable source of Na^+ can be from plagioclase in basalts which are partially weathered. The main source and reason for the high concentration of NH_4^+ during rainy season is probably from fertilizers used in farms which is being leached into the water while natural sources such as organic (metabolic processes) and inorganic (rock weathering and hydrothermal activity) could also contribute to the presence of NH_4^+ [16]. The values were above the WHO guideline limits of 0.2mg/l during the rainy season and under the limit required by the WHO drinking water norms during the dry season.

4.4. Anions in Springs from Bafia-Muyuka

The relative abundances of anions (mg/l) in different samples were as follows: $HCO_3^- > Cl^- > NO_3^- > SO_4^{2-} > HPO_4^{2-}$. Among the major anions, HCO_3^- dominates with average concentration (91.38 mg/l), followed by Cl^- (5.3mg/l), NO_3^- (2.83mg/l), SO_4^{2-} (1.00mg/l) and lastly HPO_4^{2-} (0.01mg/l). The dominance of HCO_3^- is consistent with most natural waters along the CVL [26]. This HCO_3^- may result from abundant vegetation cover. According to [13] the primary source is probably from the dissolved CO_2 in rain water and the decay of organic matter at the surface which may release CO_2 for dissolution. Weathering, precipitation and organic decay probably account for the dominance of this ion. Cl^- are present in all natural water and are major anions in water and sewage. The values of Cl^- in the study area which ranges from 1.00mg/l to 9.00mg/l were within the accepted limits. Cl^- in excess (>250 mg/l) impart a salty taste to water. According to [29] most of the Cl^- in springs comes from precipitation. Chlorine is often added to water in order to kill bacteria. If consumed in high amounts, Cl^- can be toxic and cause sufficient cell damage in the human body. Higher concentration of chlorine may cause gastrointestinal irritation when associated with sodium and magnesium [16]. NO_3^- represents the final product of the biochemical oxidation of ammonia. Pesticides, nitrogenous fertilizers, and manure are also the common probable sources of the presence of NO_3^- in spring waters of the area due to agricultural practices. Naturally, the concentration of nitrates in water is 6mg/l. exceptions for up to 10mg/l are hazardous. Nitrate ranged from 0.03 to 5.48mg/l in the study area indicating these springs as suitable for drinking [22] Similar exercise was carried out in Douala and the results obtained presented higher NO_3^- (49.8–53.8mg/l) concentration in groundwater sources associated with organic nitrogen leached from pit latrines and solid waste dumps [25]. High levels of NO_3^- in water can lead to blood poisoning and eventually death [11]. According to [9] high NO_3^- levels in water have been associated with methenoglobinemia, gastric ulcer, cancer and urinary tract diseases [7] Therefore, the monitoring of NO_3^- in drinking water supply is very important because of health effects on humans and animals. SO_4^{2-} could derive from natural source such as sulphate minerals common in igneous rocks [13]. Its concentrations were very low compared to those of [30] standards of 250mg/l. The low concentrations may be a consequence of gradual dissolution [10]. HPO_4^{2-} occurs in natural waters in low quantity as many aquatic plants absorb and store phosphorous many times their actual immediate needs. The concentration of phosphate was 0.01 to 0.02mg/l in some sampling points (EWS, MWS and SWS) and non-detectable with KWS and NWS samples. HPO_4^{2-} in natural water mostly ranges between 0.005 to 0.020mg/l [3]. The major source is from agriculture [12-18] and organic decay [32]. The general absence could mean that the application of phosphate fertilizer is very low.

Table 4. Spring water quality in Bafia-Muyuka in conformity with [30] drinking water standard. * Values above WHO limit

Parameter	WHO Limit (2004)	Range in Bafia-Muyuka Springs
pH	6.5 – 8.5	6.02 – 7.82
T (°C)	15	23.80* – 28.00*
EC (µs/cm)	750	180.00 – 302.00
Ca^{2+} (mg/l)	75	8.50 – 33.68
Mg^{2+} (mg/l)	30	2.01 – 12.84
Na^+ (mg/l)	200	0.23 – 0.78
K^+ (mg/l)	100	0.77 – 7.45
NH_4^+ (mg/l)	0.2	0.03 – 0.65*
Cl^- (mg/l)	250	1.00 – 9.00
NO_3^- (mg/l)	10	0.03 – 5.48
SO_4^{2-} (mg/l)	250	0.14 – 4.23
HCO_3^- (mg/l)	200	9.76 – 226.92
HPO_4^{2-} (mg/l)	0.30	0.00 – 0.02
Total Hardness(TH)	100	36 - 115

Comparing the results obtained with that of WHO (Table 4), the values were within the WHO drinking water standard. From the above table, one can deduce that the pH, EC, Na^+, K^+, Ca^+, Mg^+, Cl^-, $NO3^-$, SO_4^{2-}, HPO_4^{2-} and HCO_3^- concentrations of the analysed water were under the limits required by the [30] drinking water norms. These spring waters can be classed as suitable for drinking and domestic usage though Temperature values and NH_4^+ values (in some sampling points) were above the WHO limits.

4.5. Total Hardness (TH) of Springs from Bafia

Hardness of water is mainly due to the presence of salts of calcium and magnesium and this reduces lather formation and also increases the boiling point of the water [19]. The users of hard water tend to use a lot of soaps for washing. Hardness of water also leads to the formation of scales in sinks, pipe fittings and cooking utensils. According to [6], there is some suggestive evidence that long term consumption of extremely hard water might lead to increase urolithiasis, ancephaly, parental mortality and some kind of cancer and cardiovascular disorders. On the other hand water softness (low in Ca^{2+} and Mg^{2+}) could be a health problem since soft water has been linked to cardiovascular ailments [5-14] expresses hardness of water as Total Hardness (TH) and is given by TH=2.5Ca + 4.1Mg. The results from this study area show the following water types in terms of TH (Table 5).

Table 5. Spring classification based on total hardness after [5]

TH Range (mg/l)	Water type	Sampling code	No of Springs
<9	Soft	-	0
9 – 60	Slightly Hard	NWS	1
60 – 120	Moderately Hard	EWS, SWS, MWS, and KWS	4
120 – 180	Hard	-	0
>180	Very Hard	-	0

Based on the classification scheme by [5] four (80%) of the spring sources sampled were classified as moderately hard water (EWS, SWS, MWS, and KWS) while one (NWS) out (20%) of the sources was categorized as slightly hard water (Table 5). Hardness of water supply intended for human consumption is between 80 and 100mg/l [5]. As cited in [8, British Committee on Medical Aspects of food policy [4] found a weak inverse relationship between water hardness and cardiovascular disease death. This implies that people consuming soft waters have the likelihood to suffer from cardiovascular diseases than those consuming hard waters. Eighty percent (80%) of springs in Bafia were moderately hard water meaning that people living in Bafia whose only source of drinking water are springs have a low risk of contracting cardiovascular diseases. Hard water is good for drinking because the calcium and magnesium ions are used for bones and teeth formation.

5. Conclusion

Bafia-Muyuka, is made up of basaltic rocks from which several spring flow. Five springs were subjected to physico-chemical analyses. The concentration of all the parameters in all spring samples were found within the permissible limit as prescribed by [30] standard but for the temperature in both seasons and NH_4^+ during the rainy season that were above the permissible limit. The relative abundance of major cations and anions in the water (mg//l) was Ca^{2+} > Mg^{2+} > K^+>Na^+> NH_4^+ and HCO_3^- > Cl^- > NO_3^- > SO_4^{2-} >PO_4^{3-} respectively. Major ion concentrations were low, and below maximum values of the WHO standards for drinking water. The springs are moderately hard and show calcium-magnesium bicarbonate (Ca- Mg-HCO_3) facie. Based on our findings, the population of Bafia which depends on the spring water for drinking and domestic purposes face very little health worries consuming these springs.

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