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Research Article

Hydrogeochemistry of Surface and Ground Water in Alatening Village, Northwest Region, Cameroon

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The purpose of this study was to evaluate petrography and the quality of water for drinking purposes in Alatening, Northwest Cameroon, with respect to the World Health Organization (WHO) standards. The indigenes of the study area, as well as other dwellers in rural areas, consume water from these sources whose quality is unknown; thus, it can lead to contamination and waterborne diseases. Three springs and two streams of Alatening village were investigated in early December 2017 and late July 2018 for organoleptic, physicochemical, and bacteriological parameters using standard methods. The petrographic studies revealed trachyte and benmoreite, and weathering of minerals from these rocks into the soil leads to the water-rock interaction, thus water hydrogeochemistry. All the water samples were clean except that of Alabong which had slight odour due to leaf fall. pH showed acidic water with the springs of Ngog and Alabong falling below the WHO limit in the dry season. Electrical conductivity and total dissolved solids (TDS) were low implying low mineralised water which can also lead to shortage of important minerals in humans. All the essential ions were found within the WHO guideline values without any significant change in concentrations between seasons ($p > 0.05$). The water facies were such as Mg-Ca, Cl-Ca, and HCO_3-CO_3, suggesting an influence of rock silicate weathering and anthropogenic influence. Aluminium and iron contents were above the WHO limit in both seasons due to their abundance in the soils which could be a risk factor for the local population. Faecal coliforms as well as specific bacteria such as *Enterobacter, Escherichia coli, Streptococcus, Salmonella*, and *Shigella* were found in all the water samples, attributable to poor hygiene. Health data in the locality indicated the prevalence of typhoid, dysentery, and amoebiasis with a total of 2702 cases recorded between 2016 and 2017, therefore requiring treatment before consumption.

1. Introduction

The supply of a sufficient quantity of good-quality water to a community is a necessity as it does not only reduce numerous waterborne diseases but also is very often the first step towards the development of other sectors such as nutrition and sanitation [1]. Water scarcity in many parts of the world has become an unpleasant reality. So, groundwater seems to be the potential natural resource capable to reverse this situation [2] like in Morocco, groundwater constitutes an important part of the hydraulic heritage and is considered as a key to thriving agriculture and as a factor in the rapid growth of the rural population leading to considerable reduction in water reserves and increased health risks for both humans and animals. Freshwater from springs is still widely used for domestic supply in many urban and rural areas without prior water treatment or disinfection [3]. In effect, the quality of drinking water has a powerful impact on public health, and therefore, effective monitoring and comprehensive assessment of public or community drinking water systems are crucial to protect the wellbeing of the population and to allow the implementation of a preventive approach to manage the drinking water quality [4]. Water-related diseases caused by insufficient safe water supplies coupled with poor sanitation and hygiene cause 3.6 million deaths a year, mostly among children [5], and 98% of these deaths occur in the developing world. The World Health Organization (WHO) noted in 2013 that, by 2025, half of the world's population will be living in water-stressed areas.

Furthermore, the United Nations (UN) General Assembly declared in 2010 that safe and clean drinking water and sanitation is a human right, which is essential to the full enjoyment of life and all other human rights. These commitments were built on a long history of support including the UN General Assembly adopting the Millennium Development Goals in 2000 and declaring the period 2005–2015 as the International Decade for Action, "Water for Life." [6] And so, water quality assessment and sanitation monitoring are of importance [7]. Also, national standards of drinking water often require the determined allowable concentration of pollutants in water, and the World Health Organization (WHO) guidelines offer recommendations for managing the danger from hazards which could compromise safety of drinking water [8, 9].

In addition, consumption of water containing pathogenic organisms or toxic chemicals and the use of inadequate volumes of water, resulting in poor hygiene, pose serious risks to human health. For this reason, water-quality assessment and continuous monitoring are of utmost importance [5]. Water-quality assessment provides baseline information on water safety. Natural water analysis for physical, chemical, and trace element parameters is very important for public health studies. Access to safe drinking water is important as a health and development issue at national, regional, and local levels [10]. The suitability of water for domestic use is judged on the basis of organoleptic, physical, chemical, and biological characteristics which are basic and generally considered priorities [7]. In spite of the efforts of the national and international communities, 663 million people worldwide are still without improved drinking water sources, and nearly, half of them live in sub-Sahara Africa, while one-fifth live in Southern Asia. Though there was an increase in the number of people using improved water sources, the Millennium Development Goal (MDG) was not met in sub-Sahara African countries [8].

Cameroon is one of the sub-Sahara African countries where water resource management is a severe constraint to poverty alleviation and to sustainable development though rating amongst countries having the quantity of available water resources estimated to be 322 billion cubic meters, which provides annual available water per inhabitant of 21,000 m^3 [11].Today, the main difficulty with which Cameroonians are confronted is not so much access to water but more precisely the access to potable water for domestic uses. The principal urban centres are supplied with potable water by CAMWATER and Camerounaise des Eaux (CDE), while the rural population makes use of surface and groundwater resources through rivers, streams, boreholes (some equipped with manual pumps while others are not), wells, and springs. Water from these sources is generally consumed without any major form of treatment. The rural communities consume water from surface and subsurface water, where it can only be a few meters deep and of mediocre quality. With the increasing population of Alatening, many inhabitants turn to settle in areas where water is deficient in amount and poor in quality. So, the water quality has to be checked in order to meet the needs of the population and their health. In Alatening, there is no pipe-borne water supply, so the inhabitants consume mainly spring water and, at times, stream water, whose physicochemical and bacteriological properties are unknown and is poorly managed, especially in the dry season. The springs are not well maintained but exposed to dust, neighboring farms, and toilets, in contact with animals, and also experience flooding during the rainy season, signifying pollution by fertilizers and animal faeces. The quality of these water sources for home use needs to be properly checked. Health data from Holy Family Hospital and Baba II Health Centre in the study area indicated that 2702 cases were recorded between 2016 and 2017, therefore requiring treatment before consumption.

Also, rock types in the Bamenda Mountains (Santa) are basalts, trachytes, rhyolites, and basement rocks (granites, gneiss, schists, etc.). However, in Santa subdivision, rock types are basalts, trachytes, and rhyolites, and in Alatening, trachytes and benmoreites were found. The felsic lavas of the Bamenda Mountains are represented by trachytes, with less abundant benmoreites and alkaline to peralkaline rhyolites. Trachytes are aphyric (phenocrysts 65 wt. %) or porphyritic (phenocrysts > 5 wt. %). The phenocrysts are mainly alkali feldspars with subordinate green clinopyroxene. Alkali feldspars occur as euhedral elongate prisms (from mm up to cm long) showing Carlsbad twinning. Mafic rocks from the Bamenda Mountains have silica contents ranging from 41 to 52%, with MgO ranging from 2.5 to 11.3%. When compiled together with the previously studied felsic rocks of the same volcanic province [12], the range in the major element composition is consistent with a fractional crystallization process accounting for the evolution from the most mafic rocks to the more differentiated rhyolites. Weathering of these rocks contributes a lot to water chemistry leading to the water-rock interaction.

Alatening, found in the Santa subdivision of the Northwest Region of Cameroon, is one of the rural areas of Cameroon, where springs are the main sources of drinking water and mostly flowing on rocks. The population of this community consumes this water without any form of treatment since water always appears clean and mostly odourless. However, agricultural practices with the use of fertilizers and animal breeding which are the main activities of the population coupled with poor source management may render these sources unfit for consumption. Moreover, there is no documented information on spring water quality in this community. The main objective of this study was therefore to investigate the petrography and quality of Alatening community drinking water with respect to the WHO standards in order to determine its suitability for consumption and make recommendations wherever need arises. To meet up with this objective, rock and water samples from various sources were collected and analysed for physicochemical and bacteriological properties, and recommendations made based on the results were attained.

2. Materials and Methods

2.1. Study Area and Sampling Site. Alatening (Santa) is found in the Mezam division, Northwest Region of Cameroon. Located between latitudes 5°55′ and 5°67′ north and longitudes 10°15′ and 10°22′ east, Santa covers a surface area of about 532.67 km^2 with a population of about 99,832 inhabitants [9], Figure 1. A global positioning system (GPS) (Garmin eTrex Vista) was used to locate the study site geographically. It is made up of ten villages amongst which is Alatening. Alatening is a populated place with an elevation of 1597 m above sea level and has a tropical climate, characterised by two seasons, a long rainy season from mid-March to mid-October and a short dry season from mid-October to mid-March. The rainfall ranges from 2000 to 3000 mm per annum, and the average temperature is 19.6°C. The relief is characterised by many hills and gentle slopes. The hydrology of the area is made up of rivers, streams, and springs. The soil is mainly penevoluted ferralitic and aliatic. Flora and vegetation are made of forests and savannahs. The population of this village relies on agriculture as the main economic activity with the cultivation of tubers and cereals, cabbage, carrot, maize, Irish potatoes, yams, and garden crops. Livestock include cattle, horses, goats, sheep, and fowls [13]. The population depends solely on the few water sources available in the area. The sampling site and sampling points are presented in Figure 1.

2.2. Sampling and Conservation. Water samples were collected early in the morning till midday with coordinates noted and *in situ* measurement of physical parameters such as temperature, pH, conductivity, turbidity, salts, total dissolved solids, and flow rates. During the collection of water samples, great care is taken so as to avoid contamination. A total number of thirty water samples were collected from five sources in two different seasons (rainy and dry seasons). The first set of samples was collected in December, 2017 (dry season) and the second set in July, 2018 (rainy season). Water samples for chemical analyses were collected in ½ litre plastic bottles, and at each site of collection, the bottles were rinsed several times with water to be sampled. A drop of nitric acid was added in the water bottles for ion stability. After collection, water samples were kept immediately in a flask and taken to the laboratory before 24 hours. The collection was done very early in the morning before sunrise, and the samples were packaged in a cooler containing ice in order to maintain the temperature at 4°C to minimize physicochemical changes [14]. Finally, the samples were transported to the Animal Physiology and Microbiology Laboratory and Laboratory of Soil Analysis and Environmental Chemistry in the University of Dschang under 24 hours for preservation and analysis. For bacteriologic analyses, water samples were collected in ½ litre plastic bottles in which the bottles were rinsed several times with water to be sampled, and after collection, the samples were kept in the flask. These water samples were then taken to the laboratory under 24 hours.

2.3. Analyses

2.3.1. Sampling and Petrographic and Geochemical Analyses of Rock Samples. Fresh bulk rock samples were collected from the field in February, March, and April 2017, and the samples were sawed down to prepare thin sections of the rocks using classical methods. Base metals of 0.200 g of a prepared sample were added to a lithium metaborate/lithium tetraborate ($LiBO_2/Li_2O_4O_7$) flux (0.90 g) which was thoroughly mixed and fused in a furnace at 1000°C. The melt was then cooled and dissolved in 100 ml of 4% nitric acid/2% hydrochloric acid digestions and analysed by the inductively coupled plasma-atomic emission spectroscopy (ICP-AES) method in ALS geochemistry services in the Republic of South Africa.

2.3.2. Organoleptic and Physicochemical Analyses. Temperature (T), pH, electrical conductivity (EC), and total dissolved solids (TDS) were measured *in situ* with the help of a calibrated multimeter (WATERPRO01, PCS tests-5). Turbidity was measured using a turbidimeter (Model DRT, 100B, MF Scientific, Inc.) by projecting a beam of light towards the tube in which the samples were contained. The proportion of light measured is proportional to the turbidity measured in nephelometric turbidity units (NTU). Na^+ and K^+ ions were determined by flame photometry, Ca^{2+} and Mg^{2+} were determined by complexometric titration, and Cl^- was determined by the argentometric method. SO_4^{2-} ion was determined by gravimetric analysis, and NO_3^- and NH_4^+ ions were determined by Kjeldahl's distillation method. PO_4^{3-} ion was determined by UV-visible spectrophotometric analysis. HCO_3^- was determined by acid-base titration and sulphates by gravimetric analysis. Zn, Al, Fe, Pb, and Cu ions were determined by colorimetry following methods described by Rodier et al. [15] and the WHO [10]. The distribution of cations and anions (hydrochemical facies) in the study site was determined through Piper`s diagram to give the water types of the study area [16].

2.3.3. Bacteriological Analyses of Water Samples. Two methods were used: the multiple-tube fermentation technique or most probable number (MPN) technique for the presumptive determination of total coliforms and the standard count plate technique for the determination of specific bacteria as described by the WHO [11] and Nanfack et al. [17].

2.3.4. Statistical Analyses. Paired sample *t*-test was used to verify significant differences between the mean parameters for the two sampling seasons at 95% confidence interval, and Pearson correlation was used to verify the relations existing between various water parameters. Statistics was performed with the help of statistical package (SPSS) version 19.0.

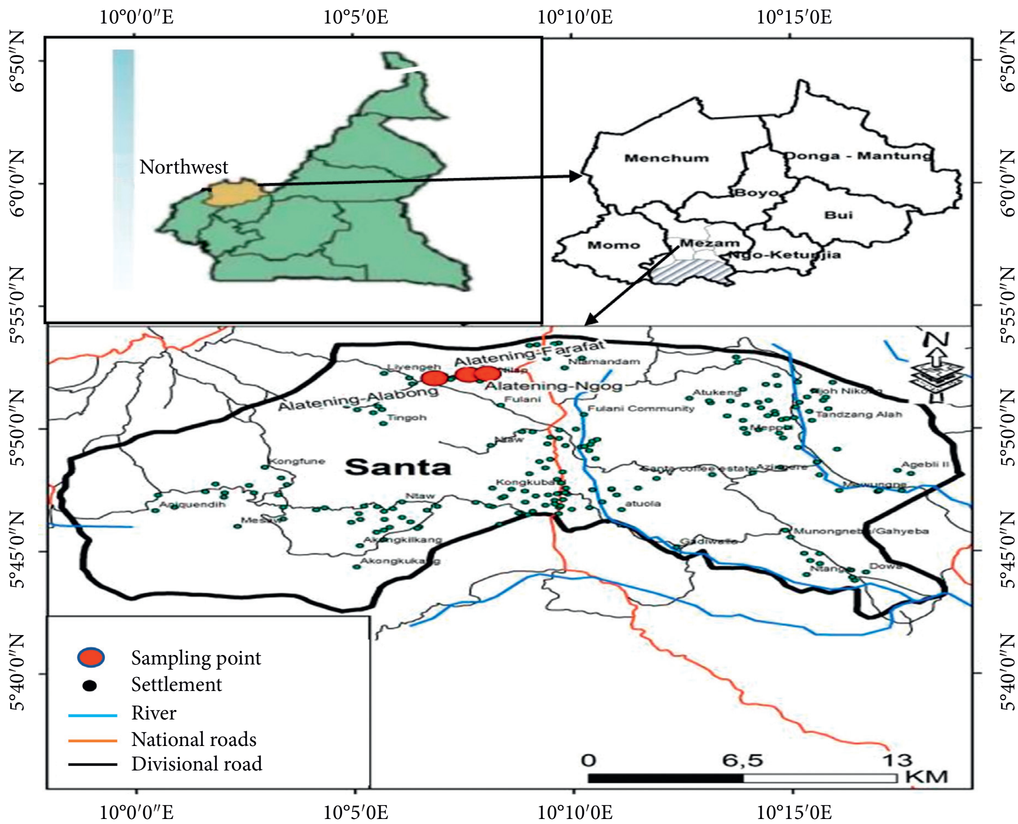

FIGURE 1: Map of Santa showing the sampling site and sampling points.

3. Results and Discussion

3.1. Results

3.1.1. Petrography. The petrographic results revealed one type of rock being trachytes as presented in Figure 2. They are fine-grained rocks in texture with crystals of feldspars ranging from 2×3 mm to 3×4 mm. These rocks were highly jointed. Trachytes vary in colour as observed in Figure 2. Trachytes of Alatening are light in colour. Rock samples here are microlitic-porphyritic in texture with their phenocrysts being alkali feldspars (sanidine) which occur in large amounts as phenocrysts, pyroxenes, and opaque oxides. Alkali feldspars (sanidine) were observed in the rock with a proportion of about 70 vol% having euhedral shape with cracks and showed Carlsbad twinning with an average size of 0.25×0.5–1.5×2.5 mm. These alkali feldspars are found in the matrix of the rocks as euhedral crystals. The minerals were averagely undergoing weathering from the edges towards the centre of the rocks. Plagioclases are mostly found in the matrix, some occurred as phenocrysts, and exhibit albite twinning with a size of about 0.25×0.5–1.5×2 mm (3). Clinopyroxenes (pyroxenes) constituted about 5% of the rock and occurred mostly in the matrix. Their sizes ranges from microcrystals to phenocrysts (0.25×0.5 mm–1.5×2.5 mm) (Figure 2).

3.1.2. Geochemical Analysis of Rocks in the Study Area. These results explain how major elements vary in the rocks, mainly trachytes, as shown in Table 1.

Trachyte has SiO_2 content from 60.5 to 61.7 wt%; Al_2O_3 from 10.65 to 12.4 wt%; Fe_2O_3 from 10.1 to 11.05 wt%; CaO from 0.16 to 0.18 wt%; MgO from 0.07 to 0.1 wt%; Na_2O from 4.11 to 4.8 wt%; K_2O from 4.16 to 4.22 wt%; and K_2O from 0.023 to 0.03 wt% in the rock samples collected from points A1–A4. It was observed that these rocks had high silica content.

Trace elemental proportions varied in trachytes of the study area from 1 to 1555 ppm. Ba values also ranged from196 to 1385 ppm, Cr from 170 to 210 ppm, Rb from 32 to 93.2 ppm, Nb from 64.3 to 196 ppm, and Zr from 246 to 933 ppm (Table 2).

The rare-earth elements also varied in their concentrations in the rock samples. Yb values varied from 7.25 to 8.84 ppm with the highest value in A4. Lu varied from 1.07 to 1.23 ppm, Y varied from 96 to 111 ppm, Nd varied from 14.25 to 147.5 ppm, and Tm varied from 1.2 to 1.43 ppm, and all these elements were higher in the trachytic rocks. These elements also showed positive correlation with SiO_2 (Table 3).

4. Results of Water Analyses

The results of all the analysed water parameters are presented in the tables. Tables 4–8 present results of organoleptic, physical, chemical, heavy metal, and bacteriological analysis for most probable number counts and bacteriological analysis for specific bacteria isolated, respectively. In all tables, SA is the sample from Alabong, SN, sample from

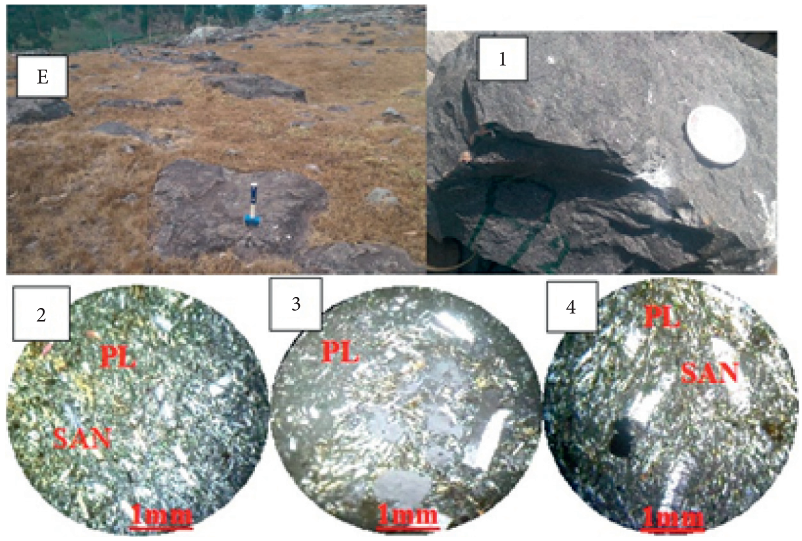

Figure 2: Macroscopic and thin sections of trachytes. E = boulders of trachytes covering a very large distance in the study area (A1–A4). 1 = rock sample with dark to grey colour, 2 = sanidine crystals following the same direction, 3 = plagioclases, and 4 = assemblage of sanidine showing twining.

Table 1: Major elements/silica in rock samples

Elements	A1	A2	A3	A4
SiO_2	61.7	61.5	60.6	61.6
Al_2O_3	10.65	12.4	12.15	10.65
Fe_2O_3	11.05	10.25	10.1	11.05
CaO	0.16	0.18	0.18	0.16
MgO	0.1	0.07	0.07	0.1
Na_2O	4.12	4.8	4.68	4.11
K_2O	4.22	4.21	4.16	4.21
Cr_2O_3	0.023	0.03	0.029	0.023

Table 2: Trace elements in rock samples.

Samples	A1	A2	A3	A4
Nb	196	64.3	195	71.2
Zr	911	246	933	347
Sr	4.8	1555	4.4	886
Ga	33.2	40.2	37.4	39.5
Cr	210	170	210	180
V	<5	198	<5	<5
Ba	1385	196	1270	199.5
Cs	1.05	2.74	1.51	2.91
Rb	91.9	39.4	93.2	32
Th	14.45	4.46	14.55	5.16
Hf	15.9	21.1	16.2	20.2
Ta	11.1	3.5	10.7	4.5
U	3.19	1.36	3.23	1.49
W	1	4	2	1
Sn	5	2	6	2

Ngog, and SF, sample from Farafat; NLS is the sample from the Nilap stream, and KK is the sample from Kie-kwifor; D: December and J: July. Figures 3–6 show the comparison in physical, chemical, and bacteriological parameters.

Analyses were carried out with the help of Statistical Package for Social Sciences (SPSS) version 19.0 and

Table 3: Rare-earth elements in rock samples.

Samples	A1	A2	A3	A4
Ce	312	314	305	318
Dy	17.65	19.9	18.1	19.45
Pr	36.7	38.3	37	38.5
Sm	26.6	26.2	26.3	26.8
Er	9.11	10.65	8.75	10.45
Tb	3.41	3.36	3.23	3.45
Eu	7.72	7.57	7.81	7.76
Ho	3.47	3.61	1.45	3.66
Gd	22.8	24.1	23.7	23.9
Ho	3.47	3.61	3.43	3.66
La	162	156.5	161	158
Lu	1.07	1.19	1.13	1.23
Tm	1.2	1.39	1.23	1.43
Nd	145.5	147	14.25	147.5
Yb	7.58	8.16	7.25	8.84
Y	96.1	108.5	96	111

Microsoft Excel. pH ranged from 8 ± 0.4 (KK) to 6.775 ± 0.25 (SF). Electrical conductivity ranged from $46.65 \pm 8.9\ \mu S/cm$ (SN) to $21.6 \pm 3.2\ \mu S/cm$ (KK), respectively. Total dissolved solids ranged from 35.6 ± 1.4 mg/L (SN) to 17.95 ± 5.3 mg/L (NLS). Turbidity values ranged from 13.45 ± 1.7 NTU (KK) to 0.735 ± 1.01 NTU (SF). Temperature ranged from $20.4 \pm 1.8^{\circ}C$ (SA) to $18.9 \pm 1.2^{\circ}C$ (KK).

According to Figure 4, EC, TDS, and T are the highest in the Ngog spring (SN) followed by Alabong and Farafat springs (SA and SF). pH was low in all the water sources.

The chemical parameters are presented in Tables 6–8. The cations such as K^+ ranged from 4.1 ± 1.4 mg/L (NLS) to 1.31 ± 0.06 mg/L (KK). Na^+ values ranged from 1.27 ± 0.14 mg/L (NLS) to 0.44 ± 0.1 mg/L (SF). Ca^{2+} values ranged from 50 ± 6.0 mg/L (SF) to 11.75 ± 0.5 mg/L (NLS). Mg^{2+} values ranged from 10.5 ± 1.8 mg/L 3.855 ± 1.15 mg/L (KK). The order of abundance of cations was

Table 4: Results of organoleptic parameters.

Source	Appearance, colour, and odour	
	December	July
SA	Clear, clean, colourless, and faint odour	Clear, clean, colourless, and odourless
SN	Clear, clean, colourless, and odourless	Clear, clean, colourless, and odourless
SF	Clear, clean, colourless, and odourless	Clear, clean, colourless, and odourless
NLS	Clear, clean, colourless, and odourless	Clear, clean, colourless, and odourless
KK	Clear, clean, colourless, and odourless	Clear, clean, colourless, and odourless
WHO	Clear, clean, colourless, and odourless	

Table 5: Results of physical parameters for five water sources in Alatening.

Samples	pH	EC (μS/cm)	TDS (mg/L)	Turbidity (NTU)	T (°C)
SA	6.195 ± 0.61	28.3 ± 2.3	23.9 ± 5.2	1.185 ± 0.31	20.4 ± 1.8
SN	6.85 ± 0.1	46.65 ± 8.9	35.6 ± 1.4	1.185 ± 2.31	20 ± 0.4
SF	6.775 ± 0.25	21.65 ± 4.3	13.05 ± 0.5	0.735 ± 1.01	19.4 ± 0.4
NLS	7.3 ± 0.6	23.4 ± 6.2	17.95 ± 5.3	13.7 ± 3.1	19.8 ± 2.6
KK	8 ± 0.4	21.6 ± 3.2	19.15 ± 2.3	13.45 ± 1.7	18.9 ± 1.2
WHO	6.5–8.5	2000	1000	0.1–5	15–25

Values presented are expressed as mean values ± standard deviation ($n = 5$).

Table 6: Results of chemical parameters (cations).

Samples	K+ (mg/L)	Na+ (mg/L)	Ca^{2+} (mg/L)	Mg2+ (mg/L)
SA	1.21 ± 0.08	0.56 ± 0.24	40.5 ± 9.1	7.655 ± 2.71
SN	1.345 ± 0.07	0.495 ± 0.03	42.5 ± 7.1	8.45 ± 2.3
SF	1.98 ± 1.26	0.44 ± 0.1	50 ± 6.0	10.5 ± 1.8
NLS	4.1 ± 1.4	1.27 ± 0.14	11.75 ± 0.5	5.515 ± 0.03
KK	1.31 ± 0.06	1.22 ± 0.02	12 ± 2.0	3.855 ± 1.15
WHO	200	200	75	30

Values presented are expressed as mean values ± standard deviation ($n = 5$).

Table 7: Results of chemical parameters (anions).

Samples	PO_4^{3-} (mg/L)	$N-NH_4^+$ (mg/L)	$N-NO_3^-$ (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)	HCO_3^- (mg/)
SA	0.155 ± 0.29	1.07 ± 1.02	1.29 ± 1.46	0.43 ± 0.12	0.37 ± 0.26	17.715 ± 14.59
SN	0.205 ± 0.35	1.22 ± 0.92	3.92 ± 3.36	0.66 ± 0.14	1.255 ± -1.8	37.49 ± 16.06
SF	0.06 ± 0.08	2.115 ± 0.97	3.22 ± 1.96	0.635 ± 0.09	1.895 ± 3.05	33.34 ± 7.76
NLS	0.005 ± 0.01	3.22 ± 0.04	1.82 ± 1.16	5.515 ± 2.03	0.73 ± 0.58	1.535 ± 0.99
KK	$0.45 \pm 0.220.4$	0.88 ± 0.08	0.88 ± 0.08	3.04 ± 0.9	0.785 ± 1.03	2.535 ± 1.01
WHO	≤5	30	45	250	250	1000

Values presented are expressed as mean values ± standard deviation ($n = 5$).

Table 8: Results of heavy metal content.

Samples	Fe^{2+} (mg/L)	Zn^{2+} (mg/L)	Pb^{2+} (mg/L)	Cu^{2+} (mg/L)	Al^{3+} (mg/L)	AS^{2+} (mg/L)	Mn^{2+} (mg/L)
SA	0.9 ± 1.4	$1.\ 0 \pm 0.04$	0.02 ± 0.00	0.265 ± 0.13	0.37 ± 0.08	0.21 ± 0.02	0.275 ± 0.15
SN	0.765 ± 1.07	0.855 ± 0.05	0.03 ± 0.04	0.225 ± 0.01	0.415 ± 0.07	0.24 ± 0.02	0.125 ± 0.03
SF	0.715 ± 0.97	1.83 ± 1.34	0.025 ± 0.01	0.365 ± 0.27	0.395 ± 0.01	0.215 ± 0.03	0.43 ± 0.06
NLS	0.02 ± 0.00	0.02 ± 0.00	0.006 ± 0.08	0.015 ± 0.01	0.01 ± 0.02	0.025 ± 0.01	0.005 ± 0.01
KK	0.005 ± 0.01	0.025 ± 0.01	0.006 ± 0.08	0.015 ± 0.01	0.01 ± 0.02	0.025 ± 0.01	0.015 ± 0.01
WHO	0.3	3	0.01	2	0.2	0.06	0.05

Values presented are expressed as mean values ± standard deviation ($n = 5$).

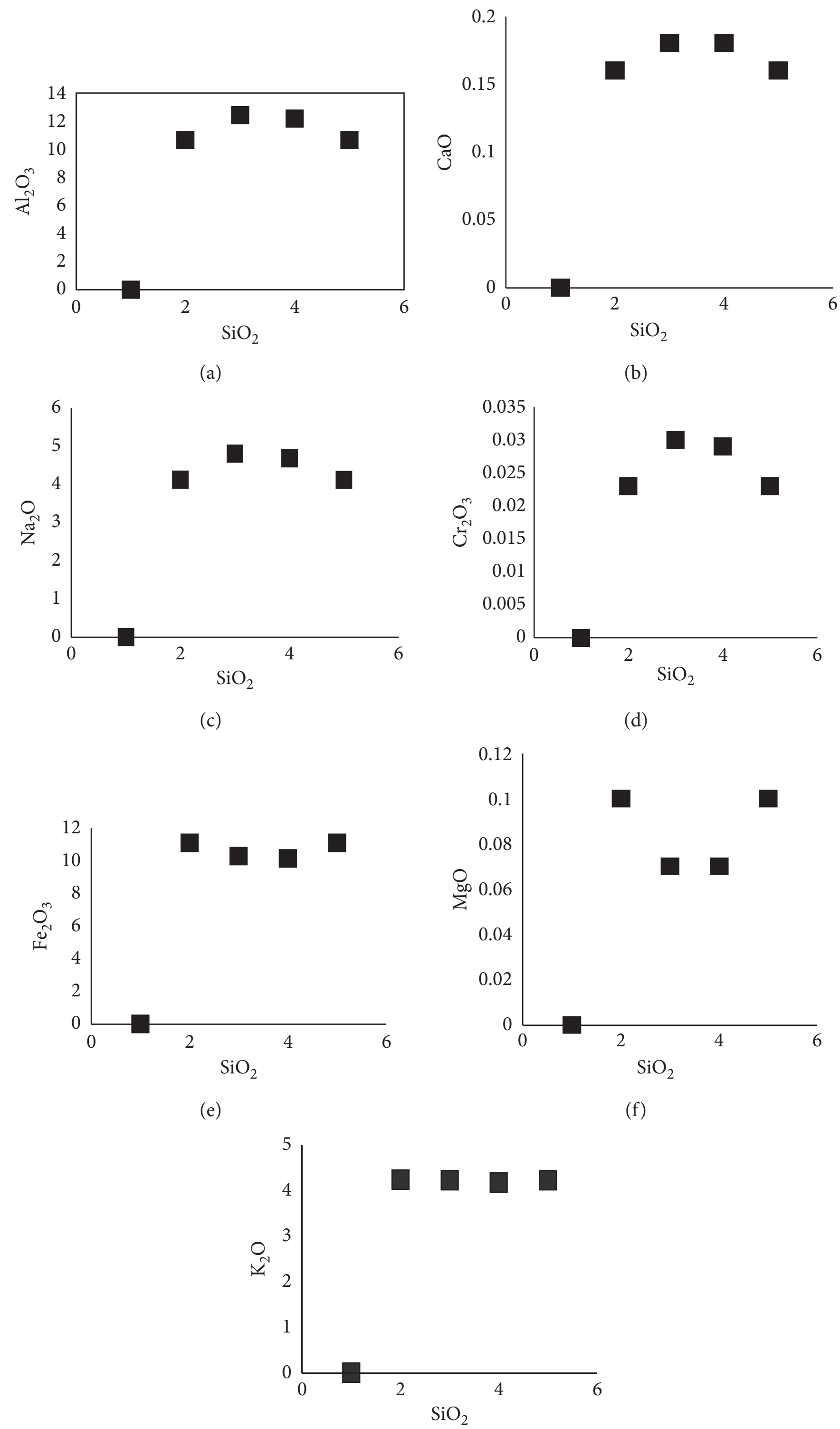

Figure 3: Harker diagrams for oxides in rock samples showing their contributions as silica content increases.

$Ca^{2+} > Mg^{2+} > K^{+} > Na^{+}$. PO_4^{3-} ranged from 0.155 ± 0.29 mg/L (SA) to 0.005 ± 0.01 mg/L (NLS). $N - NH_4^{+}$ ranged from 3.22 ± 0.04 mg/L (NLS) to 0.88 ± 0.08 mg/L (KK). $N - NO_3^{-}$ ranged from 3.92 ± 3.36 mg/L (SN) to 0.88 ± 0.08 mg/L (KK). Cl^{-} ranged from 5.515 ± 2.03 mg/L (NLS) to 0.43 ± 0.12 mg/L (SA). SO_4^{2-} ranged from 1.895 ± 3.05 mg/L(SF) to 0.37 ± 0.26 mg/L (SA). HCO_3^{-} ranged from 37.49 ± 16.06 mg/L (SN) to 1.535 ± 0.99 mg/L (NLS).The order of abundance of anions was as follows: $HCO_3^{-} > N-NO_3^{-} > N - NH_4^{+} > Cl^{-} > SO_4^{2-} > PO_4^{3-}$. Fe^{2+} ranged from

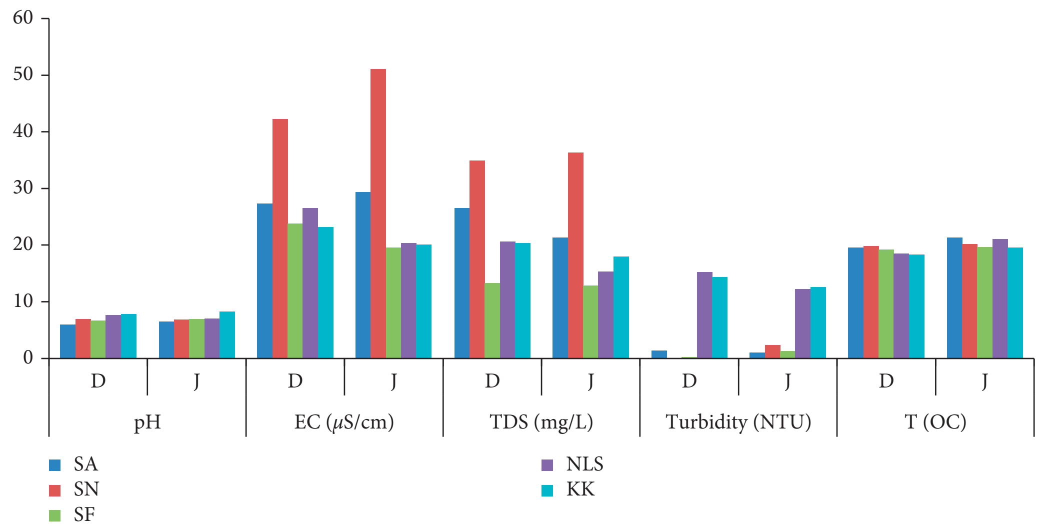

Figure 4: Comparison in physical parameters.

0.765 ± 1.07 mg/L (SN) to 0.005 ± 0.01 mg/L (KK). Zn^{2+} ranged from 1.83 ± 1.34 mg/L (SF) to 0.02 ± 0.00 mg/L (NLS). Pb^{2+} values ranged from 0.03 ± 0.04 mg/L (SN) to 0.006 ± 0.08 mg/L (KK). Cu^{2+} values ranged from 0.365 ± 0.27 mg/L (SF) to 0.015 ± 0.01 mg/L (NLS). Al^{3+} ranged from 0.415 ± 0.07 mg/L (SN) to 0.01 ± 0.02 mg/L (KK). AS^{2+} ranged from 0.215 ± 0.03 mg/L (SF) to 0.025 ± 0.01 mg/L (NLS). Mn^{2+} ranged from 0.275 ± 0.15 mg/L (SA) to 0.005 ± 0.01 mg/L (NLS).

In Figure 5, Ca^{2+} (mg/L) is the highest followed by HCO^{3-} (mg/L) and $Mg2^{+}$ (mg/L) in the water sources of the study area in both seasons.

The water sources indicated a huge significant difference with physicochemical parameters for both seasons. pH and temperature of the water sources were highly, significantly, and positively correlated with the sodium ($r = 0.900$, $p < 0.05$) content of the water sources (Table 9). The temperature of these water sources was significant and positively correlated with electrical conductivity ($r = 0.900$, $p < 0.05$). Calcium content was highly significant ($r = 0.975$, $p < 0.05$) and correlated with magnesium. The sodium content of the water sources was highly significant and positively correlated with ammonium ($r = 1.000$, $p < 0.05$), may be due to the use of fertilizers. The bicarbonate content was highly significant and positively correlated with turbidity and magnesium, respectively ($r = 0.975$, $p < 0.01$; $r = 0.895$, $p < 0.01$) content of the water sources. Turbidity was significant and positively correlated with zinc ($r = 0.900$, $p < 0.05$), lead ($r = 0.949$, $p < 0.05$), copper ($r = 0.949$, $p < 0.05$), aluminium ($r = 0.900$, $p < 0.05$), and calcium ($r = 0.900$, $p < 0.05$). Arsenic correlated positively with temperature ($r = 0.975$, $p < 0.05$) and calcium ($r = 0.900$, $p < 0.05$). Magnesium was also correlated positively with iron ($r = 1.000$, $p < 0.05$).

Figure 6 shows the presence of heavy metals with the highest in the study area being Fe (mg/L) and Zn (mg/L).

4.1. Hydrochemical Facies of the Springs. Piper's diagram was used in this study to properly characterize different hydrochemical facies (water types) and identify mixing and cation-exchange in the study area. The chemical water types of the study area were distinguished and grouped by their positions on Piper's diagram shown in Figure 7.

Bacteriologically, the springs fell under category C in the dry season, while in July, they fall under categories B, C, and D. For specific bacteria, *Enterobacter* ranged from 760 t0 150 CFU/100 mL in December and 600 to 150 CFU/100 mL in July for water sources in the study area. *Escherichia coli* ranged from 630 to 10 CFU/100 mL in December and 700 to 20 CFU/100 mL in July. *Streptococcus* ranged from 400 to 10 CFU/100 mL in December and 350 to 5 CFU/100 mL in July. *Salmonella* ranged from 25 to 00 CFU/100 mL in December and 75 to 5 CFU/100 mL in July. *Shigella* ranged from 10 to 00 CFU/100 mL in December and 15 to 5 CFU/100 mL in July. *Staphylococcus* ranged from 23 to 00 CFU/100 mL in December and 24 to 0.34 CFU/100 mL in July. The most contaminated spring is Farafat (SF) followed by Alabong (SA) and lastly Ngog (SN) in the study area. Figure 8 indicates that contamination was higher in both seasons.

The hospital data for Alatening village show that the population is highly affected by typhoid (Figure 9 and Tables 10 and 11).

Figure 8 indicates bacteria in water sources with *Enterobacteria*, *E. coli*, and *Streptococcus* projecting highly in the water sources.

4.2. Discussion

4.2.1. Petrography and Geochemistry. The petrographic studies revealed one type of rock which is trachyte, and this is confirmed by the petrography of Bamenda Mountains by Kamgang et al. [12]. The trachytic rocks constitute alkali feldspars, sanidine, plagioclase, and pyroxene. With weathering of these minerals into the soil, water-rock interaction occurs, thus water hydrogeochemistry (Table 12). Macroscopically, it showed an aphanitic-porphyritic texture

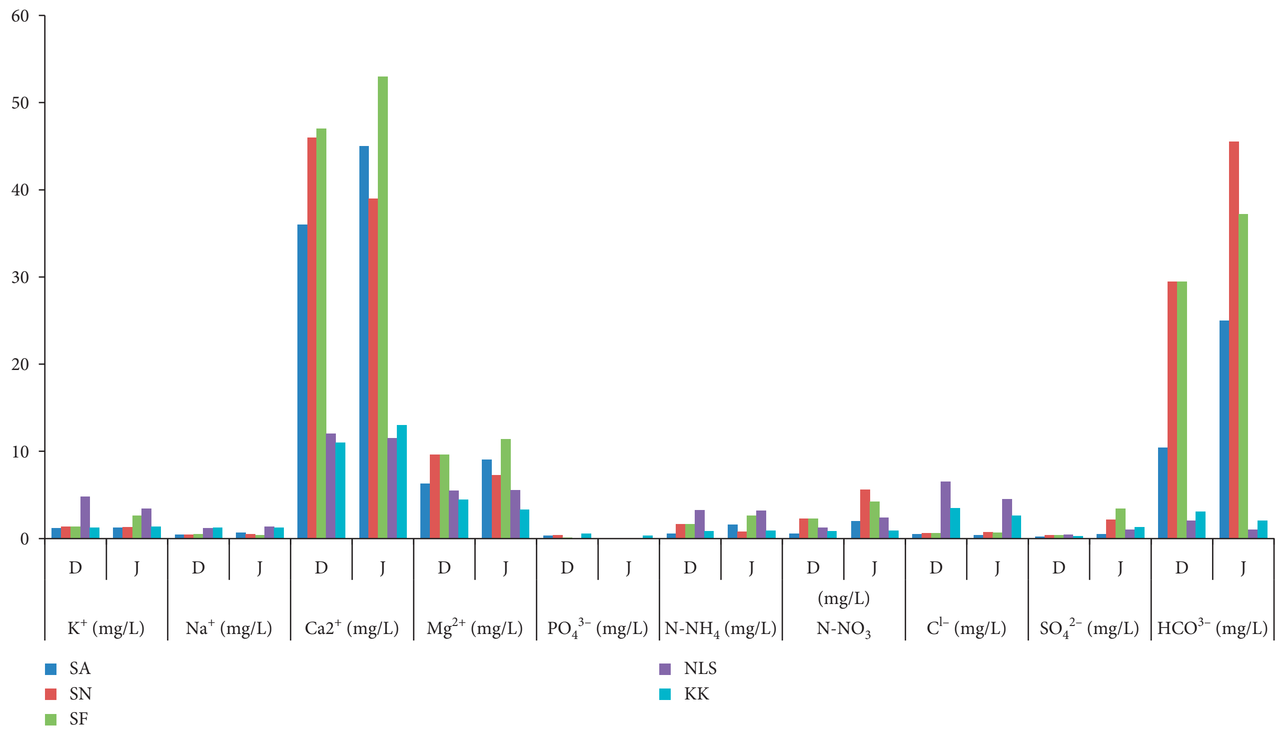

Figure 5: Comparison in chemical parameters.

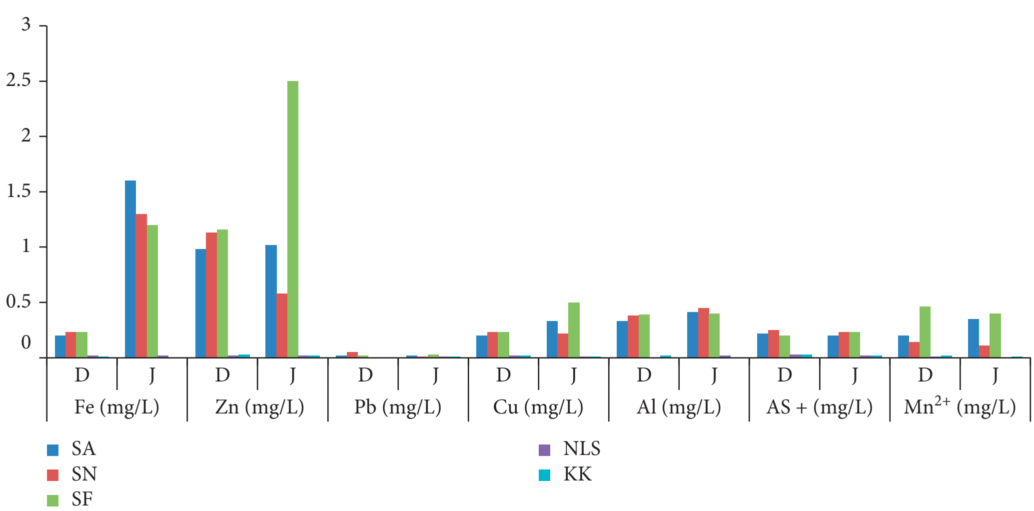

Figure 6: Comparison in heavy metals in water sources.

with large phenocrysts of sanidine. The rest of the rock is an aphyritic mass with microlitic-porphyritic texture with large phenocrysts of alkali feldspars and microcrystals of plagioclases embedded in a fine groundmass. The matrix of these rocks is made up of microlites of plagioclases, alkali feldspars, and oxides which are finely crystallised and found on laths of analcites (Figures 2 and 3). The major elements in this study area were almost the same in concentration compared to those of Kamgang et al. [12], 0.023 to 12.4 and 2.5 to 11.3%; also, the silica content is 60.6 to 61.7% in Alatening and 41 to 52% from the Bamenda Mountains by Kamgang et al. [12]. This high silica content in the rocks confirms that the rocks are acid rocks being trachytes (Table 1); thus, water mineralisation is mainly from rock weathering. Some of the major elements increased with increase in the silica content (Figures 3(e)–3(g), while others decreased (Figures 3(a)–3(d)). The trace and rare-earth elements (Tables 2 and 3) in the study area were significant and showed positive correlations with increasing concentration of SiO_2. The concentration of these elements is similar to that obtained by Kamgang et al. [12] at the Bamenda Mountains.

Table 9: Correlation of elements in water sources in Alatening.

	pH	EC	TDS	Tur	T	K^+	Na^+	Ca^{2+}	Mg^{2+}	PO_4^{3-}	N-NH_4	N-NO_3	Cl^-	HCO^{3-}
pH	1													
EC	0.500	1												
TDS	0.500	**0.900***	1											
Turbidity	0.500	0.500	0.300	1										
T	0.700	**0.900***	0.700	0.200	1									
K^+	0.400	0.200	0.100	0.100	0.000	1								
Na^+	**0.900***	0.800	0.600	0.600	**0.900***	0.300	1							
Ca^{2+}	0.700	0.400	0.000	0.200	0.700	0.100	0.600	1						
Mg^{2+}	0.667	0.564	0.205	0.872	0.221	0.154	0.667	**0.975****	1					
PO_4^{3-}	0.300	0.100	0.200	0.300	0.000	0.500	0.100	0.300	0.205	1				
N-NH_4	0.400	0.200	0.100	0.001	0.000	**1.000****	0.300	0.100	4.15	0.100	1			
N-NO_3	0.051	0.154	0.103	0.564	0.308	0.667	0.051	0.667	0.684	0.205	0.200	1		
Cl^-	0.872	0.462	0.308	0.667	0.718	0.667	0.872	0.564	0.579	0.000	0.154	0.158	1	
HCO^{3-}	0.564	0.359	0.103	**0.975****	0.718	0.154	0.564	0.872	**0.895***	1.000	0.500	0.306	0.579	1

**Correlation is significant at the 0.01 level (2-tailed), and *Correlation is significant at the 0.05 level (2-tailed).

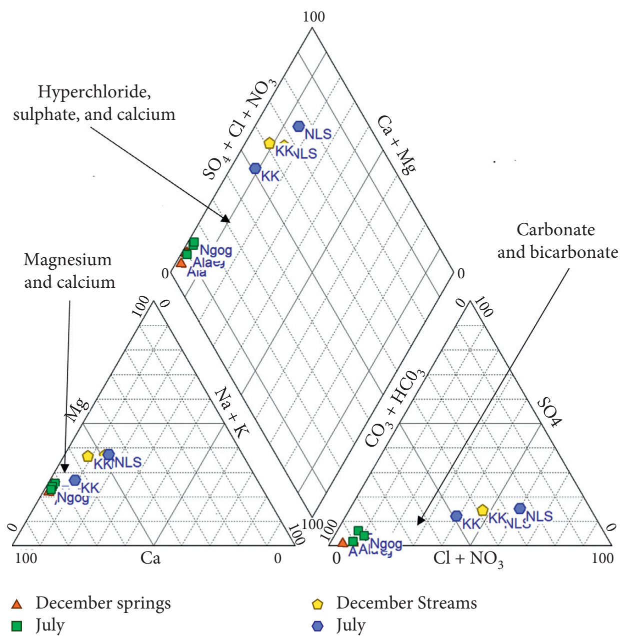

Figure 7: Piper's diagram showing variation in springs and streams.

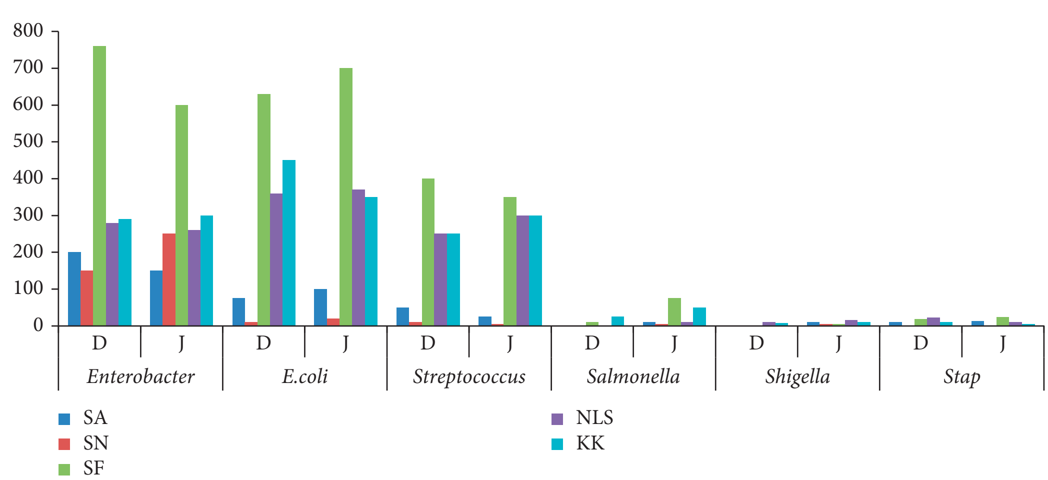

Figure 8: Comparison of bacteria species in water sources.

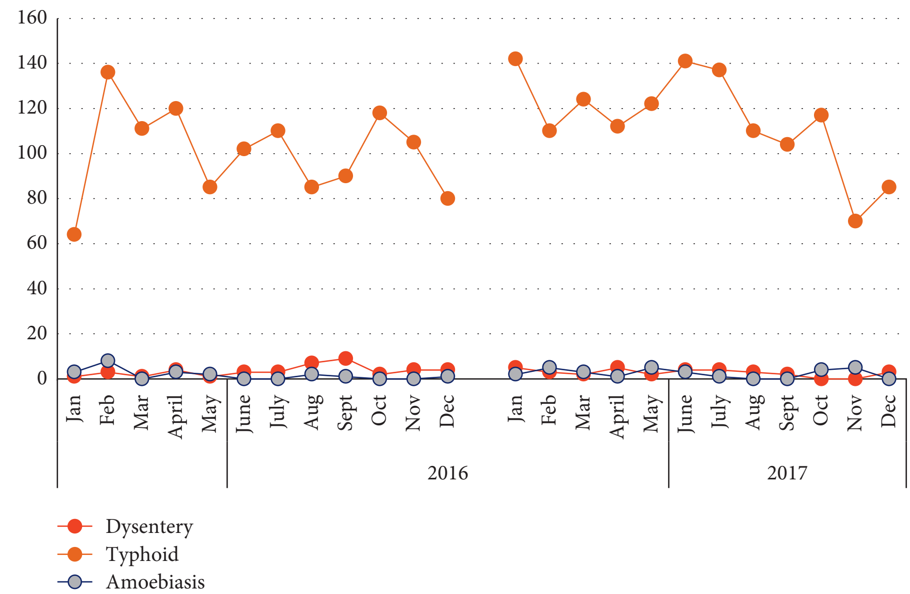

Figure 9: Monthly distribution of typhoid, dysentery, and amoebiasis in Alatening from 2016 to 2017.

Table 10: Statistics for waterborne diseases obtained from Holy Family Hospital and Baba II Health Centre for year 2016 (Alatening).

2016	January	February	March	April	May	June	July	August	September	October	November	December
Dysentery	1	3	1	4	1	3	3	7	9	2	4	4
Typhoid	64	136	111	120	85	102	110	85	90	118	105	80
Amoebiasis	3	8	0	3	2	0	0	2	1	0	0	1

Table 11: Statistics for waterborne diseases obtained from Holy Family Hospital and Baba II Health Centre for year 2017 (Alatening).

2017	January	February	March	April	May	June	July	August	September	October	November	December
Dysentery	5	3	2	5	2	4	4	3	2	0	0	3
Typhoid	142	110	124	112	122	141	137	110	104	117	70	85
Amoebiasis	2	5	3	1	5	3	1	0	0	4	5	0

Table 12: Water and rock sample locations.

Name and code of the sample	Quarter	Elevation	Latitude	Longitude	Vegetation	Rock/soil
Spring (SA)	Alabong	1617 m	N 05° 52′ 2.9′′	E 010° 06′ 49.3′′	Grassland	Trachyte/ferralitic
Spring (SF)	Farafat	1618 m	N 05° 52′ 14′′	E 010° 07′ 36.8′′	Grassland	Trachyte/ferralitic
Spring (SN)	Ngog	1633 m	N 05° 52′ 13.3′′	E 010° 08′ 02.2′′	Grassland	Benmoreite
Stream (NLS)	Nilap	1547 m	N 05° 52′ 23.1′′	E 010° 08′ 03.5′′	Farmland	Trachyte/ferralitic
Stream (KK)	Kie-kwifor	1508 m	N 05° 52′ 09.0′′	E 010° 07′ 48.0′′	Grassland	Trachyte/ferralitic

4.3. Organoleptic Parameters. Results of organoleptic parameters (Table 4) showed that all the water sources were clean, colourless, and odourless, except Alabong spring (SA), which had faint odour in December. The good organoleptic quality could be due to the fact that these are ground water which is naturally filtered as it flows vertically from the underground. Similar observations were made in Awing, Santa, by Mofor et al. [7]. Odour in SA may be due to the decomposition of organic matter around the source. This may be indicative of some sort of pollution. Ideally, safe drinking water should be clean and clear, as well as colourless and odourless. Based on these characteristics, the water sources were fit for drinking with the spring of Alabong in December being an exception.

4.4. Physical Parameters. Temperature ranged between 19.2°C and 21.3°C (Table 1) in both seasons without any significant difference ($p > 0.05$) and minimal and maximal annual temperatures of 15°C and 27°C, respectively, were shown in the study area. It also fell within the guideline range of 10°C to 25°C and could be as the result of seasonal and daily changes, shade, air temperature, water depths, and inflow of groundwater [10]. Similar temperature values were obtained by Wirmvem et al. [18] while studying the shallow groundwater recharge mechanism and apparent age in the Ndop plain, Northwest Cameroon. However, studies carried out by Wotany et al. [19] on hydrogeochemical and anthropogenic influences on the quality of water sources in the Rio Del Rey Basin, Southwestern Cameroon, Gulf of Guinea, revealed relatively high temperatures between 21°C and 29°C which was also justified by seasonal influences. Looking at the health aspect, the values were within the acceptable range of 15°C to 25°C. However, it should be noted that high water temperature enhances the growth of microorganisms and may increase problems related to taste, odour, colour, and corrosion [6].

pH of all the springs varied between 5.89 and 6.65 in December and between 6.5 and 6.9 in July with SA and SN falling below the WHO recommended range of 6.5–8.5. These results revealed barely acidic water which did not witness any significant change in pH with seasons ($p > 0.05$). Low pH of these ground water sources may be due to the presence of ions such as nitrates and sulphates and also acidic rocks in the study area [20]. The pH range established by the WHO is generally for the preservation of pipes against corrosion. For these springs which were generally collected from the source by the consumers, the obtained values had no significant impact on health.

The electrical conductivity of all the sources ranged between 19.5 and 51.1 μS/cm, while TDS ranged between 12.8 and 36.3 mg/L with a significant drop in both parameters from December to July ($p < 0.05$). Both parameters were very low compared to the WHO guideline values of 2000 μS/cm and 1000 mg/L, respectively, suggesting low mineralised and freshwater with very little dissolved solids [21]. Similar observations were made by Mofor et al. [7], on springs in Awing, Northwest Cameroon. The positive correlation between EC and TDS ($r = 1$) could be explained by the fact that EC arises from dissolved ionised solutes in water.

Turbidity in the water sources ranged from 0.03 to 2.34 NTU with SA and SN recording the highest values in December and July, respectively. There was a minor increase in turbidity in the rainy season ($p > 0.05$), which could be due to the introduction of particulate matter in the sources by rain. Based on the WHO established standard of 5 NTU, all the sources were void of turbidity contamination. Low turbidity in these sources could be due to the fact that these are ground water which is generally filtered as it flows from the underground. However, there was a possible risk of potential health effects as turbidity above 1 NTU may contribute to microbial growth and also protect them against disinfection [22, 23]. This justifies the positive correlation observed between turbidity and *Enterobacteria* ($r = 1$), turbidity and *E. coli* ($r = 1$), and turbidity and *Vibrio* ($r = 1$). These physical properties were similar to those obtained by Barakat et al. [3] of Morocco.

4.5. Chemical Properties. In both dry and rainy seasons, Na^+ was found to be between 0.39 and 0.68 mg/L, K^+ was found to be between 1.17 and 2.61 mg/L, while Cl^- was found to be between 0.37 and 0.68 mg/L without any significant deference between the dry and the rainy seasons ($p > 0.05$). Comparing these results with the WHO guideline values of 200 mg/L for Na^+ and K^+ and 250 mg/L for Cl^-, the concentrations of all the three ions were very low and did not show any health concern. Low sodium and chloride ions in the water sources could be as a result of low NaCl in the geological formations of the study area (trachytes) as both ions are generally from the decomposition of rock salt like sodium and aluminium silicates [7, 24]. According to Wirmvem et al. [21], low K^+ in water may be due to its low geochemical mobility in the soils of the study area.

In the analysed water sources, Ca^{2+} concentration was found to be between 36 and 53 mg/L; meanwhile, Mg^{2+} ranged between 6.3 and 11.4 mg/L. However, no significant difference was observed in their concentrations between December and April ($p > 0.05$). Knowing that the maximum permissible limits for calcium and magnesium ion concentration set by the WHO for drinking water are 75 mg/L and 30 mg/L, respectively, all the water sources were suitable for drinking and classified as soft water as their concentrations were below 60 mg/L [10]. These results were in disagreement with those of Mofor et al. [7] and Tiekeu et al. [25] as they reported very low levels of calcium and magnesium in ground water in Awing community and Yaoundé area, respectively. High level of calcium and magnesium in these sources could be due to their high occurrence in the soils suggesting the presence of limestone and chalk sediments in the study area [10]. The positive correlation between Ca^{2+} and Mg^{2+} ions ($r = 0.991$) suggests their common origin. Though calcium and magnesium are essential minerals for health, water with hardness above 50 mg/L will lead to lathering impairment in laundry and bathing and the scaling in pipes and some equipment in homes [22].

Water alkalinity is ensured by three ions which are HCO_3^-, CO_3^{2-}, and OH^-. Analyses revealed the absence of CO_3^{2-} and OH^-. Thus, only HCO_3^- was responsible for alkalinity in the studied springs. Its concentration ranged between 10.42 and 45.52 mg/L without any significant difference between the two sampling seasons ($p > 0.05$) and was very low compared to the WHO guideline value of 1000 mg/L. HCO_3^- is necessary as it constitutes an important buffer system which helps in lowering the acidity of water [25]. Its presence in the studied water sources could be as the result of weathering of carbonate minerals in rocks and soil of the study area.

Sulphate concentration ranged between 0.24 and 3.42 mg/L. Sulphate concentrations were insignificant in the sources regarding the WHO guideline value of 250 mg/L. Low sulphates suggest low and possible absence of evaporitic sedimentary rocks such as gypsum ($CaSO_4$) and pyrite (FeS) in the study area, and the minor increase in their concentrations in April was surely due to the effect of rain and the use of fertilizers [23].

As for nitrates, their concentration was found to be between 0.56 and 5.6 mg/L. Nitrates found in these water sources in December probably came from nitrate-producing bacteria in water, and the insignificant increase ($p > 0.05$) observed in April suggests its infiltration from wastes and fertilizers into the water body. However, these concentrations were very low compared to the WHO guideline value of 50 mg/L. Interest is centred on nitrate concentrations mostly because high nitrate levels in water have been reported to be responsible for the "blue baby" syndrome (methaemoglobinaemia) and typhoid effects [6]. The sampled sources were free from nitrate and sulphate contamination.

NH_4^+ ranged from 0.56 mg/L to 2.6 mg/L and was far below the acceptable limit of 30 mg/L prescribed by the WHO. NH_4^+ in the water sources was surely from biological breakdown of domestic and agricultural wastes, and its presence was thus an indicator of bacterial, sewage, and animal waste contamination [10, 26]. However, its low concentrations suggest no associated health risk.

Phosphate ranged between 0.01 and 0.38 mg/L in all samples, which was below the WHO limit of 5 mg/L. This could be due to its sorption on organic colloids. Similar results were reported by Mofor et al. [7] in springs in the Awing community. Though phosphorus is an essential nutritive element, phosphate has been reported to be the major contributor to the multiplication of algae contributing to the eutrophication of the medium [27] leading to the alteration of the water sources. Thus, its low concentrations were not of concern though it may have an effect on human health in the future. Most of the chemical properties were lower than those obtained by Taloor et al. [2] of the Jammu Himalaya.

4.6. Hydrochemical Facies of the Springs. The water facies were in cluster, especially in the magnesium diamond chart, for both seasons indicating no significant change in their concentrations. The water facies were such as Mg-Ca, Cl-Ca, and HCO_3-CO_3, Figure 7, suggesting an influence of natural process (rock silicate) weathering and anthropogenic influence. From Piper`s diagram, different chemical facies of analysed water mostly represent the major cations and anions for both rainy and dry seasons, indicating that there is no change in the chemical facies with the change in season. These chemical facies were similar to those obtained by Ajay et al. [2], revealing two hydrochemical dominant facies on the Piper trilinear diagram, $Ca_2þ$-$Mg_2þ$-HCO^{3-} and $Ca_2þ$-Mg_2-HCO_3-SO_2^{4-} type, which depict that water chemistry is dominated by the alkaline earth and weak acids.

4.7. Heavy Metals. All the heavy metals did not vary significantly between December and July ($p > 0.05$).

High iron in all the samples in July could be due to the fact that current water pH favoured the solubility of its oxides and hydroxides leached from nearby soils. Tamungang et al. [28] made a similar observation in ground water in Bagangté Municipality, where a high iron content was recorded in the water bodies. Though iron is vital for health, its high concentrations in the studied springs present associated health risk. Also, at levels above 0.3 mg/L, iron oxides stain laundry and plumbing fixtures, give noticeable taste to water, develop turbidity and colour, and also promote the growth of "iron bacteria." [6] The low values of lead in SN could be justified by the fact that it comes mainly from galvanized iron pipe plumbing [10], but lead was higher in SA and SF. That is to say, lead was found to be higher in some samples (SA and SN) indicating high health risk to the population, while it was low in the rest of the samples. Zinc was the second abundant element after iron in both seasons. However, it was below the WHO maximum permissible value of 3 mg/L for drinking water. Its presence could be as the result of its leaching from the soil [29]. It should be noted that drinking water containing zinc at levels above 3 mg/L may not be acceptable to consumers due to its unpleasant taste [10]. Copper levels were insignificant compared with the WHO guideline value of 2 mg/L. However, even below 2 mg/L, it could still give metallic taste to water [22]. Aluminium was second in abundance after zinc and was above the WHO guideline value of 0.2 mg/L in all the water sources. Its high concentrations were surely due to its abundance in the soils of the study area. This was a major problem since aluminium at concentrations in excess of 0.1–0.2 mg/L often leads to the deposition of the aluminium hydroxide floc and the exacerbation of discoloration of water by iron. Also, it was hypothesized that aluminium exposure is a risk factor for the development or acceleration of onset of Alzheimer disease in humans [6].

The correlation between electrical conductivity and total dissolved solids implies that the increase of one leads to an increase of the other in the study area. The correlation between pH and sodium might be due to their relationship suggesting that increase in pH will also affect the content of other elements. The significant correlation between temperature and sodium also shows that increase in temperature may influence the concentration of sodium. The highly significant content of bicarbonates in water sources gave a positive correlation with turbidity and magnesium which may also influence the growth of some bacteria.

4.8. Bacteriological Quality. Analyses revealed the presence of faecal coliforms in all the sources with mean count ranging between 10/100 mL and 50/100 mL of water (Table 13), suggesting recent contamination of water by human or animal faeces. Based on the WHO guidelines, the spring of Ngog showed a high risk for consumers and was thus unfit for drinking, falling under category C in both seasons. The other two springs (SA and SF) also fell under category C in December; meanwhile, in April, SA was acceptable for consumption (category B) and SF being grossly polluted (category D), Table 13. Detailed analysis led to the identification of specific bacteria, namely, *Enterobacter* spp, *Streptococcus* spp, *Salmonella* spp, *Staphylococcus* spp, and *Shigella* spp, with colony counts between 150 and 760 CFU/mL, 20 and 700 CFU/mL, 5 and 75 CFU/mL, 5 and 75 CFU/mL, and 5 and 10 CFU/mL, respectively (Table 14). SF was found to be the most polluted followed by SN and lastly SA. Looking at these results, none of the water sources respected the WHO guideline which recommends no bacteria of faecal origin in drinking water. Many studies carried out around Cameroon, namely, those of Temgoua [30], Wirmvem et al. [12], Nanfack et al. [11, Tamungang et al. [25], and Mofor

Table 13: Results of bacteriological analysis (most probable number).

Sample	Most probable number of coliforms in 100 ml of original water			
	December		July	
	Mean count	Category	Mean count	Category
SA	11	C	10	B
SN	30	C	40	C
SF	12	C	50	D
WHO	00, A			

A = excellent; B = acceptable; C = unacceptable, high risk; and D = grossly polluted.

Table 14: Results of bacteriological analysis (specific bacteria isolated).

Sample	*Enterobacter*		*E. coli*		*Streptococcus*		*Salmonella*		*Shigella*		*Stap*	
	D	J	D	J	D	J	D	J	D	J	D	J
SA	200	150	75	100	50	25	00	10	00	10	10	13
SN	150	250	10	20	10	5	00	5	00	5	0.00	0.34
SF	760	600	630	700	400	350	10	75	00	5	19	24
NLS	280	260	360	370	250	300	00	10	10	15	23	10
KK	290	300	450	350	250	300	25	50	07	10	10	05

et al. [7], also revealed high colonies of pathogenic bacteria in ground water. According to Nanfack et al. [17], the presence of pathogenic bacteria in these water sources was surely due to poor hygiene and sanitation. In addition, the pollution of these water sources could be explained using other factors amongst which are those related to the environment such as infiltration of organic matter in the soil and the low depth of the groundwater table and the behaviour of the population through open-air defecation. The positive correlation observed between *Enterobacteria* spp and *Shigella* spp ($r = 1$) and *Enterobacteria* spp and *Vibrio* spp ($r = 1$) was possibly due to their common origin.

The population of the study area often judges their drinking water based on organoleptic parameters such as appearance, taste, and odour. However, these expose them to water-related diseases such as typhoid, diarrhoea, amoebiasis, and dysentery given the high colonies of pathogenic bacteria in these sources. Data obtained from health centres in the locality on waterborne diseases between 2016 and 2017 confirmed the prevalence of typhoid to which amoebiasis and dysentery were also associated, as shown in Figure 9. A total of 2702 cases of these diseases were recorded during those two years with 2580 cases of typhoid, 73 cases of dysentery, and 49 cases of amoebiasis. From Figure 9, an increase was observed in the number of cases from 2016 to 2017. It should be noted that these were just some few cases out of many others as many people in this locality may prefer traditional medicine for the treatment of these diseases rather than going to the hospital. Also, others may prefer going to bigger hospitals not far from the locality for better health care. The water sources were of bad quality and thus not suitable for drinking (Figure 9).

5. Conclusion

The main purpose of this study was to assess the petrography and quality of drinking water in some populated quarters in Alatening, Northwest Cameroon, based on the WHO guidelines. Rock analysis revealed one type of rock which is trachyte with different major, trace, and rareearth element variations which gave geochemistry of the area and also contributed to water chemistry. Organoleptic parameters showed that all the water sources were clean, colourless, and odourless with the exception of Alabong spring. Looking at the physicochemical properties, all the water sources had temperatures falling within the WHO standards, and pH ranged from weakly acidic to neutral and weakly basic with low mineral content. The chemical properties indicated that the samples had below-average concentrations of cations and anions. The water facies were such as Mg-Ca, Cl-Ca, and HCO3-CO3, Figure 3, suggesting an influence of natural process (rock silicate) weathering and anthropogenic influence. The results of heavy metals indicated that iron, lead, aluminium, arsenic, and manganese were found to be above the WHO standard values in both seasons, and this was endorsed to the nature of the rocks and soils in the study area, thus presenting a low risk factor for the development or acceleration of onset of Alzheimer disease in the future. Results of bacteriological analysis revealed recent pollution of the water sources by human or animal faeces given the presence of faecal coliforms in all the water sources. Detailed analysis also revealed the presence of *Enterobacter* spp, *Streptococcus* spp, *Salmonella* spp, and *Shigella* spp. The poor bacteriological quality of these sources was related to poor hygiene and sanitation, poor maintenance, and some environmental factors; so, the population is thus exposed to waterborne diseases such as typhoid, dysentery, and amoebiasis as 2702 cases were recorded between 2016 and 2017 with an increasing tendency. Therefore, the poor bacteriological quality of the water sources is a major threat to the health of the local population. The water sources require home treatments such as boiling and chlorination before consumption.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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