Research Article

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

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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 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].

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-Saharan 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-Saharan African countries [8].

Cameroon is one of the sub-Saharan 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 6°67′ north and longitudes 10°15′ and 10°22′ east, Santa covers a surface area of about 532.67 km² 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 penevolved ferralic and alitic. 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 Dschangu 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 (LiBO₂/Li₂B₄O₇) 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 digests 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, Ca²⁺ and Mg²⁺ were determined by complexometric titration, and Cl⁻ was determined by the argentometric method. SO₄²⁻ ion was determined by gravimetric analysis, and NO₃ and NH₄⁺ ions were determined by Kjeldahl’s distillation method. PO₄³⁻ ion was determined by UV-visible spectrophotometric analysis. HCO₃⁻ 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.
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 $2 \times 3$ mm to $3 \times 4$ mm. These rocks were highly jointed. Trachytes vary in colour as observed in Figure 2. Trachytes of Alatening are light in colour. Rocks 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 (sainidine) 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 $0.25 \times 0.5$–$1.5 \times 2.5$ 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. Plagioclasses are mostly found in the matrix, some occurred as phenocrysts, and exhibit albite twinning with a size of about $0.25 \times 0.5$–$1.5 \times 2$ mm (3). Clinopyroxenes (pyroxenes) constituted about 5% of the rock and occurred mostly in the matrix. Their sizes ranges from microcrystals to phenocrysts ($0.25 \times 0.5$ mm–$1.5 \times 2.5$ 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.

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...
Ngog, and SF, sample from Farafat; NLS is the sample from the Nilap stream, and KK is the sample from Kie-kwifo; 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 Microsoft Excel. pH ranged from $8.0 \pm 0.4$ (KK) to $6.775 \pm 0.25$ (SN). 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 $35.6 \pm 1.4$ mg/L (SN) to $17.95 \pm 5.3$ mg/L (NLS). Turbidity values ranged from $13.45 \pm 1.7$ NTU (KK) to $0.735 \pm 1.01$ 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 1 and 2. The order of abundance of cations was $K^+ > Na^+ > Ca^{2+} > Mg^{2+}$. The ratios of $K^+ : Na^+$ were $0.74$ for SN, $0.36$ for SF, and $0.27$ for KK. The $Na^+ : K^+$ ratios were $0.21$ for SN, $0.13$ for SF, and $0.18$ for KK.

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## Table 1: Major elements/silica in rock samples

| Elements   | A1   | A2   | A3   | A4   |
|------------|------|------|------|------|
| SiO₂       | 61.7 | 61.5 | 60.6 | 61.6 |
| Al₂O₃      | 10.65| 12.4 | 12.15| 10.65|
| Fe₂O₃      | 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  |
| Na₂O       | 4.12 | 4.8  | 4.68 | 4.11 |
| K₂O        | 4.22 | 4.21 | 4.16 | 4.21 |
| Cr₂O₃      | 0.023| 0.03 | 0.029| 0.023|

## Table 2: Trace elements in rock samples.

| Elements | 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    |

## Table 3: Rare-earth elements in rock samples.

| Elements | 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 |
| Th       | 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  |

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 1 and 2. The order of abundance of cations was $K^+ > Na^+ > Ca^{2+} > Mg^{2+}$. The ratios of $K^+ : Na^+$ were $0.74$ for SN, $0.36$ for SF, and $0.27$ for KK. The $Na^+ : K^+$ ratios were $0.21$ for SN, $0.13$ for SF, and $0.18$ for KK.
### Table 4: Results of organoleptic parameters.

| Source | Appearance, colour, and odour December | Appearance, colour, and odour 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 | 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 ± 2.3  | 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) | Ca²⁺ (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 | PO₄³⁻ (mg/L) | N – NH₄⁺ (mg/L) | N – NO₃⁻ (mg/L) | Cl⁻ (mg/L) | SO₄²⁻ (mg/L) | HCO₃⁻ (mg/L) |
|---------|-------------|----------------|----------------|------------|--------------|-------------|
| 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     | 1.42 ± 3.36    | 0.56 ± 0.14 | 1.255 ± 1.8 | 37.49 ± 16.06 |
| SF      | 0.06 ± 0.08  | 2.115 ± 0.97    | 1.32 ± 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    | 0.515 ± 2.03| 0.73 ± 0.58 | 1.535 ± 0.99  |
| KK      | 0.45 ± 0.220.04| 3.88 ± 0.08    | 3.04 ± 0.9     | 0.785 ± 1.03| 2.535 ± 1.01| 1.535 ± 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 | Fe²⁺ (mg/L) | Zn²⁺ (mg/L) | Pb²⁺ (mg/L) | Cu²⁺ (mg/L) | Al³⁺ (mg/L) | As³⁺ (mg/L) | Mn²⁺ (mg/L) |
|---------|------------|------------|------------|------------|------------|-------------|-------------|
| SA      | 0.9 ± 1.4  | 1.0 ± 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).
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
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 Mg$^{2+}$ (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 to 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. Shigella ranged from 25 to 00 CFU/100 mL in December and 75 to 5 CFU/100 mL in July. Salmonella 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 anaphitic-porphryritic texture.
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 SiO₂. The concentration of these elements is similar to that obtained by Kamgang et al. [12] at the Bamenda Mountains.

**Figure 5:** Comparison in chemical parameters.

**Figure 6:** Comparison in heavy metals in water sources.
Hyperchloride,
sulphate, and calcium

\[ \text{Ca} + \text{Mg} \]
\[ \text{Na} + \text{K} \]
Carbonate 
and bicarbonate

\[ \text{December springs} \]
\[ \text{July} \]
\[ \text{December Streams} \]
\[ \text{July} \]

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

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

| pH   | EC   | TDS | Tur | T   | K⁺  | Na⁺  | Ca²⁺ | Mg²⁺ | PO₄⁻ | N-NH₄ | N-NO₃ | Cl⁻  | HCO₃⁻ |
|------|------|-----|-----|-----|-----|------|------|------|------|-------|-------|------|-------|
| 1    | 0.500| 0.900| 0.900| 0.900| 0.900| 0.900| 0.900| 0.900| 0.900| 0.900| 0.900| 0.900| 0.900|

**Figure 8:** Comparison of bacteria species in water sources.

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

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, Ca²⁺ concentration was found to be between 36 and 53 mg/L; meanwhile, Mg²⁺ 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 Ca²⁺ and Mg²⁺ 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 alkalininity is ensured by three ions which are HCO₃⁻, CO₃²⁻, and OH⁻. Analyses revealed the absence of CO₃²⁻ and OH⁻. Thus, only HCO₃⁻ 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. HCO₃⁻ 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 (CaSO₄) 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 (methaemoglobinemia) and typhoid effects [6]. The sampled sources were free from nitrate and sulphate contamination.

$\text{NH}_4^+$ 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. $\text{NH}_4^+$ 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 $\text{HCO}_3^- \cdot \text{CO}_3^-$, 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, $\text{Ca}_2^+\cdot \text{Mg}_2^+\cdot \text{HCO}_3^-$ and $\text{Ca}_2^+\cdot \text{Mg}_2^+\cdot \text{HCO}_3^-\cdot \text{SO}_4^{2-}$ 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]. Aluminum 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, 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...
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 ($r^2 = 1$) 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.

| Sample | Mean count December | Category | Mean count July | 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.

| Sample | Enterobacter | E. coli | Streptococcus | Salmonella | Shigella | Stap |
|--------|--------------|---------|----------------|------------|----------|------|
| SA     | 200          | 150     | 75             | 100        | 50       | 25   |
| SN     | 150          | 250     | 10             | 20         | 10       | 5    |
| SF     | 760          | 600     | 630            | 700        | 400      | 350  |
| NLS    | 280          | 260     | 360            | 370        | 250      | 300  |
| KK     | 290          | 300     | 450            | 350        | 250      | 300  |

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

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

References
[1] Helvetas, “Development of other sectors such as nutrition and sanitation,” 1985.
[2] K. T. Ajay, A. P. Rayees, A. Narsimha et al., “Spring water quality and discharge assessment in the basantar watershed of jammu himalaya using geographic information system (GIS) and water quality index (WQI) groundwater for sustainable development,” 2020.
[3] A. Barakat, R. Meddah, M. Afdali, and F. Touhami, “Physicochemical and microbial assessment of spring water quality for drinking supply in Piedmont of Beni-Mellal Atlas (Morocco),” Physics and Chemistry of the Earth, Parts A/B/C, vol. 104, p. 39, 2018.
[4] L. P. Li, A. Byleveld, and W. Smith, “Assessment of chemical quality of drinking water,” 2009.
[5] UNICEF, UNICEF Handbook on Water Quality, United Nations Children’s Fund, New York, NY, USA, 2008.
[6] WHO, Guidelines For Drinking-Water Quality, World Health Organization, Geneva, Switzerland, 2017.
[7] N. A. Mofor, E. B. Njoyim, and A. D. Mvondo-Ze, “Quality assessment of some springs in the awing community, northwest Cameroon, and their health implications,” Journal of Chemistry, vol. 2017, pp. 1–11, 2017.
[8] UNICEF and WHO, Progress on Sanitation and Drinking Water, United Nations Children’s Fund, New York, NY, USA, 2015.
[9] BUCREP, Rapport de Presentation des Resultats Definitifs, Bureau Central des Recensements et des Etudes de Population, New York, NY, USA, 2010.
[10] WHO, Guidelines for Drinking-Water Quality, World Health Organization, Geneva, Switzerland, 4th edition, 2011.
[11] WHO, Water and Sanitation Related Diseases Fact, World Health Organization, Geneva, Switzerland, 2006.
[12] P. Kamgang, E. Njonfang, G. Chazot, and F. Tchoua, “Géochimie et géochronologie des laves felsiques des monts Bamenda (ligne volcanique du Cameroun),” Comptes Rendus Geoscience, vol. 339, no. 10, pp. 659–666, 2007.
[13] UCCC, Santa Council, United Councils and Cities of Cameroon, New York, NY, USA, 2014.
[14] WHO, Water pollution, May 2014, http://www.explainthatstuff.com/waterpollution.html.
[15] J. J. Rodier, H. Beuffe, M. Bournaud et al., Analyse de l’Eau, World Health Organization, Paris, France, 1984.
[16] A. M. Piper, “A graphic procedure in the geochemical interpretation of water analyses,” U.S. Geological Survey, vol. 12, 1953.
[17] N. A. C. Nanfack, F. A. Fonteh, V. K. Payne, B. Katte, and J. M. Fogoh, “Eaux non conventionnelles: un risque ou une solution aux problemes d’eau pour les classes pauvres,” Larhyss Journal, vol. 17, pp. 47–64, 2014.
[18] M. J. Wirrmvem, M. E. Mimba, B. T. Kamchuen et al., “Shallow groundwater recharge mechanism and apparent age in the Ndop plain, Northwest Cameroon,” Applied Water Science, vol. 7, no. 1, pp. 489–514, 2013.
[19] E. R. Wotany, S. N. Ayonghe, W. Y. Fantong, M. J. Wirrmvem, and O. Takeshi, “Hydrogeochemical and anthropogenic influence on the quality of water sources in the Rio del Rey Basin,” African Journal of Environmental Science and Technology, vol. 7, no. 12, pp. 1053–1106, 2013.
[20] ODNR, Ground Water Quality, Ohio Department of Natural Resources, Columbus, OH, USA, 1997.
[21] M. J. Wirrmvem, O. Takeshi, W. Y. Fantong et al., “Hydrochemistry of shallow groundwater and surface water in the Ndop plain, North West Cameroon,” African Journal of Environmental Science and Technology, vol. 7, no. 6, pp. 518–530, 2013.
[22] A. Kuhn, W. N. Lesufi, and A. P. M. Oelofse, Quality of Domestic Water Supply Volume One, Water Research Committee, Columbus, OH, USA, 2001.
[23] D. Ghazali and A. Zaid, “Etude de la qualité physico-chimique et bactériologique des eaux de la source Ain Salama-Jerri (region de Meknes–Maroc),” Larhyss Journal, vol. 12, pp. 25–36, 2013.
[24] M. L. Belhiti, “Study of the quality physico-chemical and bacteriological and groundwater of plio-quaternary ribbon in the region of Meknes (Morocco),” Larhyss Journal, vol. 14, p. 34, 2013.
[25] W. A. Teikeu, I. J. L. Meli, P. N. Nouck, T. C. Tabod, F. E. A. Nyam, and Z. Aretouyap, “Assessment of groundwater quality in Yaounde area, Cameroon, using geostatistical and statistical approaches,” Environmental Earth Sciences, vol. 75, pp. 1–21, 2016.
[26] A. Abboudi, H. Tabyaoui, F. El Hamichi, L. Benaabidate, and A. Lahrach, “Etude de la qualité physico-chimique et contamination métallique des eaux de surface du bassin versant de Guigou, Maroc,” European Scientific Journal, vol. 10, pp. 1857–7881, 2014.
[27] S. Ladjel, Control of Physico-Chemical and Bacteriological Parameters Drinking Water, Water Trades Training Center, New York, NY, USA, 2009.
[28] N. E. B. Tamungang, T. R. Menga, N. A. Mofor, F. B. Nchorouf, and I. K. Njoyim, “Evaluation of surface and ground water quality in the Bagangte municipality-West Cameroon,” International Journal of Research and Review in Applied Sciences, vol. 28, no. 2, pp. 53–64, 2016.
[29] WHO, Nutrients in Drinking Water, World Health Organization, Geneva, Switzerland, 2005.
[30] E. Temgoua, “Chemical and bacteriological analysis of drinking water from alternative sources in the Dschang municipality, Cameroon,” Journal of Environmental Protection, vol. 2, no. 5, pp. 620–628, 2011.

ODNR, Ground Water Quality, Ohio Department of Natural Resources, Columbus, OH, USA, 1997.