Physico-Chemical and Bacteriological Characterization of Spring and Well Water in Bamenda III (NW Region, Cameroon)

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Abstract: Bamenda is a major town in the NW Region of Cameroon and constitutes part of the Cameroon Volcanic line. In the frame of this work, four springs and three wells in the Bamenda III council area were investigated to evaluate the physico-chemical and bacteriological characteristics of their waters. All the water points yielded pH values below 6.5 and were classified as acidic water. Electrical conductivity ranged between 0.04-2.38μm/cm. The relative abundance of major ions (meq/l) was $Ca^{2+} > Mg^{2+} > K^+ > Na^+$ for cations and $HCO_3^- > SO_4^{2-} > NO_3^- > PO_4^{3-}$ for anions. Major ion concentrations were within the WHO guidelines for drinking water, but Ca^{2+} (110-1770mg/l) and Mg^{2+} (97.05-236.85mg/l) concentrations were much higher and above WHO limits. Main water types in the dry season were Ca-Mg-HCO3 while in rainy season the main water types were Ca-Mg-HCO3 and a mixed Ca-Mg-SO4. Bacterial analysis revealed that the water samples were highly polluted and classified B, C and D according to Cheesbrough classification. The spring and well waters analysed are not suitable for drinking and domestic purposes therefore the population of Bamenda III which depends on the mentioned water for drinking and domestic purposes may face serious health problems if appropriate actions are not taken to prevent and mitigate the problems.

Keywords: Bamenda III, Faecal Bacterial Analysis, Physico-Chemical Analysis, Water Quality

1. Introduction

Cameroon is endowed with numerous water sources [1,2]. It is a country with the second highest volume of available water in Africa [3]. Groundwater constitutes 21.5% (57 billion m3) of this resource and plays a very important role in the socio-economic life of the country.

The setting and evolution of most forms and pattern of settlements is linked to the availability of reliable and substantial water sources, and the fertility of volcanic soils have brought through ancient times the intense settlement and agricultural exploitation of the lower flanks of volcanoes [4]. This is the case of Bamenda town, a rapidly growing town which belongs to the Cameroon Volcanic Line (CVL) the principal watershed of the country [5]. Many thermal and mineral springs typified by the Fe - Mg - Ca –HCO_3^- or Na – HCO_3^- compositions are found along the CVL [6]. The chemical composition of surface and groundwater is controlled by many factors that include composition of precipitation, mineralogy of watershed and aquifers, climate and topography as well as anthropogenic influence such as urban, industrial and agricultural activites. These factors combine to create diverse water types that change spacially and temporally [3]. When water perculates through formations, it comes in contact with geologic formations and ions are exchanged especially during the process of weathering and alteration. These rocks release minerals whose ions enter aquifers and alter the chemical composition.

Geochemical studies from groundwater and surface water can provide a better understanding of potential water quality variations due to geology and land use practices [7-9].

Knowledge of the levels of microorganisms in water is also important for indexing the health harzard associated with its use, adopting meaningful interventions and improving bacterial water quality [10]. The Bamenda III Council Area is made up of many springs and wells on which about 80% of the population depends for both drinking and domestic purposes. Characterizing the mentioned water is of great importance to determine if the population is at risk. In this paper we present the evaluation of the physico-chemical and bacteriological qualities of some springs and wells in Bamenda III.

2. Natural Setting of the Study Area

Bamenda III is found in Mezam Division in the North West Region of Cameroon between latitudes 06°00'N and 06°89'N and longitudes 10°13'E and 10°28'E (Figure 1). This town is located at the central part of the Cameroon Volcanic Line, and is implanted below the high lava plateau, at an altitude of about 1500m. Bamenda III Subdivision is made up of two villages: Nkwen and Ndzah with about 250,000 inhabitants and a surface area of 74.61km2.

The climate is mainly of the equatorial type with two main seasons, the rainy season (April to October) and the dry season (November to March). Absolute annual average precipitation ranges from 1700mm to 2824mm and exhibits fluctuations [11].

The study area forms part of the Bamenda Mountains which lie along the Cameroon Volcanic Line. It is made up of a basement rock which is mainly composed of leucogranites of Precambrian age [12]. The basement rock is overlain by volcanic materials composed of mafic and felsic lavas. The mafic lavas include basalts which outcrop as lava flows and pyroclastic deposits respectively, while the felsic lavas include trachytes and rhyolites [13].
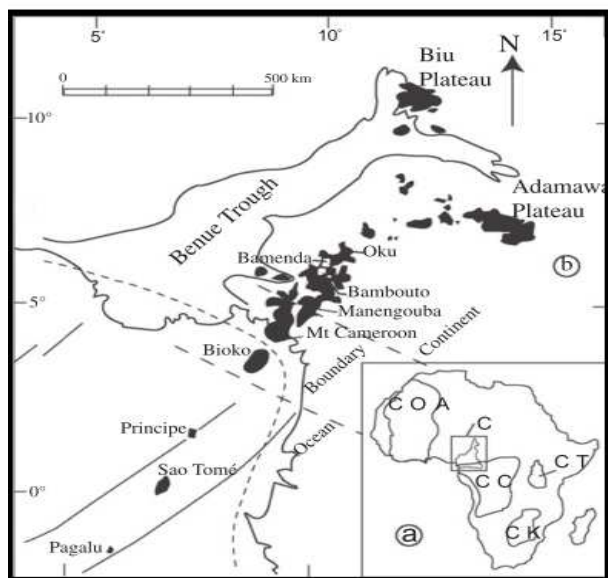

Figure 1. Location of Bamenda along the Cameroon Volcanic Line. From [14].

3. Methods

3.1. Field Work

Field studies were carried out in two phases and at different seasons of the year; the first phase took place in the rainy season (September) and the second phase in the dry season (February). Water samples were collected from 4 springs and 3 wells and at each sampling point, two sets of samples were collected and in one of the sets of samples 5ml of HCl were added to stabilise the heavy metal concentration. Sampling points were chosen in relation to their uses by the population.

3.2. Laboratory Analysis

Physico-chemical and bacteriological analyses were performed in the laboratory of the Faculty of Agronomy and Agricultural Sciences (FASA) in the University of Dschang, Cameroon.

3.3. Physical Analysis

For physical analysis, Total Dissolved Solids was determined. An NTU Turbidimeter (DRT 100B HF model type) was used to measure turbidity. Electrical Conductivity was determined using a Conductivity meter (WTW LF 521 model type).

3.4. Major Cations

Sodium (Na^+) and potassium (K^+) were determined by flame photometry. The analysis of Calcium (Ca^{2+}) was done by titration with 0.02M solution of Ca- EDTA together with 1ml of TEA and 1ml of 5% KCN. The determination of magnesium (Mg^{2+}) was done in a similar manner; ammonium (NH_4^+) was analysed using the colorimetric method.

3.5. Major Anions

Chloride (Cl^-) was analysed by titration. Nitrates (NO_3^-) and phosphate (PO_4^{3-}) were determined using colorimetry. Sulphates (SO_4^{2-}) were determined by turbidimetry and Bicarbonates (HCO_3^-) concentrations by titration.

3.6. Bacteriological Analysis

This was done on three sets of samples (two springs and one well) to determine the presence of faecal streptococcus, Escherichia coli, faecal and total coliform using the membrane filter procedure. 1ml of water sample was added to 9ml of distilled water. Each sample was diluted three times. A membrane was placed on a sterilized Wheaton Filtration funnel used to filter 20ml of undiluted sample. The funnel was sterilized after each filtration to avoid interferences. Several diluted samples were then processed so as to get filter plates with appropriate range of colonies. These filter plates were placed in an incubator at different temperature conditions for different bacteria. These were: 44oC for E-coli and feacal coliform, 35oC for streptococcus and total coliform.

4. Results

The physico-chemical characteristics of the studied water were similar, whether it was from well or from spring but significant differences were noted with the different seasons.

4.1. Physical Characteristics

Water temperatures were higher during the dry season and lower in the rainy season for all sampling points with the average of 22.6°C in the rainy season and of 26.31°C in the dry season (Figure 2). The average pH value was higher in the rainy season (5.71) than in the dry season (5.47) as shown in Figure 2, but all water points yielded acidic to barely acidic water (Table 1).

The values for EC were very low regardless of the sampling point and season but in the dry season a highest value (2.38μS/cm) was recorded in AMW3.

Turbidity was higher in the rainy season than in the dry season with the respective average value recorded of 8.14 and 2.40 (Table 1).

Table 1. *Variation of Temperature, PH, Electrical Conductivity, and Turbidity in the rainy season and dry season.*

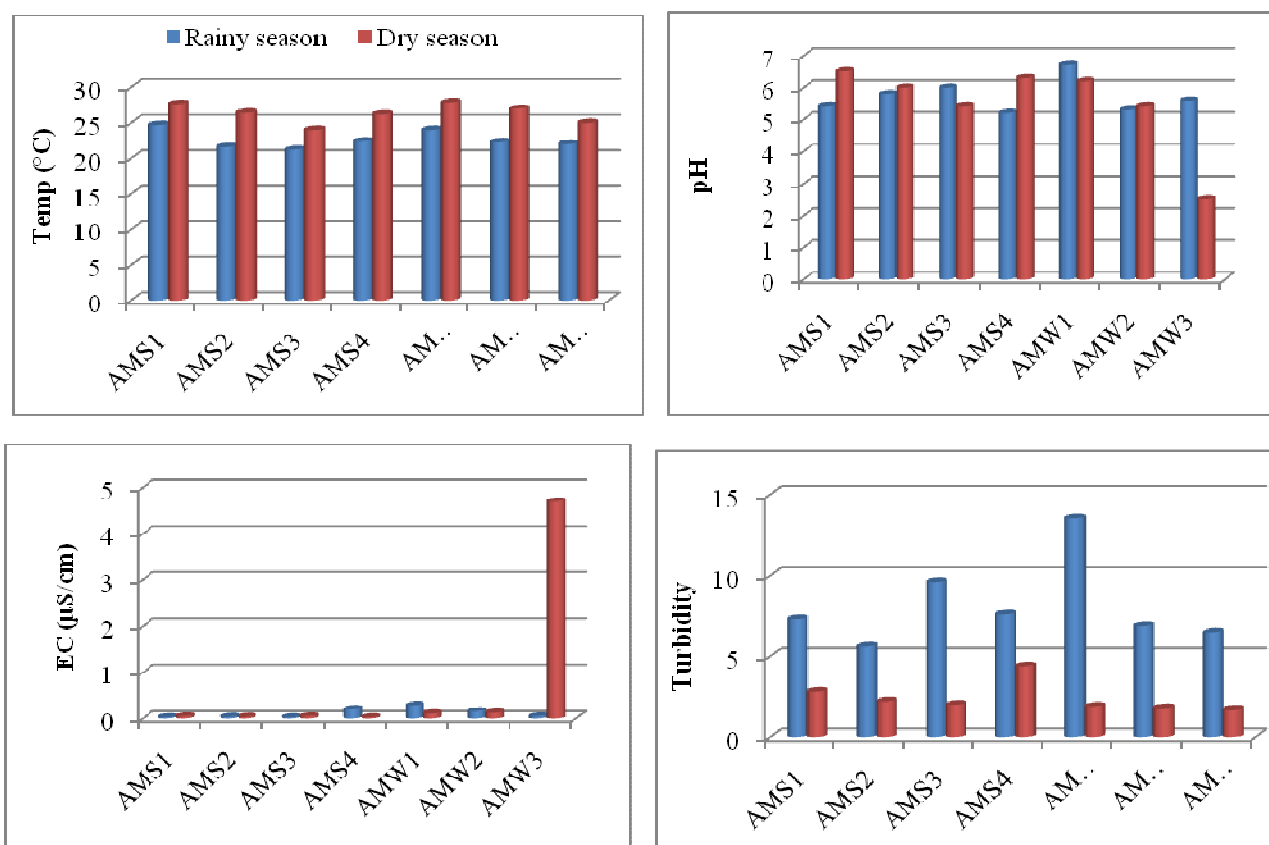|	Temperature (T°)		pH		Electrical conductivity (EC)		Turbidity	
Sampling points	**Rainy Season**	**Dry Season**	**Rainy Season**	**Dry Season**	**Rainy Season**	**Dry Season**	**Rainy Season**	**Dry Season**
AMS_1	24.7	27.7	5.4	6.5	0.03	0.05	7.3	2.8
AMS_2	21.6	26.4	5.8	6	0.04	0.04	5.6	2.2
AMS_3	21.2	24	6.0	5.4	0.03	0.05	9.6	2
AMS_4	22.4	26.2	5.2	6.3	0.20	0.03	7.6	4.4
AMW_1	24	27.9	6.7	6.2	0.29	0.11	13.5	1.9
AMW_2	22.3	27	5.3	5.4	0.16	0.13	6.9	1.8
AMW_3	22	25	5.6	2.5	0.05	4.7	6.5	1.7
Average	22,60	26,31	5.71	5.47	0.11	0.73	8.14	2.40

Figure 2. *Seasonal variation of physical parameters (Temperature, pH, Electrical conductivity, Turbidity).*

4.2. Chemical Characteristics of Cations

K^+ and Na^+ concentrations were high in the dry season and just barely detectable in the rainy season. There were no differences for the different sampling points, their respective average values for the rainy season were 0.39mg/l and

0.30mg/l, these values for dry season were 24.72mg/l and 11.37mg/l.

Regarding the average concentration in the dry season, Ca^{2+} was the most abundant cation in all the water samples with an average value above 500 mg/l (Table 2). Ca^{2+} was also higher in the dry season than in the rainy season for all samples.

Mg^{2+} was the second abundant cation present in the analysed water with an average of 232.3 mg/l in the rainy season and 126.57 mg/l in the dry season.

The NH_4^+ values were higher in the rainy season and barely detectable in the dry season (Figure 3) with average values ranging from 12.06 mg/l in the rainy season to 0.0073mg/l in the dry season.

Fe^{2+} was the least abundant cation in the water samples with the highest concentration of 1.14 mg/l in AMW_2 during the dry season. In the rainy season Fe^{2+} was not detected in AMS_3, AMS_4, AMW_1, AMW_2 and AMW_3 while in the dry season it was not detected in AMS_1 and AMS_2 (Table 2).

Table 2. *Variation of Cations in the rainy season and dry season.*

| Sampling points	K+		Na+		Ca2+		Mg2+		NH4+		Fe2+	
	Rainy Season	Dry Season	Rainy Season	Dry Season	Rainy Season	Dry Season	Rainy Season	Dry Season	Rainy Season	Dry Season	Rainy Season	Dry Season
AMS$_1$	0.39	23.64	0.11	7.94	240	320	194.4	194	8.40	0.0062	0.89	-
AMS$_2$	0.40	25.39	0.37	8.01	280	400	109.4	219	12.88	0.0048	0.83	-
AMS$_3$	0.39	25.55	0.37	12.38	60	160	145.8	255	14	0.0070	-	0.39
AMS$_4$	0.40	24.68	0.37	8.38	260	500	206.6	170	16.80	0.0083	-	0.05
AMW$_1$	0.39	24.89	0.37	5.54	256	980	328.1	12	10.36	0.0084	-	0.05
AMW$_2$	0.39	24.72	0.37	26.67	340	800	461.7	12	12.77	0.0076	-	1.14
AMW$_3$	0.39	24.18	0.11	10.64	180	660	180	24	9.24	0.0087	-	0.18
Average	0.39	24.72	0.30	11.37	230.9	545.7	232.3	126.57	12.06	0.0073	0.25	0.26
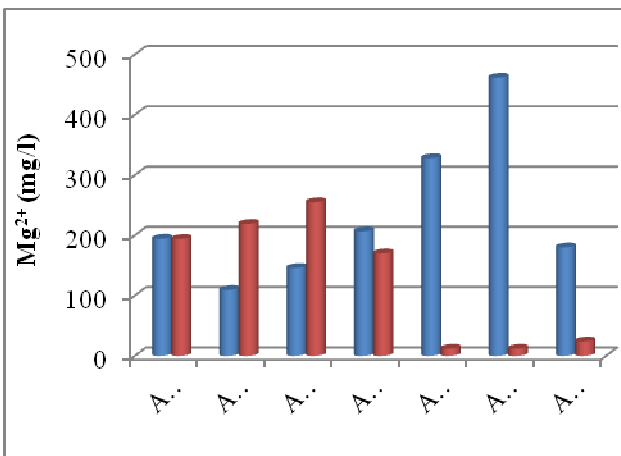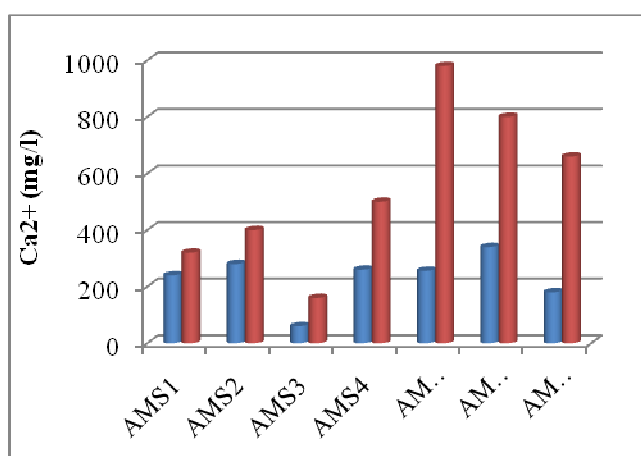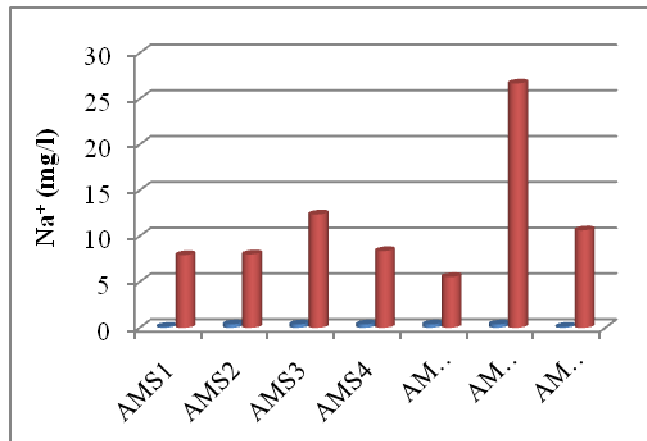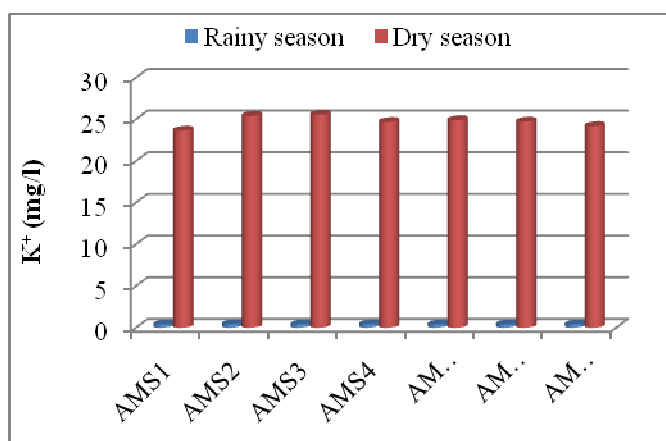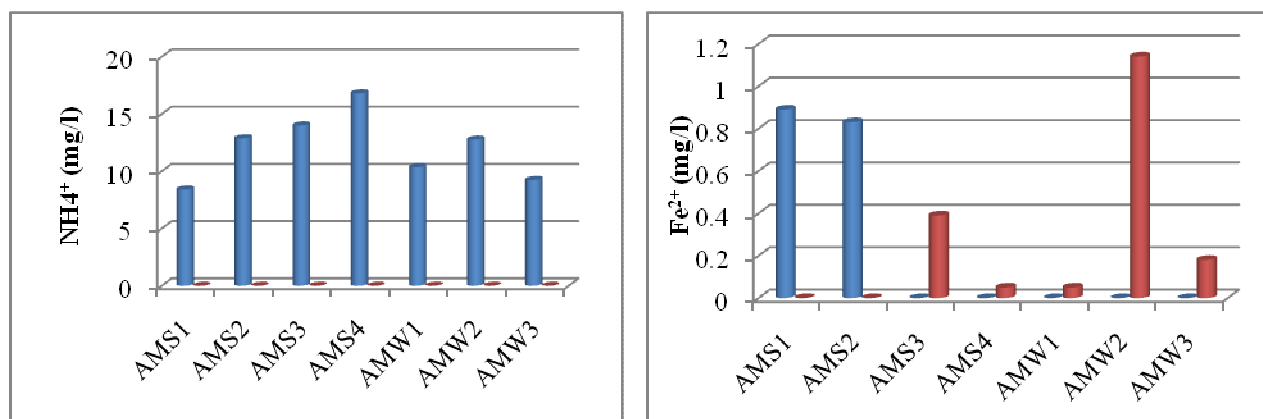
Figure 3. Seasonal variation of cations (K^+, Na^+, Ca^{2+}, Mg^{2+}, NH_4^+, Fe^{2+}).

4.2.1. Anions

Cl$^-$ was completely absent in all the samples in the dry season. In the rainy season, high Cl$^-$ values were recorded only in AMS$_4$ (158mg/l) and AMW$_2$ (270mg/l) as shown in Table 3.

Average values for HCO$_3^-$ were higher in the rainy season (65.36mg/l) than in the dry season (50.13mg/l).

The values of PO$_4^{3-}$ were higher in the dry season than in the rainy season but all the values were less than 2mg/l with an average of 0.16mg/l in the dry season and of 1.11mg/l in the rainy season (Table 3). NO$_3^-$ and SO$_4^{2-}$were barely detectable in the dry season with the respective average values of 0.0033mg/l and 0.05mg/l. In the rainy season for each cation there were just minor differences in the sampling points, NO$_3^-$ concentration yielded an average of 7.68mg/l and SO$_4^{2-}$ an average of 17.61mg/l in the rainy season as presented in table 3 and Figure 4.

Table 3. Variation of Anions in the rainy season and dry season.

Sampling points	Cl$^-$ Rainy Season	Cl$^-$ Dry Season	HCO$_3^-$ Rainy Season	HCO$_3^-$ Dry Season	PO$_4^{3-}$ Rainy Season	PO$_4^{3-}$ Dry Season	NO$_3^-$ Rainy Season	NO$_3^-$ Dry Season	SO$_4^{2-}$ Rainy Season	SO$_4^{2-}$ Dry Season
AMS$_1$	-	-	57.95	75.6	0.25	1.67	11.20	0.0028	15	0.05
AMS$_2$	-	-	30.50	40.32	0.19	1.23	8.40	0.0006	12	0.05
AMS$_3$	-	-	39.65	42.84	0.19	1.23	5.60	0.0022	18	0.06
AMS$_4$	158	-	33.55	37.8	0.13	0.80	7.28	0.0034	12	0.05
AMW$_1$	-	-	231.80	116.55	0.13	1.23	5.88	0.0048	26	0.06
AMW$_2$	270	-	30.50	37.8	0.13	0.80	7.00	0.0045	23	0.05
AMW$_3$	-	-	33.55	-	0.13	0.80	8.40	0.0048	17.3	0.05
Average	*61.14*	*0.00*	*65.36*	*50.13*	*0.16*	*1.11*	*7.68*	*0.0033*	*17.61*	*0.05*
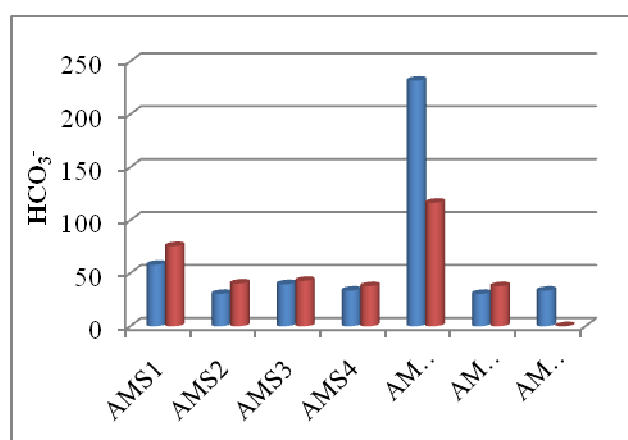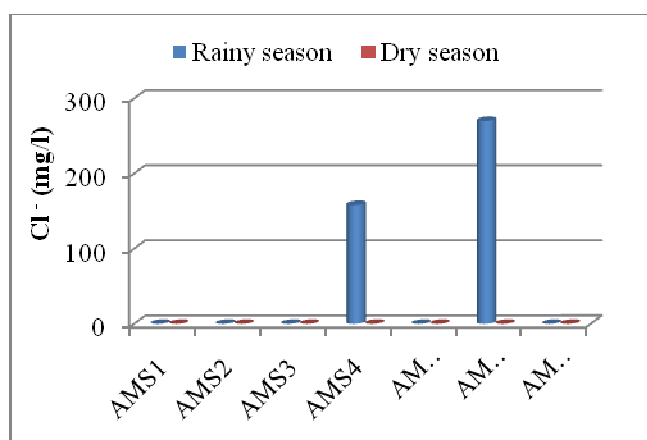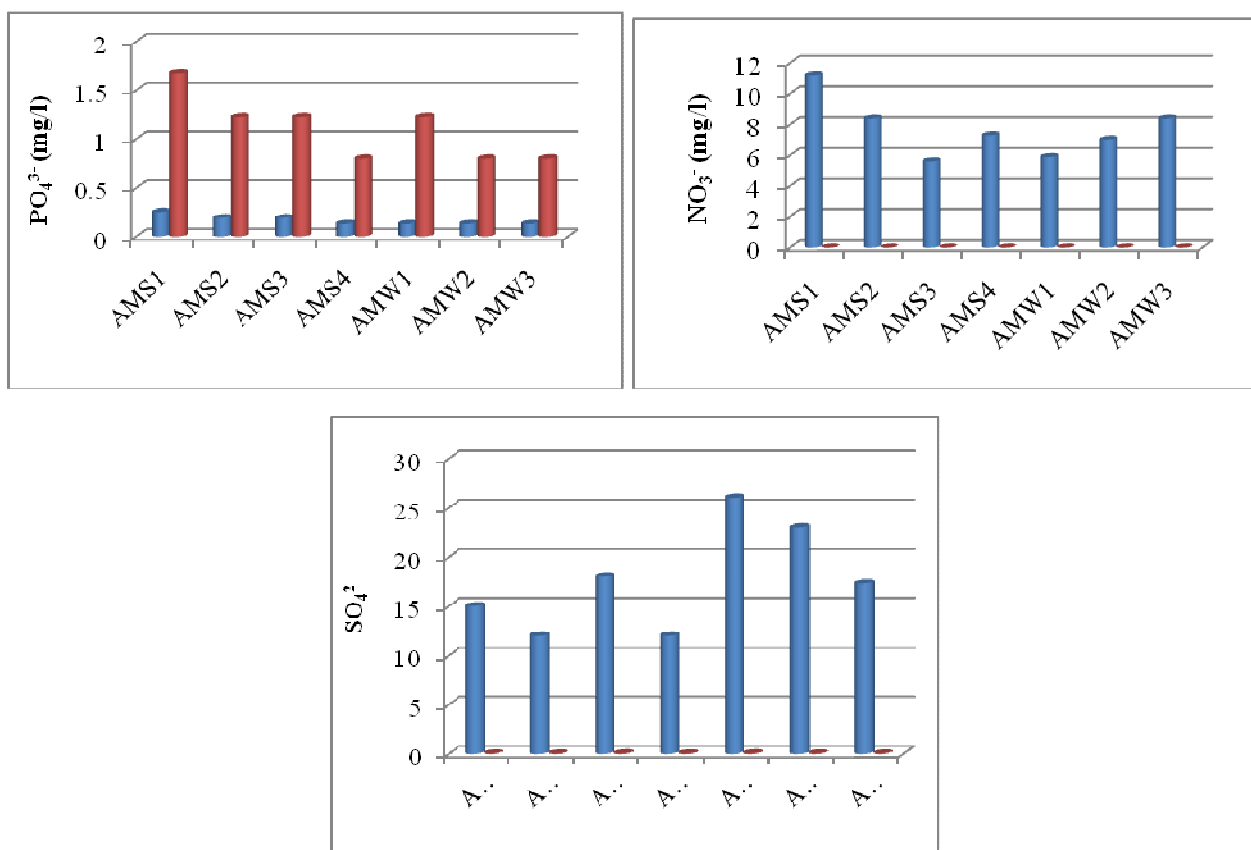
Figure 4. *Seasonal variation of anions (Cl⁻, HCO₃⁻, PO₄³⁻, NO₃⁻, SO₄²⁻).*

4.2.2. Hydrochemical Facies

The piper diagram provides information on the different chemical facies of the analysed water.
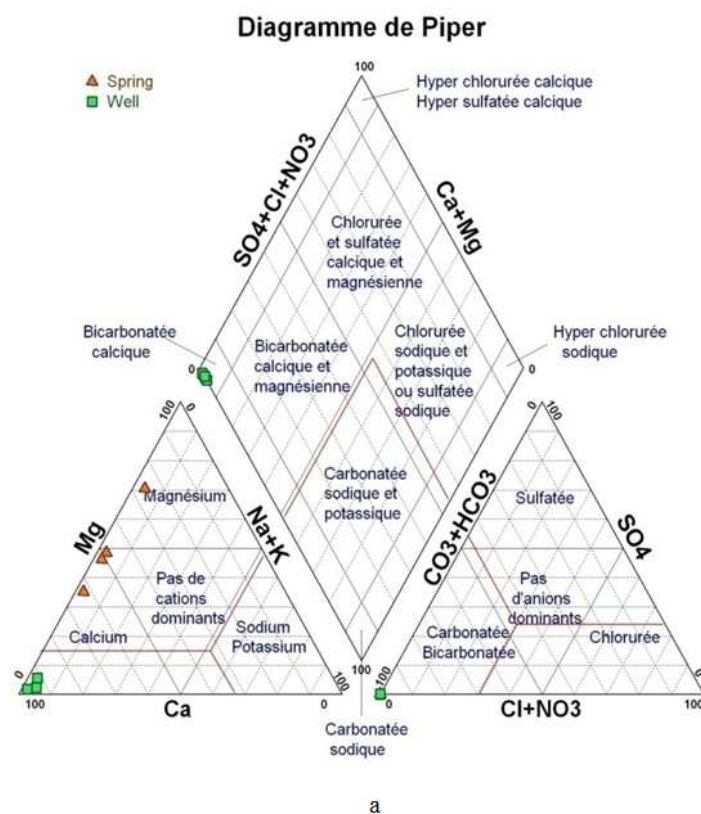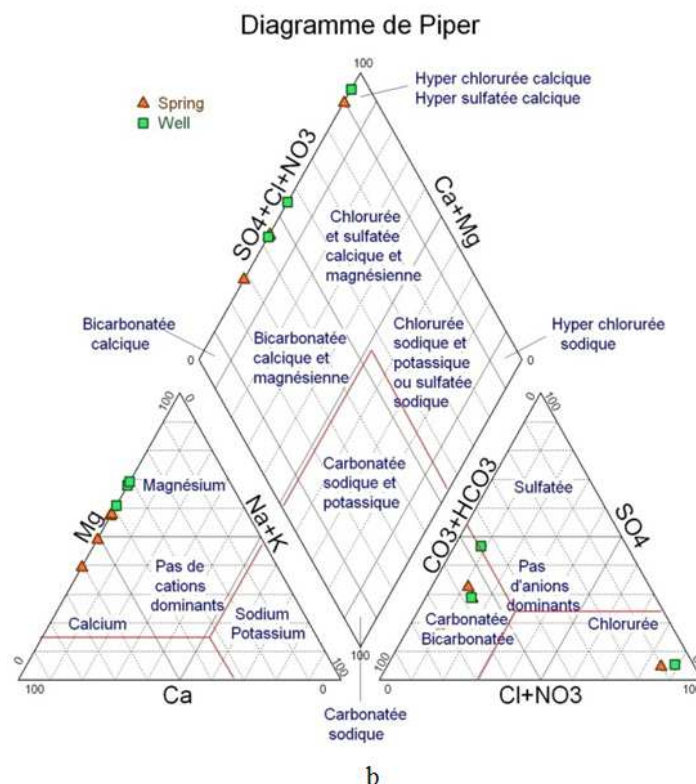
Figure 5. *Piper's diagram [15], showing the water types in Bamenda III, a) dry season b) for rainy season.*

In the dry season, the major cations and anions presented one facies of the Ca- Mg-HCO3 type (Figure 5a) whereas in the rainy season the major cations and anions presented two facies of Ca-Mg-HCO3 type and Ca-Mg-SO4 type (Figure 5b). This significant difference may be due to the hydrochemical processes taking place within the aquifer systems in different seasons. The mineralization process is more homogeneous in the dry season while in the rainy season mineralization is heterogeneous and influenced by the weathering of rocks.

4.3. Bacteriological Characteristics

Three (03) water points (AMS1, AMS2 and AMW2) were analysed for bacteria indicators of pollution as well as for specific microbes (Table 4).

Table 4. *Bacterial counts of specific microbes isolated in springs and well in the rainy and dry seasons.*

|	Enterobacteria (cfu/100ml)		E. coli (cfu/100ml)		Streptococcus (cfu/100ml)		Salmonella (cfu/100ml)		Proteus (cfu/100ml)	
	Rainy Season	Dry Season	Rainy Season	Dry Season	Rainy Season	Dry Season	Rainy Season	Dry Season	Rainy Season	Dry Season
AMS$_1$	50	100	20	30	200	50	00	00	00	10
AMS$_2$	20	200	10	20	100	70	00	10	00	50
AMW$_2$	200	300	100	200	300	200	60	15	10	00
Average	90	200	43,33	83,33	200	106,67	20	8,33	3,33	20
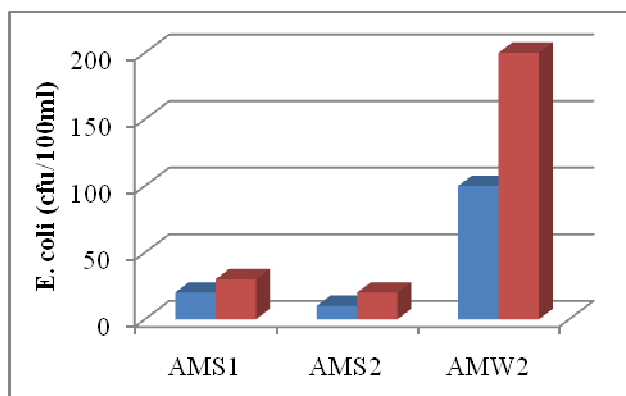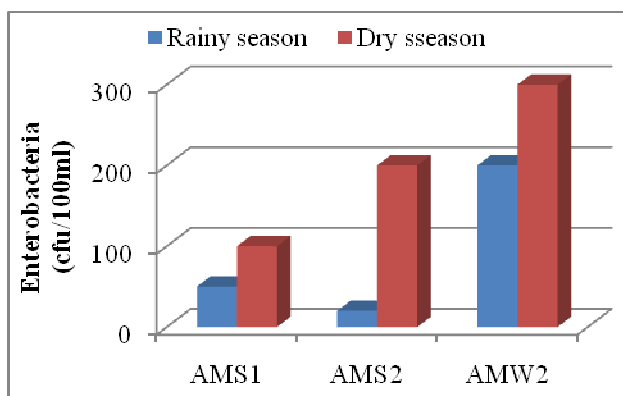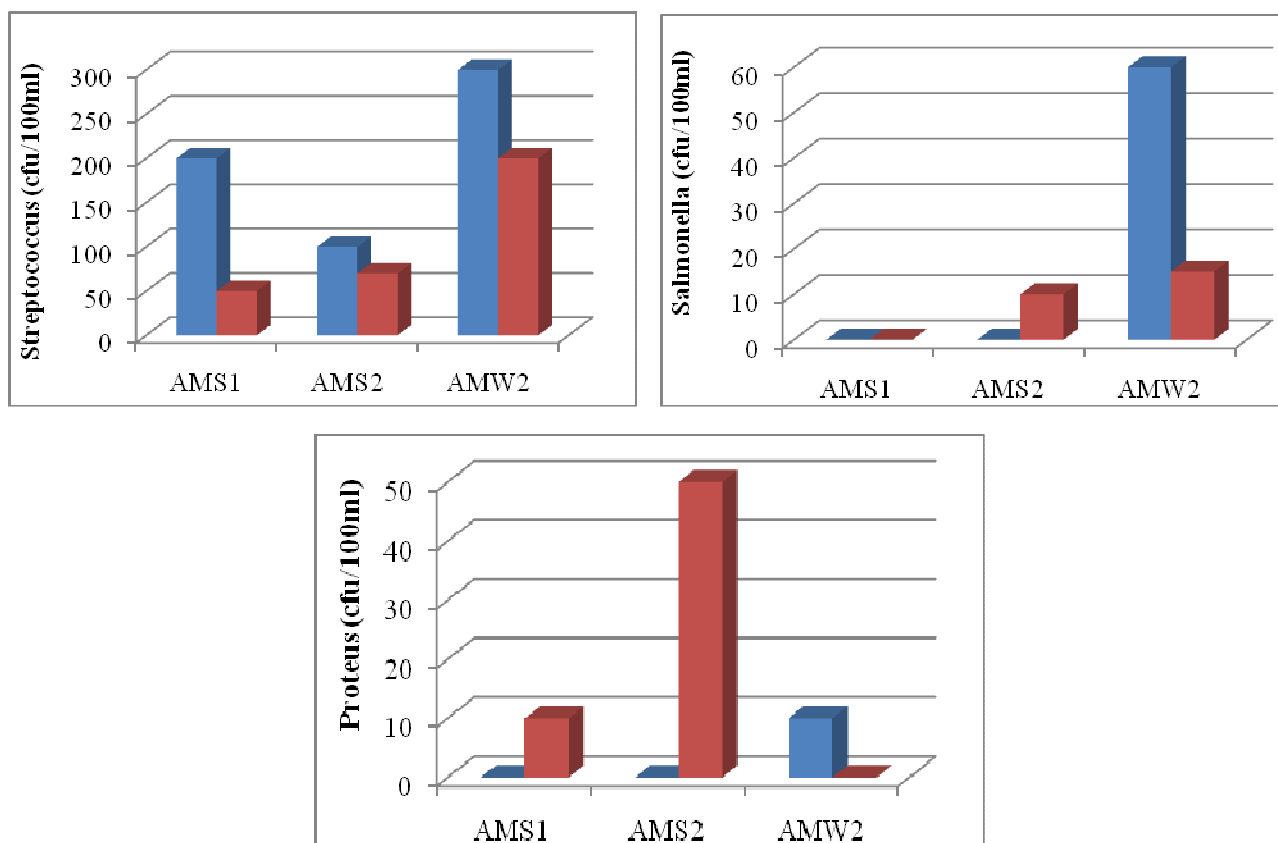
Figure 6. Seasonal variation of bacteria indicators of pollution and specific microbes.

Enterobacteria, Escherichia coli, Streptococcus, Salmonella and Proteus were detected in the water samples and the species richness varied from one water point to another: Enterobacteria, Escherichia coli and Streptococcus were present in all the sampling points whereas Salmonella and Proteus were present only in some sampling points. Higher counts were recorded in the dry season than in the rainy season with Streptococcus presenting an exception with higher counts in the rainy season (100 to 300 cfu/100ml) than in the dry season (50 to 200 cfu/100ml). Enterobacteria levels were particularly high during the rainy season (20 to 200 cfu/100ml) but increased greatly during the dry season (100 to 300cfu/100ml). On the other hand Salmonella and Proteus were absent in springs (AMS1 and AMS2) in the rainy season but registered an increase in the dry season.

5. Discussion

The major ions chemistry of groundwater and compositional relations among ionic species can reveal the origin of solutes and processes that generate water composition [16-18].

The acidic to barely acidic water may be an indication that the dissolve carbonates were predorminantly in the form of HCO_3; In Ghana [19] and in Nigeria [20] low pH has also been reported from granitic basement complex aquifers and were related to the same processes.
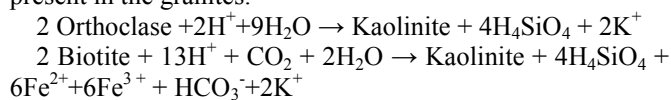
5.1. Cations

The relative abundance of the cations was as follows $Ca^{2+} > Mg^{2+} > K^+ > Na^+$, this shows that
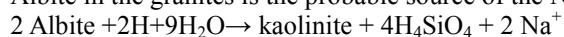
Ca^{2+} is the most abundant cation followed by Mg^{2+} in the springs and wells of the study area. Their main source may be from the weathering of calco-sodico feldspaths and hornblende in the basic rock. [21] explains that these minerals are found in basic rocks.

2 Hornblende + $30H^+$ + $9H_2O$ → Kaolinite + $12H_4SiO_4$ + $4Ca^{2+}$ + $10Mg^{2+}$ + $2Na^+$.
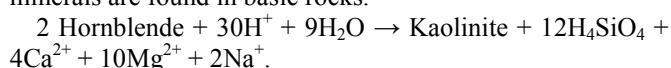
The most common source of K^+ is the silicate minerals: orthoclase, nepheline, leucite and biotite [22]. The basement rock of the study area is composed of granite and the K^+ is probably from the dissolution of orthoclase (KAlSi3O8)) and Fe Mg minerals like biotite (K (Mg Fe)$_3$ (AlSi$_3$)O$_{10}$ (OH, Fe)$_2$ present in the granites.

2 Orthoclase +$2H^+$+$9H_2O$ → Kaolinite + $4H_4SiO_4$ + $2K^+$

2 Biotite + $13H^+$ + CO_2 + $2H_2O$ → Kaolinite + $4H_4SiO_4$ + $6Fe^{2+}$+$6Fe^{3+}$ + HCO_3^-+$2K^+$

Albite in the granites is the probable source of the Na^+

2 Albite +$2H$+$9H_2O$→ kaolinite + $4H_4SiO_4$ + 2 Na^+

Meanwhile the main source of NH_4^+ is probably from fertilizers used in farms which is being leached into the water while natural sources such as organic (metabolic processes) and inorganic (rock weathering and hydrothermal activity) could also contribute to the presence of NH_4^+.

The source of Fe^{2+} is from the hydrolysis of Fe Mg rich minerals such as biotite in the granite and diorite of the study

area. The low concentration of Fe^{2+} is due to its being retained in the soil for the formation of clays, oxides and hydroxides during weathering [23,24].

5.2. Anions

The relative abundances of anions (mg/l) in different samples were as follows: $HCO_3^- > SO_4^{2-} > NO_3^- > PO_4^{3-} > Cl^-$.

HCO_3^- concentrations were high with average values ranging from 16.78 – 174.18mg/l. All the samples had values below the WHO value (200mg/l). The dorminance of HCO_3^- is consistent with most natural waters along the CVL [25]. The primary source is the dissolved CO_2 in rain water and the decay of organic matter at the surface which may release CO_2 for dissolution [22]. Weathering, precipitation and organic decay probably account for the dominance of this ion, $CO_2 + H_2O \rightarrow H^+ + HCO_3^-$ or $CO_2 + H_2O + CO_2 \rightarrow 2HCO_3^-$.

SO_4^{2-} could derive from natural source such as sulphate minerals common in igneous rocks [22]. It can also be from the oxidation of pyrite; $Fe\ S_2 + 2O_2 + H_2O \rightarrow 2\ SO_4^{2-} + H_2$. The low concentrations may be a consequence of gradual dissolution [26].

The presence of PO_4^{3-} probably indicates leaching of phosphate fertilizers from nearby farmlands.

Low concentrations of NO_3^- in the dry season suggest their adsorption in organic colloids [27]. The potential source may also be shallow pit toilets and oxidation of organic matters in biochemical processes as well as the oxidation of ammonia by Nitrosomonas and Nitrobacter bacteria.

Cl^- was absent in the rainy season and according to [28], at high altitude the decrease in Cl^- concentration is due to smaller rainfall inputs caused by rapid decrease of the absolute humidity and temperature with elevation resulting in a smaller condensation. An anormalous Cl^- concentration of 158mg/l and 270mg/l were obtained in the rainy season which might have been due to disinfection through chlorination.

6. Groundwater Suitability for Drinking and Domestic use in Bamenda III

The analytical results were evaluated to ascertain the suitability of groundwater in the study area for drinking and domestic purposes based on the WHO, 2004 standard (Table 5) and the [28, 29] classification (Table 6).

Table 5. *Groundwater quality in Bamenda III in compliance with WHO (2004) drinking water standard.*

Parameter	Range in study area	WHO limit (2004)
pH	4.1 – 6.5*	6.5 – 8.5
T (C°)	20.7 – 25.9*	15
EC (ųs/cm)	0.04 – 2.38	750
Ca2+ (mg/l)	110 – 1770*	75
Mg2+ (mg/l)	97.05 – 236.85*	30
Na+ (mg/l)	4.02 – 13.52	200
K+ (mg/l)	12.02 – 12.97	100
Cl- (mg/l)	0 – 270*	250
NO3$^-$ (mg/l)	2.801 – 5.601	10
SO42$^-$ (mg/l)	6.025 – 11.525	250
HCO3- (mg/l)	16.78 – 174.18	200

* values above WHO limit

EC, Na^+, K^+, NO_3^-, SO_4^{2-}, and HCO_3^- concentrations of the analysed water were under the limits required by the WHO (2004) drinking water norms whereas pH and T (C°) values, Ca^+, Mg^+, and Cl^- concentration values were above the WHO limits.

pH values for the study area ranged from 4.1 to 6.5 and were below the WHO guideline limit (Table 6). Even though pH has no effect on human health, it is closely related to other chemical constituents of water [3].

The temperature values were high which favour bacterial growth and may increase taste, odour, colour and corrosion problems.

Ca^+ and Mg^+ values were much higher than the WHO norms. The presence of these alkaline earth metals determines water hardness. [30] expresses Hardness of water as Total Hardness (TH) and is given by $TH = 2.5Ca + 4.1Mg$. Though hardness has no adverse effect on human health, there is an esthetic concern because of the unpleasant taste that it impacts. It can prevent formation of lather with soap, increase the boiling point of water and may cause encrustation in water supply distribution system. According to [31], there is some suggestive evidence that long term comsumption of extremely hard water might lead to increase urolithiasis, ancephaly, parental mortality and some kind of cancer and cardiovascular disorders. On the other hand water softness (low in Ca^{2+} and Mg^{2+}) could be a health problem since soft water has been linked to cardiovascular ailments [32].

WHO limit for Cl^- is 250mg/l and sample AMW_2 exceed this limit in the rainy season. Higher concentration may cause gastrointestinal irritation when associated with Na^+ and Mg^{2+} [33].

According to the [29] classification of drinking water, two of the sampling points (AMS_1 and AMW_2) could be placed in category C and one (AMS_2) under category B in the rainy season (Table 5). In the dry season, AMS_1 and AMS_2 fell under category C and AMW_2 under category D (Table 5).

Table 6. *Category of water samples according to Cheesbrough classification of drinking water.*

Sampling points	Seasons	Mean count	Category
AMS$_1$	Rainy	30	C
	Dry	35	C
AMS$_2$	Rainy	10	B
	Dry	30	C
AMW$_2$	Rainy	40	C
	Dry	90	D

These bacterial loads indicate an excessive level of pollution of the water samples [01]. Feacal coliforms such as E. coli are prevalent in the digestive tracts of warm – blooded animals and their presence in water is definite evidence of feacal contamination.

Contaminations of water points are much higher in the dry season than in the rainy season. This may be feacal bacteria accumulate and settle as a result of greater contact between water and sediments which enables significant sediment–water exchange [34].

7. Conclusion

Bamenda III, which is petrographicaly made up of two units, plutonic (granite) and volcanic (Rhyolite, basalt and trachyte), was subjected to physico-chemical and bacteriological analyses of its 7 water points: 03 wells and 04 springs.

All water samples had pH range between 4.1 and 6.5 which is below the WHO standard for drinking water. The low EC and TDS classified the water as low-mineralised and freshwater. The relative abundance of major cations and anions in the water (mg//l) was $Ca^{2+} > Mg^{2+} > K^+ > Na^+$ and $HCO_3^- > SO_4^{2-} > NO_3^- > PO_4^{3-}$ respectively. Major ion concentrations were low, and below maximum values of the WHO standards for drinking water, except for Ca^{2+} and Mg^{2+} which were higher classifying the water as hardwater.

The variety and level of faecal bacteria recorded indicate that this area is under anthropogenic influence and receives feacal contamination. None of the water points are suitable for drinking. For this reason, the population of Bamenda III, 80% of which depends on the well and spring water for drinking and domestic purposes, may face serious health problems if appropriate actions are not taken to prevent and mitigate the problems.

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