A Preliminary Hydrogeochemical Baseline Study of Water Sources Around Mount Cameroon

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ABSTRACT

The distribution of naturally occurring chemical substances around Mount Cameroon and environs has been studied with regard to their mobility under various hydrogeochemical conditions and their potential toxicity to the inhabitants living around this active volcanic dome, with reference to the international standards of the World Health Organisation (WHO) and the Commission for the European Communities (CEC). Thirty-one water samples were collected from a variety of sources, which included surface waters, hand-dug wells, springs and boreholes, and were analysed for a broad spectrum of major and trace elements based on existing laboratory facilities which include the Atomic Absorption Spectrophotometry, Flame Emission Spectrometry, and Titrimetry. The chemical and physical results (which included pH, electrical conductivity, major ions, and trace elements), were analysed using univariate, multivariate, and correlation coefficient methods. The results indicated high concentrations of Al and Na with levels far above the action level set by the WHO and the CEC. Although the evaluation of sufficient data related to health was limited by available laboratory facilities, the results indicated high concentrations of elements such as Al which has been linked to the development of various forms of dementia, particularly Alzheimer's disease in other parts of the world. This disease could equally be prevalent in the study area based on the observed results. A general softness of the waters around this mountain was also portrayed by the results and water softness has been causally linked to the development of cardiovascular diseases. An evaluation of the major ions, nevertheless, indicates that the water in the study area is potable based on international limits.

Key words:

RÉSUMÉ

La distribution des substances chimiques qui surviennent naturellement autour du Mont Cameroun et aux environs, a été étudiée relativement à leur mobilité sous les conditions hydrogéochimiques diverses et leur toxicité potentielle aux habitants qui vivent autour de ce dôme volcanique actif, tenant compte aux normes internationaux de l'Organisation Mondiale de la Santé (OMS) et à la Commission des Communautés Européennes (CCE). Trente-et-un échantillons d'eau étaient recueillis des sources variées, qui comprenaient les eaux superficielles, de puits, de source, et des trous de sonde. Ces échantillons étaient analysés pour un large spectre d'éléments majeurs et de trace. Cette analyse etait basée sur les installations existantes du laboratoire qui comprennent la Spectrophotométrie de l'Absorption Atomique, la Spectrométrie de l'Émission de la Flame, et la Titrimétrie. Les résultats chimiques et physiques (qui comprenaient le pH, la conductivité électrique, les ions majeurs, et la trace d'éléments), étaient analysés à l'aide des méthodes univariantes, multivariantes et de cœfficients de corrélation. Ces résultats indiquaient des concentrations élevées d'aluminium (Al) et du sodium (Na) avec des niveaux qui sont de loin au-dessus du niveau d'action fixé par l'OMS et la CCE. Bien que l'évaluation des données suffisantes liées à la santé, soit restrainte par rapport aux installations disponibles du laboratoire, les résultats indiquaient des concentrations élevées des éléments tels que l'aluminium qui a été lié au développement des formes variées de démence, particulièrement la maladie d'Alzheimer dans d'autres parties du monde. Cette maladie pourrait également être prédominante dans le domaine d'étude basée sur les résultats obtenus. Une douceur générale des eaux autour de cette montagne était aussi représentée par ces résultats et cette douceur d'eau a été légèrement liée au développement des maladies cardio-vasculaires. Une évaluation des ions majeurs, néanmoins, indique que l'eau dans ce domaine d'étude, est potable d'après les normes internationales.

Mots clés

1.0 Introduction

It has for long been known that the distribution of natural chemical substances in the environment can influence both animal and human health and this has become a subject of increasing concern in recent years (Plant *et al.*, 1998). The natural geological and geochemical environments contribute beneficial mineral content and bioessential elements to water, but may also give rise to undesirable and toxic properties either through deficiency or excesses of various elements.

In the developed world, people are more exposed to toxic pollutants, predominantly from anthropogenic sources, but are relatively isolated from the effects of natural potentially toxic, local geochemical anomalies, because of their diverse and varied diet. In most of the developing countries, where diet diversity is low, it is acknowledged that man is far more vulnerable to the toxic effects arising from localised natural geochemical anomalies (Plant *et al.*, 1998).

No previous work on this topic appears to have been undertaken in Cameroon. Hydrogeochemical studies (major ions) carried out by the National Water Corporation (SNEC) have indicated that the water sources in the country are generally of good quality. This paper is aimed at investigating the levels of some of the Potentially Harmful Elements (PHEs) on and around the flanks of Mount Cameroon using existing laboratory facilities in the country. The more than 231,000 inhabitants living around this mountain are highly reliant on ground and surface waters draining from weathered volcanic and sedimentary rocks. Comparative studies carried out on lava flows from various eruptions of this mountain have revealed the occurrence of some trace elements with high concentrations of Ni, Cr, Zn, Sr, Zr, Ba, Ce, and Nb (Fitton and Dunlop, 1985). Anomalous concentrations of these elements in water, may lead to harmful effects on human health.

In fact, the 1999 eruption of this mountain which was closely monitored by both national and foreign scientists, revealed a lot of uncertainties with regards to the effects of the eruptive products on the population living around this active dome. Media coverage of the event questioned the effects of gases, ash-fall and lava flows on human health. Some even suggested possible exposure to radiation from radioactive elements within the hot lava flow of Bakingili, which has remained a popular tourisitic site (Ekane, 1999). Reports on the effects of ash-fall and gases leading to skin irritations, coughing and even the withering of food crops and forests were common. The contamination of exposed water resources were said to cause diarrhoea in people who drank from such sources.

In the light of these informal reports, it is worth investigating scientifically, whether the eruptive products from this mountain have properties deleterious to human health. The objective of this study was therefore to produce a preliminary hydrogeochemical baseline data for the study area, identify areas with high or low concentrations of some of the PHEs, and attempt to evaluate the possible effects of these elements on the health of the population.

2.0 Location, Physiography and General Geology

This study is centred in Fako Division, which is one of the 6 Divisions that make-up the South West Province of the Republic of Cameroon. It lies between longitudes 8°5'E and 9°32'E and latitudes 3°50'N and 4°22'N (Figure 1). Fako Division is considered geologically important because it hosts Mount Cameroon, which is the only active volcano on the continental sector of the Cameroon Volcanic Line (CVL). Mount Cameroon erupted.6 times in the last century (1909, 1922, 1954, 1959, 1982 and 1999). It entered into another session of active eruption this century on the 28th May 2000 (Figure 1).

Fako Division has relatively high rainfall, with high agricultural productivity characterised by banana, palm, rubber and tea plantations. This area witnesses two main seasons, the dry season (November-February) and the rainy season (March-October). Much precipitation comes at the height of the rainy season (August-September) when the constant moisture-laden onshore winds bring some 10,000mm (or more) of rainfall into some parts of the Division. It therefore has the highest precipitation in Africa and is amongst the three highest in the world (Fontes and Olivry, 1977).

The area is composed mainly of volcanic rocks which range from massive basaltic lava flows around the upper slopes of Mt. Cameroon, to pyroclastic materials further down slope. The eastern flanks are composed of lahars, which are in contact (and also alternate) with the Tertiary and Quaternary sandstones and shales of the Douala Sedimentary basin (Figure 1). Pyroclastic cones are dominant on the southern slopes of the mountain and extend to Debundscha (Déruelle, *et al;* 1987, Dumort, 1968).

Déruelle *et al;* (1987) classified lavas sampled on Mount Cameroon into picrites, alkali basalts, hawaiites and mugearites. According to Fitton and Dunlop (1985), the geochemistry of volcanic rocks from the entire CVL shows that the rocks all have MgO > 4% and are relatively rich in trace elements. The weathering of the volcanic rocks might therefore be expected to lead to the presence of elevated levels of some of these trace elements in natural waters.

3.0 Methodology

3.1 *Sample Collection:* Preliminary investigations and data were obtained during a reconnaissance field trip. An orientation sample location map was developed during this phase (Figure 1). Fieldwork consisted of the recognition

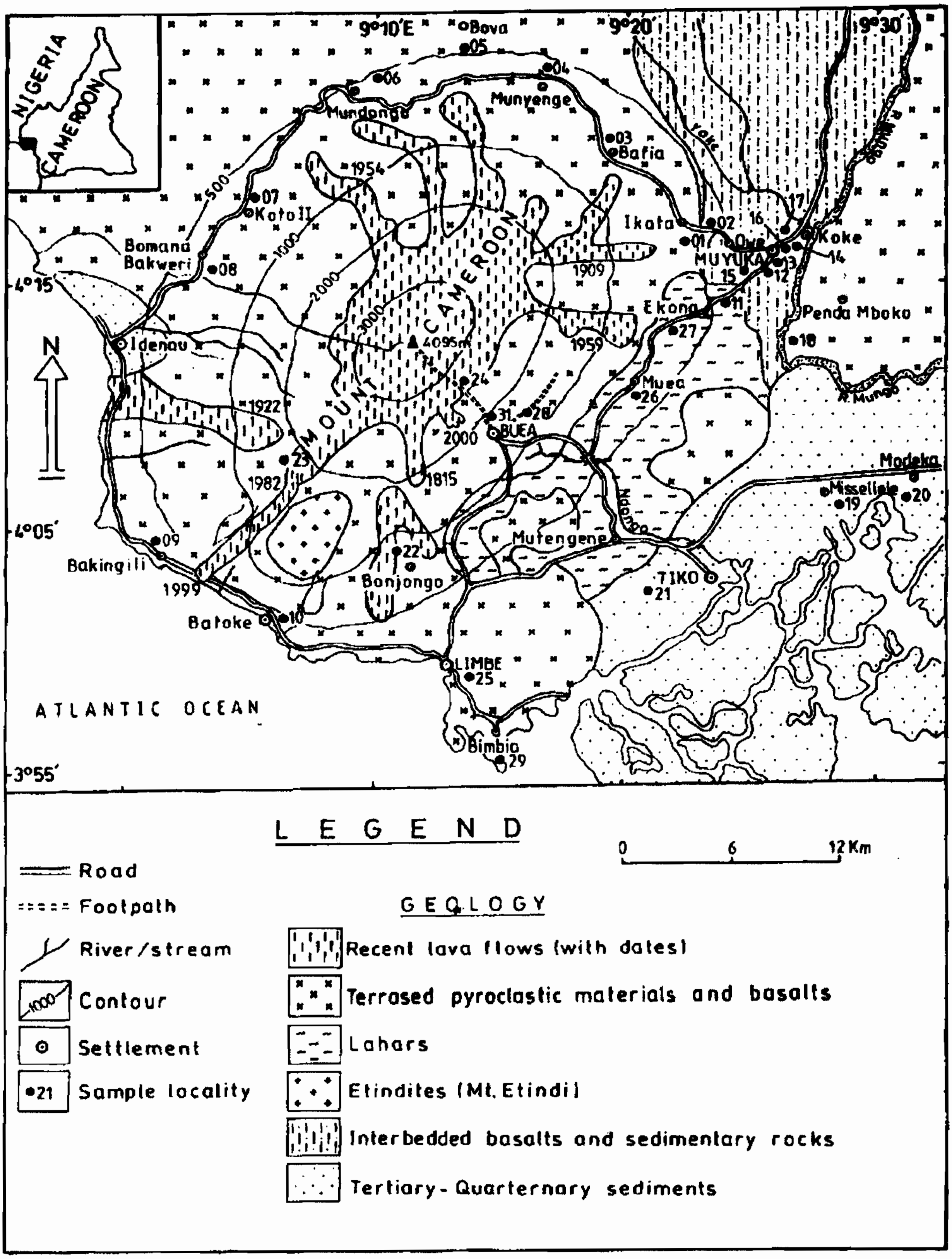

Figure 1 : Geological map and sample localities

(Redrawn with modifications after Déruelle et al., 1986).

of lithologic units, springs, hand-dug wells, surface waters, boreholes and the collection of water samples from these sources. Sampling proper was carried out during the dry season (March 2000) when base flow conditions were more likely to prevail with minimal effects of dilution from rainfall. Thirty-one water samples were collected from major supply sources in 1.5 litre polyethylene bottles and stored in an ice chest in accordance with the field sample collection procedure recommended by Todd (1980). Replicate samples were included to check for reproducibility and analytical precision.

The samples were then taken to the IITA Nkolbisong Yaounde, IRAD Ekona; and SONARA Limbe Laboratories for major and trace element analyses.

3.2 *Laboratory and Statistical Analyses:* In the laboratory, physiochemical properties such as pH and EC were analysed using the potentiometric method, while Ca, K, Mg, Na, Cl, Mn, Fe, Pb, Al, Zn and Cu were analysed using Atomic Absorption Spectrophotometry, Flame Emission Spectrometry and Titrimetry. Filtering of the samples was not carried out and this might have resulted in the evaluation of concentrations of colloidal forms of Al which could not have been anticipated in this preliminary work.

The choice of elements analysed for was limited by the existing laboratory facilities and the geochemical results obtained by Fitton and Dunlop (1985). The targetted cations were accordingly analysed for without due consideration for the HCO_3 and SO_4 anions, which, together with other cations, are normally used to check data quality using the ionic balance.

Statistical analyses of the data obtained included univariate and multivariate methods, and correlation coefficients were used in predicting ionic associations and dominations. Trilinear diagrams were also used for the visualisation and interpretation of spatial patterns of major cations in the surface and groundwater chemistry.

4.0 Results and Interpretations

The pH ranged from 4.9 to 8.1, while the EC ranged from 16.9 to 487µs/cm. Calculations for water hardness using the formula recommended by Todd (1980), revealed that 26 of the samples were soft waters, with 5 samples being moderately hard. The general softness of water around this mountain is probably due to the action of slightly acidic water on silicate rocks, which are poorly soluble.

The results of the laboratory analyses (Table 1) revealed that the waters around Mt. Cameroon have a major cation chemistry dominated by the presence of Na^+ (and K^+) based on a major cation trilinear plot (Figure 2). This is a reflection of the dominance of alkali feldspars as the major source of mineralisation of the waters around this area. Given the proximity of Mt. Cameroon to the ocean, it is likely that the dominance of

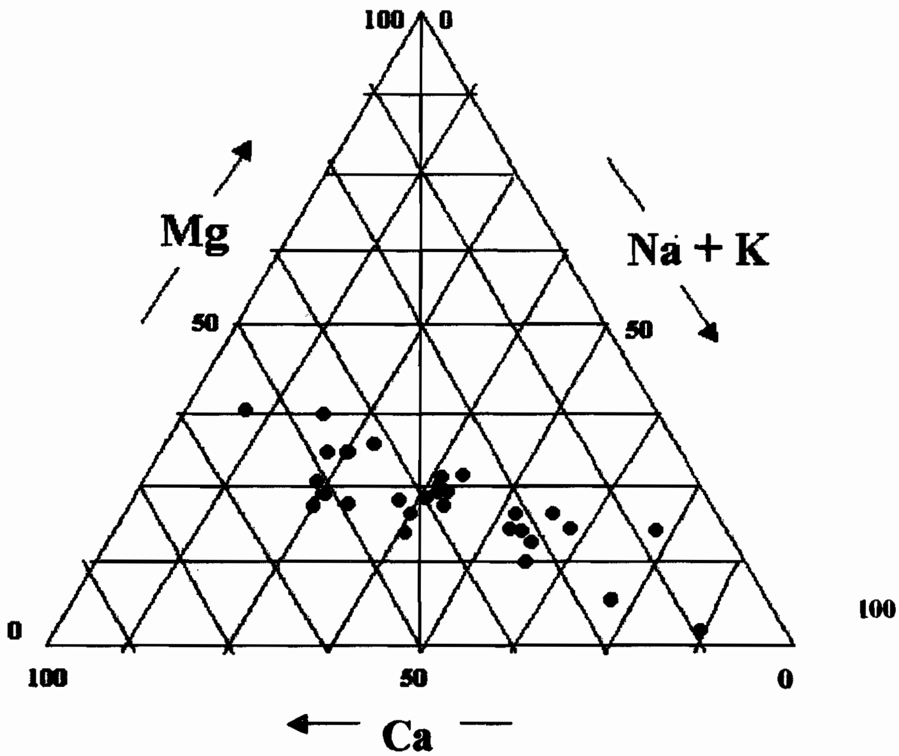

Figure 2 Major Cation Trilinear Diagram on Fako Division and Environs, indicating low Mg, Intermediate Ca and high Na+K ion concentration of the waters.

Table 1. Analytical Results from Fako Division and Environs

ample ode	Location & Class	PH	EC uS/cm	Ca ppm	Mg ppm	K ppm	Na ppm	Mn ppm	Cu ppm	Zn ppm	Al ppm	Cl ppm	Fe ppm	Pb ppm
N1	Owe(SP)	7.3	117.4	5.52	3.12	2.73	8.14	0	0	0.006	0.033	0.16	0	0
N2	Ikata(SP)	7.4	244	6.81	5.47	7.2	18.15	0	0	0.006	0.033	0.35	0	0
N3	Bafia(SP)	8.1	415	8.49	1.51	10.56	48.59	0	0	0	0	1.88	0	0
N4	Munyenge(DBH)	7.7	487	8.95	8.14	6.48	15.59	0	0	0	0	0.23	0	0
N5	Bova Bomboko(SP)	7.5	269	14.66	10.52	4.39	13.19	0	0	0	0	0.13	0	0
N6	Mundongo(SP)	7.8	319	15.22	13.09	5.92	16.39	0	0	0.012	0.033	0.17	0	0
N7	Kotto II (SP)	7.2	142.3	13.08	5.34	1.72	4.39	0	0	0.012	0.033	0.62	0	0
N8	Bomana Bakweri(SP)	7.1	61.8	6.12	2.92	0.86	2.01	0	0	0.012	0.033	0.04	0	0
N9	Bakingili(SP)	7.3	165.5	8.03	5.07	3.91	11.43	0	0	0	0.033	0.47	0	0
N10	Batoke(SP)	6.7	81.7	5.44	2.57	1.05	1.58	0	0	0	0.033	0.05	0	0
N11	Mile 29 (SP)	7.3	238	14.11	9.13	3.91	10.63	0	0	0	0.033	0.17	0	0
N12	Meanja(SW)	7.1	164.3	8.65	5.76	7.52	8.86	0	0	0	0.033	0.87	0	0
N13	Meanja(SW)	6.6	331	9.11	6.53	2.15	2.99	0	0	0	0.033	0.21	0	0
N14	Pete water (SW)	7.3	224	11.98	8.14	3.91	10.07	0	0	0	0.033	0.12	0	0
N15	Meanja water (SW)	7.3	269	7.95	4.69	7.44	10.47	0	0	0	0.033	0.2	0	0
N16	Muyuka water (SW)	7	219	8.8	6.42	11.36	11.27	0	0	0	0.033	1.07	0	0
N17	After SNEC Muyuka (SW)	7.5	184.2	8.72	4.97	3.43	8.06	0	0	0	0.234	0.05	0	0
N18	Mpundu II (SP)	7.9	315	20.87	17.12	3.19	5.17	0	0	0.006	0.033	0.24	0	0
N19	Misselele Vil'ge(SP)	5.1	185.5	6.96	2.38	14.54	8.3	0	0	0.018	0.033	2.11	0	0
N20	Modeka Village(SP)	4.9	59.1	3.26	1.23	3.24	2.63	0	0	0.012	0.033	0.39	0	0
N21	Holtforth N. Layout	7	118.8	9.41	4.16	1.51	4.04	0	0	0.012	0.033	0.32	0	0
N22	Sasse (SP)	7.4	200.5	10.58	7.96	3.63	8.87	0	0	0.012	0.033	0.06	0	0
N23	Mann spring (SP)	7	162.3	3.92	1.55	1.23	2.56	0	0	0.006	0.033	0.06	0	0
N24	Hut I (SP)	7	156.6	8.87	4.42	2.4	5.76	0	0	0.006	0.234	0.04	0	0
N25	New Town Limbe (HWD)	7.1	406	22.6	15.75	3.24	13.67	0	0	0.018	0.033	5.5	0	0
N26	Muea C.D.C camp(SP)	7.4	212.5	11.75	7.59	3.55	9.03	0	0	0.006	0.033	0.41	0	0
N27	Moli (SP)	7.7	223	12.46	8.49	4.35	11.43	0	0	0.018	0.033	0.08	0	0
N28	Ewonda (SP)	6.8	155.1	8.4	5.74	0.75	0.73	0	0	0.012	0.737	0.02	0	0
N29	Bimbia (SP)	6.2	16.9	1.76	1.08	0.44	0.37	0	0	0.006	0.033	0.01	0	0
N30	Supermont Product	7.6	163.1	12.3	7.29	3.23	8.55	0	0	0	0.033	0.1	0	0
N31	SNEC tap, Buea	7.8	169.9	17.18	11.96	6.03	13.67	0	0	0.024	0.737	0.06	0	0

SP, Spring; DBH, Deep bore hole; SW, Surface water; HDW, Hand dug well.

Table 2. Analytical results of water sources from sampling points on the leeward side of Mt. Cameroon

Sample Code	Location	pH	EC µs/cm	Ca mg/L	Mg mg/L	K mg/L	Na mg/L	Mn mg/L	Cu mg/L	Zn mg/L	Al mg/L	Cl mg/L	Fe mg/L	Pb mg/L
EN1	Owe	7.3	117.4	5.52	3.12	2.73	8.14	0	0	0.01	0.03	0.16	0	0
EN2	Ikata	7.4	244	6.81	5.47	7.2	18.2	0	0	0.01	0.03	0.35	0	0
EN3	Bafia	8.1	415	8.49	1.51	10.6	48.6	0	0	0	0	1.88	0	0
EN4	Munyenge	7.7	487	8.95	8.14	6.48	15.6	0	0	0	0	0.23	0	0
EN5	Bova Bomboko	7.5	269	14.7	10.5	4.39	13.2	0	0	0	0	0.13	0	0
EN6	Mundongo	7.8	319	15.2	13.1	5.92	16.4	0	0	0.01	0.03	0.17	0	0
EN8	Bomana Bakweri	7.1	61.8	6.12	2.92	0.86	2.01	0	0	0.01	0.03	0.04	0	0
EN7	Kotto II	7.2	142.3	13.1	5.34	1.72	4.39	0	0	0.01	0.03	0.62	0	0
Mean values		7.51	200.4	9.91	6.26	4.98	12.8	0	0	0.01	0.02	0.45	0	0

Table 3. Analytical results of water sources from sampling points on the windward side of Mt. Cameroon

ample ode	Location	pH	EC µs/cm	Ca mg/L	Mg mg/L	K mg/L	Na mg/L	Mn mg/L	Cu mg/L	Zn mg/L	Al mg/L	Cl mg/L	Fe mg/L	Pb mg/L
N9	Bakingili	7.3	166	8.03	5.07	3.91	11.4	0	0	0	0.03	0.47	0	0
N10	Batoke	6.7	81.7	5.44	2.57	1.05	1.58	0	0	0	0.03	0.05	0	0
N25	New Town Limbe	7.1	406	22.6	15.8	3.24	13.7	0	0	0.02	0.03	5.5	0	0
N29	Bimbia	6.2	16.9	1.76	1.08	0.44	0.37	0	0	0.01	0.03	0.01	0	0
N21	Holtforth N. layout	7	119	9.41	4.16	1.51	4.04	0	0	0.01	0.03	0.32	0	0
N12	Meanja	7.1	164	8.65	5.76	7.52	8.86	0	0	0	0.03	0.87	0	0
N13	Meanja	6.6	331	9.11	6.53	2.15	2.99	0	0	0	0.03	0.21	0	0
N14	Pete water	7.3	224	12	8.14	3.91	10.1	0	0	0	0.03	0.12	0	0
[ean alues		6.91	186	9.62	6.13	2.96	6.63	0	0	0.01	0.03	0.94	0	0

Na (and K) represent evaporation of marine derived rainfall.

However, a comparison of elemental variation on both the leeward and the windward sides of the mountain, as seen in tables 2 and 3 above, indicated a dominance of $Na^{+} + K^{+}$ on the leeward side with lesser concentrations on the windward side. This was however, not in conformity with expectations since the windward side of the mountain receives more moist wind rich in Na from the sea than the leeward side. The lower concentrations of these ions on the windward side could be as a consequence of more leaching of ions in the soils and rocks. This side receives more annual rainfall, (10.000mm) which probably dissolves most of the Na to form clay, thus leaving a deficit of Na^{+} on this side, while the leeward side which receives only 4.000mm of annual rainfall (Fontes and Olivery, 1977) is less leached.

Due to the dominance of $Na^{+} + K^{+}$ in the entire analytical results (Table 4), the dominant overall reaction appears to be the conversion of feldspars to Kaolinite as

Table 4. Summary of analytical results of water sources for Fako Division and environs giving range, arithmetic mean and standard deviation of observed concentrations

Element	Unit	Range	Arithmetic mean	Standard Deviatic
pH		4.90 – 8.1	7.1	0.7
EC	µS/cm	16.9 – 406	194.4	84.9
Ca	mg/L	1.76 – 22.60	10.1	4.7
Mg	mg/L	1.08 – 17.12	6.5	4.0
K	mg/L	0.44 – 14.54	4.4	3.3
Na	mg/L	0.37 – 24.3	8.78	5.59
Mn	mg/L	-	0	0
Cu	mg/L	-	0	0
Zn	mg/L	0.000 – 0.024	0	0
Al	mg/L	0.000 – 0.737	0.1	0.2
Cl	mg/L	0.01 – 5.50	0.5	1.1
Fe	mg/L	-	0	0
Pb	mg/L	-	0	0

shown in the equation (i) below:

$$\underset{\text{Albite}}{2NaAlSi_3O_5} + 6H_2O + CO_2 \longrightarrow \underset{\text{clay}}{AL_2SiO_5(OH)_4} + \underset{\text{soluble}}{4SiO(OH)_2} + \underset{\text{soluble}}{Na_2CO_3}$$

Aluminium occurs in almost all the samples except at Bafia, Munyenge and Bova Bombomko. These areas on the other hand have the highest concentrations of Na. This could however be substantiated by comparing Na/Cl ratios for sea, rain, surface, and groundwaters to see those with a molar excess of Na over Cl which will be suggestive of a feldspar origin.

Aluminium is negatively correlated with Na (Pearsonian Correlation = -0.13), indicative of the fact that they are from different sources, such that one is increasing in water at the expense of the other. It occurs in concentrations far above the WHO recommendation value in 4 areas which include SNEC Muyuka (0.234 mg/L), Hut 1 (0.234 mg/L), Ewonda (0.74 mg/L) and SNEC tap water in Buea (0.75 mg/L) (Figure 1).

Aluminium is highly insoluble above pH of 4.5 and since the pH values ranged from 4.9 to 8.1, it is possible that the Al concentrations are colloidal. Aluminium actually forms extensive colloids in the 0.2μm to 0.45μm size range and since the water samples were not filtered prior to the laboratory analyses, the observed anomalous concentrations of Al could probably be from its colloidal forms. Such colloids could have been dissolved if the water samples had been acidified.

5.0 Discussions and possible effects on health

Every element has a whole spectrum of possible health effects on a particular plant or animal. Chronic effects manifest after continued ingestion of small concentrations of an element, which then accumulates in the body until a toxic level is reached and the medical symptoms appear. The health implications of these results can be appreciated by comparing them with similar studies that have been carried out in other parts of the world (Smith *et al;* (1996), Smith *et al;* (1998), and Plant *et al;* (1998)).

The presence of dissolved Al in water supplies has been considered to be implicated in the aetiology of neurological disorders (Edmunds and Smeldley, 1995). With a WHO (1993) recommended limit for potable water being only 0.2 mg/L, elevated Al concentrations have been linked to the development of various forms of dementia, particularly Alzheimer's disease (Edmunds and Smeldley, 1995). According to Tebbutt (1983), it should be noted that there is a specialised health hazard in that kidney dialysis patients may be subjected to neurological disorders if the water contains more than 0.3 mg/L of Al. The excessively high concentration of this element in SNEC water in Muyuka, Buea, as well as at Ewonda, and at Hut 1 (Figure 1) therefore give cause for concern.

It has long been suspected that a causal link exists between water hardness and cardiovascular disease. Dissanayake *et al.*, (1992) found a negative correlation between water hardness and various forms of cardiovascular disease, and leukaemia in Sri-Lanka. The British Committee on Medical Aspects of Food Policy (COMA, 1994) also found a weak inverse relationship between water hardness and cardiovascular disease mortality. This inverse relationship simply means that people consuming soft waters have a higher likelihood to suffer from cardiovascular diseases than those consuming hard waters.

Since 26 of the 31 water samples analysed were soft waters, it is therefore probable that people living around Mount Cameroon and who drink the soft water, have a slightly elevated risk of contracting cardiovascular diseases.

6.0 Conclusions and Recommendations

The physico-chemical and statistical analyses of properties of water samples collected from 31 localities on and around Mt. Cameroon have provided useful data which has been used to identify the physical and chemical properties of the water in the study area. Particular interest has been put on the softness of the water and the concentrations of Aluminium and Sodium. Aluminium is one of the Potentially Harmful Elements whose high concentration has been shown to affect human health in other parts of the world.

This preliminary baseline study has accordingly been used to identify localities within the study area where there exists the possible prevalence of the diseases exacerbated by soft water such as cardiovascular diseases. Excessive concentrations of aluminium which have also been shown to occur in Ewonda, Hut 1, and the tap water in Buea and Muyuka, are more likely to cause neurological disorders especially in kidney dialysis patients.

The results have equally indicated a dominance of Na^+ and K^+ in the entire area, and this has been interpreted as resulting from the conversion of feldspars (albite) in the predominantly alkali basalts to Kaolin. A comparison of the concentrations of these cations on the windward and leeward sides of the mountain indicated higher values on the leeward side.

The concentration of all the eleven elements analysed showed a decreasing trend from surface water to shallow wells to springs. This is interpreted as due to the effect of long-term leaching of base cations and trace elements from the surface environment into deeper horizons. The concentrations of the major elements (K, Na, Ca and Mg) normally used in assessing water potability are however within the WHO and CEC limits.

The use of rainfall chemistry as a reference from analysis of rainfall data around the mountain, would equally be useful for comparison of reactions of the groundwater with rocks.

A further follow-up of this work with a bias towards the epidemiological aspects in the areas identified with anomalous concentrations of the elements, as well as further geochemical work on the natural baseline variations of the chemistry of natural waters around the environs of this mountain and even along the Cameroon Volcanic Line, is required to confirm these findings. In particular, concentrations of elements such as Iodine, Fluorine, Arsenic, Cerium, Selenium, and Cadmium in the water sources as well as concentrations of radioactive elements, such as Radon in particular, will provide more useful data on the Potentially Harmful Elements, and their possible health effects in this region.

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