Journal of Geoscience and Environment Protection, 2020, 8, 87-104
https://www.scirp.org/journal/gep
ISSN Online: 2327-4344
ISSN Print: 2327-4336

Assessment of Ground Water Quality in Baba I Village, North-West Cameroon

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How to cite this paper: Biosengazeh, N. F., Mofor, N. A., Tamungang, N. E. B., & Mvondo-Ze, A. D. (2020). Assessment of Ground Water Quality in Baba I Village, North-West Cameroon. *Journal of Geoscience and Environment Protection, 8,* 87-104.
https://doi.org/10.4236/gep.2020.84007

Received: March 5, 2020
Accepted: April 23, 2020
Published: April 26, 2020

Abstract

This study investigated the quality of ground water in Baba I, North-West Cameroon, in order to determine its suitability for domestic uses following World Health Organisation (WHO) guidelines. Inhabitants of this locality consume water from these sources without any prior treatment which can lead to health problems if the water sources are contaminated. Six water sources were sampled in November 2017, January, April and July 2018 and examined for organoleptic, physico-chemical and bacteriological parameters using standard methods. Results of organoleptic and physical parameters showed that most of the sources were within the WHO acceptable limits with pH varying from moderately acidic to weakly basic. Chemical properties revealed that all the analysed ions were found within the WHO guidelines and the water sources ranged from soft (hardness < 60 mg/L) to moderately hard (60 mg/L ≤ hardness ≤ 120 mg/l), with iron slightly exceeding the WHO guideline value of 0.3 mg/L in the well of Kwebessi (Wkw) in November 2017 and July 2018. Piper's trilinear diagrams showed that the analysed waters were calcium and magnesium bicarbonate type. Small to average seasonal influences were observed in the variations of temperature and the concentrations of Na^+, K^+, Ca^{2+}, Mg^{2+}, NO_3^-, and NH_4^+ ($p < 0.05$). Faecal coliforms and specific bacteria namely: *Escherichia coli, Enterobacter, Streptococcus, Salmonella* and *Shigella spp,* were identified in all the sampled waters, suggesting recent contamination of the sources by human or animal faeces. The sources were unfit for domestic uses and thus, exposed the local population to water borne diseases such as typhoid, diarrhoea and dysentery. Hence, home treatment methods such as chlorination, filtration, boiling and solar disinfection should be implemented prior to consumption.

Keywords

Ground Water, Water Sources, Physico-Chemical Properties, Faecal Coliforms, Water Borne Diseases

1. Introduction

Safe and affordable supply of potable water is a basic human need. The quality of water has a great impact on public health. Poor microbiological quality of water is likely to lead to the outbreak of infectious water borne diseases. Chemical water quality is generally not an immediate call for concern as its impact on health tends to be chronic long-term effects. However, acute effects may be encountered where major pollution has occurred or where levels of certain chemicals are high from natural sources, such as fluorides, or anthropogenic sources, such as nitrates (WHO, 2009). Although access to safe and reliable water supplies has received increased attention from governments around the world in recent years, 663 million people with 319 million in Sub-Sahara Africa, of which 80% live in rural areas, still lack improved drinking water sources and 2.5 billion people are without access to an improved sanitation facility (WHO & UNICEF, 2015; Njoyim et al., 2016a).

Cameroon is one of the sub-Sahara African Countries where access to potable water and sanitation is still a burden to the population especially in rural areas. Despite the fact that Cameroon is blessed with many available water resources estimated to be 322 billion cubic meters with an annual available water per inhabitant of 21,000 m^3 (Ako Ako et al., 2010), access to suitable water for domestic purposes is still a major public health concern as water related diseases represent about two-thirds of all the diseases in this country and are responsible for approximately 50% of death cases recorded annually (Katte et al., 2003; Wirmvem et al., 2013a). In spite of all government efforts through partnerships with Non-Governmental Organisations and the African Development Bank, Cameroon's Millennium Development Goals (MDGs) for rural water and sanitation failed, as only 44.6% and 28.8% of the rural population had access to improved water and sanitation facilities in 2015 against the targets of 80% and 60% respectively (INS, 2015).

Baba I is a rural community, found in Babessi sub-division, North-West Cameroon. In this community, pipe borne water is not functional and the population relies mainly on groundwater sources (wells, springs and manual pump boreholes) with little available information on their physico-chemical and bacteriological properties. They judge the suitability of water from any source for domestic purposes based on its appearance and odour and the water is used without any prior treatment. As noticed on the field, most of the wells are shallow and not properly protected, thus exposed to contamination. The springs are not properly taken care of as they are exposed to dust, close to farms, often shared with animals and are exposed to floods in the rainy season, suggesting their contamination by faeces and fertilizers. The boreholes are mostly used for laundry, bathing and cooking but not for drinking due to their unpleasant taste as reported by the users. Suitability of water from these sources for domestic purposes is thus questionable and there arises the need for proper quality assessment and monitoring as the population maybe exposed to water borne diseases. The main objective of this study was thus, to examine the quality of groundwater in Baba I in order to ascertain its suitability for domestic uses following WHO standards. To achieve this objective, water samples were analysed for organoleptic, physico-chemical and bacteriological properties and recommendations were made based on the findings obtained.

2. Materials and Methods

2.1. Description of Sampling Site

Baba I village (Papiakum) is one of the four villages that make up Babessi sub division and one of the thirteen villages of Ngoketunjia division in the North West region of Cameroon (**Figure 1**). It is located along the National road number 7, some 50 km away from Bamenda town. Baba I lies between latitude 6˚3'44" North and longitude 10˚29'25" East with an elevation of 1138 m above sea level. The village has both lowlands and an upper mountainous area with an estimated population of 40,000 inhabitants. Five gravity-powered catchments supply the village with water; but, for over seven years, the distribution has not been working in the whole village. In the upper part of the village, water sometimes flows through connected taps, while the lower village is completely cut off (CAMAAY, 2015). The main activities of the inhabitants are agriculture, breeding and small scale trading. The climate is characterized by a short dry season from November to February and a long raining season from March to October. The annual maximum temperature varies between 27.2˚C and 33.6˚C whereas the annual minimal temperature varies between 7.8˚C and 15.9˚C. Pluviometry varies between 1270 mm and 1778 mm of water per year. Its hydrology is characterized by the existence of small rivers, streams, springs and swamps. The ground is mainly basaltic, trachytic and/or granitic, thus favourable for agriculture and pasture. The vegetation is mainly savannah type with short stunted trees (CVUC, 2019).

2.2. Sampling and Preservation

Water samples were collected from six sources in November 2017, January, April and July 2018. At each sampling point, three samples were collected in clean and labelled polyethylene containers of 500 mL capacity each. The containers and caps were thoroughly rinsed with water to be sampled before collection. The collections were done very early in the morning before sunrise and the samples packaged in a cooler containing ice in order to maintain the temperature at 4˚C (Rodier et al., 2009). Finally, the samples were transported to the Research Unit of Animal Physiology and Microbiology and the Research Unit of Soil Analysis and Environmental Chemistry of the University of Dschang for preservation and analyses. A global positioning system (G.P.S.), (Garmin Etrex Vista) was used to locate the study site. The source type, sample code and geographical coordinates are presented in **Table 1**.

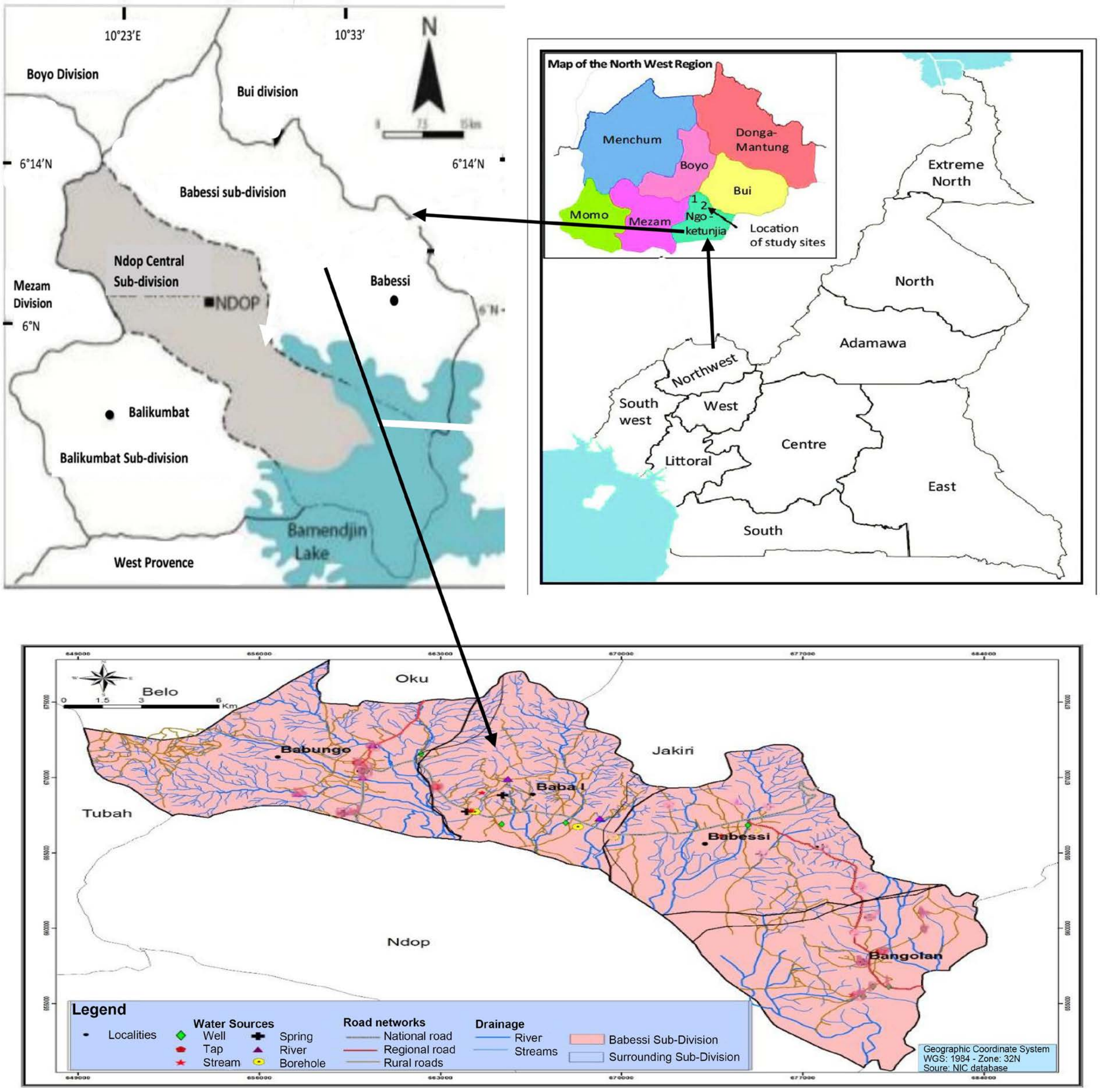

Figure 1. Map of the study area: map of Cameroon, indicating the map of North west region, map of North west region indicating the map of Ngo-ketunjia, map of Ngo-ketunjia indicating the map of Baba I in Babessi subdivision showing the sampling points.

Table 1. Source type, sample code and geographical coordinates.

Quarter	Source type	Sample code	GPS coordinates	Elevation (m)
Mechacha	Spring	Sme	N06˚02'20.2" E010˚28'54.9"	1138
Mecheche	Borehole	Bme	N06˚02'19.9" E010˚29'05.4"	1172
Kwebessi	Borehole	Bkw	N06˚01'47.3" E010˚31'14.9"	1185
Kwebessi	Well	Wkw	N06˚01'55.5" E010˚30'59.4"	1172
Meya	Spring	Smy	N06˚02'55.2" E010˚29'40.7"	1232
Koyart	Well	Wko	N06˚01'53.0" E010˚29'38.9"	1176

2.3. Laboratory Analyses

2.3.1. Organoleptic and Physicochemical Analyses

The water samples were observed with naked eyes for gross appearance and examined for offensive odour through subjective organoleptic assessment.

Temperature (T), pH, Electrical Conductivity (EC), and Total Dissolved Solids (TDS) were measured *in-situ* with the help of a calibrated multimeter (HANNAH-198128). Turbidity was measured using a turbidimeter (Model DRT, 100B, MF scientific, Inc) by measuring the propagation of light projected towards the tube containing the sample. Chloride content was determined by titrating 25 mL of each water sample with silver nitrate using potassium chromate indicator. Nitrate and ammonium were determined by Kjeldahl's distillation method: 25 mL of each sample was pipetted and placed into a distillation tube in which two drops of phenolphthalein and a small quantity of MgO were added and a pink colour was observed. The tube was then distilled and the vapour of NH_3 resulting from the alkalinisation of NH_4^+ by MgO was trapped by 100 mL boric acid contained in a 250 mL conical flask. The distillate was finally titrated under permanent stirring with 0.01 N sulfuric acid and the end point was marked by a persisting red colour. The distillation tube was removed and alllowed to cool. Devarda alloy was then added to the solution and another distillation was proceeded during which nitrate ions reduced by Devarda alloy were trapped by 100 mL of boric acid contained in a 250 mL conical flask. The distillate was once again titrated under permanent stirring with 0.01 N sulfuric acid. Phosphates were determined by UV visible spectrophotometric analysis: calibration curve was established using 0, 25, 50 and 100 ppm phosphate solutions. 10 mL boric acid, 2 mL sulfomolybdic mixture and 4 mL ascorbic acid were added to 2 mL of each sample. The mixtures were homogenised and allowed for 30 minutes for colour to develop. Finally, readings were done using a UV visible spectrophotometer at a wavelength of 700 nm. Bicarbonates were determined by acid-base titration with HCl using phenolphthalein and dilute methyl orange indicators. Sulphates were determined by gravimetric analysis. Na^+ and K^+ were determined by flame photometry while Ca^{2+} and Mg^{2+} were determined by complexometric titration with EDTA. Iron was determined by colorimetry.

2.3.2. Bacteriological Analyses

1) Multiple tube fermentation technique

100 mL water sample was distributed (1 mL amount, 10 mL amount, and 50 mL amount) in bottles of sterile selective culture broth containing lactose and an indicator. After incubation, the number of bottles in which lactose fermentation with acid and gas production occurred was counted. Lactose is fermented by coliforms present in the water. With reference to probability tables, the most probable number of coliforms in the 100 mL water sample was estimated and the water category obtained.

2) Count plate technique

Culture media for the specific bacteria were prepared and introduced into petri dishes containing 1 mL each of water sample and mixed until solidification. The petri dishes were then incubated at 44˚C for 24 hours after which colonies of bacteria were counted.

2.4. Water Quality Index

The water quality index (WQI) model simplifies the presentation of results of an analysis related to a water body as it summarises in one value a series of parameters analysed. WQI also eases comparison between different sampling sites and events (Tyagi et al., 2014; Mofor et al., 2017; Satish Chandra, 2017). In this study, sixteen important parameters were chosen for the calculation of water quality index. WQI was calculated using the weighted Arithmetic Index Method (Mofor et al., 2017; Satish Chandra, 2017). WQI values and the status of water quality are presented in **Table 2**. The following steps were used for determining the WQI. In the first step, the unit weight (W_i) for each water quality parameter was determined using the following formula:

$$W_i = \frac{K}{S_i} \tag{1}$$

where S_i is standard value of i^{th} parameter recommended by WHO; K is the proportionality constant which is calculated by using the following formula:

$$K = \frac{1}{\sum_{i=1}^{n}\left(\frac{1}{S_i}\right)} \tag{2}$$

The inverse of the sum of inverses of standard parameters is used in order to make parameters expressed by large numbers to weigh less in the final formula (Equation (4)). In the second step, quality rating or sub index (q_i) was computed for each of the parameters using the expression:

$$q_i = \frac{V_i - V_o}{S_i - V_o} \times 100 \tag{3}$$

where V_i is estimated value of i^{th} parameter in the analysed water sample; V_0 is ideal value of this parameter in pure water (it is zero for all parameters except pH = 7.0 and TDO = 14.6 mg/L); S_i is recommended standard value of i^{th} parameter given by WHO.

Table 2. Water Quality Index (WQI) and Status of water quality (Mofor et al., 2017; Satish Chandra, 2017).

WQI	Water Quality Status	Grade
0 - 25	Excellent	A
26 - 50	Good	B
51 - 75	Poor	C
76 - 100	Very poor	D
>100	Unsuitable for drinking	E

In the final step, the overall WQI was calculated by using following formula:

$$q_i = \frac{\sum_{i=1}^{n} q_i W_i}{\sum_{i=1}^{n} W_i} \tag{4}$$

Reference WQI table (Table 2) is used to deduce the sample's status.

2.5. Statistical Analyses

A one-way between groups Analysis of Variance (ANOVA) was used to explore seasonal impact on water quality at 95% confidence interval. Post-hoc comparisons were also performed using the Tukey HSD test and Pearson correlation was used to verify relationships between water parameters. The effect size was calculated using the following formula:

$$\text{eta squared} = \frac{\text{sum of squares between groups}}{\text{total sum of squares}} \tag{5}$$

Analyses were performed with the help of Statistical Package for Social Sciences (SPSS) version 20.0.

Piper trilinear diagrams were drawn using chemical properties to classify the selected ground water sources in to various hydro-chemical facies.

3. Results and Discussion

3.1. Results

Results of organoleptic parameters presented in Table 3 showed that all the water sources were clean and clear except the well in kwebessi (Wkw) which was not clear with tiny brownish debris and had rotten leaves odour.

Table 3. Results of organoleptic parameters.

Parameters	Appearance				Odour			
Month	Nov 17	Jan 18	Apr 18	Jul 18	Nov 17	Jan 18	Apr 18	Jul 18
Sme	Clear and clean	Clear and clean	Clear and clean	Clear and clean	Odourless	Odourless	Odourless	Odourless
Bme	Clear and clean	Clear and clean	Clear and clean	Clear and clean	Odourless	Odourless	Odourless	Odourless
Bkw	Clear and clean	Clear and clean	Clear and clean	Clear and clean	Odourless	Odourless	Odourless	Odourless
Wkw	Not clear with tiny brownish debris	Not clear with tiny brownish debris	Not clear with tiny brownish debris	Clear and clean	Rotten leaves odour	Rotten leaves odour	Rotten leaves odour	Rotten leaves odour
Smy	Clear and clean	Clear and clean	Clear and clean	Clear and clean	Odourless	Odourless	Odourless	Odourless
Wko	Clear and clean	Clear and clean	Clear and clean	Clear and clean	Odourless	Odourless	Odourless	Odourless
WHO	Clean and clear				Odourless			

Nov17: November 2017; Jan18: January 2018; Apr18: April 2018; Jul18: July 2018.

Results of physical parameters are presented in Table 4. Temperature ranged between 17.2˚C and 22.3˚C with a maximum mean value of (20.2 ± 0.7)˚C obtained in July 2018. pH ranged from 5.6 to 8.1 with a maximum average value of (7.2 ± 0.6). All the water sources had low Electrical Conductivity(EC) and Total Dissolved Solids (TDS) ranging from 22.0 to 95.2 µS/cm and from 16.5 to 67.6 mg/L with maximum means of (54.4 ± 25.4) µS/cm, and (34.9 ± 16.5) mg/L respectively. Turbidity fell in the range 0.5 - 3.6 NTU with a maximum mean value of (2.1 ± 1.1) NTU in July 2018.

Results of chemical parameters analysed are presented in Table 5 and Table 6. The ions analysed included major water minerals, ammonium, phosphates and Iron. Calcium and magnesium concentrations were below the WHO guideline values of 75 mg/L and 30 mg/L with maximum mean values of (39.67 ± 17.10) mg/L and (12.10 ± 2.53) mg/L respectively in July 2018. Na^+, K^+, Cl^-, HCO_3^-, SO_4^{2-}, NO_3^-, NH_4^+ and PO_4^{3-} were all found in low concentrations and ranged from 0.24 to 6.15 mg/L, 0.22 to 12.98 mg/L, 0.04 to 0.80 mg/L, 14.20 to 67.10 mg/L, 0.10 to 7.28 mg/L, 0.18 to 5.34 mg/L, 0.11 to 10.92 mg/L, 1.67 to 5.34 mg/L and 0.00 to 4.03 mg/L with maximum mean values of (2.26 ± 2.06) mg/L, (8.48 ±3.47) mg/L,

Table 4. Results of physical parameters.

Parameters	T (˚C)				pH				EC (µS/cm)				TDS (mg/L)				Tur (NTU)			
Month	Nov 17	Jan 18	Apr 18	Jul 18	Nov 17	Jan 18	Apr 18	Jul 18	Nov 17	Jan 18	Apr 18	Jul 18	Nov 17	Jan 18	Apr 18	Jul 18	Nov 17	Jan 18	Apr 18	Jul 18
Sme	19.8	17.2	18.1	20.4	7.3	6.2	7.8	6.9	43.5	64.1	53.2	51.7	37.2	43.4	36.0	36.8	0.7	0.5	0.4	0.65
Bme	20.2	19.7	20.1	19.3	6.7	6.8	6.0	7.5	87.2	95.1	75.0	95.2	51.1	63.8	49.3	67.6	2.3	0.75	1.2	2.1
Bkw	21.1	18.0	21.2	20.4	6.3	7.6	5.9	6.9	52.3	65.1	45.5	42.2	36.5	31.1	29.1	29.4	0.7	0.6	0.7	1.2
Wkw	21.0	19.0	22.3	21.1	7.3	7.7	6.6	6.3	28.8	36.6	22.0	23.0	20.3	24.6	17.2	16.5	3.6	1.9	2.8	3.5
Smy	19.0	17.2	17.3	19.6	8.1	7.3	6.8	8.0	39.3	25.4	35.0	32.1	25.0	18.2	24.2	23.0	0.5	0.6	1.2	3.0
Wko	19.5	18.5	19.8	20.5	7.5	6.4	5.6	6.2	37.3	40.3	39.8	40.5	32.1	28.0	25.1	35.6	1.2	1.5	1.1	2.3
WHO	15 - 25				6.5 - 8.5				2000				600				1 - 5			

T: Temperature; pH: Hydrogen potential; EC: Electrical Conductivity; Tur: Turbidity.

Table 5. Results of the analysed cations.

Parameters	Na^+ (mg/L)				K^+ (mg/L)				Ca^{2+} (mg/L)				Mg^{2+} (mg/L)				NH_4^+ (mg/L)				Fe^{2+} (mg/L)			
Month	Nov 17	Jan 18	Apr 18	Jul 18	Nov 17	Jan 18	Apr 18	Jul 18	Nov 17	Jan 18	Apr 18	Jul 18	Nov 17	Jan 18	Apr 18	Jul 18	Nov 17	Jan 18	Apr 18	Jul 18	Nov 17	Jan 18	Apr 18	Jul 18
Sme	0.71	0.43	0.53	1.02	1.70	0.26	2.75	5.65	27	5.80	10	24	12.50	3.57	9.60	16	1.30	0.84	1.32	5.34	0.01	0.06	0.10	0.02
Bme	1.20	0.61	0.24	1.75	1.42	0.22	1.44	2.63	38	4.50	31	68	14.20	1.81	7.80	11	1.70	0.22	0.92	2.68	0.20	0.31	0.15	0.03
Bkw	0.74	0.63	0.32	6.15	1.54	0.51	1.04	12.98	48	8.60	32	56	13	5.52	9.70	10.06	0.84	0.28	1.08	2.04	0.01	0.00	0.06	0.15
Wkw	0.63	0.71	1.07	0.98	1.23	0.60	1.03	7.76	29	3.90	6.80	34	4.90	0.11	2.34	11	0.57	0.84	0.92	1.67	0.36	0.00	0.02	0.42
Smy	0.62	0.52	0.43	2.91	2.10	0.75	2.30	11.09	32	7.80	14	28	11.50	2.71	13.6	14.50	1.35	0.25	0.24	1.84	0.00	0.00	0.00	0.01
Wko	0.40	0.24	0.34	0.76	1.10	0.81	1.03	10.74	27	6.70	10	28	6.10	0.32	4.70	10.01	1.03	0.18	1.12	4.56	0.01	0.00	0.21	0.19
WHO	200				200				75				30				30				0.3			

Table 6. Results of the analysed anions.

Parameters	HCO_3^- (mg/L)				SO_4^{2-} (mg/L)				NO_3^- (mg/L)				Cl^- (mg/L)				PO_4^{3-} (mg/L)			
Month	Nov 17	Jan 18	Apr 18	Jul 18	Nov 17	Jan 18	Apr 18	Jul 18	Nov 17	Jan 18	Apr 18	Jul 18	Nov 17	Jan 18	Apr 18	Jul 18	Nov 17	Jan 18	Apr 18	Jul 18
Sme	24.70	26.10	18.16	32.00	0.67	0.24	0.44	2.40	1.68	0.18	0.64	3.21	0.06	0.04	0.06	0.18	0.00	0.00	0.10	1.02
Bme	40.10	34.30	24.40	56.30	0.36	0.10	0.15	7.28	1.12	0.12	0.91	5.70	0.70	0.10	0.70	0.32	0.01	0.00	0.00	0.20
Bkw	35.70	45.60	58.56	68.02	0.75	0.34	0.53	1.25	1.32	0.56	2.28	1.03	0.76	0.26	0.76	0.80	0.06	0.00	0.00	0.09
Wkw	38.98	27.60	67.10	49.45	0.44	0.24	0.42	0.87	1.62	0.18	1.96	7.71	0.36	0.32	0.36	0.25	0.20	0.00	0.00	0.60
Smy	19.94	14.20	33.20	98.88	0.31	0.20	0.14	0.77	1.02	0.11	1.48	10.92	0.71	0.15	0.51	0.65	0.19	0.00	0.00	4.03
Wko	15.18	33.18	28.56	77.92	0.27	0.30	0.19	0.74	1.45	0.11	0.62	1.56	0.05	0.15	0.35	0.09	0.10	0.08	0.00	0.77
WHO	1000				250				50				250				≤5			

(0.44 ± 0.33) mg/L, (38.33 ± 19.80) mg/L, (2.22 ± 2.56) mg/L, (5.02 ± 3.84) mg/L, (3.02 ± 1.55) mg/L and (1.12 ± 1.47) mg/L respectively. Iron ranged from 0.00 to 0.36 mg/L and had a maximum mean value of (0.98 ± 0.15) mg/L.

Results of water quality index (WQI) for the analysed ground water samples are presented in **Table 7**. The combined effect of physical and chemical parameters gave water quality indices ranging between 1.79 and 124.61 with Wkw recording the highest WQI value in July.

Results of bacteriological analysis are presented in **Table 8** and **Figure 2**. Faecal coliforms were found in all the water samples with Most Probable Number ranging from 08 to 100/100 mL. Based on WHO classification, Sme in all the sampling sessions and Smy in November were acceptable for human consumption (category B) while the remaining sources were either of high risk for consumption (category C) or grossly polluted (Category D). Detailed investigations of the water samples also revealed the presence of specific bacteria in decreasing order of abundance as follows: *Enterobacter spp*, *Escherichia coli spp*, *Streptococcus spp*, *Salmonella spp* and *Shigella spp* (**Figure 2**), with colony count ranging from 15 to 350 CFU/mL, 10 to 300 CFU/mL, 15 to 250 CFU/mL, 00 to 150 CFU/mL and 00 to 157 CFU/mL respectively.

Results of One-way between groups ANOVA that was applied on the analysed water parameters are presented in **Table 9**.

3.2. Discussion

3.2.1. Organoleptic and Physical Parameters

Organoleptic parameters examined include appearance and odour. Based on observations, all the water sources were clean and clear except the well in kwebessi (Wkw) which was not clear with tiny brownish debris and had the odour of rotten leaves. The good organoleptic properties of most of these sources could be justified by the fact that these are ground waters which are naturally filtered as they flow vertically from underground. A similar observation was made by Mofor et al. (2017) while assessing the quality of some springs in the Awing community, North West Cameroon. Odour in Wkw was surely caused by the decomposition of leaves

Table 7. Water quality index values, water quality status and grades.

Sample code	WQI				Water quality (grade)			
	Nov 17	Jan 18	Apr 18	Jul 18	Nov 17	Jan 18	Apr 18	Jul 18
Sme	8.87	13.92	36.13	10.49	Excellent (A)	Excellent (A)	Excellent (A)	Excellent (A)
Bme	62.22	88.56	39.70	19.66	Poor (C)	Very poor (D)	Good (B)	Good (B)
Bkw	2.34	7.44	12.94	46.69	Excellent (A)	Excellent (A)	Excellent (A)	Good (B)
Wkw	114.16	10.64	12.27	124.61	Unfit for drinking (E)	Excellent (A)	Excellent (A)	Unfit for drinking (E)
Smy	10.68	5.34	3.53	24.17	Excellent (A)	Excellent (A)	Excellent (A)	Excellent (A)
Wko	11.48	1.79	53.84	56.80	Excellent (A)	Excellent (A)	Poor (C)	Poor (C)

Table 8. Most probable Number (MPN) of coliforms in 100 mL of water.

Parameters	Most probable Number (MPN) of coliforms in 100 mL of water							
	Mean				Category			
Month	Nov 17	Jan 18	Apr 18	Jul 18	Nov 17	Jan 18	Apr 18	Jul 18
Sme	9	10	08	10	B	B	B	B
Bme	20	40	30	90	C	C	C	D
Bkw	20	45	90	90	C	C	D	D
Wkw	40	65	30	30	C	D	C	C
Smy	10	35	50	65	B	C	D	D
Wko	45	40	100	40	C	C	D	C
WHO	0				A			

A: Excellent; B: Acceptable, Low risk; C: Unacceptable, High risk; D: Grossly polluted.

Table 9. One-way between groups ANOVA.

		Sum of Squares	df	Mean Square	F	Sig.
Temperature	Between Groups	14.688	3	4.896	3.489	0.035
	Within Groups	28.062	20	1.403		
	Total	42.750	23			
pH	Between Groups	1.939	3	0.646	1.384	0.277
	Within Groups	9.345	20	0.467		
	Total	11.284	23			
EC	Between Groups	287.408	3	95.803	0.188	0.903
	Within Groups	10,186.790	20	509.339		
	Total	10,474.198	23			
TDS	Between Groups	88.561	3	29.520	0.142	0.933
	Within Groups	4149.558	20	207.478		
	Total	4238.120	23			
Turbidity	Between Groups	4.468	3	1.489	1.626	0.215
	Within Groups	18.320	20	0.916		
	Total	22.787	23			

Continued

Na^+	Between Groups	12.966	3	4.322	3.896	0.024
	Within Groups	22.190	20	1.110		
	Total	35.157	23			
K^+	Between Groups	241.608	3	80.536	20.477	0.000
	Within Groups	78.661	20	3.933		
	Total	320.269	23			
Ca^{2+}	Between Groups	4180.288	3	1393.429	10.697	0.000
	Within Groups	2605.242	20	130.262		
	Total	6785.530	23			
Mg^{2+}	Between Groups	325.583	3	108.528	10.419	0.000
	Within Groups	208.334	20	10.417		
	Total	533.917	23			
Cl^-	Between Groups	0.314	3	0.105	1.579	0.226
	Within Groups	1.325	20	0.066		
	Total	1.639	23			
HCO_3^-	Between Groups	457.358	3	152.453	0.607	0.618
	Within Groups	5020.838	20	251.042		
	Total	5478.196	23			
SO_4^{2-}	Between Groups	16.070	3	5.357	3.240	0.044
	Within Groups	33.070	20	1.654		
	Total	49.140	23			
NO_3^-	Between Groups	79.206	3	26.402	6.888	0.002
	Within Groups	76.658	20	3.833		
	Total	155.864	23			
NH_4^+	Between Groups	23.096	3	7.699	10.967	0.000
	Within Groups	14.039	20	0.702		
	Total	37.135	23			
PO_4^{3-}	Between Groups	5.246	3	1.749	3.230	0.044
	Within Groups	10.829	20	0.541		
	Total	16.076	23			
Fe^{2+}	Between Groups	0.006	3	0.002	0.149	0.929
	Within Groups	0.254	20	0.013		
	Total	0.260	23			
Enterobacteria	Between Groups	15,803.125	3	5267.708	0.529	0.667
	Within Groups	199,112.500	20	9955.625		
	Total	214,915.625	23			
E. coli	Between Groups	24,236.458	3	8078.819	2.274	0.111
	Within Groups	7105.167	20	3552.708		
	Total	95,290.625	23			

Continued

Streptococcus	Between Groups	15,411.458	3	5137.153	1.746	0.190
	Within Groups	58,829.167	20	2941.458		
	Total	74,240.625	23			
Salmonella	Between Groups	3861.458	3	1287.153	1.063	0.387
	Within Groups	24,212.500	20	1210.625		
	Total	28,073.958	23			
Shigella	Between Groups	3841.667	3	1280.556	1.072	0.383
	Within Groups	23,891.667	20	1194.583		
	Total	27,733.333	23			

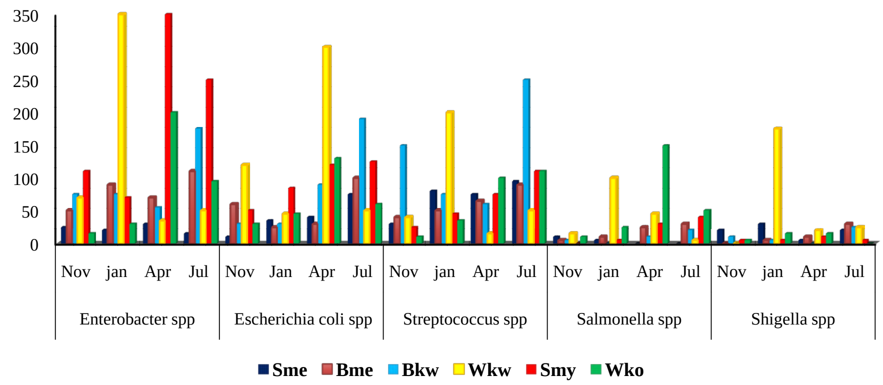

Figure 2. Specific bacteria isolated in the sampled waters between November 2017 and July 2018.

as the well was widely open to dust and leaves of trees found around. Organoleptic parameters of the water sources, except Wkw, conform to the WHO recommendation for safe drinking water and could be considered good for domestic purposes. However, there was no guarantee at this level as good domestic water must not only be clean, clear and odourless but also of good physicochemical and bacteriological quality.

Temperature values were between the minimum and maximum annual temperatures of 7.8˚C and 33.6˚C in this area (CVUC, 2019), also falling within the WHO guideline range of 15˚C to 25˚C. One-way between groups ANOVA revealed a significant difference between temperature mean values ($F(3. 20) = 3.489$, $p \leq 0.035$) (**Table 9**) and the Post-hoc comparisons using the Tukey HSD test further indicated that the difference was between mean temperatures in January and July. This was an increase, which could be as the result of seasonal changes, shade, air temperature, water depths and inflow of groundwater (WHO, 2011). However, the actual difference in mean values between groups was quite small as the effect size, calculated using eta squared, was 0.34 (Cohen, 1988). Studies carried out by Wotany et al. (2013) on the hydrogeochemical and anthropogenic influence on water quality in the Rio del Rey Basin, South Western Cameroon, Gulf of Guinea, revealed relatively high temperatures between 21 and 29˚C which was also associated with seasonal influences. Though the sources had temperatures within the guideline range, it should be noted that high water temperature enhances the growth of microorganisms and may increase problems related to taste, odour, colour and corrosion (WHO, 2017). pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS) and Turbidity did not vary significantly with seasons. Based on the results (**Table 4**), the water sources ranged from moderately acidic to weakly basic. Though some of the sources had pH values lower than the WHO established value of 6.5, it had little or no direct effects on consumer's health as the pH of stomach fluid (gastric juice) is between 1.5 and 3.5. However, careful attention to pH control is necessary during water treatment to ensure satisfactory water clarification and disinfection (WHO, 2007). The insignificant change in pH suggests little effect of the rains on the water sources. Low EC and TDS in the water sources suggest low-mineralized and freshwaters (Wirmvem et al., 2013a). The strong positive correlation observed between EC and TDS (r = 0.994, $p \leq 0.001$) could be justified by the fact that EC arises from dissolved ionic matter. Mean pH, EC and TDS obtained in January were similar to those reported by Wirmvem et al. (2013a) in ground waters in the studied area. All the waters had turbidity values far below the WHO guideline of 5 NTU, indicating the possible absence of hazardous chemicals and reduced microbial load (WHO, 2017).

3.2.2. Chemical Parameters

The presence of Ca^{2+} and Mg^{2+} in the studied water sources suggests the occurrence of limestone and chalk sendiments in the study area (WHO, 2011). Looking at their concentrations, calcium-based hardness was predominating due to the fact that magnesium is usually found at lower concentrations in groundwater (NRC, 1977). Seasonal changes also significantly influenced both ions concentrations (F(3.20) = 10.697, $p \leq 0.001$; F(2.20) = 10.419, $p \leq 0.001$ for Ca^{2+} and Mg^{2+} respectively). This was a medium change (eta squared = 0.62 and 0.61) which was further identified to be a decrease between November and January and an increase between January and July, April and July for Ca^{2+} and a decrease between November and January, an increase between January and July and between April and July for Mg^{2+}. Based on WHO classification, the waters ranged from soft (hardness < 60 mg/L) to moderately hard (60 mg/L ≤ hardness ≤ 120 mg/l) (WHO, 2011). Na^+, K^+ and Cl^- concentrations were also very low compared to WHO standards of 200 mg/L for Na^+ and K^+ and 250 mg/L for Cl^- respectively. Low sodium and chloride ions in the sampled waters could be as a result of low NaCl in the geological formations of the study area, as both ions are generally derived from the decomposition of rock salts like sodium and aluminium silicates (Belghiti et al., 2013; Mofor et al., 2017) and low K^+ may be due to its low geochemical mobility in the area (Wirmvem et al., 2013a). The positive correlation between Na^+ and Cl^- (r = 0.930, $p \leq 0.007$) suggest their common origin. Though they were in low concentrations, Na^+ and K^+ significantly fluctuated between seasons (F(3.20) = 3.896, $p \leq 0.024$ and F(3.20) = 20.477, $p \leq 0.001$ respectively). Despite the statistical significance, the actual difference in the mean concentrations of Na^+ was quite small (eta squared = 0.34) while that of K^+ was average (eta squared = 0.75) (Cohen, 1988). Bicarbonate was the only ion responsible for water alkalinity as CO_3^{2-} and OH^- were absent. Its concentrations were very low compared to the WHO guideline value of 1000 mg/L and did not significantly change with season. The presence of HCO_3^- was necessary as it constitutes an important buffer system which helps in lowering the acidity of water (Njoyim et al., 2016c). HCO_3^- originates from the partitioning of CO_2 from the atmosphere and the weathering of carbonate minerals in rocks such as limestone and dolomite. Wirmwem et al. (2013a) also reported similar concentrations of HCO_3^- in some bore holes and wells in the study area. Sulphate concentrations were insignificant regarding the WHO guideline value of 250 mg/L and did not show any significant difference between seasons. Low sulphates suggest low and the possible absence of minerals such as gypsum ($CaSO_4 \cdot 2H_2O$), pyrite (FeS), barite ($BaSO_4$), and epsomite ($MgSO_4 \cdot 7H_2O$) in the study area. The presence of sulphate in drinking-water can cause noticeable taste, and very high levels might cause a laxative effect in unfamiliar consumers (WHO, 2004).

Nitrates found in the sampled waters in January probably came from nitrate producing bacteria (*Nitrobacter*), and the significant increase observed in its concentrations between January and July ($F(3.20) = 6.888$, $p \leq 0.002$) suggest its infiltration from waste discharges and fertilisers into the water bodies. However, its concentrations were very low compared to the guideline value of 50 mg/L. Interest is centred on nitrate mostly because its high levels in water has been reported to be responsible for the "blue baby" syndrome (methaemoglobinaemia) and typhoid effects (WHO, 2017). Low sulphates and nitrates were also reported in the study area (Wirmvem et al., 2013a) and elsewhere in Cameroon (Temgoua, 2011). NH_4^+ found 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 wastes contaminations (WHO, 2011; Aboudi et al., 2014). However, its low concentrations, far below the permissible limit of 30 mg/L prescribed by the WHO, showed no associated health risk. Phosphate concentrations were also very low in all the sampled waters without any significant differences with seasons. This could be due to its sorption on organic colloids. This result was in accordance with the observation of Wirmvem et al. (2013a). Iron was below detectable limits in most of the samples in January and had relatively low concentrations in November, April and July, the exception being Wkw (0.36 mg/L). Low iron could be due to the fact that the current water pH did not favour the solubility of its oxides and hydroxides leached from nearby soils. A contrary observation was made by Njoyim et al. (2016c) in ground waters in the Bangangte municipality of Cameroon. Though iron is vital for health, its low concentrations in the studied waters has no associated health risks as it can easily be gotten from other sources. Also, at levels above 0.3 mg/L, iron oxides stain laundry and plumbing fixtures, gives noticeable taste to water, develops turbidity and colour and also promotes the growth of "iron bacteria" (WHO, 2011).

The concentrations of major anionic and cationic constituents of the water samples were plotted on a Piper trilinear diagrams (Piper, 1953) to determine the water types. The plot of physicochemical data on the diamond shaped trilinear diagram (**Figure 3**) revealed that the analysed waters were calcium and magnesium bicarbonate type which are typical of shallow fresh ground waters.

Water quality index is one of the most effective tools to monitor surface, as well as ground, water pollution and can be used efficiently in the implementation of water quality upgrading programmes. As shown in **Table 7**, the computed WQI led to the grading of the waters between excellent (A) and unfit for drinking (**Table 2**). However, WQI may not convey sufficient information about the real quality situation of water since the concealing or overstressing of a single bad parameter value can give deceptive information about the water quality. Also, there are many other water quality parameters that are not included in the index and thus, other parameters need to be examined before a conclusion can be made about the overall water quality (Mofor et al., 2017).

3.2.3. Bacteriological Parameters

The presence of faecal coliforms in the sampled waters suggests recent contamination of the water sources by human or animal faeces and the possible presence of other pathogenic organisms (Njoyim et al., 2016b; Nanfack et al., 2014). This was confirmed through the identification of specific bacteria, namely *Enterobacter spp*, *Escherichia coli spp*, *Streptococcus spp*, *Salmonella spp* and *Shigella spp* (**Figure 2**), without any significant difference in their colony counts between seasons ($p > 0.05$). Based on the WHO guideline that recommends no bacteria of faecal origin in drinking water, all the sources were unfit for domestic uses such as drinking and bathing. According to Kuhn et al. (2001), domestic water with faecal coliform content above 100 CFU/100 mL will lead to serious health effects if used for drinking and cooking and will possibly cause infections if used for

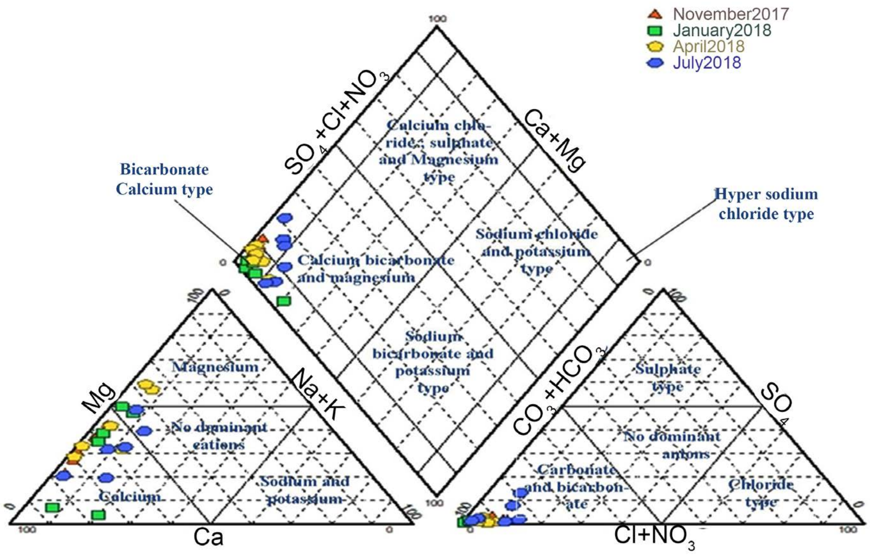

Figure 3. Piper's trilinear diagram showing ground water types.

bathing and laundry. The presence of faecal coliforms and the abundance of specific pathogenic bacteria in most of the studied water sources can be associated to poor hygiene and sanitation (Nanfack et al., 2014; Mofor et al., 2017). One of the springs, Smy, was exposed to animals, dust and floods. Also, mostly children were found using unclean containers to collect water from this source which, according to Nanfack et al. (2014) had strong pathological influences on the water source. The low contamination of the spring of Mecheche (Sme) was surely because this spring has been constructed to prevent access to animals, dust and flood and any contamination may only originate from infiltration of microbes from underground. The wells were shallow and not properly protected. In addition, the enormous pollution of these water sources could be explained using other environmental related factors such as the low depth of the groundwater table and the behaviour of the population through open-air defecation. Poor bacteriological water quality has also been reported in this area (Wirmvem et al. 2013b; Njoyim et al. 2016a). The positive correlation between these bacteria: *Enterrobacter-steptococcus* ($r = 0.926$), *Salmonella spp-Shigella spp* ($r = 0.969$), *Streptococcus spp-Salmonella spp* ($r = 0.885$) suggest their common origin. Based on the bacteriological parameters, all the water sources were unsuitable for human consumption, thus, exposing the local population to water borne diseases such as typhoid, diarrhoea and dysentery.

4. Conclusion

This study focused on the analysis of organoleptic, physicochemical and bacteriological properties of ground water, main source of domestic water, in Baba I in the North-West region of Cameroon following WHO guidelines. Results of organoleptic and physical parameters showed that most of the sources were of good organoleptic properties, had temperatures within the WHO acceptable limits with pH ranging from moderately acidic to weakly basic and had very low mineral content. Regarding the chemical aspect, all the analysed ions were found within the WHO guideline limits and the water sources ranged from soft to moderately hard with iron slightly above the WHO guideline value in Wkw in November and July respectively. Piper's trilinear diagrams also showed that the analysed waters were all calium and magnesium bicarbonate type, indicating shallow fresh ground waters. Small to average seasonal influences were observed in the variations of temperature and the concentrations of Na^+, K^+, Ca^{2+}, Mg^{2+}, NO_3^-, and NH_4^+. Looking at the bacteriological quality, Faecal coliforms and specific bacteria namely *Escherichia coli*, *Enterobacteria*, *Streptococcus*, *Salmonella* and *Shigella spp* were identified in all the sampled waters, suggesting recent contamination of the sources by human or animal faeces. The sources are unfit for domestic uses and thus, exposes the local population to water borne diseases such as typhoid, diarrhoea and dysentery. Therefore, home treatment methods such as chlorination, filtration, boiling and solar disinfection should be implemented prior to consumption.

Acknowledgements

We thank the Babessi Council for the financial support provided to enable us carry out this research.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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