Potable Water Quality and Health Nexus in Bafut Sub Division North West Region-Cameroon

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Abstract:- The consumption of unsafe drinking water is a vitalpublic health concern. This study investigates the bacteriological quality and physicochemical parameters of drinking water sources within the Sub-Division. Fieldwork conducted in February and July 2018 involved the collection of water samples from 27 springs, 8 streams, 1 borehole, 4 wells and 2 rainwater sources from 24 communities. was.Physico-chemical and microbiological analysis of the water samples was performed following the standards technique set by APHA 2016 and statistical analysis was carried out using SPSS 21 and Rockworks software. The results indicated pH values >8 (36.6%) which are above the recommended standards by WHO for drinking water and which may lead to the corrosion of pipes. Total coliform count ranged from 1 to 236 per 100ml and was observed in 64.2 % of the water samples making them unsuitable for drinking. The relative abundance of cations and anions stood at Ca^{2+}>Mg^{2+}>K+>Na+and HCO_3^->NO_3^->Cl->SO_4^{2-}->F^-. The major water type was $Ca^{2+}HCO_3^-$ and the water resources were rich in Ca^{2+} and HCO^{3-}. The mineralogy of water samples was based on water-rock interaction from weathered igneousrocks which are predominantly basalts rich in calcium. The health impacts of resultant waterborne diseases were evident in the community as shown by records from hospitals and health centers. Diarrhoea was prevalentin children between the ages of <1-10 years and cyclical occurrences of waterborne diseaseswere observed throughout the year during the wet and dry seasons. Suitable management strategies such as the protection of water sources, proper treatment and distribution of the water, as well as the protection of watershedswere identified as possible strategies for safeguardingthe quality of the water supply systems in the area.

Keywords:- *Bafut, potable water sources, physicochemical parameters microbial quality, health risks, water-borne diseases.*

I. INTRODUCTION

Worldwide, water is the most fundamental and indispensable of all natural resources and neither social and economic development, nor environmental diversity can be sustained without water (Christine2006). Groundwater is the major source of drinking water in rural areas. A significant fraction of groundwater supply sources are responsible for waterborne disease outbreaks around the world (Bhattacharjee et al. 2002). Rural water supply requires adequateconstruction and design to shun fecal matter contamination(Ferguson et al. 2012). Drinking water from such sources is expected to have ahigh probability of being free of fecal indicator bacteria and, if possible, should meet the WHO qualityguidelines.Conversely, unimproved drinking-water sources arevulnerable to permanent or temporary water-quality deterioration and often do not meet theWHO guideline values for safe drinking water.According to Afiukwa and Eboatu (2013),the quality of drinking water has a powerful impact on public health.Therefore effective monitoring and comprehensive assessment of community drinking water systems is crucial in protecting the well-being of the public.Thus, the continuous assessment of the physical, chemical and biological parameters of water constitutes an essential part of water quality control.

Water supplies continue to dwindle because of resource depletion and pollution, while demand is rising fast because of population growth (Gleick 1986), people. The situation is acute in Sub Sahara Africa where water scarcity and associated increases in water pollution are closely linked to the prevalence of poverty, hunger and disease (Nkwonta et al. 2010).Consumption of microbial contaminated unsafe drinking water is seen as one of the most common reasons for health issues in Africa. The most vulnerable population is children younger than five years old. Diarrhoea is seen as the most common waterborne disease in developing countries (UNICEF 2012).

According to Fewtrell et al.(2007), many people in rural Africa do not have access to clean water and have to walk for long distances to get water, which is still dirty and contaminated. In Cameroon,problems with waterborne diseases are increasing as more people are dying from a bacterial infections in water and this natural resource is treated with disregard (Tyler et al. 2017). Therefore, the suitability of unimproved drinking water is a serious concern especially the bacteriological quality in rural communities. This calls for a need for microbial examination of drinkingwater sources in the country. According to Katte et al. (2003), water-related diseases represent about two-thirds of all the diseases in Cameroon and are responsible for approximately 50 % of the cases of deaths recorded.

Despite this situation, only a few recent studies on the microbial quality of drinking-water have been carried out in the country such as in the cities of Douala (Ndjama et al. 2008; Ako et al. 2010; Eneke et al.2011),Yaounde (Kuitcha et al. 2010; Ateba et al. 2012); in Ndop (Wirmvem et al. 2013) in Awing(Nelson et al. 2017) and in BafutLumnwi et al. (2019). These studies revealed extremely high levels of bacteriological contamination of most drinking-water sources. Diseases of interest identified in these studies included gastroenteritis, amoebic dysentery, typhoid fever and cholera.Unfortunately, most of these studies have been limited to towns and cities with very few in village communities.

However, Nelson et al. (2017) assessed the quality of water from three springs in Awing village to ascertain their quality for human consumption based on the bacteriological and physicochemical parameters and the results revealed the presence of fecal coliforms and pathogenic bacteria in all the springs justified by the high rate of waterborne diseases recorded in the area.This is the case in Bafut Sub-Division, a community with several villages where the inhabitants depend on unprotected springs, shallow wells, streams, boreholes and rivers for drinking. Catchments in the area serve many purposes including potability, irrigation, cattle watering and fish culture. Information on water quality analysis in these catchments particularly physical, chemical and biological propertieshas not been documented in literature.The microbial and chemical quality of these sources is unknown despite the dependence of the population on these water sources. Thus, this study investigates the bacteriological quality and physico-chemical parameters of groundwater and surface water sources in the study area. Accordingly, it examines the suitability of water sources for drinking and their effects on the population.

II. STUDY AREA

BafutSub Division is situated in the North West part of the western grass field between longitudes 10º 06'N and 10º13’E, and latitude 6º05’N and 6º10’E (Figure 1). It lies along a 10km stretch of the ring road that trails along a ridge above the Menchum valleyin Mezam division. This chiefdom covers an area of 450 square kilometers with a total population of about 129,000 inhabitants (CDP 2011). Agriculture involves more than 70 % of the total population. Land use practices such as wetland reclamation and agro-pastoral activities and at least 30,000 cattle grazed in the area (Ngwa1982).

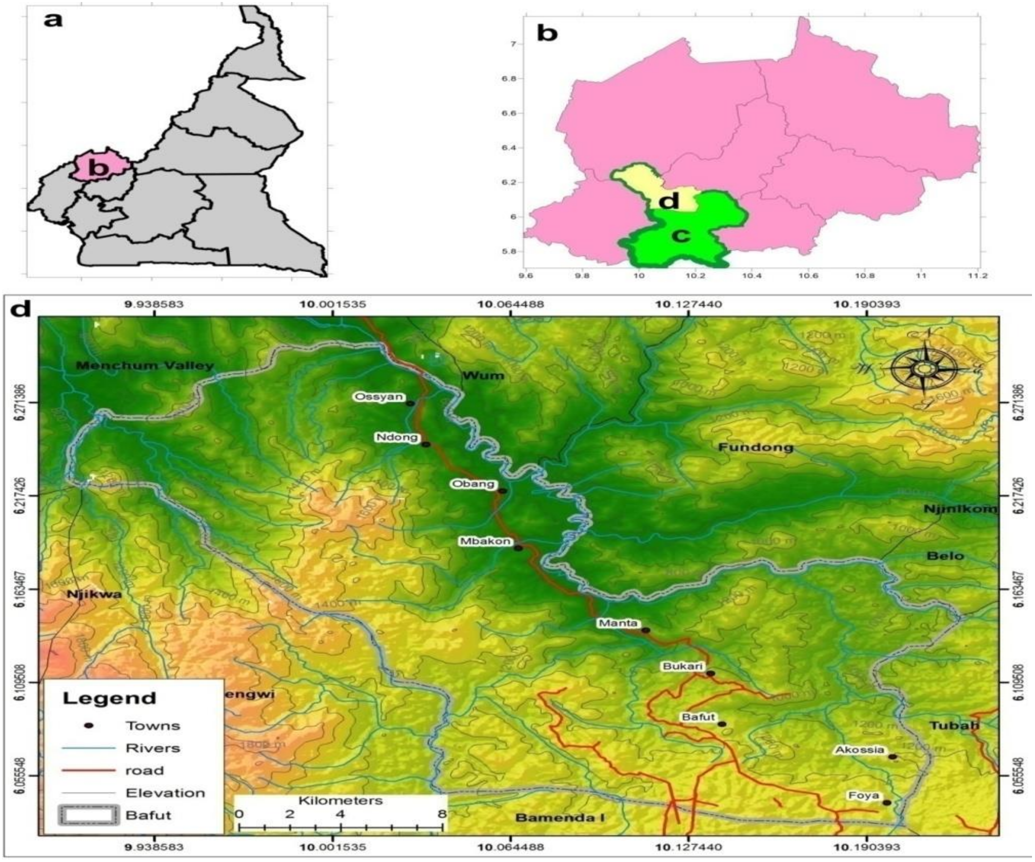

Fig. 1: Location Map of Bafut showing drainage and relief

III. GEOLOGY AND HYDROLOGY

The study area lies within the Western Highlands (Neba1999)and the underlying rocks are old granites, gneisses and rhyolite, of the precambrian era which have a cover of basaltic rocks on the surface (Ndenecho 2003).This basement forms part of the tectonically inactive African shield (Neba 1999; Marzoli et al. 1999). Chemical weathering of the basement and surrounding volcanic rocks has produced thick unconsolidated sediments, mainly of clay to sand sizes. Generally, the soils vary so much with the nature of relief. On the Bafut plateau, the dominant soil type is the coarse grain sandy soil type which stretches from the Mundum-Banji-Akofunguba axis to Mankwi, Nso through Agyati to Mforya. These sandy soils are however replaced with remnants of volcanic soils. Chemical weathering of the basement and surrounding volcanic rocks has produced thick unconsolidated sediments, mainly of clay to sand sizes. In "Mumelaah" the soil type there are mostly loam and clayish usually very black deep and fertile. Alluvial soils are found in small quantities in the narrow floodplain of Mbieand the Menchum valley (SIBADEF 2011). The area falls under the humid tropical equatorial climatetype modified by relief with 2 distinctive seasons, a long rainy season (mid-March to mid-November) and a short dry season (mid-November to mid-March). Mean annual rainfall and temperature are 2400mm and 24.5^{o}C, respectively.The main river which drains the area the Muya which takes its rise from the Bali highlands, flows in a dendritic pattern through Menchum(BafutCouncil 2011).Percolation of water through the unconsolidated sandysediments forms the groundwater aquifer system.

IV. MATERIALS AND METHODS

A. *Fieldwork, measurements of physical parameters and water sampling*

Fieldwork was carried out within the months of February and July 2018, which involved the collection of 42 water samples in duplicates from 27 springs, 8 streams, 1 borehole, 4 wells and 2 sporadic rainwater sources from 24 communities.Physical parameters were measured on-site due to their unstable nature to avoid unpredictable changes in characteristics as per the standard procedures (APHA 1998).Physical parameters analyzed included water temperature, atmospheric temperature, electrical conductivity (EC) and pH, measured insitu using a PT154ET thermometer, Cond 330i/set and WTW 315i pH meter respectively.

Water sampling points (Fig2) were noted with the aid of a Garmin GPS. At each point, land use practices were noted about their effects on water quality. Sample container preparation, storage and transportation procedures were done following the recommendations of the Standard Methods for the Examination of Water and Wastewater manual (APHA 1998). Samples were collected directly from the water sources after thorough rinsing with distilled water and water to be sampled into 0.5L and 0.25L plastic bottles for chemical and microbial analyses respectively.

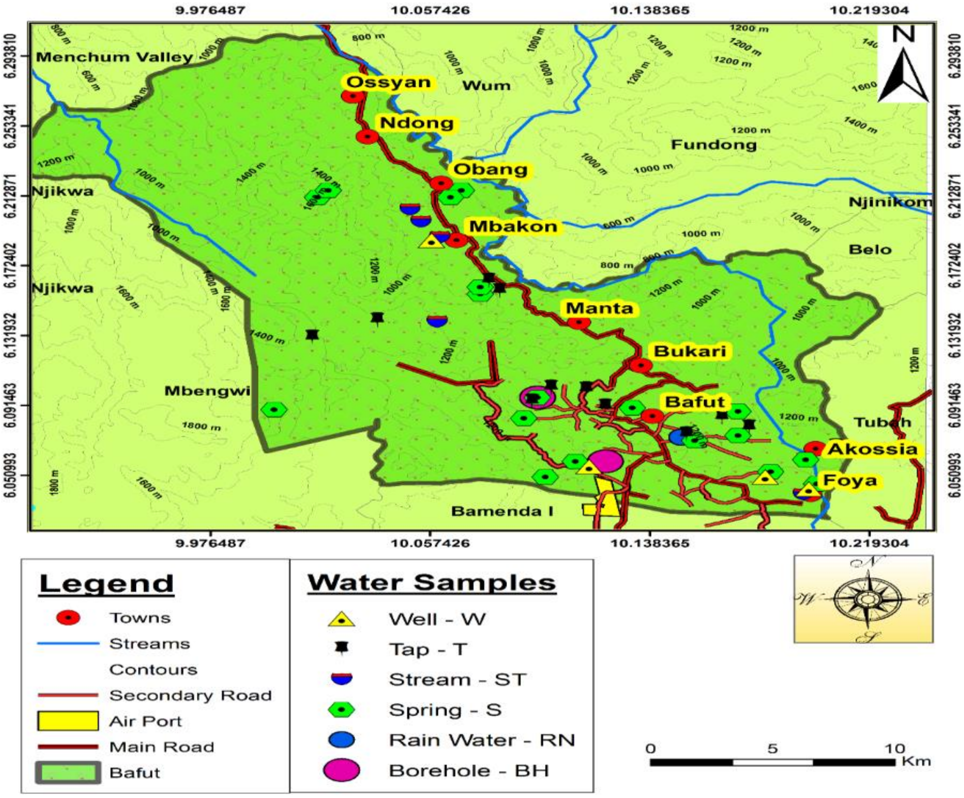

Fig. 2: Sample location map

Two periodic rainfall samples were collected in vessels cleaned withdistilled water directly from the atmosphere and from a rain gauge at Bafut meteorological station.The samples were preserved in a cooler with ice blocks in order to minimize contamination, at a temperature of 4ºC and transported to "Laboratoired'AnalyseGeochemie et l'Eau" (LAGE) of the Institute of Geological and Mineral Research (IRGM) in Yaounde, Cameroon for major ion analysis using an Ion Chromatographyfollowing the procedure byMichalski (2016). The device used was the ICS900 and ICS-1100 Dionex model. Samples meant for ion analyses were filtered through a membrane filter which allowed for the removal of particles and bacteria that could modify the results.An effluent was prepared with $NaHCO_3$ and $NaCO_3$ determined based on the type of column in use for anion analyses. From the column, the quantity of each element was obtained in parts per million (ppm) and then to milligrams per liter. For the samples meant for cation analysis, 1% nitric acid with a pH of less than two was added to keep metal ions in the solution (Michalski 2016). The charge balance for the reliability of chemical measurement calculated was within the acceptable limit of ±5% (Dominico et al., 1990).

B. Microbial and analysis

Samples for microbial analysis were transported to the Life Science Laboratory of the University of Buea, Cameroon where cultural analysis, using the standard plate count (SPC), the MacConkey and SS Agar medium and a light microscope. Stock culture and subculture on nutrient agar were done to obtain fresh colonies for microscopic analysis. Preparations of nutrient agar was done following the manufacturer's instructions and the APHA manual of 1992 and 2016. Violet red bile lactose agar and McConkey agar were used to isolate Escherichia coli from other gram-negative pathogens present in water samples that showed the presence of coliform, while SS agar was used to isolate Salmonella (Druce et al. 1957). Colony forming unit (cfu/ml) per milliliter was calculated by multiplying the average number of colonies per plate by the dilution factor of the inoculated sample.

The average number of colonies per plate was derived by dividing the total number of colonies of all plates that were inoculated by the same dilution volume and dividing the sum by the two plates used. For quality control and reliability microscopy gram control was done on all isolated slides from centrifuge samples and on isolated colonies. Microscopic analysis was done after cultural quantification of bacteria on gram stained slides. Slides were examined on a light microscope using 100x oil immersion objectives to differentiate gram-negative from gram-positive bacteria. The appearance of pink color signifies a positive result for Escherichia coli and blackish color positive for Salmonella (Njunda et al, 2013). Hospital registers were reviewed from 2003-2017 on the prevalence of waterborne diseases and causative agents.

C. Statistical analysis of data

SPSS version 22and the Pearson correlation coefficient were used to establish the relationship between water variables that best describe water quality. Piper's trilinearplot was used todetermine hydrochemical faciesthrough Rockwork software (Piper 1944). The WHO (2017) guidelines for water quality was used to evaluate the parameters analyzed for drinking water.

V. RESULTS AND DISCUSSION

A. Physio-chemical composition of water sources

The results of water sources sampled are presented in Table 1. The pH of springs, taps, wells, streams, rainwater and borehole ranged from 5.6 to 10. Sixty-five percent (65%) of these water samples were slightly acidic indicating acidic water aquifer to weak alkaline. The slightly acidic nature of the water sources was linked to the formation and dissolution of minerals (Williams and Benson, 2010). EC values ranged from 11.4 (NTAYO spring)-254 (RN1 rainwater) µS/cm with a mean of 64.8 µS/cm. These low concentrations indicate that the water sources are of low saline concentration as indicated with zero levels of salinity and low water temperature with a high spring flow rate.

TDS of all groundwater sources ranged from 8.8 (NTAYO spring, NTAYN spring)-180 (RN1 rainwater) mg/l with a mean of 45.39 mg/l indicating low mineralized water sources. The values of water temperature presented variation from 25 ° C at NT spring to 28.4° C at AKOS spring with a mean water temperature of 27.3° C. Sampling hour and location of water source in relation to shade could have influenced the temperature of water samples. Mean water temperature of 27.3° C was closer to the mean atmospheric temperature, suggesting recent recharge or climatic influence. Alkalinity levels of water samples varied from 116.72 µeq/l (MBG stream) to 2567.21 µeq/l (NJIBIPLAN well) with a mean of 941.73 µeq/l. Alkalinity levels were above WHO standards for drinking water.

Parameters	Taps				Springs				Wells				Streams				Borehole				Summary of Water samples			
	Mean	Min	Max	std	Mean	Min	Max	std	Mean	Min	Max	std	Mean	Min	Max	std	Mean	Min	Max	std	Mean	Min	Max	std
TEMP	27.3	26.0	28.0	0.7	27.0	25.0	28.0	1.1	27.8	27.0	28.0	0.5	28.0	28.0	168.0	0.0	27.5	27.0	28.0	0.71	27.32	25	28	0.88
pH	7.3	6.0	10.0	1.2	8.1	6.0	10.0	1.2	7.8	7.0	8.0	0.5	8.3	10.0	50.0	1.6	10.0	10.0	10.0	0	7.93	6	10	1.27
COND	60.2	17.0	168.0	41.8	54.1	11.0	170.0	37.3	74.5	39.0	102.0	26.1	69.7	97.0	418.0	21.8	50.5	35.0	66.0	21.92	64.85	11	254	45.78
ALC	976.6	217.4	1751.5	540.4	862.3	119.0	1864.3	595.4	1570.5	717.5	2567.2	976.3	803.4	1321.0	4820.5	565.7	642.0	631.2	652.8	15.3	941.73	116.72	2567.21	613.07
SAL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0
TDS	42.1	12.0	118.0	29.4	37.8	8.0	119.0	26.1	52.0	27.0	72.0	18.6	48.8	69.0	293.0	15.5	35.5	25.0	46.0	14.85	45.39	8	180	32.34
MES	3.4	1.0	21.0	5.6	4.4	1.0	22.0	5.2	12.5	5.0	19.0	7.1	5.0	10.0	30.0	3.0	6.5	6.0	7.0	0.71	5.12	1	22	5.52
Na^+	2.4	0.3	6.8	1.9	2.5	0.5	6.9	2.0	0.9	0.1	1.6	0.6	2.5	3.9	15.3	1.5	1.0	0.6	1.4	0.58	2.21	0.08	6.85	1.79
NH_4^+	0.1	0.0	0.2	0.1	0.2	0.0	2.0	0.5	0.0	0.0	0.1	0.0	0.7	3.9	4.1	1.6	0.1	0.0	0.1	0.06	0.19	0	3.93	0.67
K^+	1.9	0.4	3.8	1.3	2.2	0.3	4.6	1.5	1.2	0.9	1.7	0.3	3.9	13.1	23.5	4.6	1.2	1.0	1.4	0.28	4.27	0.3	86.55	13.34
Mg^{2+}	4.7	0.2	25.8	6.8	6.2	0.5	26.0	8.2	6.8	1.7	12.0	4.3	5.2	9.6	31.4	3.0	6.2	2.1	10.2	5.69	5.78	0.21	26.02	6.5
Ca^{2+}	6.4	0.4	36.0	9.7	8.2	0.4	37.0	11.8	9.3	1.6	16.7	6.3	7.0	13.4	41.8	4.4	7.9	1.6	14.2	8.89	7.63	0.35	37.02	9.31
F^-	0.1	0.0	0.2	0.1	0.1	0.0	0.4	0.1	0.1	0.0	0.1	0.0	0.1	0.3	0.5	0.1	0.0	0.0	0.1	0.02	0.09	0.01	0.38	0.09
Cl^-	0.1	0.0	0.5	0.2	0.2	0.0	1.0	0.3	0.1	0.0	0.1	0.0	0.2	0.7	1.0	0.3	0.1	0.0	0.1	0.03	0.17	0.01	1.04	0.24
NO_3^-	0.3	0.0	1.4	0.4	0.3	0.0	1.4	0.4	0.6	0.0	1.6	0.7	0.7	1.6	4.0	0.6	0.2	0.1	0.2	0.05	0.38	0	1.58	0.44
PO_4^{3-}	0.1	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.3	0.0	0.0	0.0	0.1	0.03	0.06	0	0.39	0.07
SO_4^{2-}	0.1	0.0	0.6	0.2	0.1	0.0	0.3	0.1	0.1	0.0	0.1	0.0	0.1	0.3	0.7	0.1	0.1	0.0	0.3	0.17	0.12	0.01	0.6	0.13
HCO_3^-	59.6	13.3	106.8	34.0	53.3	7.3	113.7	37.2	95.8	43.8	156.6	59.6	49.0	80.6	294.1	34.5	39.2	38.5	39.8	0.93	57.67	7.12	156.6	37.95

Table 1: Statistical summary of physico-chemical data of water resources in the study area

Conductivity (COND), Alkalinity (ALC), Salinity (Salinity), Total Dissolved Solid (TDS)

The chemical constituents analyzed were below the WHO (2017) guideline values. This could be as a result of low mineralization from a short duration of water-rockinteraction. The relative abundance of cations and anions (Figure 3) were as follows: $Ca^{2+} > Mg^{2+} > K^+ > Na^+$ and $HCO_3^- > NO_3^- > Cl^- > SO_4^{2-} > F^-$. Calcium was the dominant cation and $HCO^{3-}$was the dominant anion (Figure 2). The mean concentration of Ca^{2+} stood at 7.6 mg/l and a maximum concentration of 37 mg/l from the spring source (MB.MJ.N). This high concentration of Ca^{2+} is attributed to water-rock interaction from an igneous rock with basalts predominantly rich in calcium. In addition, a strong correlation was observed between Mg^{2+} and Ca^{2+} (r= 0.9) (Table 2) which suggests that they are from the same origin (Marshak 2007).

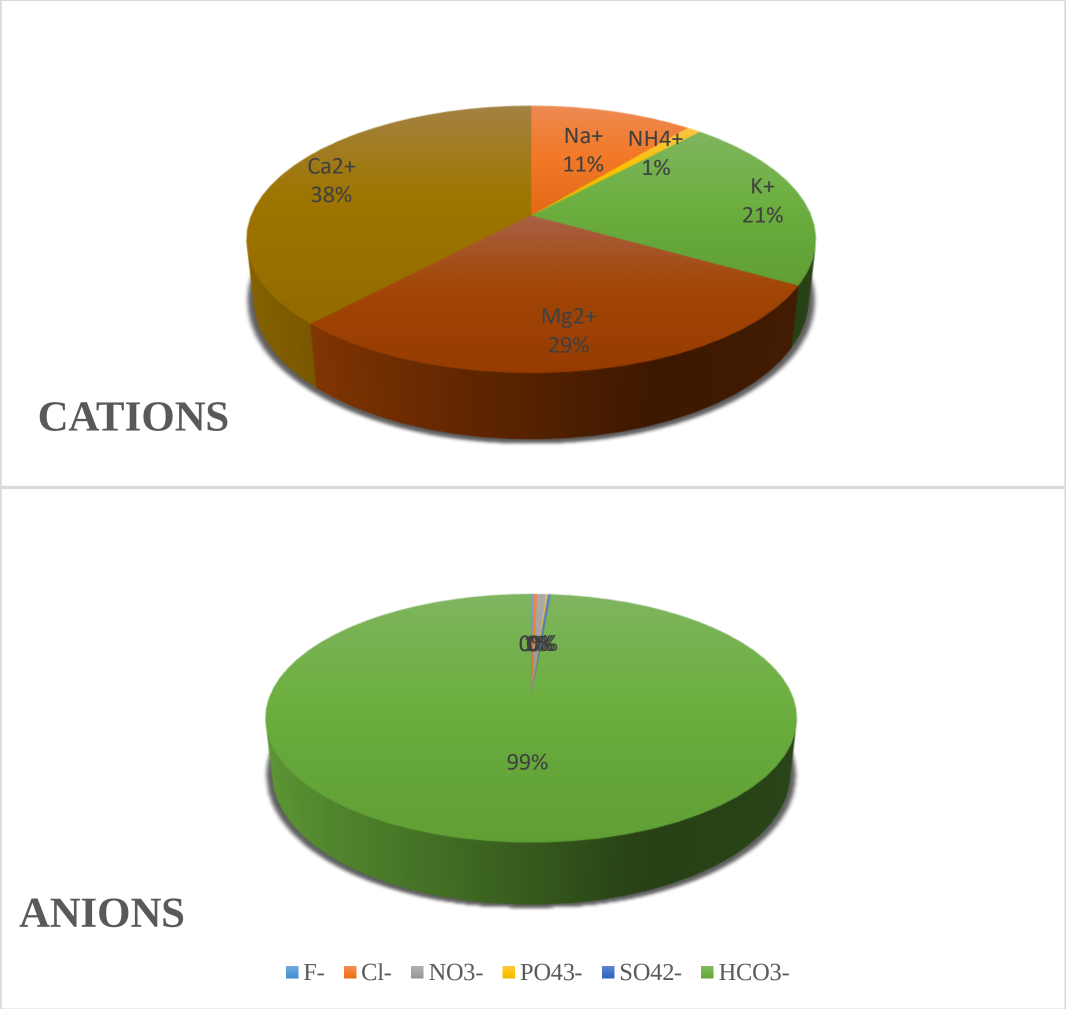

Fig. 3: Relative concentration of majorions

Nitrate had a mean concentration of 0.38 mg/l and a maximum concentration of 1.58mg/l from the stream source (NCHO). There is a positive correlation between NO_{3-} and SO_4^{2-} (r = 0.1) (Table 3) which suggests an anthropogenic source of NO_3^- from the use of fertilizers in the surrounding palm plantations and rice farms along the stretch of Northern Bafut and inputs from domestic waste that infiltrates into the groundwater sources. The correlation matrix also indicates a positive correlation between TDS-Mg, TDS-Ca, TDS-K, EC-Mg, EC-K, EC-Ca with r values of 0.55, 0.5, 0.69, 0.56, 0.69, and 0.51, respectively suggesting that the different aquifer chemistry is controlled by these parameters (Pidwirny 2006; Marshak 2007).

The ionic constituents of sporadic rainfall sample had elevated concentrations of K^+ (86.5mg/l) andCa^{2+} (10.2mg/l)with low values of Na+ and NH_4+ than the groundwater samples. This high concentration of $K^+$and Ca^{2+} in rainwateris because these were early rains usually rich in major ions in tropical regions (Eneke, et al. 2011).

	TEMP	**pH**	**EC**	**ALC**	**TDS**	**MES**	**Na+**	**NH4+**	**K+**	**Mg^{2+}**	**Ca^{2+}**	**F-**	**Cl-**	**NO_3 -**	**PO_3^{4-}**	**$SO^2{}_4^-$**	**HCO_3^-**
T^O C	1																
pH	**0.166**	1															
EC	-0.161	0.127	1														
ALC	0.074	0.087	**0.245**	1													
TDS	-0.169	0.124	1.000**	0.242	1												
MES	0.096	.412**	.448**	0.283	.443**	1											
Na+	0.16	-0.165	-0.086	0.162	-0.086	0.117	1										
NH4+	0.135	-0.065	-0.048	0.173	-0.053	-0.082	-0.033	1									
K+	-0.22	-0.061	**.694****	-0.046	**.698****	0.004	-0.077	-0.078	1								
Mg^{2+}	-0.106	.505**	**.562****	0.162	**.555****	.678**	-0.109	-0.035	0.142	1							
Ca^{2+}	-0.092	.488**	**.519****	0.124	**.511****	.677**	-0.11	-0.014	0.074	**.989****	1						
F-	0.001	0.209	0.065	0.104	0.067	.342*	0.011	0.05	-0.165	.393*	.427**	1					
Cl-	-0.044	.439**	0.041	-0.159	0.042	.480**	-0.033	0.01	-0.146	.490**	.512**	.709**	1				
NO_3 -	0.005	-0.245	-0.235	-0.145	-0.236	-0.214	0.002	-0.136	-0.099	-0.243	-0.235	-0.172	-0.14	1			
$PO^3{}_4$-	0.164	-0.068	-0.148	-0.1	-0.147	-.350*	0.01	.316*	-0.187	-.312*	-0.273	0	-0.091	0.091	1		
$SO^2{}_4^-$	-0.24	0.077	0.016	0.107	0.017	0.153	-0.285	-0.069	-0.12	0.231	0.272	.457**	.397*	0.06	-0.182	1	
HCO_3^-	0.06	0.089	0.237	**.999****	0.234	0.274	0.15	0.172	-0.052	0.159	0.121	0.095	-0.164	-0.152	-0.109	0.116	1

Table 2: Correlation coefficient matrix between chemical variables for Water Sample

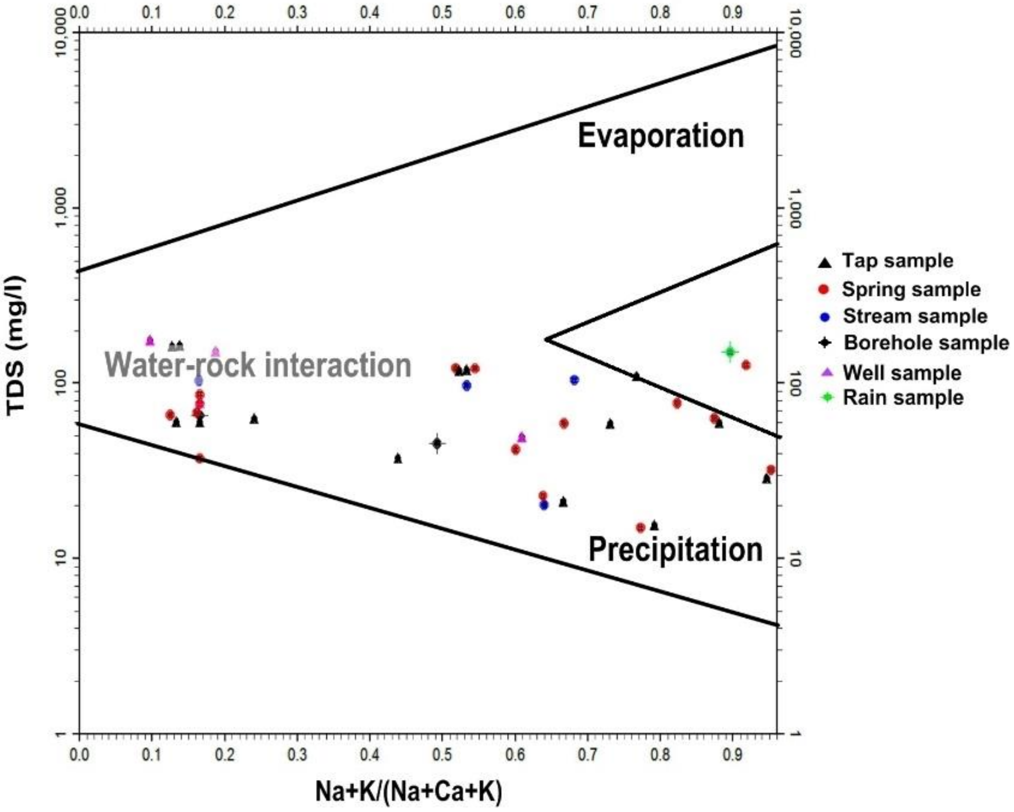

Fig. 4: Piper diagram showing different water types

Ternary plots (Piper 1944) for major cations (Ca^{2+}>Mg^{2+}>K+>Na+) and anions (HCO_3^->NO_3^->Cl->SO_4^{2-}>F^-) in all the water samples revealed different water types (Figure 4). The major water types included Ca^{2+}-HCO_{3-} ,Na+- HCO_{3-} and Na+- Ca^{2+}- HCO_{3-} with the dominant water type being Ca^{2+}-HCO_{3-}. The dominance of Calcium bicarbonate water types is due to a relatively high concentration of Calcium (Gnazou et al.2011). In addition, considering a granitic rock terrain the Na^+-HCO^{3-} water type possibly has evolved from the Ca^{2+}-HCO_{3-}.

Gibbs plots (Gibbs1970) was used to determine the possible factors controlling groundwater chemistry. The Gibbs plot from the study area proposes a chemical weathering of rocks and water rock interaction as the dominant process governing groundwater chemistry (Fig 5).

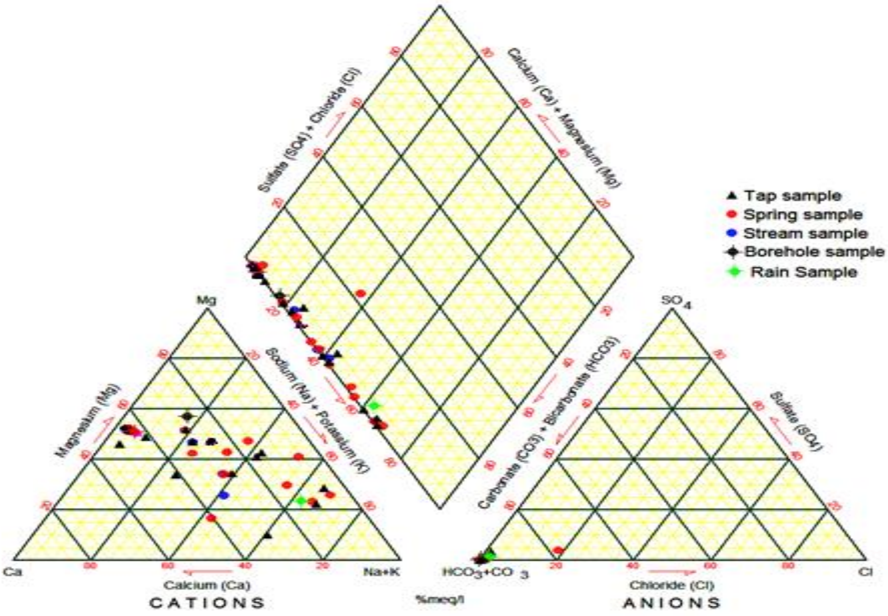

Fig. 5: Mechanisms controlling the chemistry of groundwater (after Gibbs, 1970)

The amount of dissolved ions in groundwater is mostly controlled by the surrounding rock type in the watershed, prevailing chemical reaction and water-rock interaction (Rao et al. 2017), confirming that rock dissolution is the dominant process influencing groundwater hydrochemistry.

B. Suitability of groundwater for drinking

The pH values of water resources(36.6%) were abovetheWHO recommended standard for drinking water. These high pHvalues could lead to the corrosion of pipes (WHO 2004). For water intended for drinking, Total coliform and E.Coli must be non-detectable per 100 ml of water (WHO 2017), as observed 61.9% of the water samples exceeded the standards, indicating that the water sources were unsuitable for human consumption.

Parameters	**Summary of water samples (N = 41)**			**WHO (2017) limit**	**Samples out of WHO Limit (%)**
	Min	**Max**	**Mean**		
pH	6.00	10	7.93	6.5 - 8	36.6
COND	11.00	254.00	64.85	750	0
ALC	116.72	2567.21	941.73	300	80
SAL	0.00	0.00	0.00	100	0
TDS	8.00	180.00	45.39	600	0
Na+	0.08	6.85	2.21	50	0
NH4+	0.00	3.93	0.19	1.5	1
K+	0.30	86.55	4.27	100	0
Mg^{2+}	0.21	26.02	5.78	30	0
Ca^{2+}	0.35	37.02	7.63	100	0
F-	0.01	0.38	0.09	1.5	0
Cl-	0.01	1.04	0.17	0.7	0
NO3-	0.00	1.58	0.38	50	0
PO_4^{3-}	0.00	0.39	0.06	0.3	1
SO_4^{2-}	0.01	0.60	0.12	250	0
HCO_{3-}	7.12	156.60	57.67	200	0
TCFU	0	236	10	0	61.9
E.Coli	-	-	-	0	61.9

Table 3. Groundwater quality and compliance with WHO (2017) drinking water standards

Conductivity (COND), Alkalinity (ALC), Salinity (Salinity), Total Dissolved Solid (TDS)

The EC, TDS, cations, bicarbonate and sulfate of the groundwater sources are within the desirable limits of WHO (2017). Concentrations of alkalinity (80%) and PO_4^{3-} (1% from rainwater sample) (Table 3) of the groundwater sources exceeded the WHO (2017) guidelines for drinking water.

To demonstrate the change of composition of water, a Stiff diagram (Fig. 6) showed the dominant cations and anions with concentration represented in milliequivalent (meq / L). Sodium (Na+) was the predominant cation in the South (MK,BJ S) and Northern East of Bafut (FOYC W) while Bicarbonate ($HCO_{3-.}$) was the predominant anion in these areas. $HCO_{3-.}$ were leached from various rocks into the soil and water by weathering and probably from CO_2 in the atmosphere. It can be concluded that the most predominant water type in the East and the South of Bafut was the Na-$HCO_{3-.}$water type. While Ca^{2+} was distributed predominant cation of the water samples in the North of Bafut (OBGHS, OBAL ST) and HCO_3- was the predominant anion. Therefore implying the most predominant water type in the North of Bafutwas Ca^{2+} -HCO_{3-} water type. Ca^{2+} ion was predominant due to the formation of igneous rocksmade up of basaltsand granites.

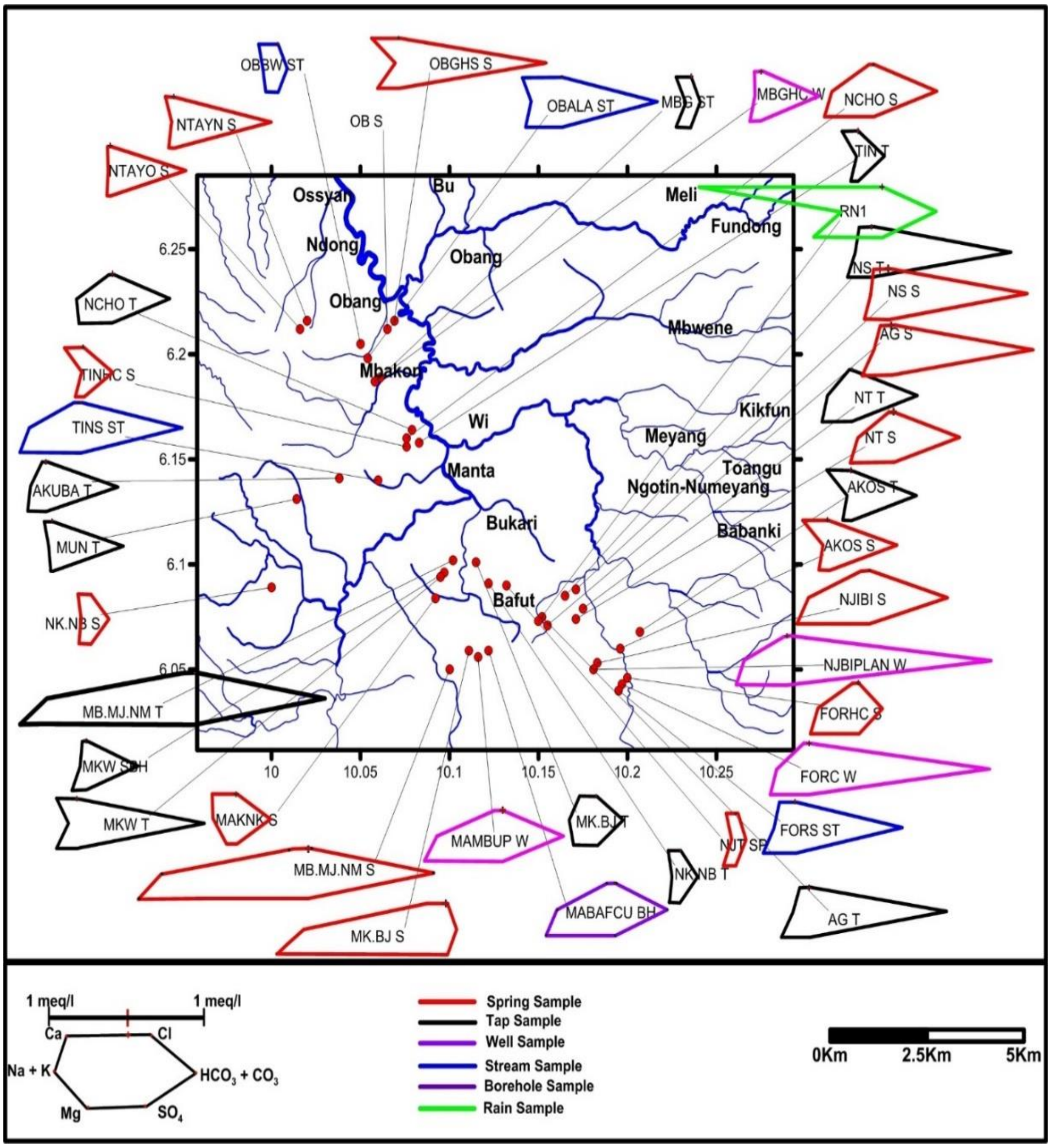

Fig. 6: Stiff diagram showing the degree of mineralization of water resources

The mineralogy of water samples based on the shapes of the Stiff Diagram (Fig 6) suggest that the water resources are rich in Ca^{2+} and HCO_3^- and specifically water from the springs, taps and stream are rich in cations Ca^{2+},Na^+, $Mg^{2+}$and anion HCO_{3-}whereas water in the boreholes and rainwater are rich in the cations Ca^{2+}, Na^+ and anion HCO_{3-} and SO_4^{2-}. The main source of recharge for the water sources in the area is the river Meya. Looking at the groundwater Stiff diagrams for Bafut Sub-Division, the shapes of the stiff diagram are similar and match the calcium-bicarbonate water zone predicted in the Piper diagrams (Fig 4). Spring was the oldest water type due to its durability within the confined aquifer and stream water source was the youngest.

C. Bacteriological quality of water sources and health effects

For water intended for drinking, Total Coliform Count (TC) must be non-detectable per 100 ml of water according to Kilungo et al. (2018)who compared the water quality of samples from wells of different designs, in order to help guide future efforts in providing affordable and sustainable interventions to improve access to clean and safe water in rural communities. Based on the bacteriological classification of drinking water (WHO, 2017), TC, which ranged from 1 to 236 countsper 100ml, (Table 4), showed that 64.2 % of the 42 water samples were contaminated, indicating that they were unsuitable for human consumption.Similar high TC counts in unprotected drinking water sources have been reported elsewhere in Cameroon (Ako et al., 2009; Kuitcha et al. 2010; Ateba et al. 2012) and in Sub-Saharan Africa (Admassu et al. 2004; Mgbakor et al. 2011; Abila et al. 2012). These may be due to uncontrolled human activities and a lack of proper water management strategies, especially in water catchments.

Community/water resource	TCfu March 2018	E.coli March	Salmonella typhi March	TCfu August 2018	E.coli August	Salmonella typhi August
FORHC T	2	†		0		
MAKNK S	0		†	0		
MKW S	0			**NS**		
OBGHS S	3	†				
AKOS T	5	†		8	†	
NK.NB T	1	†	†	0		
NS T	0			0		
MUN T	60	†		**NS**		
MK.BJ T	2	†		0		
AKOS S	0			8	†	
MKW T	0			0		
NTAYN S	1	†		**NS**		
NT T	0			0		
TINHC S	3	†		**NS**		
MB.MJ.NM T	0		†	0		
RN1	**16**	†		0		
NTAYO S	7	†		**NS**		
NJIBI S	0			**NS**		
AG T	6	†	†	0		
MUN T	1	†		3	†	
MKW SBH	**236**	†		**NS**		
MABAFCU BH	0			60	†	
FORS ST	3	†		6	†	
OB S	5	†	†	10	†	†
FORC W	0			0		
MBGHC W	3	†		400	†	
AKUBA T	0			0		
TINS ST	17	†		**NS**		
MAMBUP W	0			10	†	
NCHO T	0			17	†	
OBALA ST	3	†		80	†	
NCHO S	0			23	†	
NJBIPLAN W	0			0		
MBG ST	5	†	†	1680	†	†
TINS T	5	†		11	†	
NK.NB S	3	†	†	**NS**		
NS S	4	†		**NS**		
NT S	2	†		**NS**		
MK.BJ S	6	†		**NS**		
MB.MJ.NM S	0		†	**NS**		
AG S	17	†	†	**NS**		
RN2	**20**	†		0		
SOGET T				**NS**		
NJT SP	1		†	2	†	

Table 4: Total coliform count and bacteriological analyses of water resources

NS (Not Sampled)

Health effects from bacteriological contamination of drinking water on human health can be inferred in a given area from epidemiological data on waterborne diseases. Computed results of data on water-borne diseases from 6 health units, in the study area, are presented (Fig 7).

- *Health Units*

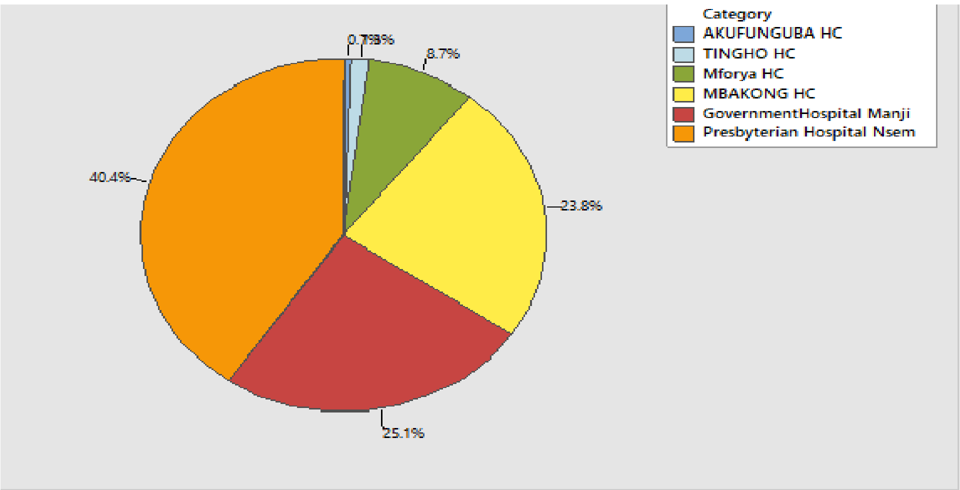

Fig. 7: Health Units

- *Sex distribution of water borne diseases*

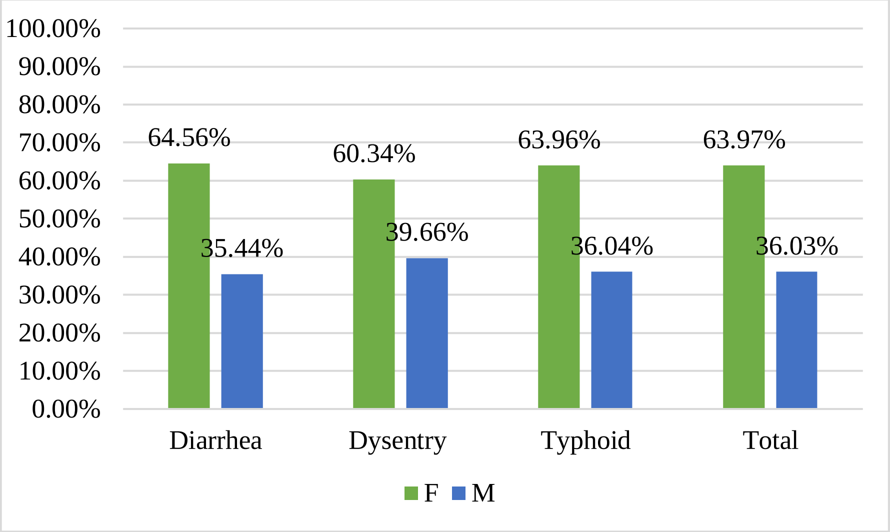

Fig. 8: Sex distribution of water borne diseases

- *Prevalence of water-borne diseases*

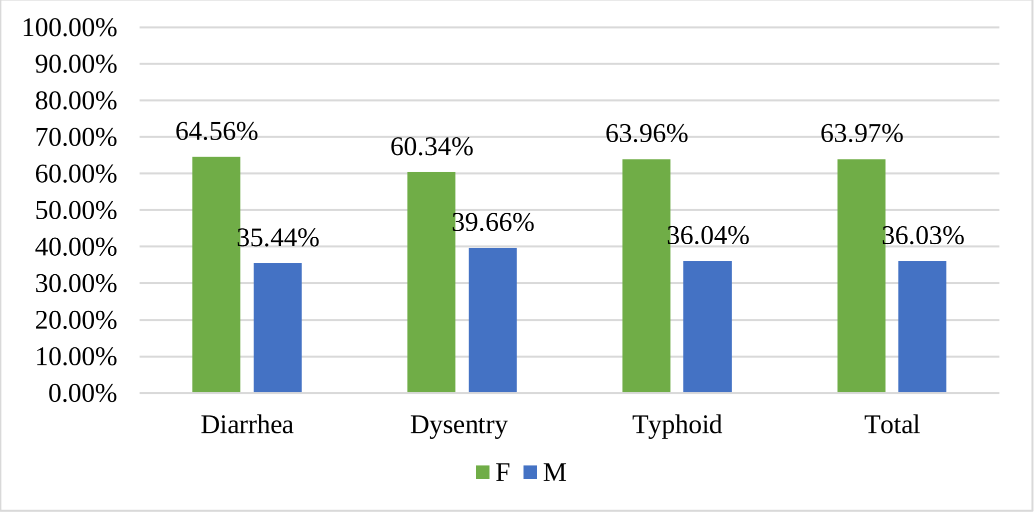

Fig. 9: Prevalence of water-borne diseases

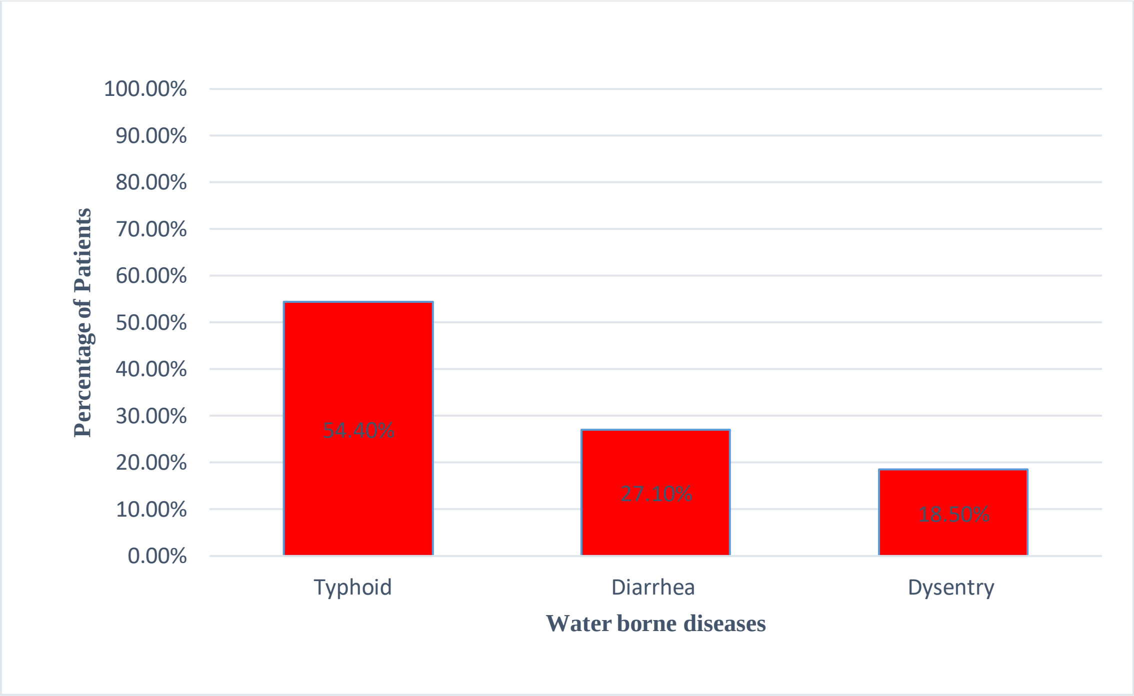

Fig. 10: Distribution of waterborne diseases

The results suggest the presence, in water, of intestinal pathogens, which may account for diarrhea, dysentery and intestinal infections in patients. Medical records from the health facilities sampled indicated that the most common waterborne diseasesweretdiarrhea and typhoidwhich affected mainly children between the ages of <1-10.This may be due to an adaptation to poor water quality such that the most vulnerable are children and likely new users. This was similar to the work of Ndjama et al. 2008; Abila et al. 2012). The female gender is more exposed to the prevalence of all water-borne diseases than the male (Fig 7b). This could be explained by the fact that women are more exposed to the utilization of water and consumption than the male sex for domestic, drinking and agricultural activities.

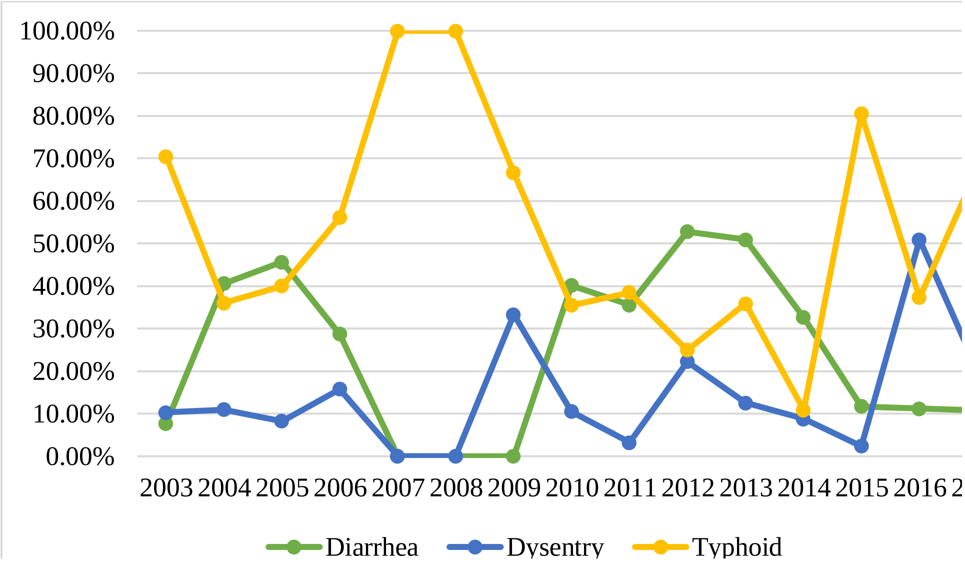

Fig. 11: Monthly and Annual distribution of water borne diseases

The monthly and annual distribution of waterborne diseases (Figure 8) shows a high prevalence during the dry season (October-March) and this can be attributed to the sole dependence on polluted groundwater and surface water resources for drinking during this season.In addition, rains from March to September carry microorganisms into unprotected water sources resulting in water-borne infections after consumption. Thesecyclical occurrences result in the prevalence of water-borne infections throughout the year. There was an increase in the prevalence of typhoid from 2003-2017 (Figure 8) and this could be due to dwindling water resources which resulted in the dependence of the population on community pipe-borne water schemes as well as on unprotected sources for drinking water. Similar results were noted from studies by Wéthé et al. (2003) in Yaoundé and by Katte et al. (2003) in Dschang equally underscored significant sections of the population who suffered from debilitating water related diseases in these towns.

VI. CONCLUSIONS

This study on the water supply, quality and health risk of waterborne diseases in the study areaindicates pH values >8 (36.6%) which is above the recommended standards by WHO (2017) for drinking water and may lead to corrosion of pipes. The chemical constituents analyzed were below the WHO (2017) guideline values.This could be as a result of low mineralization from the short duration of water rock interaction.The relative abundance of cations and anions stood at $Ca^{2+}>Mg^{2+}>K+>Na+$and $HCO_3^{-}>NO_3^{-}>Cl->SO_4^{2-}>F^{-}$. Calcium was the dominant cation and HCO_3^{-} the dominant which could be attributed to water rock interaction from an igneous rock with basalts predominantly rich in calcium.

The ionic constituents of sporadic rainfall sample were high in concentration of K^+ (86.5mg/l) andCa^{2+} (10.2mg/l)with low values of Na+ and NH_4+ than the groundwater samples. This high concentration of $K^+$and Ca^{2+} in rain wateris because these were early rains usually rich in major ions in tropical regions (Jun 2015). The mineralogy of water samples based on the shapes of the Stiff Diagram suggests that the water resources are rich in Ca^{2+} and HCO_{3-} and that the main source of recharge for the water sources in the area is River Meya.

Total coliform count ranged from 0 to 236 countsper 100ml and 64.2 % of the water samples were contaminated and unfit for drinking as equally confirmed by the high prevalence of waterborne diseases based on medical reports from health centers within the study area. The sources of contamination of the potable water sources are due to uncontrolled human activities and a lack of proper water management strategies and practices, especially within the catchment areas. This was confirmed by the prevalence of water-borne diseases in the area especially diarrhea in children between the ages of <1-10. A cyclical occurrence of water-borne infections was observed throughout the year. This was attributable to the dwindling water resources with time which has led to the dependence of the population on community pipe-borne water schemes as well as on unprotected sources of drinking water.

The conservation of water resources is essential in providing safe drinking water to the population within this area and this should be accompanied by preventing contamination from solid, organic and hazardous wastes as well as proper protection of the catchment areas of potable water sources within the area. The monitoring of drinking water quality remains a major challenge in this rural area and improved sanitation measures such as sand filtration and boiling of water are recommended as suitable approaches of purification aimed at improving thequality of potable water.

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