Novelty Journals

ISSN 2394-7357

International Journal of Novel Research in Civil Structural and Earth Sciences
Vol. 8, Issue 1, pp: (1-12), Month: January - April 2021, Available at: www.noveltyjournals.com

SUITABILITY EVALUATION FOR DOMESTIC, DRINKING AND AGRICULTURAL USES OF SOME WATER SOURCES IN KUMBO MUNICIPALITY, NORTH WEST REGION OF CAMEROON: A FUNCTION OF HYDROGEOCHEMICAL AND BACTERIOLOGICAL STUDIES

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Abstract: **The water quality of some water sources in Kumbo municipality of Bui division in the North West Region of Cameroon were analysed to obtain physico-chemical and bacteriological parameters suitable for drinking, domestic and agricultural needs. A total of 34 water samples were collected. Four samples from a water catchment in 2016, two in 2017, and 2 sporadic rain samples in 2017 were sampled. In 2018, six boreholes (BH), six streams (ST), eight open wells (OW), and eight rivers (RW) were sampled. Major ions, heavy metals and bacteriological content were analysed. Ca^{2+} was the dominant cation in order Ca> Mg >Na and K. The dominant anion HCO_3^- was followed by NO_3^-, SO_4^{2-} and Cl^-. Cl^- had an insignificant value in the water sources. The main water facies in Kumbo were; Ca-HCO_3, Ca-Mg-HCO_3 and Ca-Mg-HCO_3-NO_3. Silicate minerals, weathered mainly by acidolysis highly controlled the concentration of major ions in the water sources. A negligible concentration for the heavy metals was recorded within the water sources. This expressed an absence of aspects and sources that could introduce heavy metals into the water source environment in Kumbo. Fe^{2+} that readily converted into Fe^{3+} and Al^{3+} were witnessed in the water sources. The Sodium Absorption Ratio, Total Dissolved Solids, Residual Sodium Carbonate, Magnesium Hazard, Permeability Index, Percent sodium, pH, temperature and electrical conductivity were some parameters analysed. They all fell within acceptable domains for their uses with reference to standard norms such as the World Health Organisation, Swiss, Bureau of Indian Standards, United States Salinity Laboratory, and the European Union. Total Hardness had a value that deviated greatly in all the water sources on comparison to the WHO (2004) norm. The water sources had values that expressed their suitability for irrigation. Bacteria were identified in all of water sources, and suggested their unsuitability for drinking. Drinking water, imperatively ought to be treated to eliminate possible bacteria in all the water sources. The lithology and human activity within the proximity of the water sources greatly compromised water quality. Proper management methods must be implemented to suitably and sustainably maintain and control water quality an indispensible resource.**

Keywords: **Water sources, water quality, Suitability, Kumbo municipality.**

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1. INTRODUCTION

Kumbo municipality the headquarter of Bui division and Kumbo subdivision of the North West Region of Cameroon is an area with high subsistent agricultural practices. Economic growth associated with a rapid population growth and urbanization, has compromised land use, with impact being more demand of water for its diverse uses, notably drinking and agriculture. Furthermore, waste disposal and water provision to homes has become a major concern with the use of boreholes (BH), open wells (OW), streams (ST) and rivers (RW) within the municipality. Many studies in African cities revealed that; wells, streams and rivers were conspicuously used to supply water, with a lot of human activity posing a great risk Temgoua, (2009). Because of inadequate availability of surface water to meet human demands, ground water appears as an option to supplement the ever rising water needs. Ground water is an essential primary source for domestic and agricultural uses in most countries; hence its contamination is taken as a serious problem in these countries including Cameroon.

Ground water has a unique Chemistry which it gains as result of chemical interactions that recharge the system caused by factors such as; soil - water interactions, dissolution of primary minerals, rock- water interactions and anthropogenic sources Stallard and Edmond, (1983). The importance of ground water has initiated some detailed works on its geochemical evolution Paces, (1973). Numerous works focused on ground water quality monitoring and suitability for drinking, domestic and agricultural purposes have been advanced Garg *et al.*,(2009). These works highlighted ground water quality evaluation and monitoring of its usability as being indispensible for a sustainable management of ground water resources. Parameters, like; sodium percent (Na%), sodium absorption ratio (SAR), residual sodium carbonate (RSC) Wilcox and United States Salinity Laboratory (USSL) classifications have been used in evaluation of water suitability for irrigation and domestic needs.

This work had as target; evaluation and monitoring of water quality in some water sources in the Kumbo municipality of Bui division, in order to obtain their suitability for drinking, domestic and agricultural purposes. The data obtained from this work was expected to improve an understanding of the factors that regulate water quality. Hitherto this study, little recorded works were available for this evaluation in Kumbo municipality, presenting a gap intended to be filled with this work.

1.1 Location of study area

The geographical location of Kumbo municipality, in the North West Region of Cameroon is shown in Fig.1. The area is characterized by a tropical climate of the Mountainous west of Cameroon, with two seasons; the dry and rainy seasons analogous to the Bambouto Mountain Suchel, (1988).

1.2 Geologic context.

Geologically**,** Kumbo municipality of Bui division is part of the Bamenda highlands, a northward extension of the Bambouto Mountain part of the continental Cameroon Volcanic Line (C.V.L). The dominant geologic formations of Bui are basalts and trachytes similar to those of the Bambouto Mountain. Revealed by Kagou *et al.*, (2010), Kumbo and the Bambouto Mountain are of same volcanic origin. These observations strongly agree with the field realities that indicated trachytes, and basalts as the dominant rock types both in Kumbo and the Bambouto Mountain.

2. MATERIALS AND METHODS

A Multiparameter Hanna instrument, HI 83200 bench photometer with accompanying reagents was used. A G.P.S to locate precisely the geographical coordinates of the sampling points, a Hanna instrument to obtain the electrical conductivity, temperature and pH of water at each site was acquired. Bacteriological setup for culturing the samples and incubation was present in the analysis laboratory. A digital camera for some relevant illustrations in this work was acquired. A proper choice was made for plastic bottles of about 100 ml capacity with firm corks. A total of 34 samples were collected and analysed at the end of the expeditions.

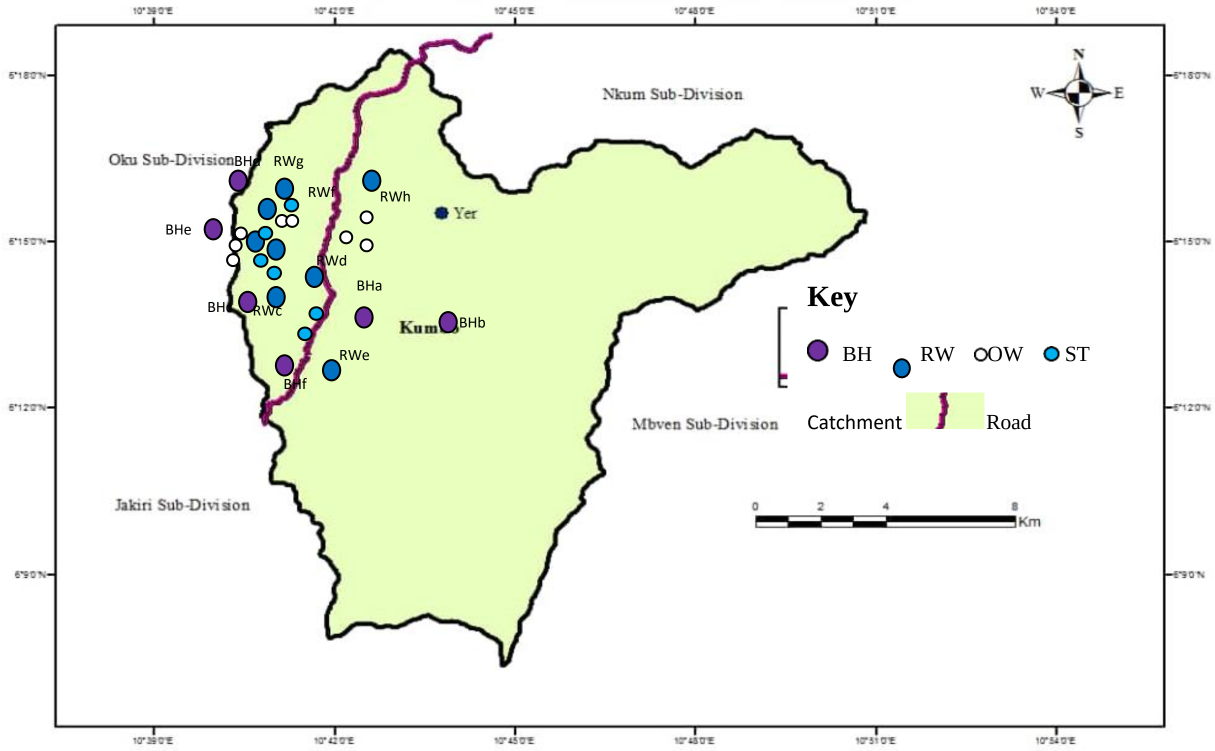

Fig. 1: Sampling points in Kumbo municipality

2.1 Methods

The sample bottles were thoroughly cleaned and rinsed with the water sample from the collection site and finally filled to the brim to avoid any atmospheric oxidation. The samples were taken immediately to the Laboratory for analysis within 12 hours.

2.2 Sampling points in Kumbo municipality

The water catchment was at Yeh, in Kumbo subdivision at a height of 1869m above sea level (a.s.l) with Longitude 010^{o} 42' 49.9" East of the Greenwich Meridian and Latitude 06^{o} 15' 53.6" North of the Equator as geographical coordinates at sampling point. The surroundings were void of any human activity and were protected with natural vegetation with some water friendly trees planted within its vicinity. The source was surface water from a stream. The rock type was dominantly basaltic. This water catchment serves a greater population of Kumbo municipality, and the divisional headquarters of Bui. Eight OW, 6 BH, 6 ST and, 8 RW samples were analyzed in 2018. There was a lot of farming in the flood plains of the rivers that drain Kumbo, with a lot of untreated waste water disposal into the rivers, from a slaughter house, hotels, prison, car washes, schools and quarry activities along the banks of the rivers within the municipality.

2.3 Physico-chemical analysis (Laboratory work)

This was done at Saint Anne's Biomedical/physicochemical Laboratory in New Bell Douala, using HI 83200 Multiparameter Bench Photometer produced by Hanna instruments Inc in the Highland industrial park in the United States of America.

2.4 Bacteriological analysis (Laboratory work)

Macroscopically samples were observed in the field and the laboratory for characteristics like; colour, presence of sediments and odour. Microscopic analysis involved; direct observation of samples under the microscope, gram stain to look for gram-negative and gram-positive organisms, Culture preparation and interpretation.

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3. RESULTS

Table 1: Physicochemical parameters from the water catchment (Yeh) in Kumbo municipality (2016 and 2017) and rain water.

ID	Yeh$_1$	Yeh$_2$	Yeh$_3$	Yeh$_4$	Yeh$_5$	Yeh$_6$	R$_{1\ (Rain)}$	R$_{2\ (Rain)}$
Alt (m)	1895	1895	1895	1895	1895	1895	……	……
T^{O}C	21.0	20.5	20.6	22.9	20.7	21.0	18.8	22.7
pH	7.0	6.9	6.8	6.9	6.7	6.8	6.5	6.0
EC (µs/cm)	0.30	0.22	0.20	0.29	0.30	0.31	0.12	0.14
TDS mg/l	192.0	140.8	128.0	179.2	123.1	124.0	123.0	121.2
Na^+ mg/l	0.14	0.13	0.11	0.12	0.12	0.10	0.02	0.03
K^+ mg/l	0.13	1.00	0.08	0.09	0.07	0.09	0.04	0.01
Ca^{2+} mg/l	30.9	30.0	30.0	30.6	30.8	29.9	0.01	0.02
Mg^{2+} mg/l	0.02	0.04	0.01	0.02	0.03	0.03	0.00	0.00
HCO_3^- mg/l	32.52	32.52	31.2	31.8	32.0	32.4	60.0	61.2
HCO_3^- mg/l	32.52	32.52	31.2	31.8	32.0	32.4	60.0	61.2
NO_3^- mg/l	11.5	09.0	08.0	10.2	09.4	10.1	08.2	08.5
Cl- mg/l	0.01	0.01	0.00	0.00	0.01	0.02	0.00	0.00
SO_4^{2-} mg/l	14.0	13.8	13.4	13.5	13.7	14.0	0.13	0.20
SiO_2 mg/l	31.4	31.2	31.0	31.3	31.0	30.9	0.00	0.01

Table 2: Physicochemical parameters from OW, BH, ST, RW

ID	Alt(m)	T^{O}C	pH	EC	Na^+	K^+	Ca^{2+}	Mg^{2+}	HCO_3^-	NO_3^-	SO_4^{2-}	SiO_2	Site name
OW$_1$	1613	21.0	5.9	0.21	0.10	0.09	34.2	8.5	31.4	11.0	12.9	32.0	Komban street
OW$_2$	1654	19.9	6.5	0.19	0.13	0.06	34.0	8.6	32.0	10.9	13.0	31.0	Tobin Mosque
OW$_3$	1721	20.9	6.8	0.23	0.11	0.08	33.9	8.9	33.2	10.6	13.3	32.9	CS Tobin
OW$_4$	1734	20.0	6.7	0.18	0.11	0.06	34.0	7.9	33.0	11.2	13.1	31.4	Catholic Univ
OW$_5$	1845	19.8	6.5	0.24	0.10	0.07	32.9	8.0	31.2	11.3	13.8	33.7	SAC
OW$_6$	1916	20.2	6.0	0.22	0.14	0.10	33.0	8.5	31.0	11.2	13.6	32.1	Bamkikaiy
OW$_7$	1946	21.2	5.9	0.20	0.12	0.09	34.0	8.5	31.2	10.8	13.9	32.0	LAP Centre k'bo
OW$_8$	1922	21.1	6.8	0.17	0.13	0.09	34.0	8.5	31.0	10.3	14.0	33.0	Pig farm Bamkikaiy
BH$_1$	1906	21.2	6.8	0.24	0.12	0.06	33.9	8.6	31.4	10.9	13.1	33.4	GS Bamkikaiy
BH$_2$	2020	22.3	6.6	0.22	0.11	0.08	33.7	8.0	30.9	11.2	13.9	33.0	CBC Kishiy
BH$_3$	1763	22.0	6.7	0.20	0.10	0.05	32.9	8.5	31.2	11.0	12.9	31.8	GS Kiyan
BH$_4$	2037	21.9	6.5	0.24	0.14	0.07	33.0	8.2	29.9	11.4	13.0	32.6	GS Tadu
BH$_5$	1968	22.2	6.7	0.20	0.11	0.06	33.1	8.3	30.0	10.6	14.0	31.9	GS Kai
BH$_6$	1742	23.0	6.6	0.18	0.13	0.08	33.7	8.0	31.3	10.8	13.5	32.0	GS Njavnyuy
ST$_1$	1695	20.0	6.7	0.19	0.11	0.08	34.1	8.5	32.0	11.0	14.4	32.1	Meluf upper
ST$_2$	1671	21.0	6.8	0.18	0.10	0.09	34.0	7.9	33.2	10.9	13.2	31.9	Meluf lower
ST$_3$	1665	19.7	6.7	0.20	0.12	0.08	33.1	8.3	30.2	11.4	13.5	31.9	Roh Bui upper
ST$_4$	1646	19.9	6.5	0.22	0.14	0.06	33.1	8.5	32.1	11.2	12.9	32.0	Roh Bui lower
ST$_5$	1874	20.0	6.6	0.16	0.11	0.07	32.9	8.5	33.4	10.8	13.1	32.0	RohKimbo up
ST$_6$	1633	21.1	6.9	0.18	0.10	0.08	31.9	8.5	33.2	10.5	13.0	32.0	RohKimbo low
RW$_1$	1687	19.9	6.5	0.21	0.13	0.08	34.1	8.1	31.0	10.1	13.0	32.8	Meluf
RW$_2$	1620	19.8	6.7	0.20	0.10	0.09	34.0	8.2	33.4	10.0	13.7	31.0	Roh Bui
RW$_3$	1615	20.0	6.6	0.22	0.13	0.08	34.3	8.3	32.0	10.2	12.9	31.6	Meluf/ Bui
RW$_4$	1610	21.0	6.8	0.19	0.14	0.07	33.9	8.5	31.2	11.5	13.4	32.5	RohKimbo
RW$_5$	1604	21.0	6.7	0.17	0.11	0.09	33.0	8.5	31.2	11.2	13.9	31.9	Bui/RohKimbo
RW$_6$	1900	21.2	6.6	0.23	0.10	0.10	33.2	8.5	32.0	10.9	14.0	30.9	Romajaiy
RW$_7$	1876	20.0	6.5	0.20	0.13	0.07	34.0	8.5	32.1	10.0	12.9	31.8	Nji-iy
RW$_8$	1860	19.9	6.8	0.21	0.14	0.08	34.1	8.0	31.2	10.5	13.3	31.7	Kinsaan

Government school. CBC= Cameroon Baptist convention. CS= Catholic school. LAP= Life abundant programme. SAC= Saint Augustine's college.

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Bacteriological parameters for water samples in Kumbo municipality

Presented in Tables 3 and 4 for the water catchment, BH, OW, ST and RW sources respectively

Table 3: Results from Yeh catchment within expeditions of 2016 and 2017

SITE (Yeh) Examination	12-02-16	31-05-16	06-08-16	18-11-16	20-03-17	15-09-17
1) Macroscopic	Colourless Clear	Colourless clear	Colourless clear	Colourless Clear	Colourless Clear	Colourless clear
2) Microscopic						
a) Fresh examination						
Helminthes	Absent	Absent	Absent	Absent	Absent	Absent
Protozoa	Absent	Absent	Absent	Absent	Absent	Absent
Algae	Absent	Absent	Absent	Absent	Absent	Absent
Yeast cells	Absent	Absent	Absent	Present	Present	Present
Mobile and immobile bacteria	Present	Present	present	Present	Present	Present
b) Gram stain						
Gram – and + bacilli	Absent	Absent	Absent	Absent	Present	Absent
Gram – and + cocci	Present	Present	present	Present	Absent	present
3) Culture						
MacConkey (Enterobacteria)	Positive	Positive	Positive	Positive	Positive	Positive
Mannitol salt agar (coccigm(+)	Negative	Negative	Negative	Negative	Negative	Negative
Sabouraud agar (c,albican)	Negative	Negative	Negative	Negative	Negative	Negative
Plate count agar	60CFU 100mlof H_2O	55CFU 100mlof H_2O	45CFU 100mlof H_2O	65CFU 100mlof H_2O	65CFU 100mlof H2O	60CFU 100mlof H_2O
4) Isolated germs	*Salmonella E. coli*	*Salmonella E.coli*	*Salmonella E.coli*	*Salmonella E.coli*	*Salmonella E.coli*	*Salmonella E.coli*

Table 4: Results from OW, BH, ST and RW in Kumbo municipality in 2018

SITE (Yeh) Examination	BH	OW	ST	RW
1) Macroscopic	Colourless/ Clear	Odourless/ brownish	Odourless/ clear	Odourless/ Brownish
2) Microscopic				
a) Fresh examination				
Helminthes	Undetected	Present	Absent	Present
Protozoa	Absent	Present	Absent	Present
Algae	Present	Present	Absent	Present
Yeast cells	Absent	Present	present	Present
Mobile and immobile bacteria	Absent	Present	Present	Present
b) Gram stain				
Gram – and + bacilli	Absent	Present	Present	Present
Gram – and + cocci	Undetected	Present	Absent	Present
3) Culture				
MacConkey (Enterobacteria)	Negative	Positive	Positive	Positive
Mannitol salt agar (coccigm(+)	Negative	Positive	Negative	Positive
Sabouraud agar (c,albican)	Negative	Positive	Positive	Positive
Plate count agar	10CFU 100mlof H_2O	70CFU 100mlof H_2O	40CFU 100mlof H_2O	80CFU 100mlof H_2O
4) Isolated germs	Non	*E. coli C. albican G.lambia*	*E.coli C.albican G.lambia*	*E.coli C.albican G.lambia*

4. DISCUSSION OF RESULTS

4.1 Physical parameters

4.1.1 Temperature

Temperatures were very low, with minimum temperature of 20.4^{o}C and maximum of 22.9 giving an average temperature of 21.7 ^{o}C. The regular trend observed in temperature at all the sampling sites during the expeditions revealed relatively similar climatic conditions that influenced recharge of the water sources.

4.1.2 pH

The values recorded ranged from 6.8 to 6.9 with an average of 6.7. 100 % of the values were less than7, which was justified by the presence of dominantly acidic volcanic rocks within the water source environments through which water percolated indicating an acidic aquifer system. Hydrolysis was the dominant weathering mechanism. It had a minimal variation with same trend expressed in the water sources. The lowest values were observed in August, with heaviest rainfall that resulted into the high concentration of H^+ which gave low pH values whereas high values were observed in March and November in the dry season with low H^+ concentrations.

4.1.3 Electrical conductivity (EC)

The solutions had relatively the same electrical conductivity because their rock types were same, with dissolution of same ions, coupled with the fact that the same rainfall prevalent in the study sites was under similar climatic conditions. The average conductivity was 0.20µS/m. The low EC values in all the water sources suggested low mineralized fresh water. Low ionic concentrations could be indicative of relatively low impact of anthropogenic activities within the water bodies as geological weathering conditions were principally the source of dissolved minerals.

4.1.4 The Total Dissolved Solids (TDS)

Calculated from EC values according to WHO, where EC < 5; TDS=640 × EC. Where EC> 5; TDS= 800 × EC. These values served in determination of water suitability for drinking and agriculture on application of relevant norms. The Kumbo water catchment had a minimum value of 179.2 with a maximum of 192 and an average of 185.6.

4.2 Chemical parameters

4.2.1 Alkali metal ions (Na^+ and K^+)

Had lower concentrations having a calculated average of 0.1and 0.11 for Na^+ in the catchment and alternate water sources. K^+ had average value of 0.6 in the catchment and 0.06 in the other sources as opposed to 8.67 and 38.98 for Mg^{2+} and Ca^{2+}respectively in the water sources. The K^+ ion had a larger size and small charge magnitude than Na^+ and can easily be dislodged from its silicate structure, accounting for a higher concentration of K^+ ions in some of the water samples than Na^+. Nonetheless, most common in igneous rock is sodium than potassium and it is more abundant in nature than potassium. The main source of potassium in ground water is from the weathering of potash silicate minerals and to an extent from potassium fertilizers used by farmers. High percentage of sodium would account for damage of soil physical properties, because it replaces Ca^{2+} and Mg^{2+} ions absorbed in soil clays and causes dispersion of soil particles. Hence the low percentage of Na^+ ions in Kumbo municipality water sources gave a positive note to agricultural practice.

4.2.2 Alkaline earth metal ions (Ca^{2+} and Mg^{2+})

Calcium very common in groundwater was evident in the water sources with an average high concentration than other cations. Magnesium had a lesser concentration than Calcium, in the water sources. This could be accounted for by the relatively more abundance of calcium in the earth than magnesium coupled with the fact that the dissolution of magnesium rich minerals is a slow process. The higher levels of the alkaline earth metal can be accounted for by their higher ionic potentials. The outcome of each liberated element depended on its ionic force and drainage speed. These ions are directly related to hardness of water.

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4.2.3 Bicarbonate (HCO_3^-)

Had concentrations ranging from 31.0mg/l to 33.5mg/l in the water samples with an average of 32.3mg/l, the highest percentage of all the anions present in the water sources. This enabled the bicarbonate ion to play a vital role in water classification. The high alkalinity values accounted for by the bicarbonate ions can tend to precipitate calcium and magnesium ions in form of calcium and magnesium carbonates. This condition reduces salinity hazard but increases Na hazard to inadmissible level. The concentrations of HCO_3^-, Mg^{2+} and Ca^{2+} constituted above 70 % of the water samples and Na^+, Cl^- and K^+ shared less than 2% in all the samples.

4.2.4 Nitrate (NO_3^-)

Concentration ranged from 10 mg/l to 10.8 mg/l with an average of 10.4 mg/l. A likely anion present in water after the bicarbonate and sulphate. Exposure to high concentrations can cause serious disorders in humans like shortness of breath, heart attack or even death as it binds with Red blood cells and limits the ability to carry oxygen, causing Methahaemoglobinaemia. The major source was an inappropriate disposal of animal waste that contributes to a high concentration as well as from application of nitrate fertilizers. Commonly encountered in water sources with faecal disposal and urine over an unprotected area raising the incidence of this ion in the water sources within the municipality.

4.2.5 Halogens

Chlorine was the halogen that was determined with an average low concentration of 0.01mg/l in all the water samples. This ion is common within water catchments after water treatment by chlorination.

4.2.6 Sulphate

This anion is found in almost all natural water and second to the bicarbonate as a major anion. It had a minimum value of 13.0 mg/l with maximum 14.1 mg/l with an average of 13.6mg/l. In the sporadic rain samples, it was also present with a minimum value 1.12 mg/l and maximum 2.03 mg/l hence an average 1.6 mg/l

5. DISCUSSION ON WATER CLASSIFICATION BASED ON THE MAJOR IONS

The order of cation dominance was Ca^{2+}> Mg^{2+}> Na+ > K+ and HCO_3^-> SO_4^{2-}> Cl- for anions in all the water sources. The chemical nature of the water was illustrated Fig. 2.

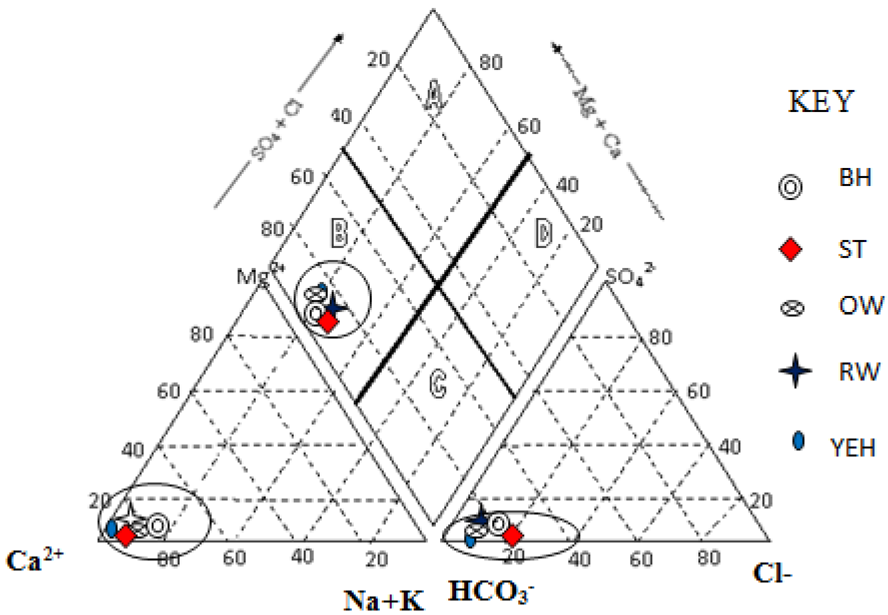

Fig .2: Piper diagram showing water types

6. DISCUSSION ON THE CHARACTERISTICS OF THE WATER QUALITY

The order of ions was; Ca^{2+}> Mg^{2+}> K^{+}> Na^{+} and HCO_3^- >SO_4^{2-}>NO_3^-> Cl^- in all water sources. The high concentration of SiO_2 after Ca^{2+} suggested that SiO_2 was also released (Si^{4+}) more into solution where it exists in form of H_4SiO_4 enhancing acidolysis of minerals. High SiO_2 also suggested the abundance of silicate minerals Srinivasamoorthy *et al.*, (2008) in agreement with dominant basaltic and trachytic rocks observed in similar terrains by Tanyileke *et al.*, (1996). Similarly, values of the concentrations of dissolved ions showed a progressive increase from zero prevalence of cations in rain water, to surface water and the highest in ground water. In the OW, BH, ST and RW samples the same trend was prevalent revealing that, rain water is enriched with cations as it percolates through the rock and soil.

7. DISCUSSION ON BACTERIOLOGICAL ANALYSIS

7.1 Macroscopic and microscopic observations

The macroscopic observation of the water samples from most sources were clear, odourless and void of any suspended particles. This indicated that, no contamination or pollution of the water samples was evident except for Open wells and rivers that indicated some colour and odour revealing eminent contamination**.** Microscopically water samples were observed as well as Gram stain tests carried out. Yeast cells with mobile and immobile bacteria were identified in all water sources except for Boreholes thus a high prevalence of bacterial infection within the water bodies. In other water sources analysed it was observed that in OW and RW, bacteria, yeast, bacilli and cocci were present in all the samples with 100% contamination. ST had present bacilli and cocci with negligible presence of bacteria and yeast hence 50% contamination, whereas the presence of bacteria, yeast, bacilli and cocci were negligible in BH with low contamination.

7.2 Gram stains analysis

This identified the presence of bacilli and cocci bacteria. Further it confirmed the presence of bacterial contamination of all the water sources. In 2 of the 4 water sources; OW and RW the bacilli and cocci were present. Cocci were present in all of the water sources with 100% prevalence.

7.3 Culture

MacConkey**,** permitted the growth of bacilli an enterobacteria that was revealed as present in all (100%) the water sources. Manitol salt agar used to identify water contaminating bacteria like *staphyllocus arious*.. Sabouraud agar was used to identify fungi that inhabit the same mileu hence like yeast it was present in all water sources except in BH. Plate count agar assessed the degree of contamination by giving a count of bacteria Colony Formation Units (C.F.U) in 100ml of water. This method revealed the presence of bacteria in all the sources (100%) with the C.F.U ranging from 5 to 60. High counts were observed in the dry season and indicated that, a higher probability of the catchments contamination with bacteria was done in the dry season. Isolated germs were prevalent in all the water sources except for BH where the germs were undetected.

8. DISCUSSION ON WATER QUALITY AND SUITABILITY

8.1 Suitability for drinking and domestic use

The drinking water guidelines of WHO (1993, 2004); B.I.S, (2003); Swiss standards and, EU norms were used to evaluate the water quality for human consumption. All water sources were colourless, whereas OW exhibited some coloration. The range of all major ions and TDS values were within the acceptable values of the guidelines for drinking. However the undetected fluoride in this work for drinking water may result to dental caries Edmunds and Smedley, (1996).The water was soft with Total hardness value ranging between 38 to 46.6 mg/l within the recommended value of < 75mg/l by Sawyer and McCarty, (1967) and minimum value of 10mg/l for Mg^{2+} with 20 to 60mg/l for Ca^{2+} according to Kozisek, (2005). Evidence is now available to confirm the health advantage of drinking water rich in Ca^{2+} and Mg^{2+} Kozisek,(2005). Cardiovascular ailments inherent in water softness Kozisek, (2005) could be a health problem in the municipality because of the softness of water. The high TDS value in our samples was consistent with observations in most exploited ground water resources in the volcanic rocks in Africa generally suitable for consumption Adelena *et al*.,(2011). The microbial quality of groundwater in tropical Africa is of serious health concern Roche, (1993) as evident in Kumbo water sources unsuitable for drinking as elsewhere Wirnvem *et al*., (2013). Standard norms indicated water samples as suitable for drinking and domestic uses. A hundred percent of the water sources have a mean Total Hardness of 121.51 that is above the WHO, (2004) limit of 100, and were all classified as moderately high according to Sawyer and McCarty classification. Davis and DeWeist, (1966); Freeze and Cherry, (1979), 100% water samples were of brine water type, with TDS values greater than 1.00mg/l according to Freeze and Cherry (1979). Total Hardness TH = 2.5Ca + 4.1 Mg with concentrations of Ca and Mg in mg/l, Todd, (1980). Concentrations above certain thresholds the water will not foam with soap due to the formation of insoluble precipitate with Calcium or Magnesium ions. 100% of Kumbo water sources were within the moderately high-water type as they had a Total Hardness within the 75-150 range.

8.2 Suitability for agriculture (irrigation purposes)

Based on; Permeability Index (PI), Percent sodium (% Na), Electrical conductivity (EC), Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Magnesium Hazard (MH), Total Dissolved Salts (TDS) and United States Department of Agriculture (USDA) classification.

8. 2.1 Permeability index (PI) or Permeability hazard

The suitability of groundwater for irrigation based on PI was calculated. Class I and class II waters good and suitable for irrigation while class III was unsuitable for irrigation, Doneen, (1964). All (100%) of Kumbo catchment (YEH), OW, BH, ST and RW belong to class I, thus good and suitable for irrigation.

8. 2.2 Percent sodium (% Na)

EC and % Na showed that all water samples were excellent to good for irrigation. Comparison of the water catchment and other sources (OW, BH, ST, and RW) with percent sodium values, to stipulations by the Wilcox, (1955) reflected the suitability of the water samples for irrigation.

8. 2.3 Sodium Adsorption Ratio (SAR)

Sodium Adsorption Ratio is most commonly used to assess suitability of irrigation water. The SAR measures sodicity in terms of the relative concentration of sodium ions to the sum of calcium and magnesium ions in a water sample, SAR was calculated and was used to predict the sodium hazard of high carbonate waters especially if they contain no residual alkali. Based on the sodicity diagram the groundwater samples were also classified. From calculations of SAR and EC, the salinity and alkalinity hazards of the water samples were evaluated. All (100%) of the samples collected were excellent on the basis of SAR. Thus, the water samples from Kumbo water sources studied were suitable for irrigation based on salinity hazard and sodium hazard.

8. 2.4 Residual Sodium Carbonate (RSC)

When the total carbonate levels exceed the amount of calcium and magnesium, the water quality can be diminished. When this excess carbonate (residual) concentration becomes too high, the carbonate combines with Ca and Mg to form scale that settles out of water, resulting in an increase both in Na% and SAR. According to Wilcox, (1955) irrigation water with RSC < 1.25 is excellent for irrigation. RSC values from -4.89 to -12.6 less than 1.25, agreed with computed values all < 1, consequently excellent for irrigation in water bodies within Kumbo municipality.

8. 2.5 Magnesium Hazard (MH)

Calculated using formula MH= Mg/ (Ca + Mg) X 100. MH value above 50 mg/l is considered to be unsuitable for irrigation. In all the water sources studied the MH value was less than 50mg/l hence considered suitable for irrigation.

9. PROCESSES CONTROLLING GROUND WATER CHEMISTRY

The water type (Ca-HCO_3 and Ca-Mg-HCO_3) depict rock- water interaction involving the dissolution of plagioclase and other aluminosilicate minerals (pyroxene and hornblende) followed by cation exchange. Silicate weathering is the possible source of Na, then the water sources will have HCO_3^- as the most abundant anion. This is because the reaction of silicate minerals with carbonic acid in the presence of water releases HCO_3^-. Therefore equilibrium with silicate is an important indicator of the hydrogeochemical process with incongruent dissolution of silicate minerals;

$$CaAl_2SiO_2O_8 + 2CO_2 + 3H_2O \longrightarrow Al_2Si_2O_5(OH)_4 + Ca^{2+} + HCO_3^- \quad \ldots\ldots\ldots\ldots\ldots 1$$

$$2NaAlSi_3O_8 + 2H_2CO_3 + 9H_2O \longrightarrow AlSi_2O_5(OH)_4 + 2Na^+ + 4H_4SiO_4 + 2HCO_3^- \ldots\ldots 2$$

Novelty Journals

ISSN 2394-7357

International Journal of Novel Research in Civil Structural and Earth Sciences
Vol. 8, Issue 1, pp: (1-12), Month: January - April 2021, Available at: www.noveltyjournals.com

Using the PHREEQC software the water samples all fall within the Kaolinite and Gibbsite domains both in Nesbitt and Wilson diagram, (1992) Fig. 3.

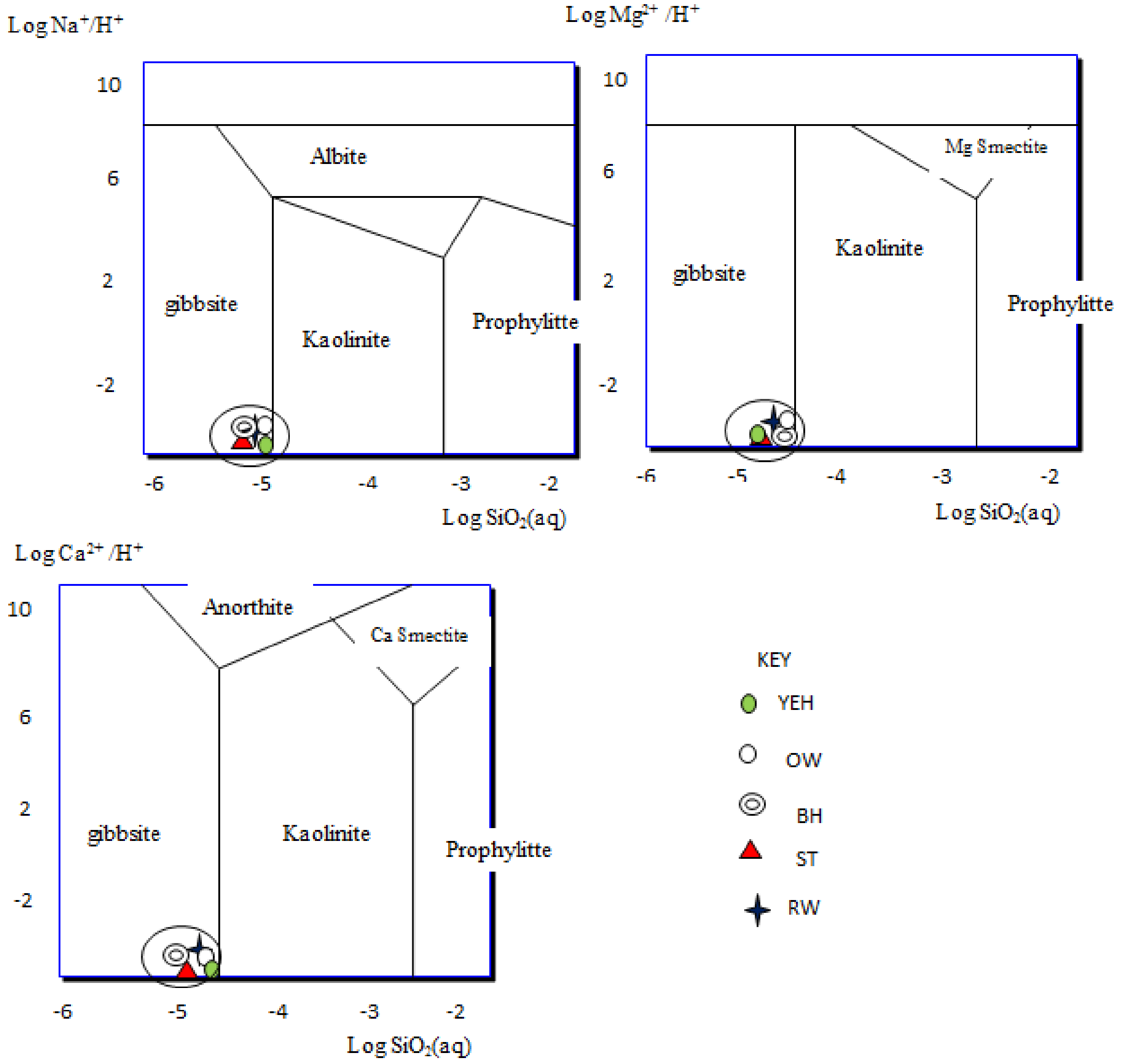

Fig .3: Kumbo municipality water samples in the activity-activity diagram Nesbit and Wilson, (1992)

10. GENERAL CONCLUSION

The water samples had the major ions within the permissible range for consumption as stipulated by various organisations. The suitability of water for irrigation a fundamental agricultural practice was assessed from % Na, EC, RSC, SAR which revealed 100% of the water samples as excellent for irrigation. MH was suitable while PI was good to suitable. Bacteria were present in all the water catchments, OW, RW, and ST with zero prevalence in BH, putting BH to be most suitable for drinking with respect to the other sources. The water sources in Kumbo municipality were very suitable for irrigation purposes, but require treatment due to bacterial infections before drinking. Kaolinitisation and gibbsitisation were dominant within the water source environment. This study fills a gap in the knowledge about the water quality that hitherto existed, and forms a background for subsequent monitoring to assess any evolution in quality, as well as suggestions for suitable mitigation measures.

ACKNOWLEDGEMENTS

This article constitutes part of a PhD research, in the department of Earth science of the Faculty of science in the University of Dschang Cameroon. Financial support was given by the Strategic Humanitarian Services (SHUMAS) Cameroon, an organization that has improvement of water quality in Cameroonian communities as one of its many concerns. Laboratory analysis was done in St Anne's Physicochemical and Biomedical laboratory in New Bell Douala using HI 83200 Multiparameter Bench photometer, innovative, efficient and rendered our data analysis within extremely minimal error margins.

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