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Evaluating Drinking Water Quality from Various Sources in a Peri Urban Area on the North Eastern flank of Mount Cameroon

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Abstract The present study aimed to calculate water quality index (WQI) through the analysis of eleven chemical parameters on the basis of the Weighted Arithmetic Index on six water sources; rain, well, stream, tap, river and spring during the dry and rainy seasons in order to assess their suitability for drinking purpose in Mbonge Marumba a peri urban area on the north eastern flank of Mount Cameroon. Water samples were collected from the field and analyzed at the nearby Ekona Research Laboratory. The Analysis of variance (ANOVA) was used to test if there were any significant differences of water parameters between the water sources and season. The WHO standard was used to compare the values of the water parameters tested through the percentage variance. Results revealed that Ca^{2+} is the most abundant cation followed by Mg^{2+}, K^+, Na^+ and NH_4^+. The relative abundance of anions (mg/l) in different water sources were as follows: $HCO_3^- > Cl^- > NO_3^- > SO_4^{2-} > H\,PO_4^{2-}$. These results reflect an influence of natural processes mainly from rock weathering. A wide variation (>-80%) between the actual values and the WHO standard was observed for most parameters with the exception of pH with a variance of -32% to -34%. HCO_3^- showed a higher value than that of the WHO standard. It ranged from 4.9 in rain water to 66.9 in tap water while the WHO standard permissible limit is 0.1. The WQI ranged from 3,137 for rain water, during the rainy season to 42,981 for tap water during the dry season. These index values revealed that the status of the various water sources in terms of ions and cations composition in the area are unsuitable for drinking.

Keywords: *anions, Cations, Drinking water quality, chemical parameters, Water Quality Index (WQI)*

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1. Introduction

Water is literally the source of life on earth and it is necessary for all life forms. Due to the fact that human physiology and man continued existence depends very much on water availability, efforts should be made to achieve a good quality of drinking water [1,2]. Water plays a great role in human nutrition and is necessary for the maintenance of personal hygiene, food production and prevention of diseases [3]. Unsafe drinking water and poor hygiene are the primary causes of death of 1.6 million children worldwide under the age of five with over 80% of them living in rural areas [4,5,6].

Developing countries are faced with problems of adequate portable water supply mainly due to their poor economies and the absence of available technology for water treatment for their growing population, resulting to the consumption of water whose quality is uncertain [7,8]. According to WHO, safe drinking water is that water with an acceptable quality in terms of physical, chemical and bacteriological parameters. Major water sources of many developing countries are streams, lakes, rivers, ponds, rain, springs and wells [9].

Despite the abundance of water bodies on earth, many people still lack access to portable drinking water simply by virtue of the fact that water must meet certain physicochemical and microbial criteria to be considered safe. It is important that water for drinking purpose should be examined frequently as contamination is unavoidable.

Cameroon, comes second in Africa after the Democratic Republic of Congo with an estimated available water resources quantity of 322 billion m^3 [10]. These water resources are spatially distributed following variations in topography, rainfall pattern and climatic changes. Mbonge Marumba holds plenty of water resource potentials in the form of stream, rivers, spring, and ground water amongst others, which if exploited, harnessed and managed sustainably can meet the needs of the population.

But this is not the case since the people face serious potable water deficiency. Water quality assessment is not carried out before use thereby resulting to the consumption of water from various sources whose quality remains questionable posing a public health risk. It is therefore important to regularly monitor the quality of water and to device ways and means to protect it. However, carrying out an evaluation of water quality from a large sample size with many parameters is difficult [11]. One way to do this is to estimate the Water Quality Index (WQI) [12].

Water Quality Index (WQI) is a well-known method as well as one of the most effective tools for assessing the suitability of water quality and communicating the information on overall quality of water [13,14] to concerned citizens and policy makers. However, water quality indices summarize data from multiple water quality parameters into a mathematical equation that rates the health of a water source with a number. It has become an important parameter for the assessment and management of water sources. However, due to the lack of information on water quality, this study was aimed at examining water chemical parameters; that is major anions and cations during the dry and rainy seasons, compared them with the WHO standards and to determine the health of various water sources to assess their suitability for drinking purpose.

2. Materials and Methods

2.1. Study Area

Mbonge Marumba is a fast-growing town emerging from a village status into a town just within a short period of time because of its strategic location within the South Western Region of Cameroon (Figure 1). The area is located between latitude 4°34’ 59.99 North of the Equator and Longitude 9°4 59.99 East. The elevation of the area is 98 meters above sea level. The climate of Mbonge Marumba is the equatorial type with two seasons. The dry season last for a minimum of four months (November – February) while the wet season spans between March and October. The total rainfall is 2210mm with the peak annual rainfall experienced in the months of July and August. There is a strong influence of climate on the water sources during the dry season especially in the flow of drinking water sources.

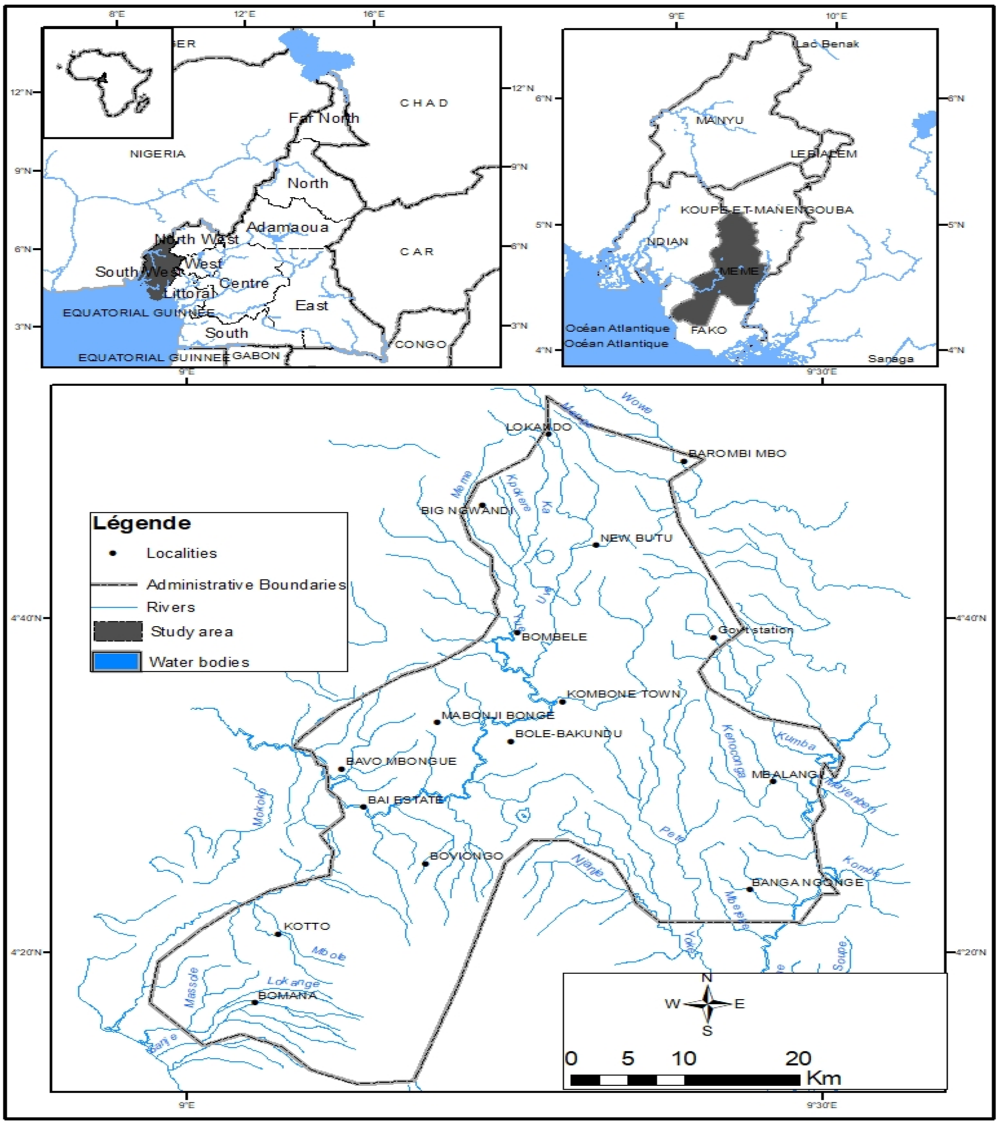

Figure 1. Location map of the study area in Cameroon (A*(B) map of the South West Region showing the study area (C) Map of the study area

2.2. Water Collection

The study was carried out on six water sources (rain, river, well, stream, tap and spring) within six sampling stations in the area. The six sampling stations were: rain water collection at Capital Street, river water from Mbengeboka,, well at New Mission Road, stream at Quandi quarter, tap water at New layout and spring at London quarter. Water samples were collected at three-time intervals (6am, 12noon and 6pm) from the six water sampling stations during the rainy season (September 2019) and the dry season (February 2020) giving a total of 36 water samples collected for the study. The samples were randomly collected from highly dependable points where residents usually collect water for domestic uses using sterilized 500 ml glass bottles following the recommendation of [3,25] for water sampling from various sources. The water samples collected were properly labeled and transported to the laboratory in an ice cool container for analysis within 24 hours.

2.3. Determination of Chemical Characteristics

A number of chemical parameters of the water samples were determined. Parameters analyzed were pH, bicarbonate (HCO^-_3), chloride (CL^-), magnesium (Mg^{2+}), nitrate ($N0^-_3$), sulphate (SO^2_4), ammonium (NH_4^+), phosphate (PO_4), sodium (Na^+), potassium (K^+) and calcium (Ca^{2+}). The parameters were determined at the IRAD Ekona Soil / Water Laboratory Centre. Sodium (Na+) and potassium (K+) which are major cations were determined by flame photometry. Calcium (Ca2+) and magnesium (Mg2+) were analyzed using the titration method with 0.02M solution of Ca and Mg-EDTA together with 1ml of TEA and 1ml of 5% KCN. The colorimetric method was used to analyze ammonium ($NH\ 4^+$). Major anions were analyzed using various methods as follows: chloride (Cl^-) and bicarbonates (HCO_3^-) concentrations by titration, nitrates ($NO3^-$) and phosphate (HPO_4^{2-}) by colorimetry, and sulphates (SO_4^{2-}) by turbidimetry.

2.4. Calculation of Water Quality Index

The WQI was calculated using the weighted arithmetic water quality index which was originally proposed by [12]. and developed by [17]. The weighted arithmetic water quality index (WQI_A) is expressed as:

$$WQI_A = \sum_{i=1}^{n} w_i q_i / \sum_{i=1}^{n} w_i \quad (1)$$

with n being the number of variables or parameters, while w_i is the unit weight of the i^{th} parameter and q_i is the water quality rating of the i^{th} parameter. The unit weight (wi) of the parameter is inversely proportional to the water standard used for the corresponding parameters.

$$W_i = k / \mathrm{Sn} \quad (2)$$

Sn = Standard acceptable value of n^{th} water quality parameter. k = Constant of proportionality and it is calculated by using the expression below:

$$k = \left[1 / \left(\sum 1 / Sn = 1,\ 2,\ 3,\ 4 \ldots n\right)\right].$$

According to [17], q_i is the water quality rating and is calculated using the following equation:

$$q_i = 100\left[\left(V_i - V_{id}\right) / \left(Sn - V_{id}\right)\right] \quad (3)$$

where Vi is the observed value of the i^{th} parameter, Sn is the standard permissible value of the i^{th} parameter and V_{id} is the ideal value of the i^{th} parameter in pure water. In this equation, all the ideal values (V_{id}) are taken as zero for drinking water except pH that has an ideal value is 7.0 (for natural/pure water) and a permissible value is 8.5 (for polluted water) [18]. The WQI value obtained was interpreted following the classification of [17,19] on Table 1 below. WQI is generally defined for the purpose for which the water is to be used for. The WQI for this study was considered for human consumption and the maximum permissible WQI for the drinking water was considered on a score 100.

Table 1. Classification of water quality using the weighted arithmetic WQI method

WQI	STATUS
0 - 25	Excellent
26 - 50	Good
51 - 75	Poor
76 - 100	Very Poor
Above 100	Unsuitable for drinking

Source: Adapted from [17,19].

2.5. Statistical Analysis

Results from the different water sources for both the dry and rainy seasons were subjected to statistical analysis. One-way ANOVA using the SPSS version 18.0 package was performed to investigate whether there are significant variations among the chemical parameters of water sources in the area. The test was also performed to investigate whether there are significant seasonal variations of cations and anions among the various water sources and also to see if significant differences were observed between the values and the WHO standard.

3. Results and Discussion

3.1. Trends of the Various Water Parameters Tested across the Water Sources and Seasons

Table 2 and Figure 2 show the values and trends of the various water parameters tested across the water sources both during the dry and rain season. The cations showed a variation across seasons. The mean concentrations were generally higher during the rainy season compared to the dry season. The reason being that agriculture is the mainstay in the area and during the rainy season there is runoff from farmlands into some water sources there by increasing the nutrient load of the elements. A similar trend was also observed for anions with the exception of bicarbonates having a higher value during the dry season.

Results revealed that Ca^{2+} is the most abundant cation followed by Mg^{2+}, K^{+}, Na^{+} and NH_4^{+}. The dominance of Ca^{2+} is likely due to the presence of plagioclase and pyroxene minerals in the basaltic rocks present in the area which are easily weathered. The average concentration of Ca^{2+} was higher in the rainy season than in the dry season. The respective average values for the rainy and dry seasons were 11.89 mg/l and 9.84mg/l respectively (Table 2). The trend also varies across water sources. Spring and well water showed the highest concentration of Ca^{2+} with average values of 20.8mg/l and 19.7 mg/l respectively. The second most abundant cation present in the analyzed water sources was Mg^{2+} with an average higher dry season concentration of 8.17mg/l and a lower rainy season value of 7.99mg/l. Its concentration was higher in spring and well water sources with means values of 14.4 mg/l and 12.15 mg/l respectively. The mean K^{+} value of 4.54, mg/l for the dry season was higher than the rainy season value of 2.52mg/l. Potassium concentration was higher in spring and well water sources with values of 5.54 mg/l and 12.82 mg/l respectively. The high concentration of Ca^{2+}, $Mg^{2+}$and K^{+} in springs and wells can be attributed to the geology of the area which is rich in these minerals The mean rainy season value of 0.56 mg/l for Na^{+} was higher than the dry season value of 0.2 mg/l. A similar trend was also observed for NH_4^{+} with a mean rainy season value of 0,2 mg/l and dry season vale of 0.01 mg/l. However, the highest concentration of Na^{+} and ammonia were also observed in spring and well water. The reason that can be advanced for this is due to runoff from adjacent farmlands into springs and wells in the area.

The anions analyzed showed a variation across water sources (Figure 2). The abundance of anions (mg/l) in different water sources were as follows: HCO_3^{-} > Cl^{-} > NO_3^{-} > SO_4^{2-} >H PO_4^{2-}. Based on the average concentration, HCO_3^{-} is the most abundant in all the water sources with exceptional high values during the rainy season. Average HCO_3^{-} values were higher in the rainy season (20.33mg/l) than in the dry season (19.68mg/l). The average concentrations were higher in tap and stream water with average values of 66.95mg/l and 1.2mg/l respectively. The dominance of HCO_3^{-} is consistent with most natural waters along the CVL [20]. Chloride is the second most abundant anion. The average concentration of Cl^{-} was higher in the rainy season (**6.17** mg/l) as compared to the dry season (**4.67**mg/l). The average concentration of Cl^{-} was higher in springs with a value of 13 mg/l followed by rain and tap water with values of 5.5 mg/l respectively. However, most of the Cl^{-} in springs comes from precipitation [21]. Chlorine is often added to tap water in order to kill bacteria. NO_3^{-} and HPO_4^{2-} average concentrations were higher in the dry season than in the rainy season as shown on Table 2. Their respective average values for the dry season were **0.98**mg/l and 1.38mg/l while the values for the rainy season were **0.12**mg/l and 0.04mg/l. The respective average values of NO_3^{-} were high in tap and well water with values of 1.82 mg/l and 1.22mg/l respectively. NO_3^{-} result from the oxidation of ammonia. Runoff from farmlands using agrochemicals and manure are the probable sources of the presence of NO_3^{-} in well and tap water in the area. SO_4^{2-} average concentrations were higher in the rainy season than in the dry season for all the water sources in the area. The ‾average concentrations were higher in tap and well water with values of 4.19 mg/l and 3.66 mg/l respectively. SO_4^{2-} is mostly derived from natural sources such as sulphate minerals common in igneous rocks [22]. The average concentration of HPO_4^{2-} was higher in the dry season with a value of **1.38** mg/l compared to the rainy season value of 0.04 mg/l. It also varied across water sources with a value of 4,18 mg/l for river water, 0.08 mg/l for well and was completely absent in the other water sources. This could be due to the fact that the application of phosphate fertilizers in the area is very low. The occurrence of HPO_4^{2-} in natural waters in small quantities is simply because many aquatic plants absorb and store phosphorous above their actual immediate needs. The range of HPO_4^{2-} in most natural water bodies is between 0.005 to 0.020mg/l [23] mostly coming from agriculture [24] and organic decay [25]. The water sources in the area are slightly acidic with a pH range between 4.08 to 6.05. Results revealed that no significant difference exist at $p \leq 0.01$ for all the parameters tested between sources and across season.

Table 2. Seasonal variations of water quality parameters

Season	Water Source	Elements										
		Na^{+}	Ca^{2+}	Mg^{2+}	NH_4^{+}	HCO_3	NO_3^{-}	SO_4^{2-}	Cl^{-}	pH	K^{+}	HPO_4^{2-}
Dry	Rain	0.04	4.49	4.96	0	4.91	0	1.03	5	4.89	0.15	0
	River	0.1	8.43	4.99	0	8.25	0	0.89	1	4.85	0.52	8.25
	Spring	0.22	19.87	15.58	0.04	8.67	0.09	1.06	12	4.08	10.75	0
	Stream	0.21	5.79	7.11	0.01	17.33	0.11	0.65	1	5.42	1.03	0
	Tap	0.11	3.19	4.3	0.01	66.79	3.41	3.42	5	5.68	1.77	0
	Well	0.54	17.88	12.06	0.02	12.12	2.25	2.15	4	4.38	13.04	0.04
	Mean	**0.2**	**9.94**	**8.17**	**0.01**	**19.68**	**0.98**	**1.53**	**4.67**	**4.88**	**4.54**	**1.38**
Rainy	Rain	0.03	5	5.73	0.01	4.88	0	2.07	6	5.01	0.16	0
	River	0.1	9.85	5.01	0.01	8.54	0	1.75	3	4.99	0.14	0.11
	Spring	1.55	21.88	13.29	0.03	9.76	0.14	2.11	14	4.17	0.33	0
	Stream	0.28	8.68	7.43	0.01	19.52	0.15	1.15	2	5.56	1.08	0
	Tap	0.33	5.47	4.27	0.02	67.1	0.23	4.95	6	6.05	0.8	0
	Well	1.08	20.45	12.24	0.03	12.2	0.19	5.16	6	4.73	12.6	0.12
	Mean	**0.56**	**11.89**	**7.99**	**0.02**	**20.33**	**0.12**	**2.86**	**6.17**	**5.08**	**2.52**	**0.04**

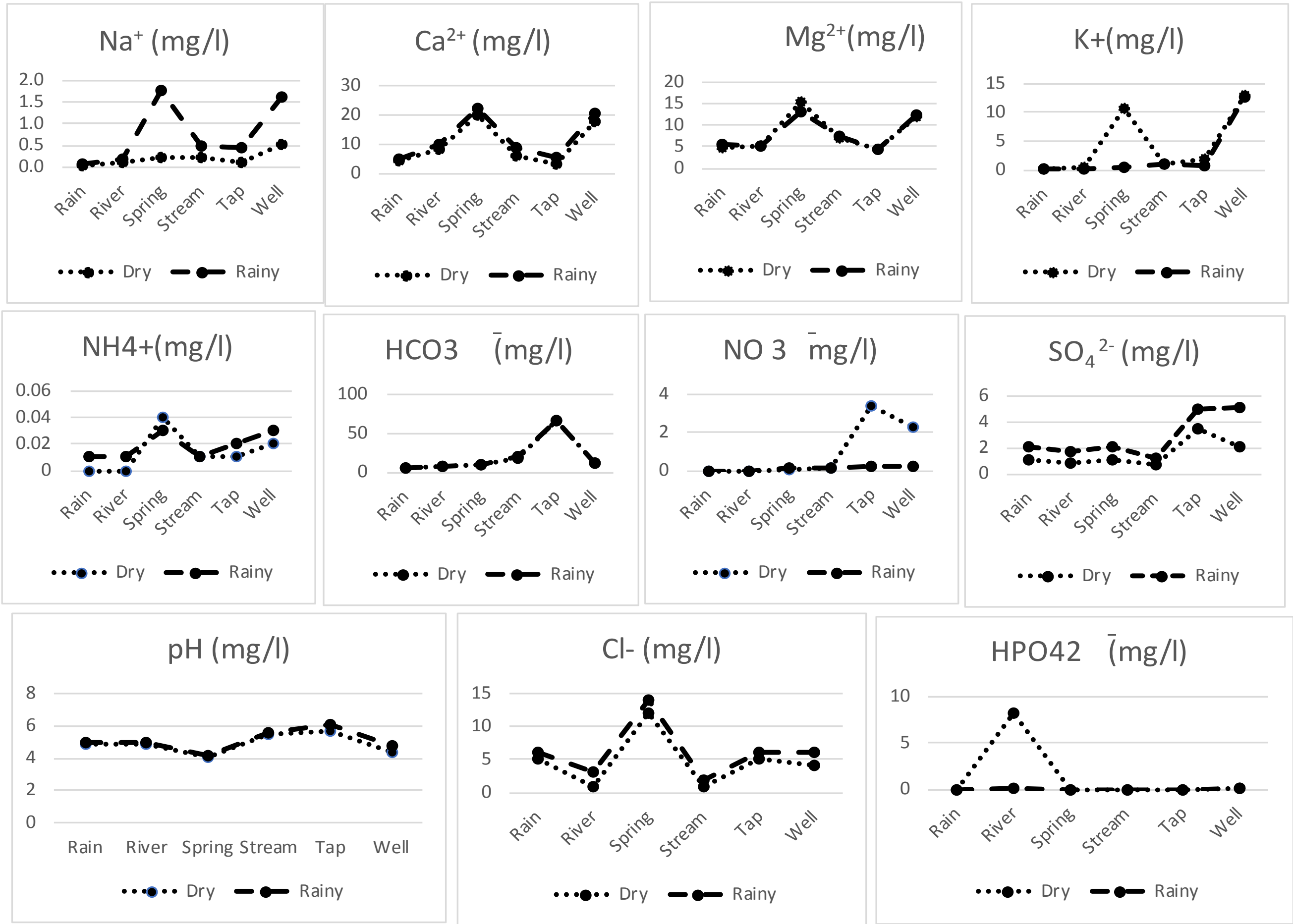

Figure 2. Graphs showing seasonal trends of the various water parameters tested across the water sources

3.2. Comparison of Water Parameters Tested and the WHO Standard

Table 3 shows the range, mean, standard deviation and coefficient of variation for the water parameters tested to the World Health Organization (WHO) [6] standard. Results revealed that the mean concentrations of Na^+, Ca^{2+}, Mg^{2+}, K^+, and NH_4^+ within water sources in the area were 0.3 mg/l, 10.92 mg/l, 8.08 mg/l, 3,53 mg/l and 0.02 mg/l respectively for the cations. The WHO standards for these elements are 110 mg/l, 200 mg/l, 50 mg/l, 100 mg/l and 0.5 mg/l respectively. Results show that the observed values of cations in Mbonge Marumba are far below the permissible limits prescribed by World Health Organization (WHO) standards for drinking water [26] thereby indicating poor water quality due to the low concentration of these essential elements. The results are in line with the findings of [27] on the physico-chemical analysis of water quality of springs in Bafia-Muyuka on the North-Eastern Flank of Mount Cameroon Cations in water play a significant role in classifying and assessing water quality. These geogenic ions are very important for human health if available in the right quantities. Calcium is very important for human cell physiology and bones and the deficiency of calcium in humans may cause rickets, poor blood clotting and bones fracture. Magnesium is very essential for the proper functioning of living organisms and Potassium s vital for human body functions like heart protection, regulation of blood pressure, protein dissolution, muscle contraction and nerve stimulus

The mean concentration of NO_3 was 0.55 mg/l compared to the WHO standard of 50 mg/l in drinking water. The results exhibit that the concentration of nitrates is lower than the standard limit. Naturally, the concentration of nitrates in water is 6mg/l. Nitrate ranged from 0 to 1.82mg/l in the study area indicating these water sources as suitable for drinking [28]. Nitrate is one of the most important diseases causing parameters of water quality particularly blue baby syndrome in infants. According to [29] high NO_3^- levels in water have been associated with methenoglobinemia, gastric ulcer, cancer and urinary tract diseases [30] Therefore, the monitoring of NO_3^- in drinking water sources is very important because of health effects on humans and animals. SO_4^{2-} concentration in natural water ranges from a few to a several 100 mg/liter, but no major negative impact of sulfate on human health is reported. The WHO [6] has established 500 mg/l as the highest desirable limit of sulfate in drinking water. In the study area, the concentration of sulfate ranges from 0.9 - 4.18mg/l with a mean value of 2.20 mg/l. The results exhibit that its concentration was lower than the standard limit and it may not be harmful for human health. The low concentrations may be a consequence of gradual dissolution [31]. Chloride is mainly obtained from the dissolution of salts of hydrochloric acid as table salt (NaCl), NaCO2 and can added through industrial waste, sewage and sea water. It has key importance for metabolism activity in human body and other main physiological processes. High chloride concentration damages metallic pipes and structure. If consumed in high amounts, Cl^- can be toxic and cause sufficient cell damage in the human body. Higher concentration of chlorine may cause gastrointestinal irritation when associated with sodium and magnesium [32]. According to WHO [6] standards, concentration of Cl^- should not exceed 250 mg/l. In the study areas, the chloride value ranges from 2 - 5.5mg/l, with a mean value of 5.42 mg/l was below the standard. HPO_4^{2-} for the various water sources were 0 mg/l for rain, spring and tap was below the permissible limit limit of 0.03 mg/l prescribed by World Health Organization (WHO) standards for drinking water [26]. The mean values for river and well water were above the standard limit making them unsuitable for drinking. One element, HCO_3^- showed a higher value than that of the WHO standard. It ranged from 4.9 in rain water to 66.9 in tap water while the WHO standard permissible limit is 0.1. High concentration of HCO_3^- may cause physiological damage or distress in humans, for example, water containing more than 45mg/liter has been reported to cause methemoglobemia in infants. The current study found that the pH values of drinking water sources ranged between 4.2 for spring water to 6.1 for tap water and is not within the WHO acceptable range of 6.5 to 8.5. This shows that the various water sources within Mbonge Marumba are not very good for drinking because of the acidic nature. Although pH has no direct effect on human health, research has however shown that it is closely related to other chemical constituents of water. Water with low pH levels is acidic and can corrode plumbing and leach metal, iron, manganese, copper, lead and zinc. High levels of lead places people at risk of health problems such as cancer, stroke, kidney disease and high blood pressure [33].

Table 3. Summary statistics of the water parameters tested to that of the WHO [6] standard

Element	Range across various water sources	Mean	Standard	CV (%)	WHO Standard
$Na^+_{(mg/l)}$	0.04 - 0.89	0.38	0.34	88	110
$Ca^{2+}_{(mg/l)}$	4.33 - 20.87	10.92	6.65	60	200
$Mg^{2+}_{(mg/l)}$	5.0 - 14.44	8.08	3.85	47	50
$NH{+}_4^+{}_{(mg/l)}$	0 - 0.03	0.02	0.01	69	0.5
$HCO^-_{3(mg/l)}$	4.89 - 66.94	20.01	21.40	106	0.1
$NO_3^-{}_{(mg/l)}$	0 - 1.82	0.55	0.71	129	50
SO_4^{2-} (mg/l)	0.9 - 4.18	2.20	1.25	56	500
$Cl^-_{(mg/l)}$	2 - 5.5	5.42	3.76	69	250
p^H	4.12 - 5.86	4.98	0.57	11	6.5 – 8.5
$K^+_{(mg/l)}$	0.15 - 12.82	3.53	4.53	128	100
HPO_4^{2-}	0 – 8.25	0.71	1.55	218	0.03

3.3. Water Quality Index

WQI is a reflection of a composite value of eleven chemical parameters tested from various water sources during the rainy and the dry season. The WQI of the study area are presented on Table 4. The WQI ranged from 3,137 for rain water, during the rainy season to 42,981 for tap water during the dry season. The high value of WQI has been found to be mainly from the higher values of bicarbonate in the various water sources These index values revealed that the status of the various water sources in terms of ions and cations composition are unsuitable for drinking.

Table 4. WQI values for various water sources during the dry and rainy season

Season	Water Source	WQI	Status
Dry	Rain	3156	Unsuitable for drinking
	River	**4378**	Unsuitable for drinking
	Spring	5581	Unsuitable for drinking
	Stream	11154	Unsuitable for drinking
	Tap	42981	Unsuitable for drinking
	Well	7799	Unsuitable for drinking
Rainy	Rain	3137	Unsuitable for drinking
	River	5500	Unsuitable for drinking
	Spring	6281	Unsuitable for drinking
	Stream	12563	Unsuitable for drinking
	Tap	43181	Unsuitable for drinking
	Well	7852	Unsuitable for drinking

4. Conclusion

The chemical parameters (cations and anions) of various water sources in Mbonge Marumba were analyzed in order to determine their suitability for drinking purpose. Results revealed Ca^{2+} as the most abundant cation followed by Mg^{2+}, K^+, Na^+ and NH_4^{+}. The abundance of anions (mg/l) in different water sources were as follows: $HCO_3^- > Cl^- > NO_3^- > SO_4^{2-} >$ H PO_4^{2-}. The values obtained were then compared with the WHO [6] standard for drinking water to ascertain their suitability. The results of most parameters tested such as Na^+, Ca^{2+}, Mg^{2+}, K, NH_4^+, NO_3^-, SO_4^{2-}, CL^- and HPO_4^{2-} for the various water sources were far below the WHO permissible limits. One element, HCO_3^- showed a higher value than that of the WHO standard. It ranged from 4.9 in rain water to 66.9 in tap water while the WHO standard permissible limit is 0.1. The Water Quality index (WQI) for the various water sources was calculated from the chemical parameters in order to evaluate the combined effects of chemical parameters on the suitability of water for drinking purpose. The calculated WQI provides an easy way of understanding the overall water quality and water management. The water quality rating for rain, river, spring, stream, tap and well water showed that these water sources are unsuitable for drinking during the period of study. Based on the findings, the consumption of water from various sources pose a potential public health in this locality. However, there is need for regular monitoring of water quality in order to detect changes in the concentration of chemical parameters and convey it to the public for appropriate measures to be put in place to ensure the supply of good quality water.

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