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Assessment of Quality Indices of Drinkable Water Sources in Dumne, Mboi and Zumo of Song Local Government Area, Adamawa State using CCME Method

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Abstract

The study explored water quality index of three drinking water sources (borehole, well & rivers water) from Mboi, Dumne and Zumo communitie, Located in Song Local Government Area, Adamawa State, Nigeria. Physicochemical parameters examined for the analyses are temperature, electrical conductivity (EC), total dissolved solids (TDS), hardness, calcium concentration, sulphate ion concentration, magnesium concentration, turbidity, total suspended solids (TSS), alkalinity, chloride ion concentration, nitrate ion concentration, fluoride ion concentration, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD) and pH. These parameters were determined using various standard experimental procedures and tools. Water quality indices were evaluated using Canadian Council of Ministers of Environment (CCME) methods. Water quality indices obtained from this research investigation showed that the borehole, well and river water from the study areas are in good condition in line with the CCME rankings. From the result obtained, the WQI of borehole water of Mboi, Dumne and Zumo are 85.45, 88.76 and 88.91 respectively while the WQI of the investigated well water are 79.73, 85.42 and 82.77 respectively. The WQI for the river water of Mboi, Dumne and Zumo was found to be 71.86, 79.56 and 76.15 respectively. Based on CCME rankings, the three water sources investigated across the three research areass are good for human use and consumption and the rating of the water quality indices are as follow: Borehole > Well > River.

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Introduction

Background of Study

Groundwater is an essential mineral resource obtained from underground at zone of saturated soils.[1] According to,[2] the quality of public health depends to a greater extent the quality of groundwater.[3] defined Quality of water generally as component of water, which is to be present

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at optimum level for suitable growth of plants & animals. Water Quality Index (WQI) is one of most effective tools to communicate information on quality of water to concerned citizens & policy makers. It thus, becomes important parameter for assessment & management of surface water.[4] Importance of water in our daily lives cannot be over emphasized. Assessment of suitability of water for domestic, agricultural & industrial purposes is of great concern all over the globe.[5] Water is most essential natural resources of ecosystem, having an integral role for both drinking as well as economic sectors.[6] It is essential component for survival of life on Earth, which contains minerals, important for human beings as well as plant & aquatic life.[7] Water covers over 71 % of earth's surface & is very important natural resource for people. Yet, only 2.5 % of earth's water is fresh & thus suitable for consumption.[8]

Water Quality Index (WQI) is considered as most effective method of measuring water quality. Number of water quality parameters are included in a mathematical equation to rate water quality, determining suitability of water for drinking.[9] Water quality has become a common research issue in water resource management field due to upsurged deterioration of surface & groundwater quality, as a result of pollution.[10] Water-borne diseases & impaired ecosystems are only samples of disastrous effects of contaminated water on public health & environmental safety.[11] According to,[10] evaluation of water quality turned into a vital issue for local authorities as well as worldwide institutions, like World Health Organization (WHO) & Food & Agriculture Organization (FAO).

However, quality of global water has rapidly declined for decades due to impact of both natural & anthropogenic factors.[12] Relatively high values could be attributed to anthropogenic activities such as application of fertilizer & animal wastes in farming as well as leaching & dissolution of phosphate & potassium from minerals that make up underlying igneous rocks in study area. Anthropogenic sources include industrial wastes & sewage sludges. This includes also due to anthropogenic activities such as excessive application of lime to soils in farming activities.[13] These anthropogenic activities are responsible for introduction of heavy metals in lakes.[14] Due to threat to our sources of drinking water as a result of various degrees of pollution, this research examined quality index of three major sources of drinking water in Dumne, Mboi & Zumo settlements.

Examination of Physicochemical Parameters for Water Quality Index

Turbidity

According to,[15] amount of solid matter present in suspended state determines how turbid water is. The turbidity test is used to determine quality of waste discharge with regard to colloidal matter & measures light-emitting capabilities of water. Turbidity is stated in a turbidity unit which equals to 1 mg/liter SiO_2. First equipment used to calculate turbidity is Jackson Candler Turbidimeter, which was calibrated using silica.[1] Increased surface runoff contributes to turbidity, which is easily measured variable that is often associated with total suspended solids (TSS) & microbial concentrations[16]

Temperature

According to,[3] temperature of water affects some of important physical properties & characteristics of water: thermal capacity, density, specific weight, viscosity, surface tension, specific conductivity, salinity & solubility of dissolved gases, etc.[15] observed permissible temperature of water according to WHO is 30°C &[3] reported that temperature of water in streams & rivers throughout world varies from 0 to 35°C.[17] reports temperature of 29°C of well water in Nigeria.

Total Dissolved Solids (TDS)

[18]stated that quantity of dissolved substance in the liquid is referred to as all dissolved solids. These compounds can be salts, minerals, metals, calcium and compounds which can be both organic and inorganic. Water with high TDS value indicates that water is highly mineralized. Desirable limit for TDS is 500 mg/l & maximum limit is 1000 mg/l which prescribed for drinking purpose.[19; 15]

Dissolved Oxygen

Dissolved oxygen (DO) refers to oxygen gas that is dissolved in water, Dissolved oxygen is most important factor in aquatic systems, since all plants and animals need oxygen for respiration. When dissolved oxygen is less than 2.8 mg/L, it is called hypoxia.[20] When data are gathered for studies of nature from a hydrobiological, ecological, or environmental protection standpoint, the amount of dissolved oxygen (below DO) in natural waters is a crucial quantity.[21] The amount of DO in water is one of the most commonly used indicators of a water body's health.[22]

Hardness of Water

Degree of hardness in water determines quality of water supply. Metal ions (minerals) that are dissolved in groundwater are cause of hard water. Some of these minerals are Ca^{2+}, Mg^{2+}, and Fe^{3+}. Magnesium and calcium are only present in natural streams in substantial amounts.[3] Water could be considered to be very hard if hardness exceeds WHO maximum permissible level of 500 mg/l.[23]

Electrical conductivity (EC)

The Conductivity or Electrical Conductivity (EC) is measurement of ability of water to conduct electric charge (current).[3] The concentration of dissolved salts and other minerals in water bodies are resonsible for their electrical conductivity.

pH of Water

Anthropogenic acidification of lakes & rivers can have dramatic and far-reaching implications for structure & function of aquatic ecosystems. Acidification occurs primarily as an outcome of acidified rain or snow depositions, whereby emissions of sulphur dioxides & nitrogen oxides into atmosphere form highly acidic precipitations that can have long-lasting effects on freshwater pH.[24]

CCME Water Quality Index

CCME WQI model consists of 3 measures of variance from selected water quality objectives (Scope; Frequency; Amplitude). These 3 measures of variance combine to produce a value between 0 & 100 that indicates overall water quality. CCME WQI values are then converted into rankings by using index categorization schema presented in Table (1) below.[25] However, while most of indices identified in literature include steps of sub-indexing & weighting, Canadian Council of Ministers of Environment Water Quality Index (CCME WQI) omitted these steps & performed final aggregation function using parameter measurements directly within fixed mathematical functions. This has made CCME most popular index. It is used for all types of water bodies, but primarily for rivers[35]

In this research finding, WQI was computed using sixteen (16) physico-chemical parameters for each sample analysed. Parameters used are pH, EC, Turbidity, Alkalinity, TSS, TDS, Total Hardness, Ca, Mg, Phosphate, Nitrate, Sulphate, Chloride, Fluoride, BOD & DO.

Table 1: CCME WQI categorization schema

Keys: CCME= Canadian Council of Ministers of Environment, WQI=Water Quality Index

S/No	CCME WQI	Ranking	Water Quality Characteristics
1	95-100	Excellent	Water quality is protected with virtual absence of threat or impairment; conditions very close to natural or pristine levels; these index values can only be obtained if all measurements are within objectives virtually all of time.
2	80-94	Good	water quality is protected with only minor degree of threat or impairment; conditions rarely depart from natural or desirable levels
3	65-79	Fair	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.
4	45-64	Marginal	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
5	0-44	Poor	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

MATERIALS & METHODS

Geographical Information of Study Area

Song (9^{0}49' 28''N 12^0 37'30'' E/9.8244^{0}N 12.625ºE) town of Adamawa State of Nigeria with population of well over 4,000 people whose climate is characterized by wet season from April to October while dry season last from November to March with mean annual rainfall of between 79 mm to 197 mm, wettest month being August & September. Temperatures are generally high throughout year except between November & February when harmattan winds tends to reduce temperature to 26.9ºC. However, mean annual temperature is around 28ºC. Relative humidity also varies seasonally in study area, with low value of about 18- 30 % between January & March, increasing in peak of 82 % between April to August & September, & declining again in October.[26]

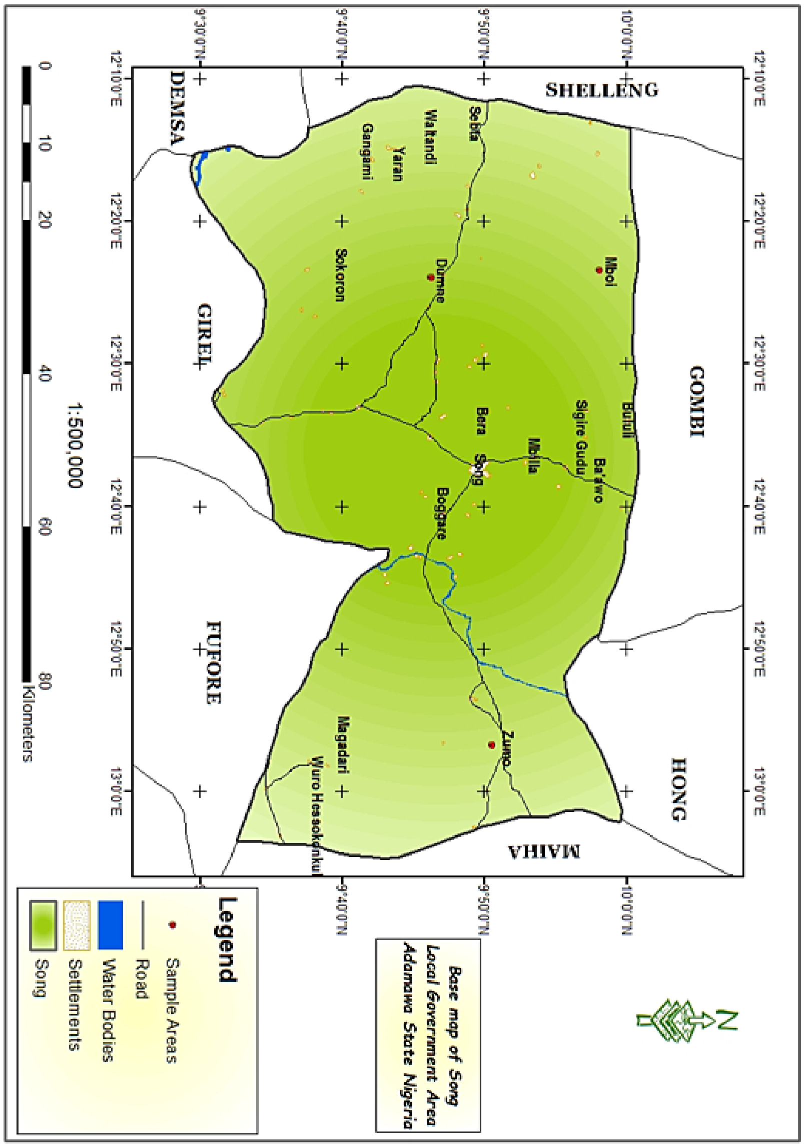

Fig. 1: Map of Song L.G.A., showing the study area Mboi, Dumne and Zumo

Sample Collection and Treatment

Samples were taken from boreholes, streams and hand dug wells in Dumne, Mboi and Zumo, all in Song Local Government Area. Water samples were collected twice during the wet & dry seasons at interval of six months. Well water samples were collected using a fetcher. Borehole & stream water samples were collected directly from taps & stream sources respectively.[33]

Standard 350 ml dipper was used to collect samples of water from borehole, well & streams and put into clean reagent plastic bottles. Two water samples destined for determination of heavy metals were acidified with concentrated hydrochloric acid (HCl) & concentrated nitric acid (HNO3) respectively to a pH ranging between 1.5 & 2.0. Third sample of water was left plain with no acidification. Water samples collected were immediately transferred to the Laboratory in the Department of Chemistry of Modibbo Adama University, Yola for further processing.[36]

Sample Analysis for Physicochemical Properties TSS, DO and Hardness determination

Determination of the total suspended solids, dissolved oxygen & total hardness were carried out according to the methods described in.[27]

Determination of pH, Temperature & conductivity

pH, temperature, conductivity of the water samples were determined according to the methods described in.[15]

Determination of Total Dissolved Solids (TDS)

The total dissolved solid was calculated according to method of[28]

Determination of Biological Oxygen Demand (BOD)
Biological Oxygen Demand was determined as using method of.[22]

Determination of Turbidity and Alkalinity

The methods of[13] were used to determine turbidity and total alkalinity of the water sampes investigated

Determination of Calcium and Magnesium Ion Concentration

The Calcium, Magnesium, Sulphate, nitrate and phosphate and Fluoride were determined for each water samples according to the methods described in.[27]

Test for Chloride and Blank Titration

The chlorides and blank titration were determined for each water sample according to the method described.[29]

Water Quality Index

In this study, data obtained from the analysis of all water samples investigated were computed using Canadian Council of Ministers of Environment (CCME) to calculate Water Quality Index (W.Q.I.) according to the formula number (7) below:

Analysis Method

To evaluate water quality of Mboi, Dumne & Zumo Borehole, Well and River Water Samples, CCME-WQI method was used.CCME-WQI method is based on following 3 elements: scope (F_1), frequency (F_2), & amplitude (F3). F_1, F_2, & F_3 are calculated as follows:

F_1(Scope)

F_1 is used to indicate percentage of indicators exceeding standard, which indicates percentage of selected parameters that do not meet their respective parameter standard values at least once during evaluation period. It can be calculated by Equation (1):

$$F_1 = \frac{Number\ of\ failed\ variables}{Total\ number\ of\ variables} \text{ x } 100 \qquad ...(1)$$

F_2 (Frequency)

F_2 indicates percentage of monitoring quantity exceeding standard, which is used to measure how often water quality objective is not met. It can be calculated by Equaetion (2):

$$F_2 = \frac{Number\ of\ failed\ tests}{Total\ number\ of\ tests} \text{ x } 100 \qquad ...(2)$$

F_3 (Amplitude)

F_3 is amplitude, measured by how much objectives are exceeded, & thus indicate amount by which failed test values do not meet their objectives. (Guideline value). Following 3 steps are required to calculate F_3.

Step 1

Number of times by which individual concentration is greater than (or less than, when objective is minimum) objective is called an excursion. When test value must not exceed objective, Equation (3) was used to calculate excursion. While test value must be no less than objective, Equation (4) was used.

$$excursion_i = \left(\frac{Failed\ test\ value_i}{Objective_j}\right) - 1 \qquad ...(3)$$

$$excursion_i = \left(\frac{Objective_j}{Failed\ test\ value_i}\right) - 1 \qquad ...(4)$$

Step 2

Total amount by which individual tests are out of compliance (normalized sum of excursions) is calculaeted as following Equation (5):

$$\text{nse} = \frac{\sum_{i=1}^{n} excursion_i}{Number\ of\ tests} \quad ...(5)$$

Amplitude (F_3) is then calculated by asymptotic function that scales normalized sum of excursions from objectives to yieeld value between 0 & 100:

$$CCME\ WQI = \left[\frac{\sqrt{F_1^2+F_2^2+F_3^2}}{1.732}\right] \quad ...(6)$$

Finally, CCME-WQI index is calculated as shown in Equation (7):

$$CCME\ WQI = \left[\frac{\sqrt{F_1^2+F_2^2+F_3^2}}{1.732}\right] \quad ...(7)$$

According to above formulas, we can obtain CCME-WQI value ranging from 0 to 100. Water quality can be divided into five categories based on CCME-WQI values calculated, listed in Table 1.[30]

Results & Discussions

Water Quality Index of Borehole Water

Results of water quality index of Mboi, Dumne & Zumo, Song borehole water is presented in Table 2.

Table 2: Results of Water quality index of Mboi, Dumne & Zumo Borehole

		Mboi Station		Dumne Station		Zumo Station	
Parameters	WHO/ICMR Standards	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season
pH	8.5	1.5	1.2	1.4	1.2	1.35	1.2
EC	300	5.335	4.74	6.5	6.167	7.225	5.15
Turbidity	5	2.75	2.66	2.05	3.765	3.015	3.875
Alkalinity	120	54.845	58.85	47.12	53.18	61	64.45
TSS	500	27.44	31.46	25.61	36.825	35.81	35.455
TDS	500	271.48	232.64	191.785	316.78	265.34	351.185
Total Hardness	300	159.07	75.24	71.01	87.57	121.205	95.625
Ca	75	58.625	73.875	47.91	61.545	62.125	62.245
Mg	50	24.6	31.645	17	31.24	31.2	48.62
Phosphate	0.3	0.615	0.76	0.525	0.83	0.685	0.66
Nitrate	10	3.125	4.345	2.15	3.345	3.25	4.75
Sulphate	150	78.26	71.545	75.135	75.56	82.13	92.525
Chloride	250	7.65	8.15	8.2	9.325	12.745	14.64
Fluoride	1.5	0.265	0.325	0.17	0.245	0.215	0.25
BOD	5	2.755	2.855	2.64	3.78	2.865	2.75
DO	5	5.185	5.255	5.32	6.3	5.045	5.52
	F1	18.75		12.5		12.5	
	F2	15.625		12.5		12.5	
	F3	16.4853122		8.153307438		7.504648855	
	WQI	85.451818		88.76020972		88.91184727	

Estimation of drinking water quality is suitable condition among emerging community health problems in this background where accessibility of secure water is at danger unpaid to normal & manmade actions.[31] Table 2 is outcome of CCME water quality index of borehole water collected for analysis in 3 selected communities under song Local Government area, Adamawa State.

Hardness is measure of ability of water to cause precipitation of insoluble calcium & magnesium salts of higher fatty acids from soap solutions. Principal hardness causing ions are Calcium, Magnesium Bicarbonate, Carbonate, Chloride & Sulphate.[32] Total hardness concentration of this study were found to increase with increase in concentration of calcium and magnesium for most season for well water and river water except for borehole water.

From outcomes, it can be seen that concentrations of respective parameters are below WHO/ICMR standards as shown in Table 2 except for phosphate 0.615, 0.76, 0.525, 0.83, 0.685, 0.66 mg/kg for wet and dry seasons of Mboi, Dumne and Zumo respectively which exceed the standard limit of 0.3 mg/kg and dissolved oxygen values of 5.185, 5.255, 5.32, 6.3, 5.045, 5.52 mg/kg for both seasons of Mboi, Dumne and Zumo stations respectively which exceed the standard limit of 5.0 mg/kg.

From the above result, the WQI for Mboi, Dumne and Zumo Borehole water are 85.45, 88.76 and 88.91 respectively. Water quality index shows quality of water in terms of index number which represents overall quality of water for any intended use which agrees with result obtained using weighted method by 32 with indices ranging from 38.52 to 48.67 for borehole water. Outcomes shows that distinguish water samples analysed from borehole water are safe for human consumption & for other domestic purposes based on CCME rankings. Total outcome of this study is contrary to results obtained by[9] whose findings revealed that 67 % of areas & water investigated were found to be very poor & categorized as unsuitable for drinking.

In contradiction to research of,[22] rainy season has lower concentration of dissolved oxygen in water compared to dry season.

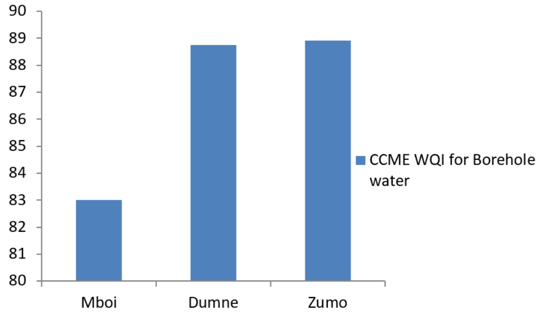

Fig 2: CCME WQI for Borehole water

Water Quality Index of Well Water

Results of water quality index of Mboi, Dumne and Zumo, Song well water is presented in Table 3 below

Table 3: Results of Water quality index of Mboi, Dumne & Well Water

Parameters	WHO/ICMR Standards	Mboi Station Wet Season	Mboi Station Dry Season	Dumne Station Wet Season	Dumne Station Dry Season	Zumo Station Wet Season	Zumo Station Dry Season
pH	8.5	1.4	1.1	1.4	1.2	1.25	1.2
EC	300	5.45	4.84	6.87	5.28	8.8	5.73
Turbidity	5	3.12	3.555	2.95	2.85	3.285	3.915
Alkalinity	120	81.345	74.35	61.23	65.655	69.045	71.23
TSS	500	42.115	46.26	36.115	51.785	46.04	46.62
TDS	500	378.455	382.52	298.41	431.76	395.885	428.145
Total Hardness	300	344.24	368.615	285.445	320.125	371.45	396.515
Ca	75	91.215	92.44	70.005	61.545	84.225	81.845
Mg	50	37.34	44.315	23.99	37.225	33.92	41.06
Phosphate	0.3	0.74	0.825	0.465	0.765	0.925	0.965
Nitrate	10	4.19	4.565	2.965	3.56	3.115	3.22
Sulphate	150	91.33	96.16	87.345	87.65	95	95.855
Chloride	250	33.13	33.89	18.34	26.45	29.025	31.62
Fluoride	1.5	0.26	0.345	0.19	0.25	0.225	0.45
BOD	5	3.125	3.325	2.975	3.015	3.215	3.43

DO	5	4.975	5.255	5.035	5.15	4.855	4.835
	F1	25		18.75		18.75	
	F2	21.875		15.625		18.75	
	F3	11.33912554		21.7043974		13.68649045	
	WQI	79.73374167		85.42502		82.7711747	

From the results in Table 3, it is clear that some parameters such as total hardness of all samples and season exceed the limit, 300 mg/kg except the value for Dumne during the wet season which is 285.445 mg/kg. For calcium concentration, Dumne is below the standard limit, 70.005 and 61.545 mg/kg respectively for the wet & dry season, compared to other two locations that have values above 75 mg/kg. For phosphate, all the values across the three locations and seasons exceed the standard limit of 0.3 mg/kg. For dissolved oxygen, all the parameters from other locations have their values exceeding the standard limits, 5 mg/kg except the values obtained from Mboi during dry season (4.975 mg/kg) and the values obtained from Zumo, 4.855 and 4.835 mg/kg which are below the standard limit compared to other. The WQI was determined to be 79.73, 85.43 and 82.77 respectively for Mboi, Dumne and Zumo Well water. Outcomes show that distinguish water samples analysed from well water are safe for human consumption & for other domestic purposes based on CCME rankings. The result obtained from this research shows the drinking well water of Mboi, Dumne and Zumo are safe for consumption, contrary to the state of drinking water in rural Bangladesh which are poor, very poor and unsuitable for drinking[9] but agrees with the findings of[30] on Weishui Reservoir with CCME WQI of 80.46, indicating that water quality will be stable in future.

Total hardness concentration of this study were found to upsurge with increase in concentration of calcium & magnesium for most season for well water and river water except for borehole water except in Dumne and Zumo during dry season where a deviation in this respect was observed.

In contradiction to the research of,[22] the rainy season has a lower concentration of dissolved oxygen in water compared to dry season except in Zumo whose dissolved oxygen concentration during dry season appeared to be less than the rainy. This is because dissolved Oxygen depends on the temperature.

Water Quality Index of River Water

Results of water quality index of Mboi, Dumne and Zumo, Song river water is presented in Table 4 below

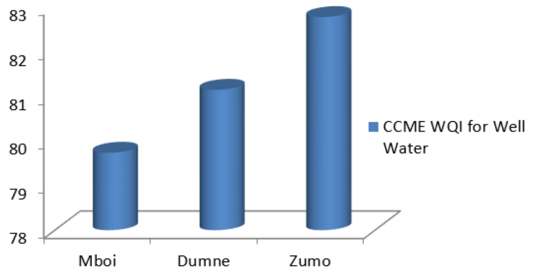

Fig 3: CCME WQI for well water

Table 4: Results of Water quality index of Mboi, Dumne and Zumo Well Water

		Mboi Station		**Dumne Station**		**Zumo Station**	
Parameters	**WHO/ICMR Standards**	**Wet Season**	**Dry Season**	**Wet Season**	**Dry Season**	**Wet Season**	**Dry Season**
pH	8.5	1.55	1.2	1.9	1.4	1.1	0.86
EC	300	4.595	3.51	2299	851.8	11.57	10.61
Turbidity	5	3.29	3.015	3.005	3.645	3.42	4
Alkalinity	120	48.345	66.77	49.175	51	52.12	58.42
TSS	500	51.925	47.675	41.84	41.835	48.825	49.125
TDS	500	411.285	515.335	318.335	449.345	430.515	511.64

Total Hardness	300	319.34	267.545	265.94	239.13	348.165	297.35
Ca	75	129.015	109.24	92.34	92.82	98.125	122.225
Mg	50	52.125	36.545	32.03	34.12	39.23	22.655
Phosphate	0.3	0.47	0.845	0.4	0.56	0.42	0.615
Nitrate	10	2.87	3.115	2.615	3.15	2.365	2.665
Sulphate	150	122.325	76.66	79.055	71.255	105.555	88.925
Chloride	250	37.34	33.62	26.455	41.225	34.92	29.545
Fluoride	1.5	0	0.175	0.14	0.165	0.025	0.0325
BOD	5	1.95	2.05	2.025	2.14	1.895	2.45
DO	5	7.36	8.825	7.315	7.445	7.615	7.775
	F1	37.5		25		31.25	
	F2	28.125		21.875		25	
	F3	13.36061451		12.23290462		10.23800113	
	WQI	71.85803234		79.56120435		76.14991768	

From the results, the concentrations of the respective parameters for total dissolved solids during dry seasons for Mboi and Zumo are 515.335 and 511.64 mg/kg respectively are above the WHO/ ICMR standards limit of 500 mg/kg as shown in Table 4. For total hardness, Mboi and Zumo during wet seasons have values of 319.34 and 348.165 mg/kg which are slightly above the standard limit of 300 mg/kg. For phosphate, dissolved oxygen and calcium, all the parameters of samples analysed were above the standard limit of 0.3 mg/kg, 5 mg/ kg & 75 mg/kg respectively for both seasons. For magnesium concentration, the value for Mboi during wet season was found only to be 52.125 mg/kg which is slightly above the standard limit of 50 mg/kg. On the other hand, in contradiction to the research of,[22] the rainy season has a lower concentration of dissolved oxygen in water compared to dry season. Total hardness concentration of this study were found to increase with increase in concentration of calcium and magnesium for most season for well water and river water except for borehole water except in Dumne and Zumo during dry season where a deviation in this respect was observed. On the other hand, this research agrees with,[30] with corresponding increase in concentration of biochemical oxygen demand as dissolved oxygen concentration increases

With respect to the reasonable concentration of magnesium concentration compared to the standard limit in all the water samples investigated, this is possibly reason for high concentration of calcium in samples investigated & it agrees with the submission of,[32] that magnesium is often associated with calcium in all kinds of water. Magnesium is essential for chlorophyll growth & acts as limiting factor for growth of phytoplankton. Therefore, depletion of magnesium reduces number of phytoplankton's population.

WQI for Mboi, Dumne and Zumo river water are 71.85, 79.56 and 76.15 respectively as shown in Table 4. Outcomes show that WQI of water samples analysed from river water is occasionally protected but sometimes threatened, a condition shown by deviation from the desirable. This could be as a result of intermittent human & industrial activities in area. This index shows that river water from these locations are not reliably fit for human consumption & for other domestic purposes based on CCME rankings. This result is disagrees with the one obtained by[32] with values of tested stream water ranging from 63.76 to 84.94 using the Weighted Arithmetic index method which indicates that stream water is poor & unsafe for human consumption.

Table 2, 3 & 4 shows water quality index of borehole, well & river water in Mboi, Dumne & Zumo in Song Local Government Area of Adamawa respectively. WQI values for borehole, well were found to be between. 71 and 89, this shows that the water sources are safe and good for consumption.[33]

With respect to low pH of all the three water sources analyzed, according to,[37] this might be as a result of decomposition of organic matter w ithin water bodies which are accompanied by releases carbon dioxide, which combines with water to form carbonic acid. Also, presence of some metals such as aluminum, copper & zinc as well as acidifying substances in earth such as calcium oxide & sodium carbonates creates low water pH as water passes over them. Although carbonic acid is weak acid, large amounts of it will drop pH. In their research,[38] reported clearly that there is generally narrow range in pH values between twenty samples of sachet water types analysed. Similarly[37] investigated pH level of drinking water supply in Omoku, Nigeria found that water was slightly acidic (low pH) with private borehole water having least pH. Researchers warn that low pH turns water into toxic solution, & it is also more attractive to heavy metals in human body.[40] Other possible causes of low pH can be attributed to acid rain, released rocks & soils that contain tetraoxosulphate (vi) acid from mining activities, fertilizers & agrochemicals used in farming activities.

EC is measure of liquid capacity to conduct electric charge. Its ability depends on dissolved ion concentrations, ionic strength, & temperature of measurements. Dissolved ions concentration is usually measured as TDS.[42] Measurement of electrical conductivity always gives pollution level & purity of water.[39] Electrical conductivity of water estimates total amount of solids in water.[41] Electrical conductivity of 3 water samples were far below standard acceptable value. According to,[38] there is no health standard guideline with conductivity, hence, EC has no direct adverse effects to human health in study area, as values in sachet water are within permissible limit set by WHO.

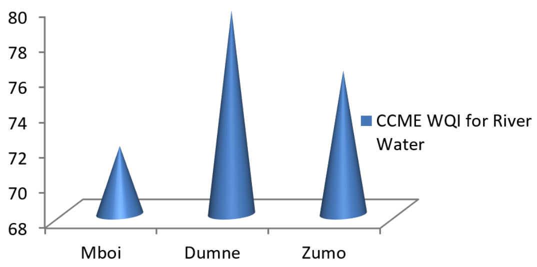

Fig 4: CCME WQI for River Water

Conclusion

The physicochemical parameters determined for borehole water samples were all found to be within acceptable values recommended by WHO & ICMR for Mboi during wet season with exception of dry season for TSS. For Dumne and Zumo water samples, all the parameters were below standard limit for both seasons. However, Phosphate & Dissolved oxygen concentration for borehole water sample for the three sample areas were above the recommended standard values.

For well water across the three study areas, the following physicochemical parameters; temperature, EC, TDS, magnesium, turbidity, TSS, alkalinity, chloride, nitrate, fluoride, BOD, pH and sulphate were all within the standard permissible limits. However, for Mboi, total hardness, calcium for both seasons and dissolved oxygen for dry season exceed the standard limit. For Dumne well water sample, total hardness for dry and dissolved oxygen exceeded the standard value but calcium for both seasons were within limit. For Zumo water sample, total hardness and calcium concentrations exceed the standard limit while the dissolved oxygen concentration for both seasons were within the permissible standard values. Phosphate concentration in the three study areas exceeded the standard value.

For river water across the three study areas, the concentrations of the following physicochemical parameters; temperature, turbidity, total suspended solids, alkalinity, chloride, nitrate, fluoride, Biological Oxygen Demand, pH and sulphate were within the standard values. However, for Mboi water sample, total dissolved solids for dry season, total hardness during wet season, magnesium during wet season and dissolved oxygen for both seasons exceeded the standard limits. For Dumne water sample, electrical conductivity for both seasons exceeded the standard limit while for Zumo river water sample, total dissolved solids for dry season, total hardness for wet season exceeded the standard value. For both seasons across the three study areas, Mboi, Dumne and Zumo, the calcium, phosphate and dissolved oxygen concentrations exceeded the standard permissible limits. Based on outcomes of this research, , it was concluded that drinking water of the study areas are good for drinking, this is as a result of physicochemical parameters in all water samples analyzed were consistent with World Health Organization standard for drinking water (WHO). Samples were analyzed for purpose of establishing a scientific proof that the drinkable water sources from Mboi, Dumne and Zumo are of quality and hence, safe for consumption. The high values and or exceeded concentration of calcium in all analyzed water sample is indication that it's a good source of calcium, an element with significance for strong bone and teeth formation. Dissolved oxygen is indicator of water quality. Due to high dissolved oxygen concentration of the water, it will be good for fish farming business. This will create job opportunities and income for the youths in these communities. Dissolved oxygen analysis measures amount of gaseous oxygen (O_2) dissolved in aqueous solution. Dissolved Oxygen (DO) is crucial parameter which is essential to metabolism of all aquatic organisms that possess aerobic respiration.[32] Amount that can be held by water depends on several factors like temperature, salinity, pressure, pH etc.[34] Three water samples (borehole, well & river) showed a very high dissolved oxygen concentration, an indication of availability of oxygen in these water sources capable of supporting life, e.g. aquatic animals.

Based on water quality indices of water samples analyzed which did not go below 70, it is concluded that all borehole, well & river water samples analysed in this research are fit & suitable for drinking & for usage in other domestic applications.

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Conflict of interest
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