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ORIGINAL RESEARCH ARTICLE

Evaluation of Quality Index of Borehole Water in Marmara and New Site Communities of Wukari, Nigeria

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ABSTRACT

The fitness of groundwater has continued to deteriorate due to increasing population, commercialization, and urbanization, among others. Water quality can be assessed on physical, chemical and biological basis. This study evaluates the physicochemical properties and quality index of borehole water in Marmara and New site community of Wukari Local Government area using standard procedure. Result showed that the mean pH, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), alkalinity, Biological Oxygen Demand (BOD) and nitrates were 6.6 and 6.9; 111.6 and 385 mg/L; 34.6 and 33.4 mg/L; 102.4 and 150 mg/L; 21.69 and 8.42 mg/L; 31.51 and 16.85 mg/L; 8.98 to 18.30 mg/L for Marmara and New site borehole water samples respectively and are within the permissible limit of the World Health Organization. Marmara recorded the highest pH, temperature, dissolved oxygen, TDS, alkalinity and nitrate while New site had higher total suspended solids, COD and BOD. WQI values of 86.03 and 80.22 were obtained in borehole water sourced from New site and Marmara respectively, rating the quality of borehole water in this study good and, on further purification, can serve for drinking and other domestic applications.

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INTRODUCTION

Water is a valuable resource and a primary constituent of the ecosystem, specifically in the form of rivers, lakes, glaciers, rainwater, groundwater etc. Besides the desire of water for drinking, water resource is critical in diverse sectors of the economy ranging from agriculture, animal production, forestry, commerce, hydropower generation, fisheries, and different innovative activities. The availability of potable water is becoming scarce due to the ever-growing population, industrialization, and urbanization. The quality of any given water may be assessed through the usage of physical, chemical, and biological parameters. Their values are dangerous for human fitness if they are above the restricted requirement set by standard organizations (WHO, 2012; USEPA, 2013).

Recently, the suitability of water resources for usage has been defined in terms of the "water quality index" (WQI) to aid in formulating and modifying policies by various environmental monitoring agencies. The introduction of WQI has become more beneficial than using individual water quality parameters to explain water quality (Bharti and Katyal, 2011; Uddin *et al.*, 2021).

The goal of WQI is to describe water fitness using a single numerical value, thereby decreasing the quantity of individual parameters to be employed when defining water quality and easing the interpretation of data (Singh *et al.,* 2013). This approach also reduces the bulk of information from the individual water quality variables into a single data to express water quality status of specific areas based on the types of quality parameters peculiar to that locality compared with established standards particular to the region. WQI are efficiently employed to monitor annual cycles, spatial and temporal changes in water quality and variations in water composition even at low concentrations (Uddin *et al.*, 2021).

Apart from the challenges of water availability, continuous discharge of sewage and pollutants into available water has reduced the amount of usable water as most surface and groundwater are being labelled

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polluted (Singh *et al.*, 2013).

Since the problem of water contamination and toxicity has increased consistently, the need to assess water quality for diverse purposes is necessary. Poor water quality has been reportedly linked to lack of fitness and general well-being. Secondly, water is one of the most used daily (USEPA, 2013). For instance, a high nitrate content beyond the National Drinking Water Quality Standard (2004) have been reported in a number of hands dug wells within the densely part of Wukari metropolis (Oyatayo *et al.*, 2015). High nitrate levels in water may be attributed to the infiltration of sewages of humans and animals from septic tanks and drainages since most boreholes are situated very close to human settlements (Shigut *et al.*, 2017). As well as anthropogenic activities like fertilizer application and leaching of the applied fertilizer into underground water resulting in changes of physiochemical parameters of water contrary to the widely held theoretical view of groundwater being the "safest" (Yakubu *et al.*, 2015; Yerima *et al.*, 2022). The need to evaluate water quality on regular basis to ensure societal welfare becomes a necessity.

This study aims to evaluate the quality index of borehole water in Marmara and the New site community of the Wukari Local Government area and compare the physicochemical parameters of the borehole water with that of the standard (WHO and USEPA). The study also provides baseline information about the water quality since it has not been reported before and this may also help in future water resource planning for the area.

MATERIALS AND METHODS

Study Area

The study area was the Wukari Local Government area located in Taraba state, Nigeria, at 7.89°N and longitude 9.78°E of the equator with a topography of 189 m above sea level; covering an area of 4,308Km^2 (Oko *et al.*, 2017).

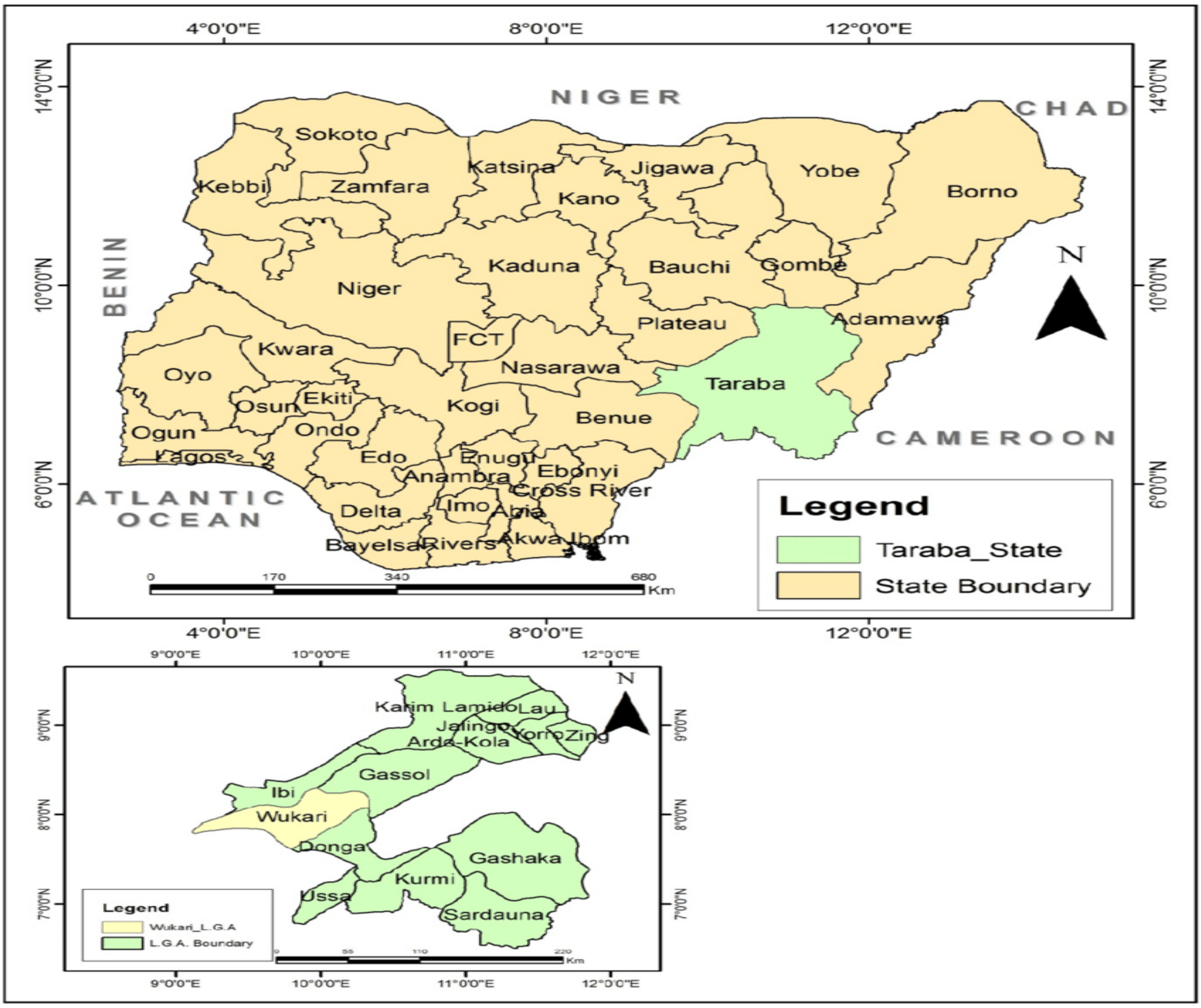

Figure 1: Map of Nigeria and Taraba State showing Wukari local Government Area. Adopted from Ministry of Land and Survey, Jalingo, Taraba State (Oyatayo *et al.*, 2015).

The primary occupation of the inhabitants is agriculture. Major cash crops produced include yam, maize, millet, rice, sorghum, cassava and other tree crops like mango, cashew, oranges and also rearing of animals which include cattle, sheep, goats, pigs and poultry with a land mass area of 4,308km^2 and a population of 241,546 people with a projected growth rate of 3.8% per annum based on the 2006 census. The town has been known for water scarcity until recently when the problem was tackle to some extent with the extensive drilling of boreholes within the town.

Like most parts of northeast Nigeria, Wukari has two seasons, dry and rainy. The dry season ranges from November to March while the rainy season ranges from April to November with an average rainfall value range from 1000 – 1500 mm, with the highest annual rainfall around July, August and September (Oyatayo *et al.*, 2015).

Sample Collection and Preparations

Ten water samples from boreholes within the geographical coordinate presented in Table 1; where five borehole water samples were collected from the Marmara community labelled M1 to M5 and five from New-site community labelled N1 to N5 both in Wukari, Nigeria. The sample collection was carried out at noon in the month of February 2022 using 750 mL capacity polyethylene bottles. Prior to collection, the bottles were thoroughly washed and doubly rinsed with deionized water in the laboratory before sample filling. Samples were immediately place in ice coolers packed with ice before transporting to the laboratory for physicochemical examinations (APHA, 2005; Shigut *et al.,* 2017). After which analysis was carried out for various water quality parameters such as pH, temperature, Dissolved Oxygen (DO), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), alkalinity, Biological Oxygen Demand (BOD) and nitrates.

Table 1: Sampling location and geographical coordinate

Sample	Geographical Coordinate	Location
M_1	7°5200.52748N, 9°4650.55168E	Hashumu mai kifi
M_2	7°5147.99337N, 9°4651.43004E	Kwararafa hospital
M_3	7°5110.20759N, 9°4746.1405E	Marmara primary school
M_4	7°5153.7239N, 9°4642.52204E	Gidan Eze
M_5	7°5140.97375N, 9°4751.5505E	Shamsun dan giwa
N_1	7°5124.21863N, 9°4729.82961E	INEC office
N_2	7°5115.61631N, 9°4741.08094E	Maman Habu
N_3	7°5110.20759N, 9°4746.1405E	Best rider
N_4	7°5115.53734N, 9°4656.8789E	Checkpoint
N_5	7°5112.41006N, 9°4781.25135E	Emokene rice mill

M = Marmara community, N = New site

Determination of Physicochemical Parameters

Analysis of water quality parameters in terms of pH, temperature, dissolved oxygen, total dissolved solids, total suspended solids, alkalinity, nitrate, BOD and COD were carried out according to standard operating procedure (APHA, 2005; APHA, 2012; Raji *et al.*, 2019). All the instruments employed were calibrated within good accuracy and precision limits. All reagents were of analytical grade. Quantifications were carried out in triplicate to minimise error due to variation (Rangeti *et al.*, 2015).

Potential Hydrogen (pH)

The pH values of the water were determined electromagnetically with a multi-parameter data logger instrument with a pH probe. The instrument was switched on and equilibrated for at least 15 minutes. The sensor probe was then rinsed in fresh distilled water and insert in the water sample to be analyzed, the instrument automatically displayed the pH reading after they were activated (APHA, 2012; Raji *et al.*, 2019).

Temperature

The temperature was *in-situ*, employing a moveable thermometer by inserting the instrument into the sample and recording the constant value (Skandaraja, 2015).

Dissolved Oxygen

The dissolved oxygen was estimated by titrimetric method founded by Winkler, where 1mL of $MgSO_4$ solution was added to 200 mL in a BOD bottle before 1mL of azide reagent and the resulting mixture was titrated with 0.025N $Na_2S_2O_3$ using starch indicator. Dissolved oxygen is equivalent to titre value (APHA, 2012; Raji *et al.*, 2019).

Total Dissolved Solids

Total dissolved solids were estimated by subtracting the suspended solids' values from the samples' corresponding total solids (Reda, 2016).

Total Suspended Solids

Total suspended solid was estimated by Hartley funnel fitted with filter paper were 100 mL of distilled water was dried in an oven at 105°C for one hour, cooled in desiccator, and the weight of its residue was obtained and labelled $W1$. The same procedure was repeated on the water sample obtained from the study area and its weight recorded as $W2$. Total suspended solid was calculated using the equation:

$$W_2 - W_1 \times 1000 \text{ mg/L}$$

Alkalinity

Alkalinity values were obtained by titrimetric methods where 50 mL of the water samples were titrated with 0.05M H_2SO_4 using phenolphthalein to indicate a colourless solution at the endpoint. The resulting solution at end point was further titrated with 0.05M H_2SO_4 using methyl orange indicator until orange red solution was obtained at end point and alkalinity calculated (APHA, 2012; Raji *et al.*, 2019).

Biochemical Oxygen Demand

The titrimetric method founded by Winkler was utilize to estimated biochemical oxygen demand. The differences in dissolved oxygen content of water sample before and after incubation at 20°C for five days in the dark using BOD bottle was obtained as biochemical oxygen demand.

Chemical Oxygen Demand (COD)

The COD was determined by adding 10 mL $K_2Cr_2O_7$ alongside 1 g of $HgSO_4$ and antibumping beads to water sample from the study area (50mL) in a reflux flask and mixed thoroughly. After which concentrated H_2SO_4 (10mL) containing Ag_2SO_4 was added gently to the mixture while swirling and refluxed for 1 hour then allowed to cool. At this point, the mixture was removed and diluted with deionized water to 150mL. The resulting solution (50mL) was titrated against standard ferrous ammonium sulphate using ferroin as indicator to an endpoint signal by the change of blue-greenish colour of ferrous ammonium sulphate to reddish-brown (APHA, 2012; Raji *et al*., 2019).

Determination of Nitrate

Nitrate content was estimated by colorimetric analysis where 10mL of 13N H_2SO_4 was added to the water sample (10mL) in a 50 mL volumetric flask while swirling and cooled to (0 - 10)^{o}C in an ice bath. At this point, 0.5mL of brucine-sulfanilic acid was added to the resulting mixture and diluted to the 50 mL mark with distilled water before refluxing at 100^{o}C for about 25 minutes for maximum colour formation; the flask was then cooled to 25^{o}C. The absorbance was read at the wavelength of 410nm (APHA, 2012; Raji *et al*., 2019).

Water Quality index Determination

First, the water quality parameters (Qp) were calculated using the expression below described by Sarita and Brahmaji-Rao, (2020).

$$Q_p = \sum_{p=1}^{n} \left(\frac{A_p - I_p}{S - I_p} \right) \times 100$$

Where: Ap is the average value of the parameters obtained under laboratory conditions, S is the standard permissible value set by recognized regulatory bodies, and Ip is the ideal parameter value. All ideal values (Ip) were taken to be zero except that of pH =7 (Uddin *et al*., 2021). The unit weight is then estimated by calculating the reciprocal value of the standard permissible value S for each parameter under consideration. The water quality index, therefore, is determined by aggregating the products of the parameter qualities and the unit weights and dividing them by the aggregate of the unit weights.

$$\mathrm{WQI} = \frac{\sum_{p=1}^{n} Q_P W_p}{\sum_{p=1}^{n} W_p}$$

Table 2: Inferential for water quality index

Range	Inference
91-100	Excellent
71-90	Good
51-70	Medium
26-50	Bad
0-25	Very bad

Source: (UNEP, 2007; Uddin *et al*., 2021).

RESULTS AND DISCUSSION

Physicochemical Characteristics of the Water Samples

The physicochemical characteristics of borehole water samples sourced from Marmara and New site communities of Wukari Local Government Area are presented in Table 3. The mean pH, temperature, DO, TDS, TSS, alkalinity, BOD and nitrates were 6.6 and 6.9; 35.54 and 35.68^{o}C; 3.06 and 3.24 (ppm); 111.6 and 385 (mg/L); 34.6 and 33.4 (mg/L); 102.4 and 150 (mg/L); 21.696 and 8.428 (mg/L); 31.512 and 16.856 (mg/L) and 8.98 to 18.304 (mg/L) for Marmara and New site borehole water samples respectively.

The result of the physicochemical characteristics of the borehole water samples showed a variable level of pH, temperature, DO, TDS, alkalinity, BOD and nitrates, which were all within permissible limits. However, the TSS was found to be higher than the permissible limit.

Table 3: Physicochemical Composition of Borehole Water from New site and Marmara and Communities of Wukari and Standard Recommendations

Parameters	Marmara	New site	WHO	USEPA	NSDWQ
pH	6.9±0.3	6.6±0.18	6.5-8.5	6.5-8.5	6.5-8.5
Temperature (^{o}C)	35.68±0.04	35.54±0.04	25	20-3	20-30
Dissolved Oxygen (mg/L)	3.24±0.26	3.06±0.23	5–7	3	5
Total Dissolved Solids (mg/L)	385.0±92.87	111.60±4.27	1000	500	500
Total Suspended Solids (mg/L)	33.40±16.40	34.60±16.56	150	50	25
Alkalinity (mg/L)	150±32	102.40±16.51	500	100	150
COD (mg/L)	8.42±2.94	21.69±10.50	250	250	50
BOD (mg/L)	16.85±5.89	31.51±17.86	100	50	100
Nitrate (mg/L)	18.30±3.50	8.98±0.65	45	10	50

Values are mean ± standard deviation, (n=5), WHO = World Health Organization, USEPA= United State Environmental Protection Agency, NSDWQ = National Drinking Water Quality Standard

pH Value

The pH influences the aesthetic fitness of water in terms of taste (WHO, 2008). It also determines if water is corrosive, the lower the pH, the more acidic the water becomes. In this study, pH values were 6.60 and 6.97 for borehole water samples analyzed in the New site and Marmara, respectively. The borehole sample in the New site was more acidic compared to Marmara and was similar to the 6.60 pH value found in borehole water at Wuryo, Gassol local government area, Taraba state (Adelola *et al*., 2015). However, the pH values of borehole water samples in both communities were within the recommended range of 6.50 to 8.50 (WHO, 2008; NDWQS, 2004; USEPA, 2013). The slightly acidic pH of the samples is more desirable since it may not impart a bitter taste to the water arising from alkalinity (WHO, 2008).

Temperature

The temperatures of the borehole water samples were 35.54^{o}C and 35.68^{o}C with respect to Marmara and the New site. The temperature values of all the samples were higher than 27.90 ^{O}C mean temperature found in boreholes water at Gassol LGA during the month of November (Adelola *et al*., 2015) as well as the permissible limit of 25°C (WHO 2008, USEPA, 2013). This may be attributed to the underground water's ambient temperature and the sampling time.

Dissolved Oxygen (DO)

Dissolved oxygen indicates health status of water, for instance low dissolved oxygen level in water indicates microbial contamination or corrosion of chemical substances in water (Chapman and Kimstach, 1996). The dissolved oxygen level of the borehole water samples was 3.06 mg/L and 3.24 mg/L for New site and Marmara respectively. The highest dissolved oxygen value was observed in borehole water samples sourced from Marmara. From the analyzed result, all water samples recorded dissolved oxygen values lower than the acceptable limit of WHO standard for drinking water, 5–7mg/L (WHO, 2008) but higher than the 3.0mg/L limit of United States Environmental Protection Agency (USEPA, 2013). Oko *et al.* (2017) reported a higher result, where the DO of borehole water varied from 3.90 to 4.70 mg/L in Rafin-kada community of Wukari, Nigeria.

Total Dissolved Solids (TDS)

Total dissolved solids are the amount of mobile charged ions, including minerals, salts, or dissolved metals in a given volume of water in mg/L. In this study, the TDS of borehole water samples was found to be highest in Marmara (385 mg/L) and lowest in New site (111.6 mg/L). TDS in borehole water sourced from Marmara was higher than the 328.2 mg/L found in hand-dug well in Sabon-gari, Zaria (Yakubu *et al*., 2017). However, TDS of all the water samples analyzed were within the 1000 mg/L recommended standards for drinking water set by the World Health Organization (2008) as well as the 500 mg/L limit of United State Environmental Protection Agency (NDWQS, 2004; USEPA, 2013).

The TDS of the water sample sourced from agreed with the 146mg/L to 467mg/L reported in groundwater around Singrauli Coalfield areas, Singrauli district of Madhya Pradesh, India (Sonkar and Jama, 2019). High level may occur due to the dissolution of weathered materials from geological formations and urban run-off (Etim *et al*., 2013; John *et al*., 2014).

Total Suspended Solids (TSS)

Total suspended solids are the dry-weight of insoluble suspended particles in a given water sample and are usually greater than 2 microns. The total suspended solids (TSS) obtained from the borehole water samples were 33.400 and 34.600mg/L for Marmara and New site respectively. The TSS of both samples were two times more than the 15.44 mg/L found in drinking water sourced from Secha, Sikela and Arbaminch, Ethopia (Reda, 2016). Even though, borehole water samples from the New site showed a slightly higher TSS than that from Marmara. Higher TSS could be as a result of decrease in the amount of soluble minerals in the borehole water samples. However, the result of this study showed that the TSS was about four times lower than 150 mg/L (WHO, 2012) but higher than the permissible limit of 25 mg/L (NDWQS, 2004) for drinking water.

Alkalinity

The alkalinity of water is due to the presence of carbonates, bicarbonates and hydroxides. The mean alkalinity content of the borehole water samples was 150 mg/L and 102.4 mg/L for Marmara and New site communities with the highest alkalinity recorded in Marmara. The values were more than 5 fold higher than the total alkalinity values of 12.33 to 29.99mg/L found in boreholes and hand-dug wells in University of Lagos and its environs (Aina and Oshunrinade, 2016) but lower than the permissible limit of 500 mg/L for drinking water (NDWQS, 2004; WHO, 2012).

Chemical Oxygen Demand

The COD of the borehole water sample was higher in New site (21.69 mg/L) and lower in Marmara (8.428 mg/L). Onwughara *et al.* (2013) reported lower COD values in borehole water samples in Umuahia (3.61 to 5.64 mg/L). The result of this study showed that the COD were lower than the permissible limit of 250 mg/L (WHO, 2012; USEPA, 2013) and 50 mg/L for drinking water (NDWQS, 2004).

Biochemical Oxygen Demand

The biochemical oxygen demand measures the amount of organics whose presence in water will deplete oxygen level in that water sample. Biochemical oxygen demand (BOD) is one of the parameters used in the evaluation of pollution in water (Etim *et al*., 2013). The BOD levels in this study are within the acceptable limit for all the water samples analyzed. The values were 16.856 and 31.512 mg/L for Marmara and the New site, respectively, where the value recorded for the New site was about twice that of Marmara but less than the 100mg/L guideline set by WHO and 50mg/L by USEPA (WHO, 2012; USEPA, 2013). Yakubu *et al.* (2015) reported a lower BOD value of 14.2, 13.6 and 15.1 mg/L in small, medium and large well within Sabon-gari, Zaria.

Nitrates

Nitrate levels in water may be attributed to the infiltration of sewages of humans and animals from septic tanks and drainages since most boreholes are situated very close to human settlements. The assertion correlates with the 18.30 mg/L nitrate level found in borehole water samples within Marmara a densely populated community compared with the 8.980 mg/L content found in New site a less densely populated settlement. The values were all less than the 36.52 to 56.32 mg/L nitrate content found in hand dug wells within Wukari town (Oyatayo *et al.*, 2015). Likewise the mean nitrate content were within the permissible limit of less than 40 mg/L set by WHO (2012) and 50 mg/L set by NDWQS (2004) in drinking water. However, the nitrate level of borehole water in Marmara (18.30 mg/L) supersedes the United States Environmental Protection Agency's 10mg/L limit set for nitrates in drinking water (USEPA, 2013).

Table 4: **Water quality index of borehole water collected from Marmara, Wukari**

Parameters	Marmara	Standard permissible level	Ideal value	Unit weight (W)	Q-rating	Q x W
pH	6.9	8.5	7	0.1176	106.66	12.54
Temperature (C)	35.680	25	0	0.04	142.72	5.708
Dissolved Oxygen (ppm)	3.24	7	0	0.1429	46.29	6.614
Total Dissolved Solids (mg/L)	385	500	0	0.002	77	0.154
Total Suspended Solids (mg/L)	33.4	25	0	0.04	133.6	5.344
Alkalinity (mg/L)	150	500	0	0.002	30	0.060
COD (mg/L)	8.428	50	0	0.02	16.86	0.337
BOD (mg/L)	16.856	100	0	0.01	16.86	0.168
Nitrate (mg/L)	18.304	50	0	0.02	36.61	0.732
				0.3945		**31.65**

Where: $\mathrm{WQI} = \frac{\sum QW}{\sum W} = \frac{31.65}{0.3945} = 80.22$

Table 5: **Water quality index of borehole water collected from New site, Wukari**

Parameters	New site	Standard Permissible level	Ideal value	Unit weight (W)	Q-rating	Q x W
pH	6.60	8.5	7	0.1176	126.66	14.89
Temperature (C)	35.54	25	0	0.0400	142.16	5.68
Dissolved Oxygen (ppm)	3.06	7	0	0.1429	43.71	6.24
Total Dissolved Solids (mg/L)	111.60	500	0	0.0020	22.32	0.04
Total Suspended Solids (mg/L)	34.60	25	0	0.0400	138.4	5.53
Alkalinity (mg/L)	102.40	500	0	0.0020	20.48	0.04
COD (mg/L)	21.69	50	0	0.0200	43.38	0.86
BOD (mg/L)	31.51	100	0	0.0100	31.50	0.31
Nitrate (mg/L)	8.98	50	0	0.0200	17.96	0.35
				0.3945		33.94

Where: $\mathrm{WQI} = \frac{\sum QW}{\sum W} = \frac{33.94}{0.3945} = 86.03$

Quality Index of the Borehole Water Samples

The water quality index indicates the overall fitness of water (Etim *et al.*, 2013). In this study, the WQI was estimated by integrating the pH value of the water, its temperature, total alkalinity, nitrate, dissolved oxygen, biochemical oxygen demand, total dissolved solids and total suspended solids and nitrates.

The results obtained for the WQI from the different sampling points were found to be 80.22 and 86.03 for borehole water sourced from Marmara and New site, respectively. The results indicate that the water sample from both Marmara and New site rating is good and can be improved on further purification (UNEP, 2007; Uddin *et al.*, 2021).

CONCLUSION

This study was conducted to ascertain the quality index of borehole water in Marmara and New site communities of Wukari, Nigeria. Seven out of the nine physiochemical parameters assessed were within standard permissible limit. From the use of the water quality index to ascertain the quality of borehole water in the communities under consideration, it is concluded that water sample from both Marmara and New site fitness rating is good and can be improved on further purification to serve as potable water for drinking and various domestic purposes.

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