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GROUNDWATER QUALITY ASSESSMENT USING WATER QUALITY INDEX IN GOMBE TOWN, GOMBE STATE, NIGERIA

[*1]Sulaiman, M. B., [2]Yahaya, Y., [3]Gimba, A. M.

[1]Department of Pure and Industrial Chemistry, University of Nigeria, Nsukka, Enugu State, Nigeria

[2]Department of Pure and Industrial Chemistry, Kebbi State University of Science and Technology, Alero, Kebbi State, Nigeria

[3]Department of Chemistry, Gombe State Polytechnic, Bajoga, Gombe State, Nigeria

[*] Corresponding Author: sulaimanmuhammadbashir@gmail.com

ABSTRACT

This study assessed water quality of groundwater in Gombe town, Gombe State, Nigeria, using the water quality index (WQI). 60 groundwater samples were collected from 10 different boreholes during the dry and rainy seasons from 2018 to 2019, and were analyzed for ten physicochemical characteristics. The results of physicochemical characteristics ranged from 6.55 to 6.93 (pH), 99.89 to 131.01 µS/cm electrical conductivity (EC), 5.09 to 5.89 mg/L dissolved oxygen (DO), 0.07 to 0.09 mg/L biochemical oxygen demand (BOD), 0.77 to 0.91 mg/L total suspended solid (TSS), 42.01 to 48.89 mg/L total dissolved solid (TDS), 0.00 to 0.01 mg/L nitrate (NO_3), 4.07 to 4.51 mg/L sulphate (SO_4), 4.78 to 6.66 mg/L chloride (Cl) and 0.13 to 0.36 mg/L fluoride (F) during dry season, while during rainy season, the results were, pH : 7.51 to 7.98, EC: 65.95 to 83.57 µS/cm, DO: 5.15 to 6.03 mg/L, BOD: 0.10 to 0.11 mg/L, TSS: 0.98 to 1.03 mg/L, TDS: 50.10 to 59.00, NO_3: 0.00 to 0.03 mg/L, SO_4: 3.78 to 4.03 mg/L, Cl: 3.78 to 6.01 mg/L and F: 0.08 to 0.12 mg/L. The results revealed that all the studied parameters were within permissible limits based on standards of the World Health Organization (WHO), and the Nigerian Standard for Drinking Water Quality (NSDWQ). However, the results showed a significant increase in values of DO, BOD, TSS, TDS and NO_3 during the rainy season compared to the dry season. The calculated values of WQI ranged between 17.30 to 25.87 during the dry season; and 19.93 to 22.49 during the rainy season. These indicate that all the studied samples are classified as “excellent” water quality for drinking purposes.

Keywords: Assessment, Groundwater, Physicochemical, Water Quality Index

INTRODUCTION

Water is the basic need for living organisms and considered as the most important valuable and natural resource that forms about 80% constituent of the ecosystem [1]. It is an essential component of life, consumed daily for domestic, industrial and agricultural purposes. The availability of good quality water is a crucial aspect for preventing diseases and improving quality of life [2]. It is therefore understandable that water is one of the prime elements responsible for life on earth. However, increase in industrialization, urbanization and agricultural activities during the recent years have deteriorated the quality of surface and groundwater [3]. Deterioration of water quality (surface and groundwater) arises from introduction of foreign compounds into the water supply system through the cross connection and water sources [4].

Groundwater remains a major source of water supply for domestic and industrial purposes in most of the Nigerian cities due to an increased demand for water supply in almost all parts of Nigeria [5]. Contamination of this groundwater has severe implications for public health, particularly in small communities and developing countries like Nigeria, where groundwater is often the preferred source of drinking water [6]. These contaminants are introduced into the water bodies through several ways, which include, leaching from dumpsite soils, weathering of rocks, dissolution of aerosol particles from the atmosphere, mining, processing and the use of metal-based materials [7]. According to some studies, about 80% of all human health issues are caused by water [8].

The adverse health effects of water contaminants are due to their toxic properties, bioaccumulation tendencies and non-biodegradable nature [9]. It is therefore, necessary to assess the water quality for public health and for aquatic life [10]. The Water Quality Index can be applied to assess the quality of major water supply sources representing the level of pollution [11]. It used to indicate the overall quality of waters in terms of single value at a certain location and time, based on several water quality parameters [12]. The aim of this present study is to determine the physicochemical characteristics and assess the quality of groundwater from Gombe town using Water Quality Index .

MATERIALS AND METHODS

Study area

The study area is Gombe town, Gombe state capital, lying between latitude 10°15′N and longitude 11°10′E (Fig.1). The study area covers a total land area of 52 km^2, north east Nigeria.

It is characterized with warm and averagely humid during the wet season. It is characterized by a tropical climate with two distinct seasons; a rainy season and a dry/harmattan season, May-October and November-April respectively, with the annual mean of temperature 28.5 ^{o}C, and annual mean of rainfall 902 mm [13]. The relative humidity ranged from 70% to 80% in August and decrease to 15 to 20% in December [14].

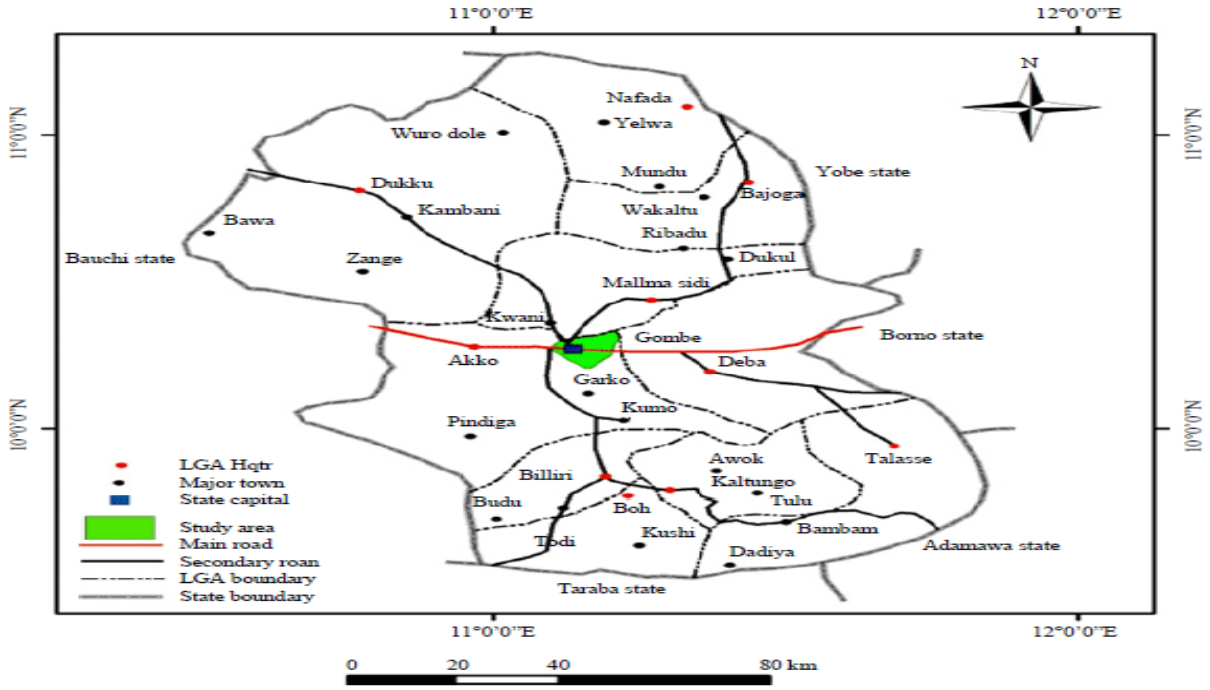

Fig. 1: Map of the Study area

Sampling and sample analysis

A total of 60 water samples were collected from 10 different boreholes at two different sampling periods at interval of two month for 12 months. Sampling was undertaken during the rainy season (November 2018 to March 2019), while during the dry season (May to September 2019). Groundwater samples from the boreholes were collected in clean sterilized 500 mL sterile bottles. At the sampling points, the sample containers were rinsed with the borehole water before filling them with the sample. The collected water samples were labeled and thereafter refrigerated at 4 °C in the laboratory prior to analyses.

The physico-chemical Characteristics of the water samples were analyzed are as follows; pH and Electrical conductivity (EC), were directly measured on site using a portable multipurpose field meter WTW pH Electrode. Chlorides (Cl^{-}) Dissolved oxygen (DO) and Biological oxygen demand (BOD) were determined by titrimetric method. Total dissolved solids (TDS) and Total

suspended solids (TSS) were determined gravimetrically. Nitrate (NO_3) and sulphate (SO_4) were calorimetrically analysed using DR890 Colorimeter [1].

Statistical Analysis

Descriptive statistics, such as mean and standard deviation (SD) were analyzed using SPSS version 20 for Windows. The mean values and analysis of variance (ANOVA) were determined. Dunnet post hoc test used to show where significant differences existed.

Water Quality Index Assessment

The assessment of water quality index in this study was determined using ten parameters. The WQI was assessed based on the standards of drinking water quality recommended by the World Health Organization, [15] and the Nigerian Standard for Drinking Water Quality, [16].

The weighted arithmetic index method of Brown [17], was used for the calculation of WQI of the water samples.

The quality rating (Qn) was calculated using the following expression.

$$Qn = \frac{100\,[Vn - Vo]}{[Sn - Vo]} \qquad \text{Eq (1).}$$

Where; Qn =· Quality rating for the Water quality, Vn =· Estimated value of a given water sample, Sn =· Standard permissible value, Vo =· Ideal value in pure water (0 for all other parameters except the parameters pH = 7.0 and Dissolved oxygen (DO =14.6 mg/L).

The unit weight (Wn) was calculated by a value inversely proportional to the recommended standard value Sn of the corresponding parameter, as shown below in the following expression.

$$Wn = \frac{K}{Sn} \qquad \text{Eq (2).}$$

Where; Wn =· unit weight, Sn =· standard permissible value, K =· constant of proportionality.

The overall water quality index was calculated using the following expression.

$$WQI = \frac{\sum QnWn}{\sum Wn} \qquad \text{Eq (3).}$$

The suitability of WQI values for human consumption was according to [1, 18], rated as follows; (0-25) Excellent, (26-50) Good, (51-75) Bad, (76-100) Very Bad (>100) Unfit for drinking.

Table 1: Drinking water standards and unit weights for WQI determination

S/No.	Parameters	Standard permissible level (Sn)	Ideal value (Vo)	Unit weight (Wn)
1	Ph	[ab]6.5-8.5	7.00	0.1176
2	EC µS/cm	[ab]1000	0.00	0.0010
3	DO mg/L	[a]5	14.6	0.2000
4	BOD mg/L	[a]5	0.00	0.2000
5	TSS mg/L	[a]500	0.00	0.0020
6	TDS mg/L	[ab]500	0.00	0.0020
7	NO3 mg/L	[ab]50	0.00	0.0200
8	SO_4 mg/L	[b]100	0.00	0.0100
9	Cl mg/L	[ab]250	0.00	0.0040
10	F mg/L	[b]1.5	0.00	0.6666

[a] Values are given by World Health Organization
[b] Values are given by Nigerian Standard for Drinking Water Quality (NSDWQ)

RESULTS AND DISCUSSION

The concentration (mean ± standard deviation) of the physicochemical characteristics of 10 groundwater samples during dry and rainy seasons is presented in Table 2. pH is an important parameter that can be used to assess water quality application and extent of contamination in water bodies [1, 19]. The results of pH in all the sampling points ranged from 6.55 to 6.93 during dry season, while in rainy season, pH ranged from 7.51 to 7.98. The recorded values of pH were significantly greater during rainy season compared with dry season ($p < 0.05$). This observation may due to the surface run off from storm water to increased infiltration of aquifers. In general, the values of pH obtained in this study were within the WHO and NSDWQ standards of 6.5-8.5. The mean values of electrical conductivity in all the sampling points ranged from 99.89 to 131.01 µS/cm during dry season, while 65.95 to 83.57 µS/cm during rainy season. The increase in electrical conductivity in dry season may be due to a decrease in water content. Similar studies recorded lower electrical conductivity values in groundwater in Enugu north district [20], in groundwater samples in Obio Akpor, River State [21] and in groundwater in Yola [22]. The higher dissolved oxygen in water is essential or many aquatic organisms; it affects the solubility of the majority of the nutrients in an aquatic ecosystem [23]. The recorded value of dissolved oxygen in this study ranged from 5.09 to 5.89 mg/L during dry season, while it ranged from 5.15 to 6.03 mg/L during rainy season. This observation is similar to the findings of Sulaiman *et al.* [1] and Mustapha *et al.* [24] as reported in their studies. The Biochemical oxygen demand is a parameter used to assess the organic load in water bodies [1]. The BOD

concentration ranged from 0.07 to 0.09 mg/L during dry, while it ranged from 0.10 to 0.11 mg/L during rainy season. The results of this study were found to be below the permissible limit set by WHO (5 mg/L). The results obtained in the study were similar to the findings reported by Etim *et al.* [25]. The Total suspended solid are solids that can be filtered out on an asbestos mat or filter papers, i.e, suspended solids are non filterable solids and also measures the physical observable dirtiness of a water resource [26]. The TSS obtained in this study ranged from 0.77 to 0.91 mg/L during dry season, while 0.98 to 1.03 mg/L during rainy season. The Total dissolved solids is the amount of dissolved substances in the water. The total dissolved solids in this study ranged from 42.01 to 48.89 mg/L during the dry season, while during rainy season it ranged from 50.10 to 59.00 mg/L. These indicate an increase in total dissolved solid in the rainy season water samples which may be due to increase in the concentration of soluble species from the environment entering the water body. This observation is in line with what was reported by Sulaiman *et al.* [26], and Olatunji *et al.* [27]. The results obtained in both season were below the recommended limit by WHO and NSDWQ (500 mg/L). The higher content of nitrate ion in water causes methaemoglobinaemia in infants less than 6 months old [28]. The mean values of nitrate in this study ranged from 0.00 to 0.01 mg/L during dry season, while it was 0.00 to 0.03 mg/L during rainy season, and were all found to be below the permissible limit of (50 m/L) set by WHO and NSDWQ. This is similar to the findings reported by Ahmed *et al.* [29]. The concentrations of sulphate in the water samples ranged from 4.07 to 4.51 mg/L during dry season, while it was 3.78 to 4.03 mg/L during rainy season. The mean values of sulphate in the water samples collected sources were quite below (250 mg/L) recommended limits set by WHO and NSDWQ. The chloride concentration of 250 mg/L and above, impart a particular taste to water and Chlorides are mineral salts and therefore are not affected by biological actions [26]. In this study, the content of chloride ion ranged from 4.78 to 6.66 mg/L during dry season, while it was 3.78 to 6.01 during rainy season. Thus the water from all samples recorded low levels of chloride, and there was within permissible limit recommended by the WHO and NSDWQ (250 mg/L) for drinking water. The recorded values in this study were lower than those reported by Odiba *et al.* [30]. The mean values of fluoride in the water samples ranged from 0.13 to 0.36 mg/L during dry season, while it was 0.08 to 0.12 mg/L during rainy season, and were all found to be below the standard permissible limit recommended by the WHO (75 mg/L) for drinking water.

Table 2**:** Physico-chemical characteristic of groundwater samples in Gombe town during dry and rainy seasons

	Dry season									
Locations	**pH**	**EC**	**DO**	**BOD**	**TSS**	**TDS**	**NO_3**	**SO_4**	**Cl**	**F**
BH_1	6.66± 0.01	105.10±0.05	5.65±0.04	0.09±0.0	0.83±0.08	45.87±008	0.01±0.0	4.51±0.05	6.33±0.0	0.08±0.04
BH_2	6.83±0/03	110.03±0.10	5.51±0.03	0.08±0.0	0.87±0.06	48.89±0.0	BDL	4.31±0.04	6.65±0.0	0.10±0.03
BH_3	6.84±0.02	103.13±0.09	5.23±0.04	0.07±0.0	0.79±0.06	48.01±0.0	0.01±0.0	4.51±0.04	4.89±0.0	0.09±0.02
BH_4	6.93± 0.01	102.05±0.07	5.31±0.02	0.09±0.0	0.80±0.07	41.87±0.0	0.01±0.0	4.11±0.03	4.78±0.0	0.06±0.02
BH_5	6.55±0.05	100.31±.011	5.33±0.03	0.08±0.1	0.91±0.09	45.88±0.0	BDL	4.13±0.05	6.66±0.0	0.06±0.03
BH_6	6.67±0.01	131.01±0.08	5.09±0.03	0.07±0.1	0.89±0.08	47.00±0.0	BDL	4.09±0.03	6.71±0.0	0.07±0.04
BH_7	6.70±0.07	109.10±0.07	5.13±0.04	0.08±0.1	0.88±0.08	47.18±0.0	BDL	4.07±0.03	4.98±0.0	0.09±0.04
BH_8	6.63±0.08	120.20±0.09	5.89±0.02	0.09±0.1	0.78±0.07	48.89±0.0	BDL	4.09±0.04	5.53±0.0	0.11±0.03
BH_9	6.65±.0.08	99.890±0.09	5.78±0.02	0.07±0.0	0.77±0.04	46.58±0.0	BDL	4.11±0.02	5.87±0.0	0.12±0.02
BH_{10}	6.58±0.07	113.51±0.08	5.53±0.04	0.08±0.0	0.87±0.05	42.01±0.0	BDL	4.25±0.04	4.96±0.0	0.08±0.02
	Rainy season									
BH_1	7.58±0.05	78.53±0.07	6.01±0.02	0.10±0.0	1.02±0.09	57.71±0.0	0.03±0.0	3.83±0.03	4.54±0.0	0.08±0.03
BH_2	7.60±0.03	83.57±0.08	5.76±0.02	0.11±0.0	0.98±0.09	51.81±0.0	0.01±0.0	4.03±0.03	5.35±0.0	0.10±0.02
BH_3	7.59±0.02	69.87±0.08	5.53±0.03	0.10±0.0	1.01±0.07	50.04±0.0	0.02±0.0	4.13±0.02	3.87±0.0	0.09±0.04
BH_4	7.63±0.02	65.95±0.07	5.94±0.02	0.10±0.0	1.00±0.08	56.89±0.0	0.02±0.0	3.97±0.04	3.83±0.0	0.06±0.05
BH_5	7.98±0.01	71.04±0.06	5.69±0.04	0.10±0.0	1.03±0.05	57.37±0.0	0.02±0.0	3.78±0.04	6.01±0.0	0.06±0.04
BH_6	7.64±0.02	81.01±0.06	5.15±0.02	0.11±0.0	1.02±0.07	58.39±0.0	0.01±0.0	3.88±0.03	6.00±0.0	0.07±0.03
BH_7	7.51±0.07	70.63±0.05	6.03±0.03	0.11±0.0	1.02±0.06	59.00±0.0	0.02±0.0	3.93±0.02	3.78±0.0	0.09±0.02
BH_8	7.58±0.04	68.35±0.04	6.00±0.03	0.11±0.0	1.01±0.07	50.10±0.0	0.01±0.0	4.01±0.04	4.03±0.0	0.11±0.04
BH_9	7.73±0.03	71.81±0.06	6.01±0.04	0.11±0.0	1.00±0.07	58.17±0.0	0.01±0.0	4.00±0.04	4.00±0.0	0.12±0.05
BH_{10}	7.65±0.01	80.05±0.05	5.78±0.02	0.10±0.7	1.03±0.08	51.15±0.0	0.01±0.0	4.02±0.03	3.98±0.0	0.08±0.02

All the parameter in mg/L except pH and EC (µS/cm), BDL= Below detectable limit

Table 3: Water Quality Index (WQI) and ratings of the groundwater samples

Locations	WQI (dry season)	Quality rating	WQI (rainy season)	Quality rating
BH_1	16.938	Excellent	20.208	Excellent
BH_2	24.159	Excellent	21.431	Excellent
BH_3	22.064	Excellent	21.367	Excellent
BH_4	19.401	Excellent	19.938	Excellent
BH_5	17.438	Excellent	22.387	Excellent
BH_6	20.925	Excellent	21.627	Excellent
BH_7	22.381	Excellent	20.131	Excellent
BH_8	23.158	Excellent	21.267	Excellent
BH_9	25.878	Excellent	22.490	Excellent
BH_{10}	17.300	Excellent	20.991	Excellent

The WQI values for all water samples for each season are presented in Table 3. In the present study, the WQI was calculated twice for each season. The results of WQI obtained from the different season ranged from 17.30 to 25.87 in dry season and 19.93 to 22.49 in rainy season, the index values revealed that the status of the water samples was in excellent in ranking. Base on the WQI, the groundwater samples are suitable for consumption and other domestic purposes.

CONCLUSION

This study was conducted to assess the water quality of groundwater in Gombe town. The results of this study revealed a significant difference in the quality of groundwater samples studied in dry and rainy season. The Water Quality Index of the water samples study ranged from 17.30 to 25.87 in dry season and 19.93 to 22.49 in rainy season. In both seasons, the calculated WQI revealed that the status of water samples was excellent in ranking. Therefore the groundwater samples are suitable for consumption and other domestic purposes.

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