Seasonal Assessment of Underground Water Quality

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Abstract: ***Levels of physiochemical parameters and heavy metals in water collected in dry and wet seasons from some boreholes in Wamba Area of Nasarawa state, Nigeria were assessed. Physicochemical parameters were determined using standard methods. Metal concentrations were quantified using atomic absorption spectrometer (AAS). Physicochemical quality index (WQI) and metal pollution index (HQI) were also determined. Water pH was slightly alkaline for both seasons.Highest levels of total solids (405.33±1.0 mg/l), electrical conductivity (526±0.00), total alkalinity (225.00±1.0 mg/l) and total dissolved solids (315.00±0.00 mg/l) were recorded in BH_3, while total dissolved solids and total solids were highest in BH_4 (93.00±1.0 mg/l and BH_5 (22.00±1.41 mg/l) respectively in dry season. Levels of most physicochemical parameters were significantly ($P \leq 0.05$) higher in the dry season. Concentrations of Al (0.07±0.003 mg/l), Cd (0.04±0.00 mg/l) and Cu (0.14±0.00 mg/l) were highest in BH_1 in dry season. Concentration of Zn was the highest in the boreholes, while Fe and Pb were recorded at low levels. Concentrations of Cd (0.80±0.01 mg/l), Cu (15.40±19.20 mg/l) and Fe (0.01±0.00 mg/l) were significantly ($P \leq 0.05$) higher in the wet season. Physicochemical quality index (WQI) and heavy metal pollution index (HQI) show that water from the boreholes were unpolluted.***

Keywords: Quality indices,water, borehole, heavy metals, physicochemical parameters

1. Introduction

One of the most important environmental issues today is groundwater contamination [1]. Among contaminants affecting water resources, heavy metals receive particular concern considering their strong toxicity, even at low concentration [2]. Heavy metals are elements with atomic weight between 63.596 and 200.590, and specific gravity 4.0 at least 5 times than that of water [3].Heavy metals can be emitted into the environment from natural and anthropogenic sources. Anthropogenic sources include, mining, indiscriminate disposal of treated and untreated effluent containing toxic metal, as well as metal from tannery, steel plant, battery industries and thermal power plant [4]. The major source is chemical pollution by agrochemical industry and the public dumping of toxic household waste in landfills.

Heavy metals exist in water as colloidal, particulates and dissolved phases. Metals in water bodies are of either of natural or anthropogenic origin [2]. Some of the metals are essential in sustaining life. For instance, calcium, magnesium, potassium and sodium must be present as nutrients for normal body function. Also, copper, iron, molybdenum and zinc are needed at low level as catalyst for enzyme activities. However, excess exposure to some of these metals may result to toxicity. Heavy metals can cause health effect with varying symptoms depending on the nature and quantity of the metal ingested [5]. They produce their toxicity by forming complexes with proteins involving carboxylic acid (-COOH), amino ($-NH_2$), and thiol (-SH) groups. When metals bind to these groups, they inactivate important enzyme systems or affect protein structure, which is linked to the catalytic properties of enzymes. Sometimes they cause the formation of radicals which oxidizes biological molecules, thereby modifying them, subsequently, affecting their ability to function properly, which may result to malfunction or death of the cell [6].

The levels of heavy metals and physico-chemical parameters of ground water vary [7]. These parameters changes widely due to pollution types and seasonal fluctuations, hence a continuous monitoring of ground water becomes necessary in order to minimize the ground water pollution, and have control on the pollution caused agents [8]. The research was therefore carried out to assess the quality of water from some boreholes and wells in residential areas.

2. Materials and Methods

2.1 Study Area

Wamba with Head Quarter at Wamba town (Fig. 1) is one of the thirteen (13) Local Government Areas in Nasarawa State. It shares common boundaries with Bokkos Local Government Area of Plateau State to the East, Akwanga Local Government of Nasarawa State to the west, Sanga Local Government area of Kaduna State to the South. The Local Government Area is located close to Farin Ruwa falls, one of the highest water falls in Africa [9]. The dry season spans from October to March, while the wet season is from April to September [10]. More than 80% of the inhabitants are predominantly farmers, while few engage in fishing business [7].

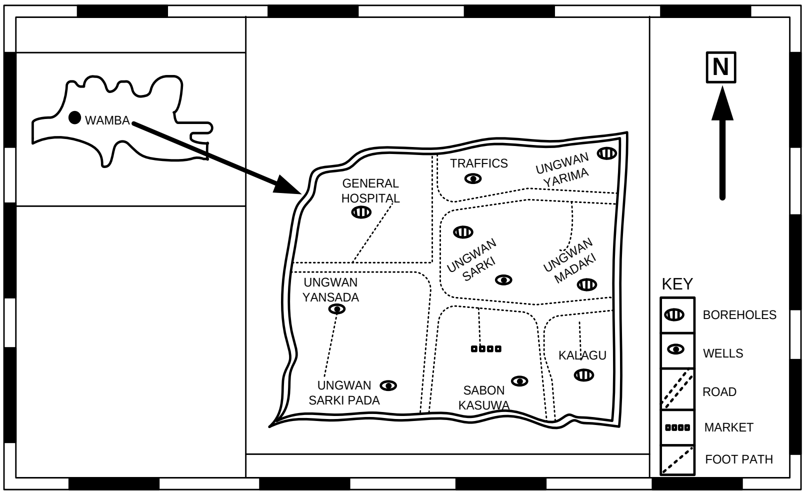

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FIGURE 1. Map of wamba local government showing study area and sampling points.

2.2 Sampling

Borehole and well water samples were collected into four liter plastic containers from five different locations (Fig. 1) in wet (July, 2015) and dry (March, 2011) seasons. Prior to samples collection, the plastic containers were rinsed three times with the water sample, tightly covered, and labeled appropriately, and then put in an ice-parked cooler and transported immediately to the laboratory for further analysis [11]. The water samples were then preserved at low temperature (4 ^{0}C) to prevent deterioration due to microorganisms.

2.3 Determination of physicochemical properties

Temperature, pH, electrical conductivity, and total dissolved solids were determined immediately using Jelway multi - purpose portable meter model 430, while dissolved oxygen (DO) was determined with the aid of Bicotek Portable DO analyzer (model JPB – 607A) at the point of sampling. Other physico-chemical parameters were also analyzed using standard method of water examinations [12].

2.4 Water Digestion

Concentrated hydrochloric acid (5 cm^3) was added to 250 cm^3 of the water sample, evaporated to 25 cm^3 on the hotplate and transferred into 50 cm^3 standard flask, and then filled up to mark with de –ionized water. Heavy metal concentrations were quantified using Graphite Atomic Absorption Spectrometer (GAAS model AA 990).

2.5 Determination of water physicochemical quality index (WQI)

The method involves calculating the quality parameter (QP) first [13].

$$Qp = \sum_{P=1}^{N} \left[\frac{Ap-Ip}{S-Ip}\right] x\ 100 \qquad (1)$$

Where Ap = average value of parameters determined under laboratory condition
S = standard permissible value from recognized organization/bodies.
Ip = Ideal value for the parameter; (All ideal values (Ip) are taken to be zero, except that of pH= 7, DO =14.6 and fluorides =1. The unit weight is calculated by taking the reciprocal value for the standard permissible value for the parameter considered.

The water quality index is then determined by aggregating the products of the parameter quality and the unit weights and dividing by the aggregate of the unit weights.

$$WQ1 = \frac{\sum_{P=1}^{N} QpWp}{\sum_{P=1}^{N} Wp} \qquad (2)$$

Wp = unit weight of parameters

2.6 Determination of heavy metals quality index (HQI)

The HQI represents the total quality of water with respect to heavy metals. The proposed HPI was developed by assigning a rating or weightage (Wi) for each selected parameter. The rating system is an arbitrarily value between zero and one, reflecting the relative importance of individual quality consideration, and can be defined as inversely proportional to the recommended standard (S_i) for each parameter. The standard values for drinking water (S_i) refer to the maximum allowable concentration in drinking water in absence of any alternate water source. The maximum value (I_i) is the ideal value of ith parameter which is determined.

$$HPI = \frac{\sum_{i=1}^{N} WiQi}{\sum_{i=1}^{N} Wi} \qquad (3)$$

Where = Qi = Sub Index of the ith parameter.
Wi = Unit Weightage of the ith parameter.
N = The number of parameters considered.

Weighted arithmetic index method has been used for calculation of HPI. The unit weight (Wi) was calculated as

$$Wi = k/Si \qquad (4)$$

Where k = proportionality constant, Si = standard permissible value of ith parameter.
The Sub – Index (Qi) of the parameter is calculated as

$$Q_i = \sum_{i=1}^{N} \frac{[M_i - I_i]x\ 100}{S_i - I_i} \qquad (5)$$

Where M_i = monitored value of heavy metals of the ith parameter

li = Ideal value of the ith parameter
Si = Standard value of the ith parameter in ppb.

The quantity $[Mi - li]$ indicates numerical difference of two values, ignoring the algebraic sign; that is the absolute value. Generally the critical pollution index of HPI value for drinking water is considered as 100 [14]. In computing the HPI, unit weightage (Wi) was considered as a value inversely proportional to the maximum admissible concentration (MAC) of the corresponding parameter.

3. Statistical Analysis

Statistical techniques employed for the treatment of data for the analysis include mean, standard deviation (SD) and analysis of variations (ANOVA).

4. Results and Discussion

4.1 Physicochemical parameters

The levels of physico-chemical parameters of borehole water for dry and wet season are presented in Tables 1 and 2 respectively. pH values varied from 6.30 $\pm$ 0.00 to 7.70 $\pm$ 0.01 for dry season and 6.73 $\pm$ 0.03 to 7.70 $\pm$ 0.02 in the wet seasons. The highest and lowest pH values were recorded in BH_2 and BH_4 respectively for both seasons. The pH values were similar to pH report for drinking water quality by [15]

Temperature values varied from 3.40 $\pm$ 0.00 to 34.00 $\pm$0.00 ^{0}C and 27.80$\pm$ 0.00 to 31.20 $\pm$0.00 ^{0}C for dry and wet seasons respectively. BH_5 recorded the highest temperature values for the two seasons. The temperature values were slightly higher than the results recorded for a ground water quality in Lagos state, Nigeria [13, 16].

Electrical conductivity values varied from 185.00 $\pm$ 0.10 to 496.00 $\pm$ 0.00 µS/cm and1.88.00 $\pm$ 0.04 to 471.00 $\pm$ 0.10 µS/cm indry and wet season respectively. The highest electrical conductivity values were recorded in BH_1 in dry season and BH_3 in the wet season, while the lowest in levels were obtained in BH_4. The electrical conductivity values recorded were higher than the results reported for physico-chemical analysis in drinking water quality at Jigjiga city, Ethiopia [17]. Generally ground water tends to have high electrical conductivity due to the presence of high amount of dissolved salts. EC is a decisive parameter in determining suitability of water for particular purpose.

Acidity values varied from 28.33 $\pm$ 0.23 to 46.00 $\pm$ 1.41 mg/L and 0.80 $\pm$ 0.00 to 1.80 $\pm$ 0.03mg/L for dry and wet seasons respectively. The highest acidity values were recorded in $BH_{1,}$ irrespective of season. Total solids, total dissolved solids, and total suspended solids levels varied from 196.00$\pm$ 0.00 to 405.33 $\pm$ 1.0 mg/L, 111.20 $\pm$ 0.00 to 315.00 $\pm$ 0.00 mg/L, and 41.00 $\pm$ 0.00 to 90.00 $\pm$ 0.00 mg/L respectively in the dry season. The highest levels of TS and TDS were recorded in BH_3, while the lowest in BH_4. TSS was highest in BH_2 and the lowest in BH_1. The TS, TDS, and TSS levels were lower than the value reported for borehole water in Eyen community [18].

The highest total alkalinity and total hardness values were recorded in BH_2 in the dry season. The total alkalinity values were higher compared to the results reported for drinking water quality at Arbamich town [15], while total hardness levels were lower compared to the results (150-300 mg/L) reported by Soladoye [19].

Dissolved oxygen values varied from 3.85 $\pm$ 0.10 to 5.00 $\pm$ 0.10 mg/L and 4.80 $\pm$ 0.00 to 5.30 $\pm$ 0.10 during dry and wet seasons respectively. The highest and the lowest dissolved oxygen contents obtained during dry and wet periods were recorded in BH_4 and BH_5 respectively.The DO values were within the range (3.20 to 8.40 mg/L) reported for underground water in Lagos Nigeria [20]. The highest BOD values were recorded in BH_4 in dry season. The BOD values were lower compared to the results (4.03 $\pm$ 0.02 to 26.40 $\pm$ 0.72 mg/L) for portable water in Ibadan metropolis [21]. Seasonal mean levels of physico-chemical parameter in borehole water during dry and wet seasons (Tables 3) showed that higher levels were recorded in the dry season. Acidity, TDS, TSS, total alkalinity, total hardness and BOD decreased significantly ($P \leq 0.05$) in the wet season

4.2 Metal concentrations in borehole water

The result for metal concentration in borehole for dry season (Table 4) and wet season (Table 5) show that the highest aluminum value was at BH_2, in dry season, while the highest and lowest levels were recorded in BH_4 and BH_1 respectively for wet period. The values for aluminum were slightly higher than result (0.5 to 1.0 mg/L) reported for ground water [22].

Table 1: Levels of physico-chemical parameters in borehole water in dry season

Parameter	BH_1	BH_2	BH_3	BH_4	BH_5	Mean±SD	CV(%)
pH	7.50±0.01^a	7.70 ±0.01^a	6.90±0.10^a	6.30±0.00^a	7.30±0.00^a	7.14±1.00	14
Temperature (^{o}C)	32.10±0.00^a	31.40±0.00^a	32.50±0.00^a	31.70±0.00^a	34.00±0.20^b	32.34±1.02	3
EC (µS/cm)	496.00±0.00^a	368.00±1.0^b	526.00±0.00^c	185.00±0.10^d	243.00±0.00^d	364.00±153.30	42
Acidity (mg/L)	46.00±1.41^a	46.00±0.00^a	37.00±1.0^b	33.33±1.0^c	28.33±0.23^d	28.13±8.00	21
TS (mg/L)	338.00±0.00^a	311.00±1.0^a	405.33±1.0^b	196.00±0.00^c	213.00±1.0^b	293.00±88.00	30
TDS (mg/L)	297.00±0.00^a	222.00±1.0^a	315.00±0.00^c	111.20±0.00^d	146.00±0.00^e	218.24±90.00	41
TSS	41.00±0.00^a	90.00±0.00^b	89.00±0.00^c	84.80±0.00^d	66.00±0.00^c	74.20±21.00	28
Alkalinity (mg/L)	185.33±1.0^a	316.00±3.0^b	225.00±1.0^c	130.33±2.0^d	132.00±0.00^d	198.00±77.00	39
Hardness (mg/L)	12.63±0.12^a	15.10±0.21^b	13.20±0.42^c	12.90±0.01^a	13.30±0.01^a	13.42±1.00	7
DO (mg/L)	4.73±0.10^a	4.90±0.10^a	3.85±0.10^b	5.00±0.10^c	5.00± 0.10^c	5.00±1.00	20
BOD (mg/L)	3.23±0.10^a	3.40±0.10^a	2.50±0.00^b	3.90±0.10^a	3.70±0.10^a	3.35±1.00	30

BH: Borehole

Table 2: Levels of physico-chemical parameters in borehole water in wet season

Parameter	**BH$_1$**	**BH$_2$**	**BH$_3$**	**BH$_4$**	**BH$_5$**	Mean±SD	CV (%)
pH	7.70±0.01^{a}	7.70±0.02^{a}	7.31±0.002^{a}	6.73±0.03^{b}	7.13±0.01^{a}	7.30±0.30	4
Temperature (^{o}C)	27.80±0.00^{a}	28.73±0.01^{a}	30.78±0.00^{b}	30.53±0.002^{b}	31.20±0.00^{c}	29.80±1.50	5
EC (µS/cm)	471.00±0.10^{a}	342.00±0.10^{b}	541.00±0.10^{c}	188.00±0.04^{d}	242.00±1.41^{d}	357.00±149.00	42
Acidity (mg/L)	1.80±0.03^{a}	1.40. 00±0. 00^{a}	1.20±0.00^{a}	0.80±0.00^{d}	1.20±0.02^{a}	1.30±0.40	31
TS (mg/L)	362.00±0.10^{a}	254.00±0.10^{b}	397.00±0.10^{c}	178.30±0.02^{d}	197.00±0.00^{e}	278.00±88.40	32
TDS (mg/L)	77.30±0.50^{a}	49.00±0.10 ^{b}	90.30±050^{c}	93.00±0.00^{c}	50.00±0.00^{b}	72.00±21.30	30
TSS (mg/L)	18.33±0.20^{a}	19.00±0.00 ^{b}	18.00±0.00^{a}	19.00±0.00^{b}	22.00±1.41^{c}	19.30±2.00	10
Alkalinity (mg/L)	173.00±0.10^{a}	136.30±0.20^{b}	113.00±0.10^{c}	50.00±1.41^{d}	116.30±0.20^{c}	118.00±45.003	8
Hardness (mg/L)	11.42±0.01^{a}	11.34±0.00^{a}	12.10±0.01^{b}	11.10±0.01^{a}	11.40±0.01^{a}	11.50±0.40	4
DO (mg/L)	5.30±0.00^{a}	4.93±0.10^{a}	4.80±0.00^{a}	4.80±0.00^{a}	5.30±0.10^{a}	5.0030	6
BOD (mg/L)	1.60±010^{a}	1.33±0.02^{a}	1.53±0.50^{a}	2.43±002^{b}	1.70±0.10^{a}	1.700.40	24

BH: Borehole

Table 3: Seasonal mean levels of physico-chemical parameters in borehole water

Parameter	Dry season	Rainy season
pH	7.14+1.00^{a}	7.30±0.30^{a}
Temperature (^{o}C)	32.34±1.02^{a}	29.80±1.50^{a}
EC (µS/cm)	346.00±153.30^{a}	357.00±149^{a}
Acidity (mg/L)	28.13±8.00^{a}	1.30±0.40^{b}
TS (mg/L)	293.00±88.00^{a}	278.00±88.40^{a}
TDS (mg/L)	218.24±90.00^{a}	72.00±21.30^{b}
TSS (mg/L)	74.20±21.00^{a}	19.30±2.00^{b}
Alkalinity (mg/L)	198.00±77.00^{a}	118.00±45.00^{b}
Hardness (mg/L)	13.42±1.00^{a}	11.50±0.40^{b}
DO (mg/L)	5.00±1.00^{a}	5.00±0.30^{a}
BOD (mg/L)	3.35±1.00^{a}	1.70±0.40^{b}

Table 4: Concentrations (mg/L) of heavy metals in boreholes water in dry season

Parameter	BH$_1$	BH$_2$	BH$_3$	BH$_4$	BH$_5$	Mean±SD	CV (%)
Al	0.07±0.003^{a}	0.10±0.02^{a}	0.08±0.00^{a}	0.00±0.00^{b}	0.04±0.00^{c}	0.10±0.04	40
Cd	0.04±0.003^{a}	0.02±0.003^{a}	0.02±0.003^{a}	0.03±0.003^{a}	0.02±0.003^{a}	0.03±0.01	33
Cu	0.14±0.00^{a}	0.00±0.00^{b}	0.03±0.00^{c}	0.00±0.00^{b}	0.13±0.003^{a}	0.10±0.004	4
Pb	0.00±0.00^{a}	0.00± 0.00^{a}	0.02±0.003^{a}	0.00±0.00^{a}	0.01±0.003^{a}	0.01±0.01	100
Ni	0.12±0.003^{a}	0.16±0.00^{a}	0.02±0.00^{b}	0.00±0.00^{a}	0.01±0.003^{a}	0.10±0.01	10
Fe	ND	ND	ND	ND	ND	-	-
Zn	0.22±0.003^{a}	0.41±0.003^{b}	0.21±0.003^{a}	0.00±0.00^{c}	0.00±0.00^{c}	0.20±010	50

BH: Borehole, ND: Not detected

Table 5: Concentration (mg/L) of heavy metal in boreholes water in wet seasons

Parameter	**BH$_1$**	**BH$_2$**	**BH$_3$**	**BH$_4$**	**BH$_5$**	Mean±SD	CV (%)
Al	0.02±0.003^{a}	0.10±000^{b}	0.04±0.00^{a}	0.24±0.003^{c}	0.80±0.00^{e}	0.10±0.01	10
Cd	0.65±0.003^{a}	0.69±0.003 ^{a}	0.83±0.003^{a}	0.80±0.003^{a}	0.80±0.00^{a}	0.80±0.01	1
Cu	31.00±0.00^{a}	2.00±0.030^{b}	0.01±0.003^{c}	0.00±0.00^{d}	44.00±0.03^{e}	15.40±19.20	125
Pb	0.21±0.00^{a}	0.20±0.00^{a}	0.19±0.003^{a}	0.20±0.00^{a}	0.22±0.00^{a}	0.20±0.001	1
Ni	0.01±0.00^{a}	0.01± 0.00^{a}	0.01±0.003^{a}	0.00±0.00^{a}	0.00±.00^{a}	0.01±0.00	0
Fe	0.01±0.003^{a}	0.01±0.003^{a}	0.01±0.003^{a}	0.01±0.003^{a}	0.00±0.00^{a}	0.01±0.00	0
Zn	0.10±0.003^{a}	0.01±0.003 ^{a}	0.01±0.003^{a}	0.01±0.003^{a}	0.00±0.00^{a}	0.03±0.004	3

BH: Borehole

Table 6: Seasonal variation in heavy metal concentration (mg/L) in borehole water

Parameter	Dry season	Rainy season
Al	0.1 0± 0.04^{a}	0.10 ± 0.01^{a}
Cd	0.03 ± 0.01^{a}	0.80 ± 0.01^{b}
Cu	0.10 ± 0.004^{a}	15.40 ± 19.20^{b}
Pb	0.01 ± 0.01^{a}	0.20 ± 0.001^{a}
Ni	0.01 ± 0.01^{a}	0.01 ± 0.00^{a}
Fe	0.00±0.00^{a}	0.01 ± 0.00^{b}
Zn	0.20 ± 0.10^{a}	0.03 ± 0.004^{a}

Table 7: Quality indices for borehole water in dry and wet seasons

	Dry Season		**Rainy Season**	
Borehole	WQI	HQI	WQI	HQI
BH$_1$	92.00	0.15	36.50	0.40
BH$_2$	80.50	0.15	33.00	0.40
BH$_3$	83.30	0.20	33.50	0.34
BH$_4$	61.50	0.10	28.40	1.00
BH$_5$	57.50	0.10	36.00	0.00

WQI: Physico-chemical water quality index,
HQI: Heavy metal quality index

Cadmium values varied from 0.02 $\pm$ 0.003 to 0.04 $\pm$ 0.003 mg/L and 0.65 $\pm$ 0.003 to 0.83 $\pm$ 0.003 mg/L for dry and wet season respectively. The highest cadmium value was

recorded in BH_1, while the highest level for wet season was recorded in BH_3 and the lowest in BH_1. The cadmium values were lower compared to the results (0.009 mg/L to 0.446 mg/L) reported for ground water in Kaltungo LGA, Gombe State [23]. The highest copper values were recorded in BH_1in the dry season and in BH_5 in the wet season. The copper values were also lower compared to results (0.031 to 0.596 mg/L) reported in Kaltungo LGA [23].

Lead values varied from 0.00 $\pm$ 0.00 mg/L to 0.02 $\pm$ 0.003 mg/L and 0.19 $\pm$ 0.003 to 0.22 $\pm$ 0.00 mg/L in dry and wet season respectively. The highest lead value in dry season was in BH_3. The highest lead level was recorded in BH_5 (0.22 $\pm$0.00 mg/L) and the lowest was in BH_3 (0.19 $\pm$ 0.003 mg/L) for the wet season. The lead value was lower compared to the results (0.120 to 0.880 mg/L) for ground water in the vicinity of an oil depot in Nigeria [24].

The highest nickel values for dry and wet season were recorded in BH_2 (0.16$\pm$ 0.00 mg/L) and BH_3 (0.01 $\pm$ 0.003 mg/L) respectively. Iron was not detected in dry season, but varied from (0.00 $\pm$ 0.00 to 0.01 $\pm$ 0.003 mg/L) in wet season. The iron values were lower than the ranged (0.695 to 0.979 mg/L) reported for Fe content in Chandormalu underground water resources [25]. The highest zinc concentrations were recorded in BH_2 (0.41 $\pm$ 0.003 mg/L) and in BH_1 (0.10 $\pm$ 0.003 mg/L) in dry and the wet season respectively. The Zn values were lower than the range (0.002 to 0.277 mg/L) reported in drinking water quality in the state of Perak, Malaysia [26].

Seasonal mean concentrations of heavy metals (Table 6) were slightly higher in the wet seasons, except for Ni and Zn. Iron was not detected in dry season. The variation in heavy metal concentrations in the borehole were not significantly different ($P \leq 0.05$), except for Cd, Cu, and Fe. The values recorded were above the WHO [27] standard for drinking water, except for Pb, Fe and Zn.

Borehole water quality indices for dry and wet seasons (Table 7) indicated that WQ1 values varied from 57.50 to 92.00 in dry season, and 28.40 to 36.50 during wet season. The highest WQ1 value was in BH_1 for both periods of analysis. The HPI values varied according to season. The highest HPI value was recorded in BH_1 and the lowest in BH_5 for the wet seasons. WQI values were lower than the average (80.77) reported for groundwater quality in Ilorin metropolis [28]. WQ1 and HPI values were lower compared to the critical pollution index. The greater the pollution index value, the greater threat to human life on consumption of water from such sources.

5. Conclusion

Levels of electrical conductivity, total solid, total dissolved solid and total alkalinity were higher during the dry seasons, while pH, temperature and DO showed a similar trend in both seasons. Acidity, TDS, TSS, total alkalinity, total hardness and BOD levels decreased significantly ($P \leq 0.05$) in the wet season. Metal concentrations were higher in the wet season, except for Al, Ni and Zn. The levels of Cd, Cu and Fe in dry and wet seasons were significantly different ($P \leq 0.05$). WQI and HPI indicated that the water from the boreholes were unpolluted and of better quality in the wet season. The levels of physicochemical parameters and heavy metals were also observed to be within the WHO permissible limits for drinking water.

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