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Physicochemical Studies of Public Hand-Pump Borehole Water in Onueke, Ezza Local Government Area of Ebonyi State, Nigeria

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Abstract: Physicochemical studies were carried out on fifteen public hand–pump borehole water in Onueke, Ezza South Local Government Area of Ebonyi State, Nigeria during the dry and rainy seasons to determine their suitability for drinking using standard physicochemical techniques. The physical characteristics measured were temperature, pH, electrical conductivity, borehole depth, total suspended solids, total dissolved solids and total solids while the chemical characteristics studied were total alkalinity, total hardness, total chlorides, calcium hardness, magnesium hardness, sulphates and nitrates. The heavy metals determined were lead, copper, iron and zinc. The results showed that the water samples complied with theWorld Health Organization Standard for potable water in terms of the physical and chemical characteristics except the pH and total hardness of some of them which were above the permissible limits. In addition, the values for lead during both seasons were above the limit recommendedby regulatory bodies. Correlation analysis showed that the temperature, total chlorides and nitrates were significant ($P<0.05$) indicating that the parameters were affected by seasonal variation. There is the urgent need to treat the affected water from the boreholes to avert any health hazard that might arise from their consumption. Sand filtration, addition of lime as well as periodic physicochemical analysis of the water from such boreholes is recommended.

Keywords: Physicochemical, Characteristics, Public, Hand-Pump, Borehole Water

1. Introduction

Water is one of the most important, precious natural resources that are indispensable to life. It is essential in the life of all living organisms, from the smallest plants and microorganisms, to the most complex living system known as human body [1, 2]. It is significant due to its unique chemical and physical properties [3].

The quality of borehole water is the resultant of all the processes and reactions that act on the water from the moment it condensed in the atmosphere to the time it is discharged by a well or spring and varies from place to place and with the depth of the water table [4]. Borehole water has unique features which render it suitable for public water supply [5]. It is particularly important as it accounts for about 88% safe drinking water in rural areas, where populations are widely dispersed and the infrastructure needed for treatment and transportation of used surface water does not exist [6].

During passage through the ground, water dissolves minerals in rocks, and collects suspended particulate matter particularly those from organic sources as well as pathogenic microorganisms from fecal matters [7]. Major ions in drinking water correlate with palatable mineralization that affects the quality of drinking water [8]. Although some of the heavy metals such as zinc, manganese, nickel and copper act as micro-nutrients at low concentration, health risk due to heavy metals contamination of water through soil has been reported [9]. Some of these toxic heavy metals include lead and chromium [10].

Lead may interfere with the red blood cell chemistry, cause delay in the normal physical and mental development in babies and young children, cause delay in hearing and learning abilities of children and a slight increase in blood pressure in some adults. The presence of chromium in drinking water has been shown to result in chronic toxic effect including liver and kidney damage, internal hemorrhage and respiratory disorders in animals and humans upon ingestion while high levels of nitrate can cause methamoglobinemia or blue baby syndrome. These metal contaminants of underground water may come from natural processes and anthropogenic activities [11]. In addition, rural water may also have excessive amount of nitrate as a result of microbial action on agricultural fertilizers and when ingested, the nitrite compete for oxygen in the blood [12].

Water is one of the most important compounds of the ecosystem but as a result of increased human population, industrialization, application of fertilizers to crops, indiscriminate disposal of untreated refuse and other man made activities, ground water is becoming increasingly polluted with organic and inorganic chemicals which are dangerous to health, hence the necessity to determine the quality of water from boreholes at regular intervals, therefore in this work, the physicochemical characteristics of the public hand-pump borehole water in Onueke, an agrarian community in Ezza South Local Government Area of Ebonyi State, Nigeria were studied.

2. Materials and Methods

2.1. Boreholes Locations

The public hand-pump boreholes used in this work were sited at the following locations in Onueke:

(1) Community Secondary School Amuzu
(2) NteziAmuzu
(3) UBA Road Onueke
(4) Orinte Playground Amuzu
(5) Ndufu Amana Village Square
(6) Ochudo Estate Onueke
(7) Motor Park Onueke
(8) Umuanyingor Ndufu Ezzama
(9) Pie-Junction Ndufu Ezzama
(10)Sacred Heart Parish I Onueke
(11)Sacred Heart Parish II Onueke
(12)Ezza High School Amuzu
(13)Oferekpe Play Square 1 Ezzama
(14)Oferekpe Play SquareII Ezzama
(15)Central School Onueke

2.2. Samples Collection

Water samples were aseptically collected from fifteen public hand-pump boreholes sited by the State Government in different locations in Onueke in Ezza South Local Government Area of Ebonyi state, Nigeria. They were collected using sterile two litre screwed-capped plastic containers. The containers were first washed with detergents and rinsed with sterile distilled water. Each of the well-labeled containers was thereafter rinsed with the water from the respective boreholes three times before collecting the samples for use. The pH and temperature of the water samples were measured at the site of collection using a pH meter and thermometer respectively and transported to the laboratory, where they were analysed physicochemically as done by Onuorah et al [13] within twenty four hours of collection. The boreholes were sampled during the dry (January – March, 2018) and the rainy (April – June, 2018) seasons.

2.3. Determination of the Physical Characteristics

2.3.1. Measurement of Temperature

The temperature of each water sample was measured using a centigrade thermometer. This was done at the point of collection by immersing the thermometer vertically into a beaker containing the water sample. The thermometer was thereafter allowed to stand until the reading stabilized and the value was taken and recorded.

2.3.2. Measurement of pH

The pH of each of the water samples was measured using a pH meter (Jenway). The pH meter was standardized using pH buffers of 4.0 and 7.0. The water sample was introduced into a beaker, the pH meter was switched on and its electrode was lowered into the water sample. The pH value was taken and recorded when the meter reading stabilized.

2.3.3. Measurement of Electrical Conductivity

The electrical conductivity (EC) of each water sample was determined using Aquapro digital water tester conductivity meter. The water sample was introduced into a beaker to the desired mark. The meter was thereafter switched on and allowed to stabilize for five minutes before it was lowered into the sample in the beaker. The electrical conductivity of the sample was read and recorded when the meter reading became stable.

2.3.4. Measurement of Boreholes Depth

The depths of the boreholes from which the samples were collected were obtained from Ebonyi State Rural Urban Water Supply and Sanitation Agency (EB-RUWASSA) which is an agency under Ebonyi State Water Corporation Board responsible for both urban and rural water schemes, especially construction and maintenance.

2.3.5. Measurement of Total Suspended Solids (TSS)

A Whatman filter paper was dried and the weight recorded. It was carefully fitted into a funnel placed in a conical flask. One hundred milliliters of the water sample were passed through the funnel. The filter paper was carefully removed and dried in an oven at 105°C for twenty seconds and allowed to cool after which it was re-weighed.

$$\text{Total suspended solids (mg/l)} = \frac{(A - B) \times 1000}{\text{Volume of sample}}$$

Where A = Weight of filter paper + suspended solids
B = Weight of filter paper
1000= One litre

2.3.6. Measurement of Total Dissolved Solids (TDS)

A clean conical flask was dried at 105°C for thirty-seconds in an oven. It was allowed to cool, then weighed and the value recorded. One hundred milliliters of the water sample were measured and dispensed into the pre-weighed well-labeled conical flask. The flask was evaporated to dryness in an oven and allowed to cool after which it was re-weighed and the weight recorded.

$$\text{Total dissolved solids (mg/l)} = \frac{(A - B) \times 1000}{\text{Volume of sample}}$$

Where A = Weight of filter paper + dissolved solids
B = Weight of filter paper
1000= One litre

2.3.7. Measurement of Total Solids (TS)

Total solids were obtained from the total dissolved solids and total suspended solids.

Total dissolved solids(TDS) + Total suspended solids (TSS) = Total Solids (TS).

2.4. Measurement of Chemical Characteristics

2.4.1. Measurement of Total Alkalinity

One hundred milliliters of the water sample were introduced into a 250ml conical flask. Two drops of bromocresol green indicator solution were added and the mixture was thereafter titrated with 0.02N sulphuric acid till a yellow colour was obtained. The titre value was thereafter recorded.

2.4.2. Measurement of Total Hardness

One hundred milliliters of the water sample were introduced into a 250ml conical flask. 1ml of buffer solution was added to give a pH of 10 and 0.2ml of sulphuric acid was also introduced.0.02ml of Eriochrome Black T indicator solution was added and the mixture was titrated with Ethylenediaminetetraacetic acid (EDTA) till a blue colour was obtained after which the titre value was recorded.

2.4.3. Measurement of Total Chlorides

One hundred milliliters of the water sample were introduced into a 250ml conical flask. 1ml of potassium dichromate indicator solution was added and the mixture was titrated with silver nitrate solution till a reddish brown color was obtained. The titre value was thereafter recorded.

2.4.4. Measurement of Calcium Hardness

One hundred milliliters of the water sample were introduced into a 250ml conical flask. 0.5ml of a mixed indicator which was made up of ammonium purpurate and sodium chloride was added. The pH of the mixture was adjusted to 12.0 with 1ml of sodium hydroxide. The mixture was thereafter titrated with EDTA till a purple colour was observed. The titre value was thereafter recorded.

2.4.5. Measurement of Magnesium Hardness

Magnesium hardness was obtained from the total hardness and calcium hardness.

Magnesium Hardness= Total Hardness – Calcium Hardness x 0.234.

Where 0.234 = constant

2.4.6. Measurement of Sulphates

One hundred milliliters of the water sample were passed through a filter paper. 10ml of barium nitrate were added to the filtered water sample to avoid precipitation. A new filter paper was weighed and the weight recorded. The water containing the barium nitrate was passed through the new filter paper which was later oven-dried at 105°C for 30 seconds and re-weighed.

$$\text{Sulphates (mg/l)} = \frac{(A - B) \times 1000}{\text{Volume of sample}}$$

Where A = weight of filter paper + suspended particles
B = weight of filter paper
1000= one litre

2.4.7. Measurement of Nitrates

Fifty milliliters of the water sample were pipetted into a porcelain dish and evaporated to dryness on a hot water bath. 2ml of disulphonic acid were added to dissolve the residue. Concentrated solution of sodium hydroxide and distilled water were added with stirring to produce an alkaline solution. The solution was filtered into a Nessler'tube and made up to 50ml with distilled water. The absorbance of the solution was read after colour development at 410nm using a spectrophotometer (PD303UV). A standard graph was plotted by placing the concentration along the X-axis and the absorbance along the Y-axis.

$$\text{Nitrates} = \frac{\text{Absorbance of Sample}}{\text{Absorbance of Standard}} \times \text{Concentration of standard}$$

2.4.8. Measurement of Heavy Metals

The heavy metals measured were lead, copper, iron and zinc. The water sample was thoroughly mixed by shaking and one hundred milliliters of it were introduced into a 250ml beaker. The sample was digested using concentrated nitric acid and thereafter filtered into a sample bottle. The digested sample was aspirated into the oxidizing air-acetylene flame and when the aqueous sample was aspirated, the absorbance was read using the varian AA240 Atomic Absorption spectrophotometer.

2.5. Statistical Analysis of Data

The data obtained for both seasons were subjected to correlation analysis using IBM SPSS version 20.

3. Results

The physical characteristics of the public hand-pump borehole water samples during the dry season are presented in Table 1. The temperature values ranged from 29°C to 31°C; pH from 7.2 to 8.8; electrical conductivity from 55µs/cm to 785µs/cm; boreholes depth from 150 to 300 feet; total suspended solids, 0.01 – 0.84mg/l; total dissolved solids, 0.01 – 18.12mg/l while the total solids ranged from 0.04 to 18.30mg/l.

Table 1. *Physical characteristics of the public hand-pump borehole water samples during the dry season.*

Sampleslocation	Temp (°C)	pH	EC (µs/cm)	Boreholes Depth (feet)	TSS (mg/l)	TDS (mg/l)	TS (mg/l)
(a)	31	7.5	55	200	0.20	0.48	0.68
(b)	30	8.0	785	160	0.36	0.84	1.20
(c)	31	8.5	752	300	0.16	1.18	1.34
(d)	29	7.9	402	180	0.09	0.16	0.25
(e)	30	7.8	391	150	0.07	0.11	0.18
(f)	31	7.9	219	160	0.08	0.05	0.13
(g)	30	8.3	643	180	0.03	0.01	0.04
(h)	29	7.6	432	150	0.01	0.75	0.76
(i)	30	8.6	330	170	0.25	0.54	0.79
(j)	29	7.2	91	160	0.24	0.64	0.88
(k)	30	7.9	394	170	0.18	0.41	0.59
(l)	30	8.0	499	160	0.18	18.12	18.30
(m)	29	7.9	369	150	0.25	0.84	1.09
(n)	30	8.8	711	160	0.84	1.64	2.48
(o)	29	8.1	398	170	0.46	1.20	1.66
WHO Standard	25-40	6.5-8.5	1000	-	30	500	100

Temp = Temperature
EC= Electrical Conductivity
TSS= Total Suspended Solids
TDS= Total Dissolved Solids
TS= Total Solids
= No Standard

The physical characteristics of the public hand-pump borehole water samples during the rainy season are shown in Table 2. The temperature values were 28-30°C, pH, 7.5 – 9.0; electrical conductivity, 79 – 802µs/cm; boreholes depth, 150 – 300 feet; total suspended solids, 0.01 – 0.48mg/l; total dissolved solids, 0.00 – 16.16mg/l and total solids, 0.13 – 16.31mg/l.

Table 2. *Physical characteristics of the public hand-pump borehole water samples during the rainy season.*

Samples location	Temp (°C)	pH	EC (us/cm)	Boreholes Depth (feet)	TSS (mg/l)	TDS (mg/l)	TS (mg/l)
(a)	30	7.7	79	200	0.30	0.38	0.68
(b)	29	8.1	802	160	0.18	0.94	1.12
(c)	29	8.7	767	300	0.09	1.04	1.13
(d)	28	8.0	398	180	0.13	0.72	0.85
(e)	28	7.9	400	150	0.12	0.01	0.13
(f)	30	8.1	230	160	0.48	0.61	1.09
(g)	30	8.5	700	180	0.25	0.00	0.25
(h)	29	7.8	515	150	0.15	0.00	0.15
(i)	30	8.7	350	170	0.01	0.55	0.56
(j)	29	7.5	97	160	0.20	0.48	0.68
(k)	29	8.0	420	170	0.24	0.64	0.88
(l)	29	8.2	520	160	0.15	16.16	16.31
(m)	28	8.2	429	150	0.19	0.53	0.72
(n)	29	9.0	773	160	0.26	0.90	1.16
(o)	28	8.4	422	170	0.38	0.64	1.02
WHO Standard	25-40	6.5-8.5	1000	-	30	500	100

Temp = Temperature
EC= Electrical Conductivity
TSS= Total Suspended Solids
TDS= Total Dissolved Solids
TS= Total Solids
= No Standard

The chemical characteristics of the public hand-pump borehole water samples during the dry season are shown in Table 3. Total alkalinity values were 5-38mg/l; total hardness, 10-248mg/l; total chlorides, 11.0–50.65mg/l; calcium hardness, 0.06–0.67mg/l; magnesium hardness, 2.41-60.67mg/l; sulphates, 0.12–2.28mg/l and nitrates, 2.13–8.37mg/l.

Table 3. *Chemical characteristics of the public hand-pump borehole water samples during the dry season.*

Samples location	Total alkalinity (mg/l)	Total hardness (mg/l)	Total chlorides (mg/l)	Calcium hardness (mg/l)	Magnesium hardness (mg/l)	Sulphates (mg/l)	Nitrates (mg/l)
(a)	17	34	20.52	0.06	8.25	0.82	2.33
(b)	14	230	15.15	0.67	55.72	0.40	4.45
(c)	27	204	47.55	0.57	49.43	0.98	4.17
(d)	5	144	14.52	0.55	34.86	0.94	4.29
(e)	17	66	17.52	0.09	16.02	0.80	8.37
(f)	38	218	50.65	0.59	52.83	0.12	4.46
(g)	13	52	17.52	0.09	12.61	1.04	3.52
(h)	26	224	15.52	0.45	54.32	0.78	2.13
(i)	16	228	11.00	0.65	55.25	0.94	4.23
(j)	34	140	21.52	0.37	33.93	0.16	4.56
(k)	9	18	17.52	0.10	4.35	0.34	6.31
(l)	26	248	49.55	0.46	60.67	0.98	7.92
(m)	16	10	17.52	0.09	2.41	0.88	6.50
(n)	17	142	29.53	0.42	34.40	0.84	8.19
(o)	24	170	18.52	0.53	41.18	2.28	6.47
WHOStandard	250	100	250	75	150	100	10

The chemical characteristics of the public hand –pump water samples during the rainy season are presented in Table 4. Total alkalinity values were 5 - 39mg/l; total hardness, 10-246mg/l; total chlorides, 10.51-50.56mg/l;calcium hardness, 0.06 – 0.69mg/l; magnesium hardness, 2.41 – 59.67mg/l;sulphates, 0.12 – 2.20mg/l and nitrates, 2.13 – 8.38mg/l.

Table 4. *Chemical characteristics of the public hand-pump borehole water samples during the rainy season.*

Samples location	Total alkalinity (mg/l)	Total hardness (mg/l)	Total chlorides (mg/l)	Calcium hardness (mg/l)	Magnesium hardness (mg/l)	Sulphates (mg/l)	Nitrates (mg/l)
(a)	16	18	15.52	0.10	4.35	0.80	4.46
(b)	13	246	17.52	0.46	59.67	0.12	3.52
(c)	39	10	49.55	0.09	2.41	1.04	2.13
(d)	9	170	21.52	0.53	41.18	0.78	4.23
(e)	17	142	10.51	0.42	34.40	0.88	4.56
(f)	27	34	17.52	0.06	8.25	2.20	2.33
(g)	14	230	50.56	0.69	55.72	0.84	4.46
(h)	24	204	29.53	0.57	49.43	0.98	4.17
(i)	17	144	17.52	0.55	34.86	0.34	4.29
(j)	5	66	17.52	0.06	16.02	0.16	8.38
(k)	34	218	14.52	0.59	52.83	0.94	8.19
(l)	26	52	47.55	0.09	12.61	0.94	6.48
(m)	17	224	15.15	0.45	54.32	0.98	6.50
(n)	16	140	20.52	0.37	33.93	0.82	6.31
(o)	17	228	18.52	0.65	55.25	0.40	7.91
WHOStandard	250	100	250	75	150	100	10

The heavy metals characteristics of the public hand-pump borehole water samples during the dry season are shown in Table 5. Zinc ranged from 0.00 to 0.05mg/l, iron, 0.00-0.28mg/l; lead, 0.29-0.50mg/l while copper was not detected in any of the samples analyzed.

Table 5. *Heavy metalscharacteristics of the public hand-pump borehole water samples during the dry season.*

Samples location	Lead (mg/l)	Copper (mg/l)	Iron (mg/l)	Zinc (mg/l)
(a)	0.29	0.00	0.02	0.03
(b)	0.33	0.00	0.28	0.04
(c)	0.30	0.00	0.08	0.03
(d)	0.36	0.00	0.06	0.05
(e)	0.39	0.00	0.13	0.03
(f)	0.33	0.00	0.28	0.03
(g)	0.41	0.00	0.15	0.02
(h)	0.45	0.00	0.04	0.04
(i)	0.50	0.00	0.25	0.03
(j)	0.49	0.00	0.25	0.01
(k)	0.39	0.00	0.12	0.03
(l)	0.39	0.00	0.00	0.05
(m)	0.36	0.00	0.19	0.05
(n)	0.41	0.00	0.28	0.00
(o)	0.30	0.00	0.19	0.03
WHO Standard	0.01	1.00	0.30	3.00

The heavy metals characteristics of the public hand–pump borehole water samples during the rainy season are presented in Table 6. The values of zinc were 0.00 – 0.05mg/l; iron, 0.00 – 0.28mg/l while lead ranged from 0.29 to 0.50mg/l. Copper was also not detected in any of the samples studied.

Table 6. *Heavy metals characteristics of the public hand-pump borehole water samples during the rainy season.*

Samples location	Lead(mg/l)	Copper(mg/l)	Iron (mg/l)	Zinc(mg/l)
	0.41	0.00	0.13	0.03
	0.30	0.00	0.28	0.03
	0.36	0.00	0.15	0.02
	0.39	0.00	0.00	0.04
	0.39	0.00	0.02	0.05
	0.49	0.00	0.28	0.05
	0.50	0.00	0.08	0.03
	0.45	0.00	0.06	0.00
	0.41	0.00	0.04	0.01
	0.33	0.00	0.25	0.03
	0.39	0.00	0.25	0.03
	0.36	0.00	0.12	0.03
	0.30	0.00	0.20	0.04
	0.29	0.00	0.19	0.05
	0.33	0.00	0.28	0.03
WHO Standard	0.01	1.00	0.3	3.0

4. Discussion

The temperature values of the borehole water samples ranged from 29 to 31°C during the dry season (Table 1) while the values were 28-30°C during the rainy season (Table 2). The values were within the WHO standard for drinking water quality of 25-40°C. Thevalues were similar to those obtained by Josiah et al [14] that reported a temperature range of 26-32°C which they attributed to the intensity of sunlight and effect of increased nutrients from industrial discharge. Temperature has been reported to influence the chemical and biochemical characteristics of water[15].

The pH values of the borehole water samples measured during the dry and rainy seasons were within the alkaline range. The values obtained during the dry season were 7.2-8.8 while those obtained during the rainy season ranged from 7.5 to 9.0. 13.3% and 20% of the samples during the dry and rainy seasons respectively were above the WHO recommended standard of 6.5 to 8.5. These findings were similar to those obtained by Basavaraja et al. [16] who reported pH values ranging from 7.5 to 8.4 and Abdullahi et al. [17] that obtained pH values which ranged from 7.51 to 7.60.

The electrical conductivity values of all the samples analyzed during both seasons were within the World Health Organization permissible limit of 1000us/cm. Electrical conductivity is an indicator of water quality and soil salinity, hence the high values obtained in some of the samples analyzed showed moderate to high salinity. This agreed with Bernard and Ayeni [18] who reported a mean conductivity value of 135us/cm for the samples they studied. The boreholes varied in depth from 150 to 300 feet during both seasons (Tables 1 and 2). The depth of any water borehole is usually dependent on the geology of the soil.

The values for the total suspended solids were 0.01 to 0.84mg/l during the dry season (Table 1) and 0.01 to 0.48mg/l during the rainy season. The values for both seasons were within the WHO acceptable standard of 30mg/l. However, Onwughara et al. [19] reported that the total suspended solids of the samples they analyzed ranged from 31.3 to 55.0mg/l. The detection of total suspended solids in water samples is an indication of the presence of suspended matters in them.

The total dissolved solids in the samples ranged from 0.01 to 18.12mg/l during the dry season (Table 1)and 0.00 to 16.16mg/l during the rainy season (Table 2). The values obtained during both seasons were within the WHO permissible limit of 500mg/l for potable water. Okoye and Adiele [20] and Bernard and Ayeni[18] however reported values of 6.4 to 34.5 mg/l and 81.0mg/l respectively for the samples they examined. Total dissolved solids in water indicated the presence of solid materials in such water.

The total solids were from 0.04 to 18.30 mg/l during the dry season (Table 1) and 0.13 to 16.31mg/l during the rainy season (Table 2). The values obtained during both seasons were within the WHO recommended standard of 100mg/l for potable water. However, Okoye and Adiele[20]reported that the total solids in the samples they analyzed ranged from 10 to 90mg/l.

The total alkalinity for the dry season ranged from 5 - 38mg/l (Table 3) and 5 - 39mg/l during the rainy season (Table 4). Okoye and Adiele[20] however reported total alkalinity values of 0.5 to 24.5 mg/l for the water samples they analyzed. The values obtained during both seasons were within the WHO standard of 250mg/l. Increase in total alkalinity of water is due to an increase in bicarbonates in such water [16].

The values for the total hardness during the dry season were 10-248mg/l (Table 3) and 10-246mg/l during the rainy season (Table 4). Most of the boreholes sampled (66.7%) did not comply with the WHO permissible limit of 100mg/l during both seasons. The results obtained in this study were similar to those obtained by Abddullahi et al. [17]. Hardness of water is usually due to the presence of calcium and magnesium ions in water.

The total chlorides obtained during the dry season were 11.00 – 50.65mg/l (Table 3) and 10.51 – 50.56mg/l during the rainy season (Table 4). The total chlorides values obtained during both seasons were within the WHO permissible limit of 250mg/l. This result agreed with that obtained by Okoye and Adiele[20]. Chlorides in drinking water may originate from natural sources, sewage and industrial effluents, urban runoff containing de-icing salt and saline intrusion [18]. High levels of chlorides makewater unfit for drinking by imparting salty taste and may harm metallic pipes [10].

Calcium hardness values of the samples during the dry season ranged from 0.06 to 0.67mg/l (Table 3) and 0.06 to 0.69mg/l during the rainy season (Table 4). The values obtained during both reasons were within the WHO standard of 75mg/l for potable water. Calcium when present in suitable concentration is known to regulate a number of neuron –muscular excitability, blood coagulation, secretery processes, enzyme reactions, intracellular action of a number of hormones and formation of bones.

The magnesium hardness of the samples during the dry season ranged from 2.41 to 60.67mg/l (Table 3) while the values were 2.41-59.67mg/l during the rainy season. The values obtained during both seasons were within the WHO permissible limit of 150mg/l for potable water. High levels of magnesium in drinking water will render such water objectionable to consumers and may even become hazardous to health [19].

The values obtained for the sulphates during the dry season were 0.12-2.28mg/l (Table 3) while they were 0.12-2.20mg/l during the rainy season (Table 4). The values obtained during both seasons were within the WHO standard of 100mg/l for potable water. The result agreed with Okoye and Adiele [20] who reported that the sulphates in the samples they analyzed ranged from 0.05 to 0.13mg/l. Sulphate has been reported to have deleterious effect on young children who are very sensitive to it [21].

Nitrates level of the samples during the dry season were 2.13-8.37mg/l (Table 3) while the values of nitrates during the rainy season were 2.13-8.38mg/l (Table 4). The values obtained during both seasons were within the WHO permissible limit of 10mg/l for potable water. The result is in agreement with that obtained by Okoye and Adiele[20]. Nitrate represents the final product of the biochemical oxidation of ammonia [22]. Monitoring of nitrate in drinking water supply is very important because of its health effects on humans and animals.

The values of lead obtained during both the dry and rainy seasons were 0.29-0.50mg/l (Tables 5 and 6). The values were above the WHO standard of 0.01mg/l for potable water. Okoye and Adiele [20] however did not detect lead in the water samples they studied. Increase in levels of lead in water may cause health problems such as cancer. Copper was not detected in all borehole water samples during both the dry and rainy seasons (Tables 5 and 6). This result agreed with Olajubu and Ogunika [21] who did not detect copper in the water samples they analyzed. The WHO recommended standard for copper in drinking water is 1.0mg/l. The occurrence of copper in boreholes may be as a result of dissolution of copper material directly into such water.

The iron content of the water samples during both the dry and rainy seasons ranged from 0.00 to 0.28mg/l (Tables 5 and 6). The values were within the WHO standard of 0.3mg/l for drinking water. This result is in agreement with the work of Abdullahi et al. [17] and Okoye and Adiele[20] who reported that the boreholes water they analyzed contained iron in the range of 0.02-0.27mg/l and 0.01-0.25mg/l respectively.

The values obtained for zinc during the dry and wet seasons were 0.00-0.05mg/l (Tables5 and 6). The values were within the WHO permissible limit of 3.0mg/l. The result agreed with the reports of Okoye and Adiele[20] concerning the presence of zinc in drinking water. Zinc is one of the trace elements which the body requires in small amount for its development.

The temperature, total chlorides and nitrates had significant correlation at $P<0.05$ indicating that seasonal variation had significant effect on the levels of these parameters in the water samples analyzed.

5. Conclusion

This study showed that the samples analysed complied with the World Health Organization standard for potable water in terms of the physical, chemical and heavy metals characteristics analyzed except the pH and total hardness which values were above the standard in some of the borehole samples and the lead content, therefore such boreholes water must be treated to safeguard the health of the consuming public. Passage of the water through sand filters (rapid and slow), addition of lime as well as periodic assessment of the water physicochemical quality are recommended.

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