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ORIGINAL RESEARCH ARTICLE



Effect of seasonal variations on the physicochemical characteristics of spring water in Oji River LGA, Enugu State Nigeria

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ABSTRACT

This study was conducted to determine the effect of seasonal variations on the physicochemical characteristics of spring water samples in Oji River Local Government Area of Enugu State, Nigeria. Water samples were collected in sterile plastic water containers at the point of discharge during the dry and wet seasons and analyzed physicochemically using the standard methods for the examination of water and wastewater. The results showed that the colour (7-14.2 TCU); pH (7.18-8.4); temperature (24.6-28.1 °C); electrical conductivity in wet season (128.5-285.6 µs/cm); total dissolved solids (114.7-401 mg/L); total suspended solids (101.8-423.6 mg/L); total hardness (58-255 mg/L); total acidity (3.55-19.5 mg/L); total alkalinity (9.2-47 mg/L); biological oxygen demand (1.70-3.28 mg/L); nitrate (0.73-2.23 mg/L); ammonium in wet season (0.18-0.34 mg/L); zinc (0.011-0.085 mg/L); mercury (0.001-0.005 mg/L); copper (0.002-1.008 mg/L) and iron (0.031-0.318 mg/L) of water were within the WHO standard for drinking water quality while the phosphate (0.14-1.08 mg/L), lead (0.013-0.098 mg/L) and ammonium in dry season (0.48-0.75 mg/L) levels were not found within the prescribed limit of WHO drinking water standards. Therefore, this investigation indicated that the spring water is unfit for drinking without adequate treatment. Liming, boiling and ozonation treatment techniques are recommended for the treatment of water.

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INTRODUCTION

Water is one of the key elements for the survival of living things on earth, because it plays an indispensable role in the maintenance of life. The average water intake required by man per day is between 3.7 litres and 4.0 litres (15-18 cups) for male and 2.7 litres and 3.0 litres (11-14 cups) for female (Agah *et al.*, 2018). Water supply and accessibility is goal no. 6 of the sustainable development goals (SDGs) and aims at ensuring environmental sustainability. Access to safe drinking water is critical to human health and development (Edbert *et al.*, 2017). Water that is good for drinking is important to human physiology and man's contin-

ued existence depends so much on its availability. Potable water is a fresh water body that is unpolluted, suitable for drinking, odourless and tasteless (Onuorah *et al.*, 2020). It boils at 100 °C, freezes at 0 °C, is neutral to litmus and has an atmospheric pressure of 760 mmHg. Spring water is a form of groundwater, which has its source in the aquifers of the underground pool of a water body (Onuorah *et al.*, 2020; Berglind and Viggo, 2013). The inhabitants of Oji River LGA of Enugu State heavily depend on spring water sources for their water needs and there's no form of treatment before usage. Traditionally, groundwater had been considered the least water source to be contaminated by human or animal wastes, most especially ground water from the

deep, confined aquifers (Berglind and Viggo, 2013). It is assumed that water passing through rocks and soil, filters off most impurities and microbial contaminants, thereby leaving the consumers with little concern of groundwater contamination.

Pollution of groundwater occurs when much of undesirable or harmful substances find its way into the aquifers, exceeding the water's natural ability to remove the undesirable material, dilute it to a harmless concentration or convert it to harmless form (Edbert et al., 2017; Onuorah et al., 2020). It's estimated that 80% of all illnesses is related to water and sanitation, and that 15% of all child deaths under the age of 5 years in developing countries results from diarrhoeal diseases (WHO, 2003; WHO, 2004). The presence of certain chemicals such as iron, copper, zinc, mercury, lead, cadmium, nitrate, nitrite, calcium and magnesium salts, phosphate and ammonium can also be detrimental to human health (Shittu et al., 2008). Spring water bodies in Oji River LGA of Enugu State are Obii, Omumo, Ogbanenu, Uruku, Ogba, Ngene-akpu, Onwii and Ovu and are located in the five communities of the local government area. They serve as the major source of drinking water for the people, and also used for irrigation for agriculture, domestic and other purposes during the dry and wet seasons. This study will create awareness on the physicochemical parameters of the spring water within the LGA during both seasons and recommends possible means of treatment of the water before use.

MATERIALS AND METHODS

Study area

This study was on the spring water sources in Oji River Local

Government Area of Enugu State, Nigeria. Farming, petty trading, teaching and artisans are the major occupation of the people of the area. Oji River Local Government Area (LGA) is one of the seventeen LGAs in Enugu State of Nigeria (Figure 1). It is located at the Northeast part of the state, and covers an area of 451.8 km² with a total land mass of 7,161 km² of Enugu State. It has an estimated population of 173,800 with a population density of 347.8/km (Nigerian National Bureau of Statistics, web). The five sampling communities were Achi, Akpugoeze, Awlaw, Inyi and Ugwuoba communities. Its geographical coordinates are 6° 14'52" North, and 7°30'85" East, and it borders Anambra and Abia States, Southeast, Nigeria. The LGA is characterized by tropical climate with distinct wet and dry seasons.

Sampling and analysis

Two seasonal samplings were carried out between November, 2018 and October, 2019, and the period represented alternating seasons of dry (November, 2018 to March, 2019) and wet seasons (April to October, 2019) within the communities. Water samples were collected following standard sampling guidelines and methods as described by the American Public Health Association (2012). The samples were taken from the point of discharge at each location. Two sources of spring water each from Awlaw (Omumo spring water and Obii spring water, decoded as sites 2 and 3); Akpugoeze (Ogbanenu spring water and Ngene-akpu spring water, as sites 4 and 5); Inyi (Uruku spring water and Ogba spring water, as sites 6 and 7) and Ugwuoba (Ovu spring water and Onwii spring water, as sites 8 and 9) were sampled, while one was sampled from Achi (Iyi-agu spring water, decoded as site 1) for both seasons. Since sampling was done for 12 months, this brought the sample size to 45 in dry season (November, 2018 to March, 2019) and 63 in wet season (April to October, 2019) and 108 for both seasons. Water samples for physicochemical analysis were collected using freshly blown plastic water containers. Prior to sample collection, the containers were thoroughly rinsed with the water to be sampled. The samples were transported to Graceland Research & Analytical Laboratory, Awka Anambra State, Nigeria where they were analysed. The physicochemical parameters were determined according to the procedures described by APHA (2017). Temperature, pH, colour, electrical conductivity, total dissolved solids, total suspended solids, total acidity, total alkalinity, total hardness, biochemical oxygen demand, nitrate, phosphate, ammonium, lead, iron, zinc, mercury, copper and cadmium were determined.

Statistical analysis

Data was entered in a spreadsheet, checked and errors corrected before exporting to SDA 7.0 Statistical Software (WINKS). Comparison for variations between the sampling sites was done using two-way ANOVA. Paired t-test was used to analyze the seasonal variations between the dry and wet seasons. The results are presented in tables.

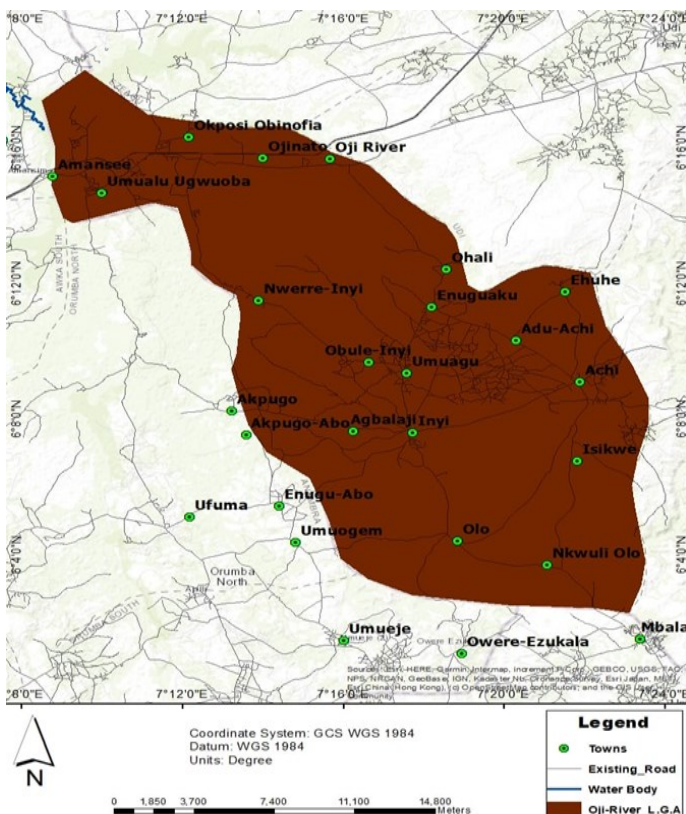


Figure 1. Map showing the sampling sites in Oji River LGA, Enugu State, Nigeria.

RESULTS AND DISCUSSION

Mean values of the physical parameters studied in the water samples during the dry and wet seasons

The mean values of the physical parameters studied in the water samples during the dry and wet seasons are presented in Tables 1 and 2, respectively. The data showed that pH, colour, TSS, and TDS were all within the maximum permissible limits of WHO standards for drinking water and the means ranged from 6.8-8.4 (pH); 7-14.2 TCU (colour); 101.08-423.6 mg/L (TSS) and 114.7-401 mg/L (TDS). Differences between the sites showed that site 8 had the highest level of TSS (198.3-423.6 mg/L), while site 9 had the highest level of TDS (268.5-401 mg/L). Water temperature was within the limit in the wet season (24.6-26.6°C) and all the sites in the dry season except for site 2 (25.8-28.1°C). Analysis of variance indicated that there was no significant difference in the water temperature between the nine sites. However, seasonal variations showed that the temperature was significantly high in the dry season. Electrical conductivity values in the wet season were all within the maximum permissible limit (128.5-285.6 µS/cm) whereas most sites (5 out of 9) in the dry season (408-535.8 µS/cm) were above the limit as set by WHO (2006) recommendation of <400 µS/cm. Differences in sites showed that water from site 9 had the highest EC and was significantly different ($p < 0.001$) from those at the other sites. Paired comparison using *t* test showed that EC was significantly high ($p < 0.001$) in the dry season.

Mean values of the chemical parameters examined in the water samples during the dry and wet seasons

The mean values of the chemical parameters examined in the

water samples during the dry and wet seasons are presented in Tables 3 and 4, respectively. The data showed that the values of total acidity (TAci) and total alkalinity (TAlI) were all within the maximum permissible limit as set by WHO (2006) to be 100mg/L. Total acidity values were high in the wet season, and the means ranged from 8.02-19.5 mg/L than in the dry season of 3.55-8.06 mg/L. Total alkalinity was also higher in the wet season than in the dry season, with 13-47 mg/L and 9.2-33.78 mg/L respectively. Site 6 had the highest values of total acidity for the dry and wet seasons as 8.06 mg/L and 19.5 mg/L, respectively. Similarly, site 9 also had the highest values of total alkalinity as 33.78 mg/L and 47 mg/L for dry and wet seasons, respectively. Differences between the sites showed that site 1 had the lowest total alkalinity levels of 9.2 mg/L and 13 mg/L for dry and wet seasons, respectively. Also, site 1 had the lowest total acidity levels of 3.28 mg/L and 8.02 mg/L for the dry and wet seasons, respectively. Paired comparison using *t* test indicated that TAci and TAlI were significantly high ($p < 0.001$) in the wet season. The total hardness (TH) levels, measured by its calcium and magnesium content of carbonates, showed that they were within the maximum permissible limit of 100-300 mg/L as set by the WHO (2006). The total hardness ranged from 58 - 255 mg/L in all the sites. Site differences showed that water from site 9 had the highest TH values, followed by water from site 6 and they were significantly different ($p < 0.001$) from those at the other sites. Paired comparison using *t* test showed that TH was significantly high ($p < 0.001$) in the wet season than the dry season. Total hardness levels also showed that site 1 had the least value. The degree of hardness in drinking water is important for its aesthetic and acceptability by consumers, and also for economic considerations and wellbeing of the people.

Table 1. Mean values of the physical parameters studied in the spring water samples of Oji River LGA during the dry season.

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Range	WHO Limits
pH	7.7	7.3	7.21	7.58	8.2	7.18	8.3	8.4	8.16	7.18-8.4	6.5 - 8.5
Colour (TCU)	9.2	7.5	8.1	8.7	7.6	7.9	8.5	8.3	7.0	7.0-9.2	15 (colour less)
Temp. (°C)	27	28.1	26.8	25.8	26.5	27	26	27	26.8	25.8-28.1	27
EC (µs/cm)	320	408	357.55	415.08	433.17	395.6	387.89	478	535.8	320-535.8	400
TSS (mg/L)	101.08	121	231	192.7	181.5	136.3	178.76	198.34	185.4	101.8-231	500
TDS (mg/L)	358.5	331	298	311	285	315	365	387	401	311-401	500

Table 2. Mean values of the physical parameters studied in the spring water samples of Oji River LGA during the wet season.

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Range	WHO Limits
pH	6.9	7.47	8.13	6.8	7.4	7.8	7.2	8.3	8.0	6.8-8.3	6.5 - 8.5
Colour (TCU)	14.2	12.8	12	12.2	11.5	12	13.2	12.5	10	10-14.2	15 (color less)
Temp. (°C)	25.1	26.6	24.9	25	25.07	24.6	25.5	25.2	25.3	24.6-26.6	27
EC (µs/cm)	134.95	145.18	154.6	181.5	187.05	128.5	141.87	215.6	285.6	128.5-285.6	400
TSS (mg/L)	324.8	387.52	344	298.51	311.90	327	322.55	423.6	401.5	298.51-423.6	500
TDS (mg/L)	234	261.9	184.8	185.6	201	114.7	199.85	214	268.5	114.7-268	500

Table 3. Mean values of the chemical parameters examined in the spring water samples of Oji River LGA during the dry season.

Parameter (mg/L)	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Range	WHO Limits
Total acidity	4.96	3.55	4.05	5.35	7.45	8.06	4.32	6.50	7.65	3.55–8.06	100
Total alkalinity	9.2	14.5	13.0	15.5	21.8	24.5	29.10	0.5	3.78	9.2–33.78	100
Total hardness	58	75	105	35.5	125	165	140	161	210	58–210	100–300
BOD	3.20	2.90	2.85	2.95	2.80	3.10	3.28	2.65	3.05	2.65–3.28	<5.0
Nitrate	1.05	0.89	0.99	1.04	0.85	0.73	0.76	0.86	1.08	0.73–1.08	<45
Phosphate	0.26	0.15	0.14	0.16	0.20	0.22	0.18	0.15	0.25	0.14–0.26	<0.1
Ammonium	0.75	0.48	0.52	0.60	0.72	0.66	0.64	0.59	0.62	0.48–0.75	<0.5

Table 4. Mean values of the chemical parameters examined in the spring water samples of Oji River LGA during the wet season.

Parameter (mg/L)	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Range	WHO Limits
Total acidity	8.02	12.5	11.05	13.0	13.5	19.5	8.35	9.8	15.85	8.02–19.5	100
Total alkalinity	13	21.8	19.8	24	30.5	36.7	41.5	44.6	47	13–47	100
Total hardness	85	125	145	189	175	215	185	190	255	85–255	100–300
BOD	2.10	1.85	1.82	1.70	1.80	1.90	2.03	1.95	2.25	1.70–2.25	<5.0
Nitrate	2.10	1.83	1.95	2.02	2.06	1.27	1.58	2.23	2.15	1.25–2.23	<45
Phosphate	0.92	1.08	0.86	0.94	0.66	0.65	0.70	0.55	0.72	0.55–1.08	<0.1
Ammonium	0.22	0.21	0.20	0.18	0.24	0.34	0.18	0.22	0.19	0.18–0.34	<0.5

All the BOD₅ values (1.70–3.28 mg/L) were within the permissible limit as set by the WHO (2006). Site 7 recorded the highest average level of 5.31 mg/L for both seasons, followed by site 1 (5.30 mg/L). Analysis of variance showed that there was no significant difference ($p = 0.208$) in the BOD₅ levels between the different sites. Paired comparison using t test showed that BOD₅ values were not significantly high ($p < 0.001$) in the dry season. Nitrate ranged between 0.73–2.23 mg/L and they were all within the maximum permissible limits. Site 8 had the highest level of 2.23 mg/L while site 6 had the least value of 0.73 mg/L. Seasonal variations between the sites showed that the levels of nitrate were significantly high in the wet season than dry season. The nitrate level in the dry season ranged from 0.73–1.08 mg/L and 1.25–2.23 mg/L in the wet season. For phosphate, the levels ranged from 0.14–1.08 mg/L and they were all above the maximum permissible limit. Site 2 had the highest level of phosphate with 1.08 mg/L while site 3 had the least value of 0.14 mg/L. Comparison between the sampling sites showed insignificant differences in the levels of phosphates between the sampling sites. Seasonal variations between the nine sites indicated that there were increased levels of phosphates in the wet season than the dry season. Also, the seasonal variations showed that the phosphate level was significantly high ($p < 0.001$) in the wet season. The ammonia levels between the sites ranged from 0.18–0.75 mg/L. The levels in the wet season were all within the maximum permissible limit, whereas the levels in the dry season were all above the permissible limit (0.52–0.75 mg/L) except for site 2 with a value of 0.48 mg/L. Comparisons between the sampling sites showed insignificant differences in the levels of ammonia between the sampling sites. Seasonal variations between the nine sites indicated that there were increased levels of ammonia in the dry season than the wet season. Also, the seasonal variations showed the ammonia level was significantly high in the dry season.

Mean values of heavy metals parameters examined in the spring water samples during the dry and wet seasons

The mean values of heavy metals parameters examined in the spring water samples during the dry and wet seasons are presented in Tables 5 and 6, respectively. Some elements were not detected or were below detection limit especially during the dry season. The levels of zinc, mercury and copper were all within the maximum permissible limit, with zinc levels ranging from 0.011–0.085 mg/L; mercury: 0.001–0.005 mg/L; and copper: 0.002–1.008 mg/L. Copper in most sites was not detected in the dry season except for site 5, site 8 and site 1. In almost all the sites, cadmium was not detected or was below detection limit (< 0.001 mg/L), except at site 7 where it was recorded at 0.032 and 0.010 mg/L for wet and dry seasons, respectively. Iron levels were all within the maximum permissible limit, except at site 1 during the dry season where it was recorded at 0.318 mg/L, above < 0.3 mg/L limit. Lead levels were all above the maximum permissible limit of 0.01 and they ranged from 0.013 mg/L in site 4 during the dry season to 0.098 mg/L in site 1 during the wet season. When compared by site, site 1 had significantly high ($p < 0.001$) levels of iron and lead than the other eight sites. Seasonal variations showed that the levels of heavy metals were significantly high ($p < 0.001$) in the dry season except for lead which had higher values in all the sites in the wet season.

The pH of a substance is used to express the intensity of the acid and alkaline condition of such substance (Chadne, 2014). The pH of all the sampled water was within the WHO limit (6.5–8.5). During the dry season, the pH in all sites was above neutral, 7 and alkaline (7.3, 7.58, 7.7, 8.16, 8.3 and 8.4), whereas during the wet season, some sites recorded below the neutral (6.8, 6.9) and acidic. The result agreed with the report of Ukpong and Peter (2012) on the physicochemical parameters in drinking water in Ibeno Local Government Area of Akwa Ibom State. The alkaline nature of the water source especially during the dry season can

be attributed to a number of factors such as the presence of inorganic acids from decaying vegetation (Ukpong and Peter, 2012; Paschke *et al.*, 2001), dissolved carbon dioxide and the dissolution of carbonate salts (Onuorah *et al.*, 2020). Water in a pure state is neither acidic nor basic. Temperature plays a critical role in the metabolic activities of organisms and also affects the solubility of oxygen in water (Gopalkrushna, 2011; Kataria *et al.*, 2011). The temperature values during both seasons were within the WHO limit of 27°C (Tables 1 and 2) except for site 2 which had 28.1 °C during the dry season. The result agreed with the findings of Onuorah *et al.* (2020) on Iyifeyi stream of Ugwobi Abbi, Uzo-Uwani LGA of Enugu State and that of Akubuenyi *et al.* (2013) on some of the sources of water in Calabar, Nigeria. The values of temperature were found to be higher during the dry season than wet season. Jaji *et al.* (2007) also reported increased levels of temperature on water quality assessment of Ogun River, Nigeria during the dry season.

Colour in drinking water is usually due to the presence of organic matter (primarily humic and fulvic acids) associated with the humus fraction of soil or the presence of iron and other metals, either as natural impurities or as corrosion products (Bernard and Ayeni, 2012). Water in its pure state has a slight blue colour that becomes a deeper blue as the thickness of the observed sample increases, though relatively small quantities of water appear to be colourless. The blue colour of water is an intrinsic property and is caused by selective absorption and scattering of white light. The colour of the spring water sources investigated during both seasons (Tables 1 and 2) did not exceed the recommended limit as set by the WHO (2006) and there was no significant seasonal variation in colour. This agreed with the reports of Onuorah *et al.* (2020) on Iyifeyi stream, Ugwobi-Abbi, Enugu State Nigeria and Krishna *et al.* (2011) on Kaveri River, India.

Electrical conductivity is a measure of the capacity of a water sample to conduct electric current as well as the relative level of total dissolved salts in the water (Gopalkrushna, 2011; Chadne, 2014). The electrical conductivity of the spring water during wet season were within the WHO recommended limit (Table 2), whereas most sites exceeded the recommended limit during the dry season. Similar results were obtained by Uduosoro and Umoren (2014) in their assessment of surface and ground water quality. Higher values of EC during the dry season may be attributed to concentrated dissolved salts as a result of human activities (Chindo *et al.*, 2013). Total Dissolved Solids (TDS) is a measure of both anions and cations in a water body. Total

dissolved solids in ground and surface water could come from natural and or anthropogenic sources such as agricultural runoff, industrial effluents, sewage and the chemicals used in the treatment of water (Edet *et al.*, 2012; Saana *et al.*, 2016). The TDS during both seasons were within the WHO recommended limit (Tables 1 and 2). The result also agreed with the reports of Onuorah *et al.* (2020) and Uduosoro and Umoren (2014) on surface and groundwater qualities. Total suspended solids (TSS) in water affect the aesthetic appeals of drinking water and even bathing water. Water that is high in TSS is more of an aesthetic than a health hazard (Gupta *et al.*, 2017). TSS is a precursor to turbidity due to silt and organic matter (Essumang *et al.*, 2011; Shawai *et al.*, 2018). The values obtained in both seasons were within the WHO recommended limit (Tables 1 and 2) and agreed with the results of Shittu *et al.* (2008) on the physicochemical and bacteriological analyses of water used for drinking, and that of Edet *et al.* (2012) on the bacteriological and physicochemical quality of stream water in Nduetong Oku, Uyo, Akwa Ibom State, Nigeria.

The acidity and alkalinity of water are its quantitative capacity to react with strong base and acid, respectively. Strong mineral acids and weak acids such as carbonic and acetic as well as hydrolyzing salts such as aluminium or iron sulphates may contribute to measured acidity. Similarly, strong base such as salts of calcium or magnesium carbonates can contribute to measured alkalinity (Chandra *et al.*, 2011). There were no significant seasonal variations in the total acidity and alkalinity obtained during both seasons. This result agreed with Krishna *et al.* (2011) who observed no significant seasonal variation in the physicochemical parameters studied in Kaveri River, India. The values obtained during both seasons were within the WHO range for potable water (Tables 3 and 4). Hardness of the water is the property that decreases the lather formation of soap and increases scale formation in hot-water heaters and low-pressure boiler at high levels. Total hardness is mainly due to calcium and magnesium salts (Gopalkrushna, 2011; Chadne, 2014) and is derived from limestone or industrial effluents. The value for total hardness in this study did not exceed the WHO recommended limit (Tables 3 and 4) for both seasons. The values obtained in this study were similar to those reported by Onuorah *et al.* (2020) for stream water used for drinking purposes and Essumang *et al.* (2011) for ground water. The spring water samples can be classified as soft water based on WHO (2004) classification.

Table 5. Mean values of heavy metals in water sampled at the nine study sites of Oji River LGA during the dry season.

Parameter (mg/L)	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Range	WHO Limits
Zinc	0.085	0.071	0.068	0.059	0.046	0.038	0.061	0.039	0.028	0.028–0.085	<5.0
Iron	0.318	0.292	0.219	0.167	0.145	0.176	0.213	0.171	0.162	0.167–0.318	<0.3
Lead	0.028	0.013	BDL	0.013	0.018	0.023	0.045	BDL	0.018	BDL–0.045	<0.01
Cadmium	BDL	0.003	ND	0.002	ND	ND	0.010	ND	BDL	ND–0.010	<0.003
Mercury	ND	0.002	ND	BDL	0.002	ND	ND	0.001	ND	ND–0.002	0.006
Copper	0.002	ND	ND	ND	0.085	ND	ND	0.023	BDL	ND–0.085	<2.0

ND: Not detected. BDL - Below Detection Limit (<0.001 mg/L)

Table 6. Mean values of heavy metals in water sampled at the nine study sites of Oji River LGA during the wet season.

Parameter (mg/L)	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Range	WHO Limits
Zinc	0.028	0.016	0.019	0.016	0.013	0.020	0.018	0.026	0.011	0.011–0.028	<5.0
Iron	0.211	0.118	0.093	0.059	0.117	0.122	0.018	0.031	0.041	0.031–0.	<0.3
Lead	0.098	BDL	BDL	0.015	0.071	0.076	0.081	BDL	0.095	BDL–0.098	<0.01
Cadmium	0.002	0.021	0.002	0.010	0.001	0.002	0.032	0.002	0.003	0.001–0.032	<0.003
Mercury	0.005	0.004	0.003	0.001	0.004	0.003	ND	0.004	0.002	ND–0.005	0.006
Copper	0.056	0.087	0.095	0.56	0.83	0.67	1.008	0.84	1.005	0.056–1.008	<2.0

ND: Not detected; BDL: Below Detection Limit (<0.001 mg/L)

Biochemical oxygen demand indicates the amount of organic waste present in water. BOD₅ values obtained in this study during both seasons were within the maximum limit of 5.0 mg/L (Tables 3 and 4) as set by the WHO (2006). However, BOD₅ levels were higher in the wet season than dry season and this can be attributed to eutrophication of nutrients into the water source during the season. This agreed with the reports of Ukpong and Peter (2012) on the physicochemical analysis of drinking water and Edet *et al.* (2012) on the physicochemical analysis of stream waters in Nduetong Oku Community, Uyo. Nitrate is the most highly oxidized form of nitrogen compounds and is commonly present in surface and ground water samples. It is the final product of the biochemical oxidation of ammonia (Chindo *et al.*, 2013). High nitrate concentration in drinking water has been widely reported to have detrimental effects on pregnant women and babies less than six months old (Akubuenyi *et al.*, 2013; Longe and Balogun, 2010) and could be a source of eutrophication in the receiving water. The values obtained for nitrate in this study were within the WHO limit for drinking water (Tables 3 and 4). The results agreed with Chadne (2014) who reported values that were within the WHO limit and observed seasonal variations in physicochemical parameters of the water samples investigated.

The phosphate levels were above the WHO limit for both seasons, whereas the ammonium levels were above the standard for dry season only (Tables 3 and 4). Phosphate levels were higher in the wet season (0.55–1.08 mg/L) than dry season (0.14–0.26 mg/L). This can be attributed to the usage of artificial fertilizers, made of phosphate, nitrate and potassium, in the cultivation of bitter leaf and ugu leaf around the sites. The residues of fertilizers and other pesticides can permeate the soil particles and rock layers during the wet season, thereby polluting the aquifers of the spring water. The values of phosphate agreed with the report of Gopalkrushna (2011) on the assessment of physicochemical status of groundwater samples in Akot city where the phosphate levels were all found to be above the standard limit. Similarly, Akubuenyi *et al.* (2013) reported that phosphate levels in major sources of drinking water in Calabar metropolis, Nigeria were above the standard limit as set by the WHO (2006). The values obtained for the heavy metals during both seasons were within the WHO limit except for lead which had higher values than the recommended limit. Heavy metals were not detected in many sites and some sites had metals below detection limit (BDL). BDL

means there's presence of such metal in the water sample but could not be measured. Heavy metals are needed at low levels for enzymatic activities as catalysts. Their presence in the spring water samples can be through weathering of rocks and leaching. The values obtained for zinc, copper, iron and lead in this study agreed with the reports of Onuorah *et al.* (2020), who investigated the heavy metals parameters in Iyifeiyi stream of Ugwobi-Abbi, Enugu State, Nigeria. Similarly, the values obtained for mercury and cadmium agreed with the report of Ukpong and Peter (2012), on the heavy metals parameters of drinking water in Ibeno Local Government Area of Akwa Ibom State. Cadmium, mercury and copper were not detected in most sites during the dry season and this agreed with the report of Kataria *et al.* (2011) on the study of physicochemical parameters of drinking water of Bhopal City. High levels of these metals may be hazardous to human health (Akubuenyi *et al.*, 2013).

Conclusion and recommendations

The quality of the spring water investigated was acceptable in terms of the majority of the physicochemical parameters during the dry and wet seasons of 2018/2019. However, the samples did not comply with the WHO standard in terms of lead and phosphate levels for both seasons; electrical conductivity and phosphate levels for dry season. There was no significant variation in the physicochemical parameters of the spring water samples during the dry and wet seasons. Therefore, the spring water must be subjected to adequate treatment before drinking and other domestic purposes. Government should organize programmes to educate the rural dwellers on the need for proper personal hygiene's before visiting the spring water. Local authorities in the communities should ban activities like washing of clothes, motor-cycles and tricycles near the spring water. Also, Government and non-governmental organizations should render assistance by providing potable water supply to the residents of Oji River Local Government Area. Water from the springs should be treated before consumption, to avert a public health problem.

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