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Physical, chemical and some trace metal analysis of Ugbogui River, Edo State, Nigeria

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Key words: Physical and chemical parameters, Trace metal, Water quality, Nigeria, Permissible limits

Abstract

The physical, chemical parameters and some trace metals of Ugbogui in Edo State, Nigeria were investigated from August 2015 to April 2016. Four stations were studied from upstream to downstream using standard methods. A total of thirty-three (33) physical and chemical characteristics and trace metal contents were examined; Air and water temperatures, depth, transparency, colour, turbidity, flow velocity, pH, total alkalinity, conductivity, and dissolved solids. Other includes dissolved oxygen, oxygen saturation, biochemical oxygen demand, chloride, phosphate, sodium, nitrate, sulphate, potassium, calcium, magnesium, iron, lead, copper, zinc, nickel, cadmium, vanadium, and chromium. Eleven (11) parameters exhibited clear seasonal variations. However, there were highly significant differences ($p< 0.01$) in the values of depth, colour, total suspended solids, biochemical oxygen demand$_5$, chemical oxygen demand, chloride, bicarbonate, phosphate, sulphate, iron, manganese, zinc, copper, chromium, and cadmium among the stations. The anthropogenic activities had negatively impacted at station 3 of the river, although most of the recorded values were still within permissible limits.

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Introduction

Water, a fundamental requirement for all living organism, performs a lot of physiological functions for organisms and it also serves as a support for a vast number of aquatic species (Mouri *et al.*, 2011). Over time, water requirements have extended to drinking and personal hygiene to fisheries, agriculture, transportation of goods, industrial production, cooling of power plants, hydropower generation and recreational activities such as bathing or fishing (Mouri *et al.*, 2011). Interestingly, the largest demands for water quantity, such as for agricultural irrigation and industrial cooling, require the least in terms of water quality. These demands for water has placed this important resource under serious pressure as its abstraction and use leads to deterioration in both quality and quantity, which in turn impacts not just the aquatic ecosystem but also its availability for human consumption (UNEP, 2008; Omoigberale and Eweka, 2010; Omoigberale and Ogbeibu, 2010; Wogu and Okaka, 2011; Olomukoro and Dirisu, 2014).

Every freshwater body has an individual pattern of physical and chemical characteristics which are primarily determined by the climatic, geomorphological, and geochemical conditions prevailing in the drainage basin and the underlying aquifer. However, in recent times, anthropogenic activities have become a major determinant of water quality (Vitousek *et al.*, 1997; Santi and Tavares, 2009; Omoigberale and Ogbeibu, 2010; Rim-Rukeh and Agbozu, 2013). According to Chapman (1996), if surface waters were totally unaffected by human activities, up to 90-99 percent of global freshwaters would have natural chemical concentrations suitable for aquatic life and most human uses. Physical and chemical characteristics, such as temperature, total dissolved solids (TDS), conductivity, dissolved oxygen (DO), biochemical oxygen demand (BOD_5) and a host of others provide a general classification of water bodies of a similar nature. Significant alteration in any of these physical and chemical characteristics either through natural or anthropogenic cause compromises the integrity of the aquatic system, thereby affecting aquatic biota which depends largely on a relatively stable physical and chemical properties for optimum productivity.

Most organisms living in a water body are sensitive to any change in their environment, but different organisms respond in different ways. The larger organisms tend to migrate to other habitats if conditions become unfavourable, while sessile or floating organisms like zooplankton remain to respond and the new environment. Some of these responses include death, reduced reproductive capacity and inhibition of certain enzyme systems necessary for normal metabolism which ultimately led to alteration in the ecosystem diversity.

Material and methods

Study area and sampling stations

Ugbogui River is located between Latitude 06⁰45'24" N and Longitude 005⁰ 43' 54" E in the South-Western part of Edo State and cut across Benin-Lagos expressway in Ovia South-West Local Government Area. It is the major river that drains the Ugbogui community. The river runs through Okpokhumi, Sabongida communities and empties into the Osse River. The region is notable for its intensive cocoa farming, plantain production and other types of crop farming. A vast number of these farms are located along the riverbank.

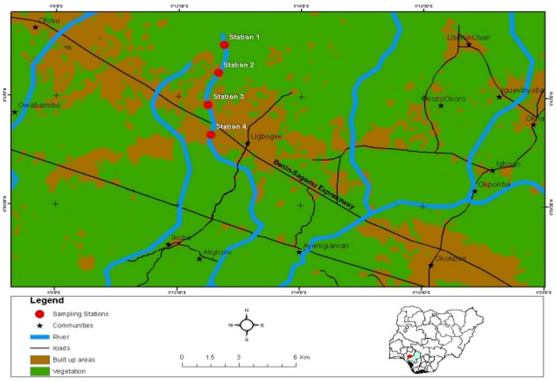

Fig. 1. A map of the drainage pattern of the Ugbogui River showing the study stations.

Samples collection and analysis

Air and water temperature, flow rate, pH and conductivity of the water samples were determined in-situ using mercury-in-glass thermometer, surface floatation technique, pH meter (HANNA H184243) and conductivity meter (HACH 44600-00), respectively.

Turbidity was measured using a visible spectrophotometer (Vs72IG model), BOD_5 and DO were determined using Winkler's method (APHA, 2005) in the laboratory. Heavy metals were analyzed with Atomic Absorption Spectrophotometer (Solaar UNICAN 969). Flame emission photometry method was used in the determination of the exchangeable bases (sodium, potassium, calcium, and magnesium) concentration in the water samples.

Besides the basic statistical measurement of central tendency and dispersion to characterize the stations in terms of the physical and chemical conditions, inter- stations comparisons were carried out to test for the significant difference in the conditions of the parameters using the Analysis of Variance (ANOVA) described by Ogbeibu (2014). Where significant value ($p<0.05$) were obtained, Duncan Multiple Range (DMR) tests were performed to determine the site of significant difference using the computer SPSS 20.0 windows application. Correlation analysis including Pearson correlation coefficient and Principal Component Analysis (PCA) via Varimax rotation method were used to determine the relationships between the parameters. Data analyses were done using SPSS 20.00 version for PCA, Microsoft excel (2003) for Pearson correlation coefficient and multivariate descriptive statistics as described by Rencher (2003). Taxa richness (d), general diversity (H) and evenness index (E) were calculated for zooplankton fauna using window package SPDIVERS BAS.

Results

The physical and chemical parameters and trace metal contents of the studied river are presented in Tables 1 and 2 respectively. The air temperature ranged between 19°C and 29°C while the surface water temperature ranged between 20.5°C and 28°C. The pattern of fluctuation for both air and water temperature varies among all stations. Water depth ranged from 18cm and 92cm and stations 3 and 4 were significantly different ($p< 0.01$) while turbidity ranged from 1.5NTU and 13.3NTU and stations 1 and 4 were significantly different ($p< 0.05$).

The mean flow velocity was lowest in station 2 (11.6cm/s) while stations 1 (14.6cm/s), 3 (16.5cm/s) and 4 (23.7cm/s) had high mean values which increased spatially and station 4 was significantly different ($p< 0.05$). Colour ranged from 6.6 and 12.2 and station 1 was significantly different ($p< 0.01$). Temporarily, there was a distinct seasonal pattern in the variation of turbidity.

The pH values revealed that the water was moderately acidic to moderately alkaline with a range of 5.2 to 7.1. The conductivity values ranged from 42.6μ/cm to 273μ/cm while total dissolved solids which followed the same spatial variation trend ranged between 21.9mg/l and 99.9mg/l. There was a clear seasonal variation in both conductivity and total dissolved solids; values increased from dry to wet season. The dissolved oxygen content ranged from 4.1mg/l and 6.4mg/l, concentrations generally increased with rains while the values of BOD_5 ranged between 1.1mg/l and 4.7mg/l with station 4 being significantly different ($p<0.01$). The temporal variation of DO and BOD_5 was irregular. The chloride concentration ranged between 15.2mg/l and 55.2mg/l in an irregular temporal variation. Nitrate values ranging from 0.06mg/l to 3.88mg/l were observed throughout the period of study. Peak values were recorded in the rainy season months and lower values in the dry season months while sulphate and phosphate values observed ranged from 0.30mg/l to 1.52mg/l and from 0.38mg/l to 3.37mg/l respectively. There was no clear seasonal pattern observed in sulphate and phosphate fluctuations. There was a significant difference in the values recorded in all the stations ($p<0.01$) and ($p<0.05$) for sulphate, phosphate, and nitrate. The cations such as sodium and potassium values ranged from 0.73mg/l to 2.32mg/l and 0.09mg/l to 0.49mg/l respectively. In both cases, a significant difference was observed in all stations ($p<0.05$). On the other hand, the concentration of calcium ranged between 1.65mg/l and 6.71mg/l while magnesium values ranged between 0.5mg/l and 2.0mg/l. There was a significant difference in the values of all stations ($p<0.05$).

Table 1. Mean and standard error of physical and chemical parameters of Ugbogui River, Ugbogui, Nigeria during the nine (9) months study period

Parameters	Station 1 (X±SE)	Station 2 (X±SE)	Station 3 (X±SE)	Station 4 (X±SE)	p-value	Standard FMEnv permissible limit	Standard WHO permissible limit
Air Temp. (°C)	24.67±0.99 (19.0 -28.0)	25.17±0.98 (21.0-28.0)	25.22±1.06 (19.5-8.0)	25.72±1.07 (19.5-29.0)	P > 0.05	N/A	N/A
Water Temp. (°C)	25.22±0.85 (21.0 -27.5)	25.11±0.87 (20.5-28.0)	25.17±0.85 (21.0-8.0)	24.72±0.81 (20.5-27.0)	P > 0.05	35.00	N/A
Water Depth (cm)	60.56±4.33 (51.0- 92.0)^a	59.75±3.66 (39.0-76.0)^a	30.94±1.42 (22-36)^b	32.11±2.92 (18-42)^b	P < 0.01*	N/A	N/A
Velocity (cm/s)	14.61±2.14 (7.19-25.61)^b	11.60±1.51 (6.65-21.52)^b	16.53±2.30 (9.86-24.18)^b	23.73±4.47 (10.56-47.62)^a	P < 0.05	N/A	N/A
Colour (Pt.Co)	7.30±0.85 (3.2-10.8)^b	11.87±1.19 (6.2-16.4)^a	12.24±1.72 (4.9-19.0)^a	6.60±1.02 (2.2-10.3)^a	P < 0.01*	15.00	N/A
Turbidity	5.97±0.75 (2.8-9.1)^b	9.12±0.64 (5.7-1.5)^a	8.39±1.10 (3.5-13.3)^a	5.67±0.92 (1.9-8.9)^b	P < 0.05	15.00	N/A
TSS (NTU)	8.79±0.72 (5.4-11.6)^b	14.09±1.34 (7.8-19.1)^a	14.07±1.74 (5.9-21.4)^a	8.66±1.17 (4.1-13.5)^b	P < 0.01*	5.00	5.00
TDS (mg/l)	52.47±6.58 (21.9-96.8)^b	64.86±3.48 (42.1-76.2)^b	71.74±7.34 (41.0-99.9)^a	52.79±3.40 (38.9-70.4)^b	P < 0.05	1000	30.00
pH	6.02±0.23 (5.2-7.1)	5.86±0.16 (5.4-6.9)	6.28±0.11 (5.9-6.9)	6.19±0.09 (5.8-6.5)	P > 0.05	6.50–8.50	6.50–8.50
Conductivity (μ/cm)	100.20±9.33 (42.6-135.5)^b	146.79±13.70 (84.8-221.6)^a	157.76±20.57 (81.7-273.4)^a	111.14±7.26 (76.4-140.2)^b	P < 0.05	N/A	100
Oxygen Saturation (mg/l)	5.51±0.16 (4.6-6.2)	5.06±0.21 (4.1-6.1)	5.43±0.23 (4.4-6.4)	5.38±0.23 (4.1-6.2)	P>0.05	7.50	5.00
BOD_5 (mg/l)	2.64±0.3154 (1.5-4.7)^a	3.34±0.26 (1.7-4.3)^a	3.30±0.21 (2.5-4.4)^a	2.11±0.18 (1.1-2.6)^b	P < 0.01*	20.00	N/A
COD (mg/l)	11.60±1.71 (2.4-18.5)^c	29.54±2.72 (16.0-42.7)^b	17.52±1.74 (7.2-24.6)^a	10.98±1.28 (4.2-15.9)^c	P<0.01*	40.00	N/A
HCO_3 (mg/l)	22.79±2.93 (12.2-42.7)^b	37.25±2.37 (24.4-47.4)^a	43.46±4.15 (24.4-67.1)^a	22.19±2.48 (12.9-36.6)^b	P<0.01*	200.00	N/A
Na^{2+} (mg/l)	1.28±.13 (0.73-1.88)^a	1.52±0.09 (1.18-1.97)^a	1.69±0.16 (1.11-0.74)^a	1.23±0.15 (0.85-2.32)^b	P<0.05	200.00	50.00
K^{2+} (mg/l)	0.19±0.03 (0.09-.34)^a	0.24±0.04 (0.12-0.49)^a	0.21±0.03 (0.06-0.31)^a	0.12±0.01 (0.08-0.18)^b	P<0.05	5.00	N/A
Ca^{2+} (mg/l)	2.77±0.30 (1.90-2.54)^b	3.52±0.32 (2.54-5.34)^a	4.05±0.41 (2.45-6.71)^a	2.67±0.29 (1.65-4.74)$_b$	P<0.05	1.00	200.00
Mg^{2+} (mg/l)	0.81±0.07 (0.5-1.2)^b	1.14±0.76 (0.7-1.5)^a	1.21±0.09 (0.9-1.6)^a	0.92±0.13 (0.6-2.0)^b	P<0.05	N/A	150.00
Cl^- (mg/l)	21.24±1.70 (15.2-31.9)^b	39.43±2.39 (28.4-48.2)^a	40.41±4.46 (17.7-55.2)^a	24.98±1.90 (17.7-35.5)^b	P<0.01*	5.00	400.00
PO_4^{3-} (mg/l)	0.93±0.13 (0.38-.38)$_b$	2.41±0.24 (1.14-3.18)^b	2.25±0.32 (0.83-3.37)^a	0.98±0.10 (0.59-1.46)^a	P<0.01*	5.00	N/A
NH_4N (mg/l)	0.07±0.01 (0.04-.13)^b	0.22±0.03 (0.11-0.47)^a	0.27±0.08 (0.06-0.85)^a	0.10±0.02 (0.02-0.23)^b	P<0.05	<1.00	N/A
NO_2^- (mg/l)	0.06±0.03 (0.01-.28)^b	0.12±0.01 (0.08-0.17)^b	0.16±0.03 (0.04-0.33)^a	0.08±0.02 (0.03-0.21)^b	P<0.05	N/A	3.00
NO_3^- (mg/l)	1.45±.31 (0.06-2.39)^a	2.27±0.30 (0.22-3.10)^a	2.29±0.42 (0.57-3.88)^a	1.19±0.21 (0.10-1.85)^b	P<0.05	10.00	50.00
SO_4^{2-} (mg/l)	0.69±0.055 (0.39-.86)^b	1.13±0.11 (0.61-1.81)^a	1.17±0.11 (0.53-1.52)^a	0.79±0.09 (0.30-1.11)^b	P<0.01*	500.00	500.00

*Significantly difference means ($p < 0.05$). Range in parenthesis

The values of the heavy metals were generally low. Iron values ranged from 0.16mg/l to 4.42mg/l with values recorded in the rainy season months. Manganese ranged from 0.001mg/l to 0.18mg/l. Zinc values ranged from 0.07mg/l to 0.99mg/l, while copper and chromium ranged from 0.01mg/l to 0.18mg/l and 0.00mg/l to 0.09mg/l respectively. While that of cadmium and nickel ranged from 0.007mg/l to 0.15mg/l and 0.00mg/l to 0.08mg/l respectively. Cadmium and nickel did not show any clear trend in their temporal variations. Lead ranged from 0.07mg/l to 0.19mg/l. Most of high lead values were recorded in the month of September. There were high significant difference observed among the heavy metals ($p<0.01$).

Table 2. Mean and standard deviation of some trace metal contents of Ugbogui River, Edo State, Nigeria during the nine (9) months study period

Parameters	Station 1 (X±SE)	Station 2 (X±SE)	Station 3 (X±SE)	Station 4 (X±SE)	p-value	Standard FMEnv Permissible limit	Standard WHO Permissible limit
Fe^{3+} (mg/l)	0.68±0.14 (0.16-1.33)[b]	1.62±0.38 (0.52-4.42)[a]	1.56±0.24 (0.63-3.06)[a]	0.73±0.14 (0.33-1.81)[b]	P<0.01*	1.00	N/A
Mn^{2+} (mg/l)	0.06±0.01 (0.001-0.094)[b]	0.10±0.01 (0.057-0.139)[a]	0.11±0.02 (0.04-0.18)[a]	0.04±0.01 (0.01-0.09)[b]	P<0.01*	0.05	N/A
Zn^{2+} (mg/l)	0.21±0.04 (0.07-0.51)[b]	0.66±0.07 (0.23-0.89)[a]	0.54±0.11 (0.14-0.99)[a]	0.24±0.038 (0.10-0.39)[b]	P<0.01*	1.00	N/A
Cu^{2+} (mg/l)	0.06±0.01 (0.03-0.12)[a]	0.08±0.01 (0.04-0.18)[a]	0.07±0.01 (0.03-0.10)[a]	0.03±0.01 (0.01-0.11)[b]	P<0.01*	0.10	N/A
Cr^{6+} (mg/l)	0.01±0.002 (0.000-0.026)[b]	0.04±0.01 (0.014-0.095)[a]	0.05±0.01 (0.01-0.07)[a]	0.02±0.003 (0.002-.024)[b]	P<0.01*	0.05	N/A
Cd^{2+} (mg/l)	0.02±.003 (0.01-0.032)[b]	0.06±0.01 (0.03-0.13)[a]	0.07±0.01 (0.03-0.15)[a]	0.016±0.002 (0.007-0.024)[b]	P<0.01*	0.01	N/A
Ni^{2+} (mg/l)	0.01±0.002 (0.00-0.02)	0.02±0.01 (0.00-0.07)	0.02±0.008 (0.00-0.08)	0.01±0.002 (0.00-0.02)	p>0.05	0.05	N/A
Pb^{2+}(mg/l)	0.02±0.01 (0.008-0.075)[a]	0.05±0.01 (0.017-0.112)[a]	0.06±0.02 (0.02-0.19)[a]	0.02±0.01 (0.00-0.06)[b]	P<0.05	0.05	N/A
V^{2+} (mg/l)	0.01±0.0018 (0.000-0.019)	0.020±0.01 (0.000-0.068)	0.02±0.01 (0.000-0.026)	0.01±0.002 (0.00-0.02)	p>0.05	0.01	N/A

*Significantly difference means ($p < 0.05$). Range in parenthesis.

Discussion

The physical and chemical parameters investigated in this study showed the water quality and the general variability of these parameters along the sampled stretch. Surface water temperature follows air temperature, and it is influenced by the composition of turbidity, vegetation cover, runoffs, and heat exchange with air (Onuwudinjo, 1990; Imoobe and Oboh, 2003; Edokpayi *et al.*, 2012; Ogbeibu *et al.*, 2012). The observed temperature range in the study for air and water which is typical of tropical rivers. Ekeh and Sikoki (2003) recorded a similar range of in New Calabar River. However, the effects of cloud cover and river flow on the air and water temperature have been implicated in fluctuations in temperature of tropical rivers (Imoobe and Oboh, 2003). There was a progressive temperature increase across each sampling stations which could be because air temperature increased as sampling progressed in each sampling day.

The observed water level mean values were lower in the dry season than in wet season which could be because of the influence of tidal action and surface run-off during the rainy seasons. Factors such as pH, Dissolved Oxygen, Turbidity, and suspended solids are higher during high water level, while transparency, conductivity, NO_3^-, PO_4^{3-} and Na^+ are higher during low water level. Similar findings were reported by Anyanwu (2012) at Ogba River and Uwadiae, (2014) for Epe Lagoon. Water depth showed a seasonal pattern of variation in the study and this trend is consistent with reports from most Nigerian inland waters (Imoobe and Oboh, 2003; Arimoro *et al.*, 2007; Edegbene and Arimoro 2012; Ogwo and Okereke, 2014). The variations in depths are usually with the rainfall pattern of the drainage basin. Lower depths recorded during the rainy season especially in stations 1 and 2 could be attributed to heavy siltation associated with an increase in rainfall exacerbated by the increased floodwater entering the river system.

Flow rate (velocity) is a function of the amount and width of the water channel. There was an increase in flow rate during the rainy season months in Ugbogui River due to run-off of erosion from the nearby town which increased the water volume. Ikomi *et al.* (2003); Olomukoro and Egborge (2004); Udebuana *et al.* (2015) reported similar findings. Colour was generally higher in the dry season than in the rainy season months because with reduced rainfall and little or no allochthonous materials introduced into the river via runoffs, the river experienced a relatively tranquil state which made more particulate matters to settle at the bottom leaving clearer and more transparent water.

Turbidity consists of suspended particles in the water and may be caused by several materials, organic or inorganic. Turbidity was generally higher in the wet season than in the dry season because of the influx of particulate matters with runoffs during the rainy season caused an increase in suspended solids. The observed values in this study which is within the FMEnv permissible limit which was same as Amadi and Efiuvwevwere (2015) in Ogodogbo creek, Niger Delta.

Total Suspended Solids (TSS) is the material in water that affects the transparency or light scattering of the water and is typically composed of fine clay or silt particles, plankton, organic compounds, or other microorganisms while Total dissolved solids (TDS) are a measure of dissolved matter (salts, organic matter, minerals, etc.) in water and inorganic constituents comprise most of the total concentration of TDS. TSS and TDS were higher in the wet season than in dry season which could be attributed to the fasting flowing nature of the river during the wet season, run-offs from sediment and catchments watershed. The settlings of dissolved salts coupled with the uptake of ions may be adduced for the lower TDS values in the dry season. Similar findings were reported for Calabar River by Akpan *et al.* (2003) and Udofia *et al.* (2014) for Akpa Yafe River.

Acidity or alkalinity is a measure of hydrogen ions concentration in a sample (Tebbutt, 1992), the average pH values across the stations were less than 7. Thus, pH values of the river indicate slightly acidic nature and correspond with findings of Rim-Rukeh *et al.* (2006) for the Orogodo River and Kaizer and Osakwe, 2010) for River Ethiope. The acidic nature of rivers in Nigeria had earlier been noted by different aquatic ecologist (Holden and Green, 1960; Egborge, 1971; Egborge *et al.*, 1986). Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulphate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminium cations (ions that carry a positive charge). Conductivity is also affected by temperature, the warmer the water, the higher the conductivity. The conductivity values obtained in this study is like the findings for Keiskamma River by Fatoki *et al.*, (2003) and Arimoro *et al.*, (2007) for Warri River, Delta State, Nigeria. The concentrations of conductivity and TDS were lowest at the upstream and highest at the downstream.

Dissolved oxygen is an important indicator of the water quality, ecological status, productivity, and health of an aquatic ecosystem. Higher dissolved oxygen recorded in the rainy season could be because of low temperature and increased dilution of water. Therefore, meteorological condition like rainfall and wind help to increase dissolved oxygen and is consistent with the reports of Ewa *et al.*, (2011) for Omoku Creek and Braide *et al.*, (2004) who attributed seasonal fluctuation to the effect of temperature on the solubility of oxygen in water and asserted that DO is indirectly proportional to BOD. Both Biological Oxygen Demand (BOD) and Chemical Oxygen demand (COD) tests are measures of the relative oxygen-depletion effect of organic wastes in the water. The BOD is a direct measurement of oxygen requirement and an indirect measurement of biodegradable organic material in water. The concentration of BOD was high indicating a high load of organic wastes in the river. The observed range of BOD in this study is like the reports by Iwuoha and Osuji (2012) in Imo and Udebuana *et al.*, (2015) in Okhuo River. The mean concentration of BOD was above the permissible limits of FMEnv (0). The mean concentration of BOD values was higher in the rainy season than the dry season. The concentration of chemical oxygen demand values was low compared with (Badsi *et al.*, 2010) whose COD values ranged from 100 to 520mg/. Chemical oxygen demand (COD) varied highly significant ($P<0.01$) across the 4 stations. The mean concentration of COD was higher in the dry season than in the wet season.

Sodium, potassium, calcium, and magnesium showed significant variations across the study stations. The concentration of sodium recorded was higher than that of Ikhuoriah *et al.* (2015). The concentration of potassium in the water was lower than that of Ikhuoriah *et al.* (2015). The mean concentration of potassium recorded in the wet season was not significantly higher (P>0.05) than that of the dry season. Calcium is a very essential element which serves as a nutrient in our body. Excess amount of calcium (Ca^{2+}) can damage the kidney and impact hardness to the water. The concentration of calcium was low when compared with the values of 6.75-34mg/l recorded by Imoobe *et al.* (2008) in Ekpan Creek. The concentration of calcium was significantly higher (P>0.05) across all stations. Excess concentration of magnesium in water causes water hardness which may further cause cardiovascular mortality. The mean concentration was higher (P<0.05) at stations 1 and 4 which was significantly different (P<0.05) for other stations.

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