Assessment of the physical and chemical properties of Lake Oguta (Nigeria) in relation to the water quality standard established by the Nigerian Federal Ministry of Water Resources

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ABSTRACT

Constant assessment of physical and chemical parameters in freshwater ecosystems is largely recommended. This is even more important when water resources, *e.g.* lakes in most countries, serve as a source of water for domestic and commercial purposes, and /or when freshwater ecosystems represent a refuge for most aquatic organisms. In this paper, we investigated the physical and chemical properties of water resources at three sampling stations of Lake Oguta, comparing the weekly values (June-July 2018) with the water quality standard established by the Nigerian Federal Ministry of Water Resources (FMWR). The parameters analyzed included water temperature, pH, dissolved oxygen (DO), chemical and biological oxygen demand (COD, BOD), potassium, magnesium, sodium, calcium, phosphate, nitrate, chloride and sulphate. Most of the cations (calcium, magnesium and sodium), anions (phosphate, nitrate, chloride and sulphate), as well as water temperature, BOD and DO were below the quality standard limits. The basic chemistry and temporal variations may have been caused mostly by natural factors such as geology, topography, meteorology, hydrology, water levels and biological activity. Being in line with the recommended standard levels, the nutrient concentrations, pH and hardness in the current study may indicate favourable conditions for the life of aquatic organisms and contemporary co-existence with the human exploitation for drinking purposes. Nevertheless, to assure a safely and conscious exploitation of this water resource, we recommend continuity in the monitoring studies. To assure an accurate evaluation of the physical and chemical parameters, future studies should include a larger sample size and extended study periods (including other seasons).

INTRODUCTION

Water characteristics and quality are defined by specific physical, chemical and biological properties, and how these properties impact the survival, reproduction, growth and management of aquatic life (Aduwo and Adeniyi, 2019). Indeed, the sustainability and development potential of any country may not be possible without water (Salla and Ghosh, 2014). Lakes may be monitored for recreational, domestic and/or used as a component of hydro-power generating systems. In developing countries, lakes are primarily used by the local inhabitants for transportation, fishing, washing, cooking and irrigation practices (Okoro *et al*., 2014). However, most records these days indicates that water quality is increasingly deteriorating, and this is cause of a global concern (Mahananda *et al*., 2005). A previous study (Salla and Ghosh, 2014) emphasized that about 75% of surface water may be contaminated by different kinds of pollutants. Pollutants may include heavy metals (Awoyemi *et al*., 2014) or nutrients (*e.g.* phosphate and nitrate) from industrial discharges (Mahananda *et al*., 2005) or agricultural activities. Higher concentrations of nutrients, *e.g.* phosphorus and nitrogen, may cause hypoxia and algal bloom (Anitha, 2002; Garg *et al.,* 2009), which may cause low light penetration, obstruction of oxygen levels and loss of aquatic life and biodiversity (*e.g.* fish mortality) (Parashar *et al*., 2006). For these reasons, the constant monitoring of water quality in lakes is essential and can be conducted by quantifying the level of physical and chemical parameters. The physical properties of a lake include water temperature, colour, odour and taste, solids and turbidity (Aduwo and Adeniyi, 2019), while the chemical assessment involves the measurements of cations, anions, nutrient compounds, toxic and non-toxic compounds, and oxygen demands by inorganic and organic substances (Ademoroti, 1996).

A typical lake and a major source of water for the local population of South-Eastern and Niger-Delta region in Nigeria is Lake Oguta. The lake serves as a source of income to the community (fishing and also dredging the lake for sand, which is used in the construction industries) (Nfor and Akaegbobi, 2012). However, the lake has been exposed to threats due to excessive oil exploration (Isinkaye and Emelue, 2015) and sewage disposal (Nfor and Akaegbobi, 2012). Currently, records on the physical and chemical status of the lake are needed, but very few are existing or have been explored (Nfor and Akaegbobi, 2012). The investigation of water quality levels (physical and chemical properties) of Lake Oguta by a comparison with a set of standards (Dirican, 2015) may provide information for Government management policies (Patil *et al*., 2012). The objective of this paper is to evaluate water quality and potential human exploitation (including drinking purposes) of Lake Oguta using a suitable subset of variables measured at weekly intervals. The parameters that have been measured, *i.e.* water temperature, pH, dissolved oxygen, chemical and biological oxygen demand, potassium, magnesium, sodium, calcium, phosphate, nitrate, chloride and sulphate were compared with the standards assessed by the Nigerian Federal Ministry of Water Resources FMWR (NIS, 2015).

METHODS

Study area

Imo State is located in South-Eastern Nigeria; currently, the State is famous for its largest natural lake or fresh water lake, Lake Oguta (Nfor and Akaegbobi, 2012) (Fig. 1). The lake is located in a low-lying platform, at 50 m above sea level, between latitudes 5°4''and 5°44' N, and longitudes 6°45'and 6°50' E. Four rivers (Njaba, Awbuna, Utu and Orashi) are connected to the lake (Ahiarakwem and Onyekuru, 2011). However, all year round, rivers Njaba and Awbuna discharges into the lake, while Utu Stream flows in during the rainy season (Ahiarakwem *et al*., 2012). The river Orashi flows past the lake in its South-Western portion. It is recorded that, the total annual inflow from the rivers and streams is about 25,801 m^3 (Ahiarakwem, 2006), while the annual return and overland flow into the lake is estimated to be about 69,000 and 138,000 m^3 (Okoro *et al*., 2014). Also, the annual recharge of the lake from precipitation is about 693,000 m^3, while the annual groundwater inflow into the lake has been estimated (2,750,400 m^3) (Ahiarakwem *et al*., 2012). Indeed, the total annual water inflow, heavily outweighs the total annual outflow, thus, the lake is adequately recharged all the year round (Ahiarakwem, 2006). The surface area of the lake ranges between 1.8 km^2 and 2.5 km^2. The shoreline length is around 10 km; maximum and mean depths are 8.0 m and 5.5 m,

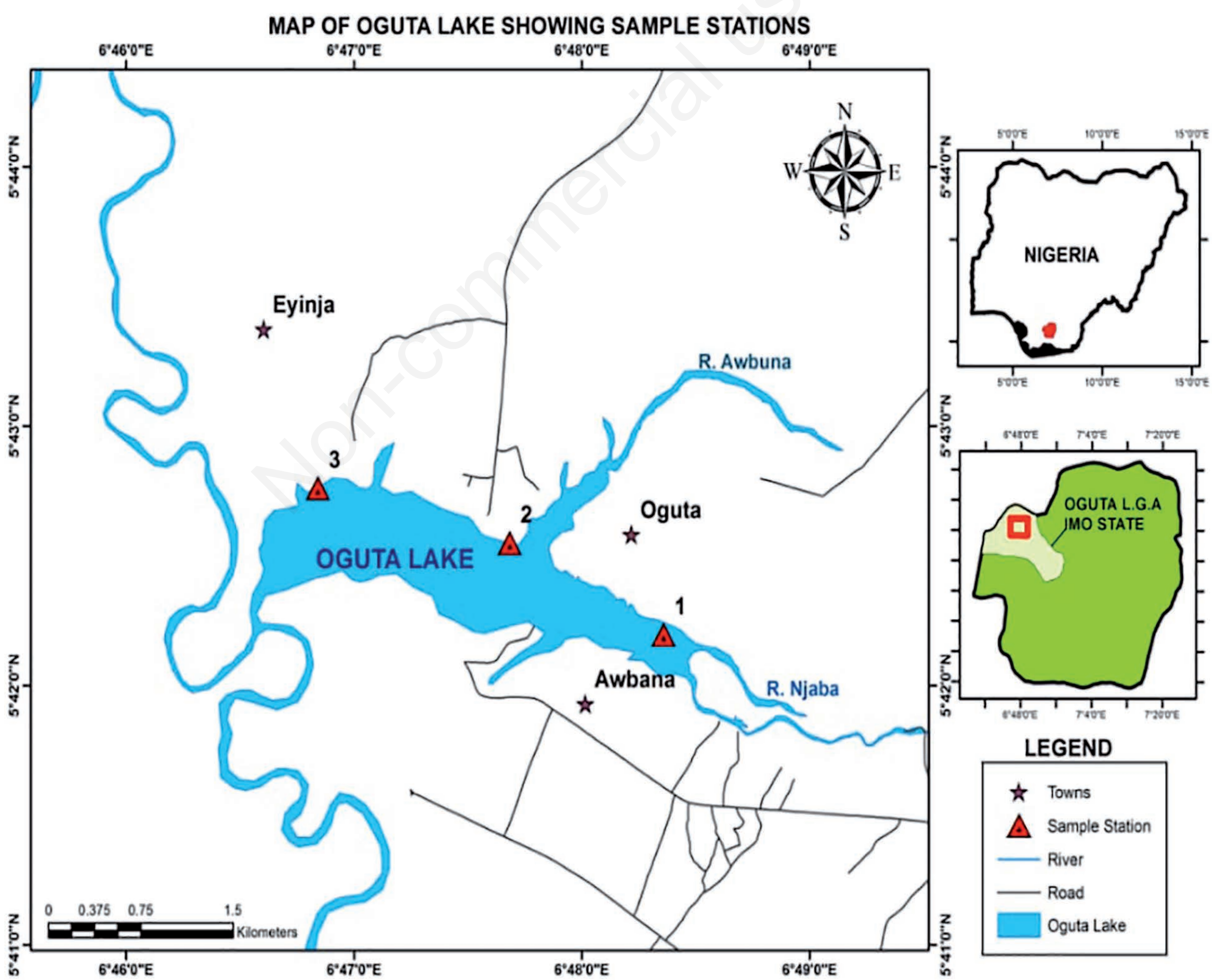

Fig. 1. Map of Lake Oguta. Sampling stations are indicated with red triangles.

respectively (Nfor and Akaegbobi, 2012). May be, owing to the low cation concentration and alkalinity of the water, conductivity may range between 8.6-30 µS cm^{-1} (Odigi and Nwadiaro, 1988; Okorondu and Anyadoh-Nwadike, 2015); also, the surface water temperature (24-31°C), Secchi-disc-transparency (0.61-4.50 m) (Odigi and Nwadiaro,1988; Nwadiaro, 2018) may vary seasonally with rainfall. The lake experiences a weak, unstable thermal stratification, which may develop towards the middays of the warmer months (*i.e.* April-August) (Nwadiaro, 2018).

Selection of sampling site, data collection and processing

After a pre-sampling survey aimed at assessing the general characteristics of the lake and activities in the catchment, we identified three peculiar zones, *i.e.* station 1, or lake bank (human activities active, *e.g.* washing); station 2, lake flows into each other; and station 3, area with active farming. We traversed the lake using a boat and collected water samples every week, from June to July, 2018. The distance between sampling stations was 2.5 km; and before sample collection, we ensured that the containers were thoroughly rinsed with the lake water. During our sample collection we were guided by a standard procedure (APHA, 1998; Awoyemi *et al*., 2014). Water samples were collected by gently lowering the container into the lake (Ozoko, 2015). In the field, each water sample was first analysed to quantify dissolved oxygen (DO) using the Winkler's method (Aduwo and Adeniyi, 2019). We measured also, the surrounding temperature (28.0-33.0°C) and water temperature (25.5-27.8°C) for each station using a mercury-in-bulb thermometer (graduation 0-360°C). The probe was lowered into the water for at least five minutes, and readings were recorded immediately while the thermometer was still in the water, necessarily to avoid interference with ambient temperature. Hydrogen activity (pH) was measured using a portable Hanna Field pH meter (Model PHS 25), inserted into the water and allowed to attain a steady value. Further, water samples for chemical analyses were preserved using 10 ml 6N HNO_3 (Awoyemi *et al*., 2014), and transported to the National Center for Energy Research and Development Laboratory, University of Nigeria, Nsukka, Enugu State (6º 51'21" N 7º23'45" E). In the laboratory, biochemical oxygen demand (BOD) was quantified using iodiometric titration (Aduwo and Adeniyi, 2019). While chemical oxygen demand (COD) was quantified in the laboratory using the chromic acid wet digestion titrimetric method (Awoyemi *et al*., 2014). An ultraviolet atomic absorption spectrophotometer (Ozoko, 2015), was used for quantification of cations, *i.e.* sodium (Na^+), potassium (K^+), magnesium (Mg^{2+}) and calcium (Ca^{2+}). While the major anions, *i.e.* phosphate (PO_4^{3}-), nitrate (NO_3-), sulphate (SO_4^{2}-), were assessed through ion chromatography (Dionex) (APHA, 1998; Dirican, 2015).

Statistical analysis

Data were analysed using SPSS (Statistical Package for Social Science) version 20.0; the physical and chemical parameters were first checked for normality and homogeneity of variance. Analysis of variance (ANOVA) was used to test the level of significance (set at $P<0.05$); Duncan's New Multiple Range Test (DNMRT) was used to separate monthly station means.

RESULTS

The results of the physical and chemical parameters quantified from the analysis of Lake Oguta, compared to water quality standard established by the Nigerian Federal Ministry of Water Resources (FMWR), are presented in Tab. 1. Water temperature was significantly different between months in two stations, *i.e.* stations 2 and 3 ($P=0.01$ and $P=0.03$, respectively). The range of values in the three stations (25.6-27.8°C), was below the Federal standard limit (<35ºC). Values of pH were significantly different between months in station 3 ($P=0.03$); the pH range in the current study (6.5-7.1) was within the standard limit (6.5-8.5). Also, DO range was below (3.4- 5.7 mg L^{-1}) the standard limit (7.5 mg L^{-1}), and was not statistically significant between months in the three stations ($P>0.05$). COD values ranged between 24.4 and 26.7 mg L^{-1}; differences between months were statistically significant only in station 3 ($P=0.01$). BOD was significant between months in stations 1 and 3 ($P=0.01$ for both); further, the range of BOD values recorded in the three stations (3.9-5.9 mg L^{-1}) was below the standard limit (8.3 mg L^{-1}). Potassium (2.6-4.3 mg L^{-1}) showed significant differences between months in stations 1 and 2 ($P=0.01$). Sodium (1.3-2.5 mg L^{-1}) showed significant differences in station 3 ($P=0.03$); below the standard limit (200 mg L^{-1}). Among algal macronutrients, *i.e.* phosphate and nitrate; phosphate concentrations (0.9-1.3 mg L^{-1}) showed no differences between months, and having lower values compared to the standard limit (<13.5). While nitrates ranged between 2.4 and 5.8 mg L^{-1} below the standard limit (50 mg L^{-1}) with significant differences between months in station 3 ($P=0.01$). Other parameters ranged between 10.5 and 14.0 mg L^{-1} (chloride) and 3.5 and 5.6 mg L^{-1} (sulphate). At the stations 1 and 2, differences in chloride concentrations were statistically significant ($P<0.05$), while sulphate was significant only in station 1 ($P=0.04$); these two parameters were below the standard limit. The water parameters measured, *e.g.* magnesium and calcium especially in its complex form, *i.e.* $mgCaCO_3$ (150 mg L^{-1}), is used as an indicator of water hardness in Nigeria (NIS, 2007). Magnesium concentrations were significantly different in station 3 (P=0.01) and ranged between 3.1 and 4.6 mg L^{-1}, below the standard limit (20 mg L^{-1}), while calcium values were not statistically different between months in any of the three station, and ranged between 1.9 and 2.9 mg L^{-1}, below the standard limit (150 mg L^{-1}).

DISCUSSION

In the current study, the range of surface water temperature in the three stations was not beyond the Federal standard (<35°C) and also within the values reported in other studies, *e.g.* 26.5-33°C (Oluyemi *et al.*, 2010); 26.4-31°C (Rim-Rukeh, 2013); 25-28°C (WHO, 2011); and 24.2-26.2°C (Nwoko *et al.*, 2015). Usually, air temperature can seriously influence water temperature, hereby causing differences in the surface and / or mid-bottom level temperature of a lake. Such changes in water temperature can also influence other water quality indices (Dirican, 2015). In the current study, the weather condition was cooler due to several rain showers experienced at the sampling station. High temperature values increase the metabolic rate of aquatic organisms, with important effects on O_2 production and consumption. In case of excessive primary production, this can cause a

Tab. 1. Monthly variations in the physical and chemical parameters in the three sampled stations, and comparison with the limits set by the standards of the Nigerian Federal Ministry of Water Resources.

Variable	Duration		Station 1	Station 2	Station 3	FMWR
Temperature (°C)		June	27.17 ± 0.18	26.60 ± 0.06	27.78 ± 0.15	<35.0 6.5-8.5
		July	26.67 ± 0.13	25.57 ± 0.19	27.17 ± 0.12	
	t-test, P-value		2.261, 0.087	5.316, 0.006	3.182, 0.033	
pH		June	7.10 ± 0.15	6.70 ± 0.12	6.50 ± 0.06	
		July	6.97 ± 0.18	6.93 ± 0.09	6.83 ± 0.09	
	t-test, P-value		0.571, 0.598	1.606, 0.184	3.182, 0.034	
DO (mg L^{-1})		June	3.73 ± 0.15	5.67 ± 0.15	3.77 ± 0.09	7.5
		July	3.40 ± 0.15	5.53 ± 0.15	3.93 ± 0.12	
	t-test, P-value		1.581,0.189	0.649, 0.552	1.118, 0.326	
COD (mg L^{-1})		June	25.17 ± 0.12	24.36 ± 0.10	26.67 ± 0.12	
		July	25.56 ± 0.13	24.41 ± 0.10	25.67 ± 0.04	
	t-test, P-value		2.226, 0.090	0.401, 0.709	7.973, 0.001	
BOD (mg L^{-1})		June	4.38 ± 0.20	3.85 ± 0.10	4.74 ± 0.14	8.3
		July	5.90 ± 0.06	4.05 ± 0.10	5.67 ± 0.07	
	t-test, P-value		7.233, 0.002	1.411, 0.231	5.899, 0.004	
Potassium (mg L^{-1})		June	3.27 ± 0.17	2.58 ± 0.01	4.13 ± 0.05	
		July	4.16 ± 0.07	3.01 ± 0.06	4.30 ± 0.13	
	t-test, P-value		4.866, 0.008	6.697, 0.003	1.206, 0.294	
Magnesium (mg L^{-1})		June	3.68 ± 0.16	3.13 ± 0.07	3.65 ± 0.05	
		July	4.29 ± 0.15	3.37 ± 0.09	4.64 ± 0.04	20
	t-test, P-value		2.779, 0.050	2.040, 0.111	14.569, 0.0001	
Sodium (mg L^{-1})		June	2.22 ± 0.15	2.38 ± 0.41	2.17 ± 0.07	200
		July	1.71 ± 0.12	1.33 ± 0.06	2.51 ± 0.08	
	t-test, P-value		2.718, 0.053	2.539, 0.064	3.307, 0.030	
Calcium (mg L^{-1})		June	2.48 ± 0.09	2.17 ± 0.17	2.80 ± 0.12	150
		July	2.30 ± 0.15	1.93 ± 0.09	2.90 ± 0.12	
	t-test, P-value		1.026, 0.363	1.265, 0.275	0.612, 0.573	
Phosphate (mg L^{-1})		June	1.01 ± 0.04	0.90 ± 0.05	1.16 ± 0.09	< 13.5
		July	1.23 ± 0.13	0.88 ± 0.04	1.30 ± 0.12	
	t-test, P-value		1.568, 0.192	0.313, 0.770	0.938, 0.401	
Nitrate (mg L^{-1})		June	3.90 ± 0.15	2.70 ± 0.06	4.90 ± 0.06	50
		July	4.60 ± 0.21	2.43 ± 0.29	5.83 ± 0.09	
	t-test, P-value		2.711, 0.053	0.900, 0.419	8.854, 0.001	
Chloride (mg L^{-1})		June	12.70 ± 0.12	10.53 ± 0.26	13.77 ± 0.19	250
		July	13.53 ± 0.18	11.47 ± 0.03	14.00 ± 0.10	
	t-test, P-value		3.953, 0.017	3.556, 0.024	1.107, 0.330	
Sulphate (mg L^{-1})		June	4.43 ± 0.23	3.50 ± 0.17	5.30 ± 0.06	100
		July	5.20 ± 0.12	3.90 ± 0.10	5.57 ± 0.15	
	t-test, P-value		2.945, 0.042	2.000, 0.116	1.706, 0.163	

FMEV, Nigerian Federal Ministry of Environment; pH, hydrogen ion concentration; DO, dissolved oxygen; COD, chemical oxygen demand; BOD, biological oxygen demand. All values expressed as mean ± standard error mean (±SEM). The level of significance between months was set at P<0.05.

successive fall in the level of dissolved oxygen concentrations due to mineralization of organic matter. Such changes may retard the growth and reproduction of some fishes and in some severe conditions result to the death of the more vulnerable organisms.

By the current pH records, Lake Oguta can be classified as weakly acidic to neutral, *i.e.* within the Federal standard (6.5-8.5), and other records, *e.g.* 6-9 in (WHO, 2011); 6.5-8.9 (Oluyemi *et al*.,2010) and 5.1-7.4 in (Rim-Rukeh, 2013). These results indicate a sufficient buffering property of the lake, suggesting safe agricultural and domestic uses (Oluyemi *et al*., 2010). Additionally, the current pH recorded may be adequate for the life of most aquatic organisms. In fact, a previous study recommended a range of 6.5-8.5 for most fishes to thrive (Egemen, 2011). On the other hand, studies suggest that DO value higher than 10 mg L^{-1} indicate bad or sub-optimal conditions for the growth of aquatic fauna (Clerk, 1986; Bhatnagar and Singh, 2010; Ekubo and Abowei, 2011). Further, high DO concentrations may indicate excessive algal proliferation (Reynolds, 2006). Here, the DO recorded at the three stations was not beyond the Federal limit (7.5 mg L^{-1}), although quite low, and near the limit for most aquatic life (Franklin, 2013). However, the DO values for this study may be considered around or above values recommended for fish to survive (3-5 mg L^{-1}; Gorde and Jadhav, 2013). The mean BOD (3.9-5.9 mg L^{-1}) was not beyond the Federal limit (8.5 mg L^{-1}) or WHO (2011) limits, and also not within other ranges from the same lake, *e.g.*, 0.2-0.3 mg L^{-1} (Nwoko *et al*., 2015). The COD, which is the amount of oxygen needed to carry out oxidation of organic waste by using strong oxidizing agent (Awoyemi *et al*., 2014), was not beyond other standards, *e.g.* 20- 60 mg L^{-1} (WHO, 2011). However, the values were above other recorded values, *e.g.* 0.69- 6.74 mg L^{-1} (Oluyemi *et al*.,2010).

Phosphate level was below the Federal standard (<13.5 mg L^{-1}) and even below ranges reported in other studies (Aduwo and Adeniyi 2019). Values above the Federal standard may indicate pollution, because it is considered high (OECD, 1982). Usually, sewage phosphate-based fertilizers used for agricultural activities are the cause of higher phosphate content in water. The nitrate content recorded here, are far below the Federal (10 mg L^{-1}) and the WHO (2011) standards (50.0 mg L^{-1}), and below concentrations reported in a previous studies (37.2-43.9 mg L^{-1}; Igbinosa *et al*., 2012). Higher phosphate and nitrate level promote eutrophication (Ryding and Rast, 1989).

Potassium concentrations (2.6-4.3 mg L^{-1}) in the current study were slightly above other records (*e.g.* 2.1-2.6 mg L^{-1}; Aduwo and Adeniyi, 2019), while sodium was far below the Federal standard (200 mg L^{-1}). Sulphate and chloride values were below the FMWR standard. Chloride can form many compounds (NaCl, $CaCl_2$ and $MgCl_2$), at varying concentrations in most natural waters (Awoyemi *et al*., 2014). Cloride is largely transported into the lake water by the dissolution of salts present in the soil and / or from polluting sources such as sewage and trade wastes (Shaikh and Mandre, 2009). Higher values of chloride may affect water taste; however, these values are generally lower during the rainy than dry season (Shaikh and Mandre, 2009; Awoyemi *et al*., 2014). Other measured parameters like magnesium and calcium contribute to water hardness. Total hardness of any water may be defined as the sum of calcium and magnesium concentrations and is normally expressed as milligrams of calcium carbonate equivalent per litre (Karim and Panda, 2014). In the present study, the hardness levels were very low compared to the Federal standard and other studies (*e.g.* 229-1494 mg L^{-1}; Awoyemi *et al*., 2014). This is probably because there are less deposits of limestone materials around the lake, which is why the lake experienced low values of hardness (Vermani and Narula, 1995).

CONCLUSIONS

The results presented in this paper indicates that some of the physical and chemical parameters in Lake Oguta were below Nigerian Federal Ministry of Water Resources standard. For example, the physical parameters (temperature), the cations (calcium, magnesium and sodium), anions (phosphate, nitrate, chloride and sulphate) as well as BOD and DO were all below the FMWR standard. Usually, the variations observed may be due to natural causes (geological, topographical, meteorological, hydrological and biological) and water level, as well as anthropogenic impacts. At present, no attempts were made to disentangle the contribution of natural and anthropogenic factors to the chemical conditions of the lake. Further, considering the short period analysed, and to assure an accurate evaluation of the physical and chemical parameters, it is stressed that future studies should include a larger sample size and extended study periods (including all the seasons).

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