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PHYSICOCHEMICAL AND MICROBIOLOGICAL CHARACTERISTICS OF WATER SAMPLES FROM THE BORGU SECTOR OF KAINJI LAKE NATIONAL PARK, NIGERIA

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ABSTRACT: The *quality of water resources in any ecosystem provides significant information about the available resources for supporting life in such ecosystem. The study therefore assessed the physicochemical and microbiological characteristics of water samples from the Borgu Sector of Kainji Lake National Park, Nigeria. The study was carried out at Borgu sector of KLNP purposively selected based on the availability of perennial waterholes. Water samples were collected from four waterholes for two seasons (dry and wet). Water samples were subjected to physicochemical [temperature, pH, total dissolved solid, electrical conductivity, total suspended solids, dissolved oxygen (DO), nitrate, chloride, phosphate, sulphate, biological oxygen demand and chemical oxygen demand (COD)] and microbiological (total coliform and fungal counts) analyses using standard methods. Data collected were subjected to descriptive statistics and T-test at* $\alpha_{0.05}$ *and compared with WHO permissible limits. The result showed that DO and COD levels of all the water samples were above the WHO guideline while there were significant seasonal variation in the values of temperature (t=4.93), EC (t=2.46), TDS (t=2.33), nitrate (t=3.66), chloride (t=4.91) and COD (t=4.23) in the waters sampled across the seasons of sampling. Salmonella / Shigella and Staphylococcus aureus were observed to be absent while the total coliform and fungi counts were observed to be higher than the WHO permissible limit for drinking water. The presence of thermo-tolerant such as Klebsiella sp and Enterobacter sp observed in the study may be an indication of faecal contamination. Periodical monitoring of the river water quality in Kainji Lake National Park is required to protect drinking water resources, encourage recreational activities and provide a good enabling environment for wildlife.*

KEYWORDS: Water quality, Seasonal variation, anthropogenic activities, Kainji Lake National Park

INTRODUCTION

Water is essential at every stage of life for any living organism (Kamble *et al.*, 2008) as all organisms on earth needs water for their growth and other physiological processes. As such, the availability of good quality water is an indispensable criterion for improving quality of life. The quality of water in an environment is fundamental and crucial to the survival of biotic component of such environment. According to Rajesh *et al*. (2002), the quality of water resources in any ecosystem provides significant information about the available resources for supporting life in such ecosystem. The quality of water, often described in terms of the physical, chemical and microbiological characteristics (Diersing, 2009) is basically a measure of the condition of water relative to the requirements of one or more biotic species or to human need and/or purpose.

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River systems are the primary means of disposal of waste, especially industrial effluents and sewage discharges from surrounding communities (Raji *et al.*, 2015). These wastes have a great deal of influence on the contamination of aquatic systems, due to its ability to alter the physical, chemical and biological nature of the receiving water body (Fakayode, 2005). As such, river water pollution is not only an aesthetic problem, but also a serious ecological and public health problem as well. The dynamics of water quality presents complex patterns and variability which are dependent on a varying unpredictable factors may be hydrological, meteorological, anthropogenic or from eutrophication (Bu *et al.*, 2010; Omotoso *et al.*, 2015). Anthropogenic activities such as the non-rational use of fertilizers and pesticides, industrialization and the lack of public awareness of the protection of the environment, often lead to an imbalance of the ecosystem and generate pollutants that can alter the physicochemical and biological quality of aquatic resources (Togue *et al.*, 2017). The analysis of the physicochemical and microbiological characteristics of water is necessary to understand ecological and environmental pathways of aquatic resources (Patil *et al.*, 2012). Though Ajibade *et al.* (2008) assessed the water quality of major rivers in Kainji Lake National Park, the inadequacy of recent database on physicochemical and microbiological characteristics of water constitutes a barrier to assessing wildlife and environmental health in Kainji Lake National Park. This study therefore aimed at examining the physicochemical and microbiological characteristics of water samples from the Borgu sector of Kainji Lake National Park, Nigeria.

METHODOLOGY

Study Area

The Kainji Lake National Park (KLNP) was established in 1979 by the merger of two former game reserves, Borgu game reserve (located in Niger and Kwara States) and Zurguma game reserve (located in Niger State) and is located approximately 560 km north of Lagos, and 385 km Southwest of Abuja, the Federal Capital Territory of Nigeria with a total area of 5,340.82 km^2. The park lies approximately between latitudes 9^0 40' N and 10^0 30' N and longitudes 3^0 30' E and 5^0 50' E. The soils of the park have been described as ferruginous tropical soils (Ubom, 2006) and the variation in soil properties influence the distribution of the vegetation complex. The topography of KLNP is such that the terrain of the park is gently undulating with the highest elevation (excluding the hills) about 300 – 350 m above sea level. The vegetation of the park is Northern Guinea Savannah comprising of *Burkea africana, Detarium microcarpum,* wooded savanna, *Isobelina tomentosa* woodland, *Diosspyros mespiliformis* dry forest, *Terminalia macroptera tree savanna, Isobelina* savanna woodland, Riparian forest woodland and Oli river complex(Tyowua *et al.*, 2012). The park is also rich in fauna species such as baboons (*Papio anubis*), kobs (*Kobus kob*), lions (Panthera leo), bushbuck (*Tragelaphus scriptus*), waterbuck (*Kobus defassa*), hippopotamus (*Hipopotamus amphibius*), crocodiles (*Crocodylus niloticus*) and so on.

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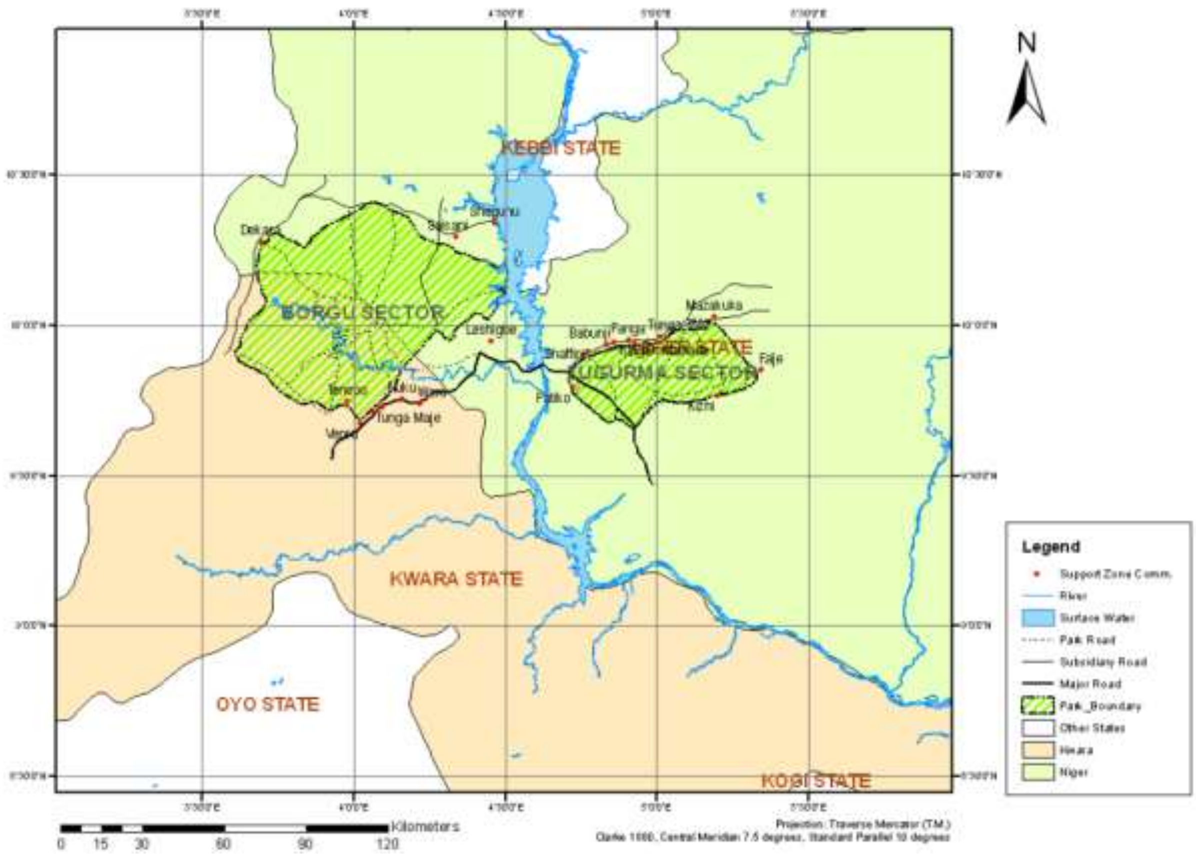

Figure 1: Map of Kainji Lake National Park showing Borgu and Zugurma Sectors
Source: Tyowua *et al.*, 2012

Sample Site Selection

This study was carried out at Borgu sector of Kainji Lake National Park (KLNP), purposively selected based on the availability of perennial rivers and biodiversity richness sequel to a thorough reconnaissance survey of the park.

Samples Collection and Technique

Water sampling at four sampling stations (Oli River, Kilometer 3, Kilometer 5 [Crocodile pool] and Kilometer 8 [Hippo pool]) was performed using the grab sampling technique. Water samples were collected randomly at each sampling station into sample bottles that were properly rinsed and labelled adequately. All the water samples were after collection, taken to the laboratory within forty-eight (48) hours of collection for physicochemical and microbiological analyses. Collection of samples was done with the help of park rangers for two seasons (dry and wet) so as to evaluate the impact(s) of seasonal variation on the parameters to be assessed.

Laboratory Analysis of Water Samples

Physicochemical parameters such as pH was determined by using a pH meter (portable HI9813-5) while the temperature (temp), electrical conductivity (EC) and total dissolved solids (TDS) were

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determined using HM Digital Waterproof EC/TDS/TEMP Combo Meter Model COM-100 after calibration at 25^oC. The total suspended solids (TSS), chloride (Cl^-), nitrate (NO_3^-), phosphate (PO_4^{3-}), sulphate (SO_4^{2-}), dissolved oxygen (DO), chemical oxygen demand (COD), biological oxygen demand (BOD), and microbiological characteristics such as total bacterial and fungi count were analyzed *ex-situ* (in the laboratory) according to the method as described by APHA (2008).

Statistical Analysis

Data collected were subjected to descriptive (mean, standard deviation), inferential (T-test) statistics and compared with WHO permissible limits. Post-hoc test (LSD) was used to determine significant differences across the seasons of sampling with statistical significance set at $\alpha_{0.05}$. All the statistical analyses were performed with SPSS software (version 20.0).

RESULTS

Physicochemical Characteristics of Water Samples

The result showed that during the dry season of sampling, the pH of Oli River (5.90) and temperature of all the water samples were below the WHO permissible range while DO and COD of all the water samples were above the WHO guideline (Table 1). Similarly during the wet season of sampling, only the temperature (31.20) and COD (36.00) of Oli River and the DO of all the water samples were higher than the WHO permissible limit (Table 2). Significant seasonal variation was observed in the physicochemical parameters while the mean values of physicochemical parameters of the water samples showed that temperature (wet season), DO and COD were above the WHO permissible limit (Table 3). Statistically, there were significant seasonal variation in the values of temperature (t=4.93), EC (t=2.46), TDS (t=2.33), nitrate (t=3.66), chloride (t=4.91) and COD (t=4.23) in the waters sampled across the seasons of sampling ($P<0.05$).

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Table 1: Physicochemical Characteristics of water samples in Borgu sector of Kainji Lake National Park (Dry season, 2018)

Water stations	Coordinates	pH	Temp (^{O}C)	EC (µS)	TDS (mg/l)	TSS (mg/l)	SO_4^{2-} (mg/l)	PO_4^{3-} (mg/l)	NO_3^- (mg/l)	Cl^- (mg/l)	DO (mg/l)	COD (mg/l)	BOD (mg/l)
Oli River	N 09°54'43.0 E 003° 57'11.3	5.90	10.70	59.00	33.00	163.00	0.15	0.00	0.01	11.91	8.20	92.00	ND
KM 3	N 09°54'11.8 E 003° 58'24.2	6.70	20.10	74.00	34.00	37.60	0.07	0.00	0.05	5.96	7.10	44.00	1.22
KM 5	N 09°53'54.0 E 003° 59'07.4	7.30	10.00	74.00	34.00	144.00	0.05	0.00	0.05	13.90	8.20	68.00	ND
KM 8	N 09°54'02.6 E 003° 59'43.1	6.90	21.00	60.00	35.00	149.00	0.20	0.01	0.03	15.88	7.20	104.00	ND

Note: ND – Not Detected

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Table 2: Physicochemical Characteristics of water samples in Borgu sector of Kainji Lake National Park (Wet season, 2018)

Water stations	Coordinates	pH	Temp (°C)	EC (µS)	TDS (mg/l)	TSS (mg/l)	SO_4^{2-} (mg/l)	PO_4^{3-} (mg/l)	NO_3^- (mg/l)	Cl^- (mg/l)	DO (mg/l)	COD (mg/l)	BOD (mg/l)
Oli River	N 09°54’43.0 E 003° 57’11.3	6.80	31.20	78.00	38.00	65.00	0.88	ND	ND	ND	7.45	36.00	1.80
KM 3	N 09°54’11.8 E 003° 58’24.2	7.20	29.60	80.00	34.00	116.00	0.18	ND	ND	2.01	6.10	ND	ND
KM 5	N 09°53’54.0 E 003° 59’07.4	6.50	30.00	78.00	36.00	204.00	0.18	ND	ND	2.01	7.80	ND	ND
KM 8	N 09°54’02.6 E 003° 59’43.1	7.10	29.70	74.00	39.00	33.00	0.15	ND	ND	ND	7.10	ND	ND

Note: ND – Not Detected

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Table 3: Mean values of Physicochemical Parameters of water samples in Borgu sector of KLNP

Parameters	**Mean Values ± Standard Deviation**		**WHO Permissible Limit (2011)**
	Dry Season (January 2018)	**Wet Season (June 2018)**	
pH	6.71 ± 0.56	6.90 ± 0.32	6.5 – 8.5
Temp (°C)	15.45 ± 5.91	30.13 ± 0.74	25 - 30
EC (µS/cm)	66.75 ± 8.38	77.50 ± 2.52	250
TDS (mg/l)	34.00 ± 0.82	36.75 ± 2.22	500
TSS (mg/l)	123.40 ± 57.76	104.50 ± 74.62	-
SO_4^{2-} (mg/l)	0.12 ± 0.07	0.35 ± 0.36	400
PO_4^{3-} (mg/l)	0.00 ± 0.01	0.00 ± 0.00	5.0
NO_3^- (mg/l)	0.04 ± 0.02	0.00 ± 0.00	10
Cl^- (mg/l)	11.91 ± 4.29	1.01 ± 1.16	200
DO (mg/l)	7.68 ± 0.61	7.11 ± 0.73	7.5
COD (mg/l)	77.00 ± 26.61	9.00 ± 18.00	7.5
BOD (mg/l)	0.31 ± 0.61	0.45 ± 0.90	2.0 - 6.0

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Microbiological Characteristics of Water Samples

The result showed that during the dry season, the heterotrophic plate counts recorded in the water samples ranged from 0.20×10^2 cfu/ml to 0.50×10^2 cfu/ml. *Staphylococcus aureus* and *Salmonella / Shigella sp*. were not observed in all the water samples. Furthermore, highest fungi count of 0.30×10^2 cfu/ml was observed in Km 8 while the highest total coliform count was observed in Oli River (Table 4). Similarly in the wet season, the heterotrophic plate counts recorded in the water samples ranged from 1.20×10^2 cfu/ml to 12.00×10^2 cfu/ml while *Staphylococcus aureus* and Salmonella / Shigella sp. were also not observed in all the water samples. The highest fungi count of 3.00×10^2 cfu/ml was observed in Km 3 while highest total coliform count was observed in Km 5 (Table 5). Statistically, there were no significant differences in the counts of total heterotrophic bacteria, Fungi and total coliforms in the waters sampled ($P<0.05$) while statistical significant variation ($t=2.05$) was observed only in the fungi load between the seasons of sampling.

Water holes	**Total Heterotrophic bacterial count ($x10^2$cfu/ml)**	***Staphylococcus aureus* count ($x10^2$cfu/ml)**	**Salmonella/ Shigella spp count ($x10^3$cfu/ml)**	**Fungi count ($x10^2$cfu/ml)**	**Total Coliform count (MPN/100ml)**	**Microflora Observed**
Oli River	0.30	0.00	0.00	0.20	350	*Bacillus sp., Enterobacter sp., Flavobacterium sp., Aspergillus niger*
Km 3	0.20	0.00	0.00	0.10	140	*Bacillus sp. Enterobacter sp., Aspergillus niger* .
Km 5	0.30	0.00	0.00	0.10	170	*Bacillus sp, Enterobacter sp., Aspergillus flavus* .
Km 8	0.50	0.00	0.00	0.30	280	*Bacillus sp, Enterobacter sp., Aspergillus niger, Aspergillus fumigatus*

Table 4: Microbial Characteristics of water samples in Borgu sector of Kainji Lake National Park (Dry season, 2018)

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Water holes	**Total Heterotrophic bacterial count ($x10^2$cfu/ml)**	***Staphylococcus aureus* count ($x10^2$cfu/ml)**	**Salmonella / Shigella spp count ($x10^3$cfu/ml)**	**Fungi count ($x10^2$cfu/ml)**	**Total Coliform count (MPN/100ml)**	**Microflora Observed**
Oli River	4.50	0.00	0.00	1.00	450	*Bacillus sp., Enterobacter sp.,*
Km 3	2.10	0.00	0.00	3.00	780	*Bacillus sp. Enterobacter sp., Flavobacterium sp., Aspergillus niger* .
Km 5	12.00	0.00	0.00	2.00	160,000	*Bacillus sp. Flavobacterium sp. Enterobacter sp., Klebsiella sp. Aspergillus flavus*
Km 8	1.20	0.00	0.00	0.00	2000	*Bacillus sp. Enterobacter sp.,*

Table 5: Microbial Characteristics of water samples in Borgu sector of Kainji Lake National Park (Wet season, 2018)

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Table 6: Mean values of microbiological parameters of water samples in Borgu sector of KLNP

Parameters	Mean Values ± Standard Deviation		WHO Permissible Limit
	Dry Season (January 2018)	**Wet Season (June 2018)**	
Total Heterotrophic Bacteria count($x10^2$cfu/ml)	0.33 ± 0.13	4.95 ± 4.90	100 cfu/ml
Staphylococcus aureus Count 0($x10^2$cfu/ml)	0.00 ± 0.00	0.00 ± 0.00	100 cfu/ml
Salmonella/Shigella count ($x10^2$cfu/ml)	0.00 ± 0.00	0.00 ± 0.00	100 cfu/ml
Fungi Count($x10^4$cfu/ml)	2.35 ± 97.48	407.06 ± 795.33	100 cfu/ml
Total Coliform count ($x10^2$cfu/ml)	123.40 ± 57.76	104.50 74.62	0 per 100 ml

DISCUSSION

The environmental quality is greatly focused on water because of its importance in maintaining the human and ecosystem health (Rajiv *et al*., 2012). Rivers are therefore vital freshwater systems that are critical for the sustenance of wildlife and ecological health. The variation in water quality in a given environment is often influenced by geological formations and anthropogenic activities (Badmus *et al.*, 2014). From our study, temperature range obtained in dry and wet season was higher than Ajibade *et al.* (2008) who reported surface temperature to range between 22.6 - 31 ^oC in dry season and 21 – 26 ^oC in wet season. This change could be attributed to the effect of global warming or climate change. The pH recorded in the study was within the WHO permissible range though Ajibade *et al.* (2008) had earlier reported the non-potability of river waters in KLNP during the dry season due to low pH values. Higher mean pH value was observed during the wet season of sampling. This disagrees with Adetuga *et al.* (2019a) who reported higher values of pH during the dry seasons of sampling in Old Oyo National Park. Ibrahiem *et al.* (2012) attributed pH increase to sea water intrusion and the flourishing photosynthetic process of aquatic plants. Similar to Omonona *et al.* (2017), the levels of EC, TDS, TSS sulphate, phosphate, nitrate, and chloride observed in this study were relatively low when compared with WHO permissible limit though seasonal variations were noticed in their concentrations. Adetuga *et al.* (2019a) earlier reported the levels of sulphate, TS and TSS to be above the WHO permissible limit in the sampled waterholes of Old Oyo National Park, Southwest Nigeria. The BOD, which is an indicator of organic load in water, was observed to be below the WHO permissible limit as well. The mean levels of EC, TDS, sulphate and BOD were higher during the wet season while the mean concentrations of TSS, nitrate, phosphate and chloride in the water samples were observed to be higher during the dry season of sampling. Omonona *et al.* (2017) and Adetuga *et al.* (2019a) also reported similar seasonal variations in their respective studies. Though the dissolved oxygen concentration in natural waters depends on the

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physical, chemical and biological activities in the water body, it is crucial for the survival of aquatic life and used to evaluate the degree of freshness of a river. The DO level observed in this study was found to be above the WHO permissible limit and maybe attributed to the low level of nutrients and TSS as averred by Adetuga *et al.* (2019a). High DO is very vital for aquatic organisms as it is required for the metabolism of aerobic organisms and organic matter decomposition (Ezzat *et al.*, 2012). Also, DO level observed in this study was found to be higher during the dry season than the wet season. Omonona *et al.* (2017) and Adetuga *et al.* (2019a) reported higher dissolved oxygen level during the wet season at Omo Forest Reserve and Old Oyo National Park respectively. Similarly, the COD level during the dry season of sampling was observed to be higher during the dry season and above the WHO permissible limit. The higher values of COD observed during the dry season may be attributed to discharge of sewage and domestic wastes that find their way into the sampled waters as well as possible decay of organic matter favoured by high temperature (El-Amier *et al.*, 2015). It may also be as a result of the activities of micro-organisms which decomposes the massive inflow of organic waste brought about by wind and run-off (Meme *et al.*, 2014).

The quality of water is often expressed not only in terms of the physicochemical parameters but also microbiological characteristics as well. According to Sandy and Richard (1995), microbiological quality of drinking water is usually expressed in terms of the concentration and frequency of occurrence of particular species of bacteria. The coliforms are among the group of indicator bacteria that have been used to measure the microbiological characteristics of water. Besides, they are among the major contributions to the contaminants of surface and recreational waters (Cabral, 2010). The study showed that Salmonella / Shigella (enteric pathogens) and *Staphylococcus aureus*, regarded as important indicators of the whole aquatic ecosystem health (Kumar *et al*., 2010), were observed to be absent. The total heterotrophic bacteria count (THBC) observed in the study was below the WHO permissible limit in both seasons of sampling but their presence in surface water has implications for animal and public health, especially pathogenic organisms as averred by Adetuga *et al.* (2019b). The THBC was higher during the wet season as compared with the dry season and this further shows the contamination extent by the easily decomposable organic matters. The total coliform count was observed to be higher than the WHO permissible limit for drinking water. Adetuga *et al.* (2019b) also reported similar findings and ascribed increased water concentration and more drinking from animals as a probable cause. Also, higher total coliform count was observed during the dry season of sampling as compared with wet season. This agrees with Omonona *et al.* (2017) but disagrees with Nnane *et al.* (2011) who opined that greater incidence of pathogen loads is likely to occur when there is high rainfall. A very high fungi count was observed during the wet season of sampling which was above the WHO permissible limit. The major fungi species observes include *Aspergillus niger* and *Aspergillus fumigatus* and their presence is of ecological importance. The absence of *E. coli* in the water samples implies no recent faecal contamination and this could be attributed to minimal or lack of animal faecal wastes (wild and livestock) and open defecation. Ajibade *et al.* (2008) earlier reported *E. coli* in the major rivers of Kainji Lake National Park, Nigeria. Omonona *et al.* (2017) also reported absence of *E. coli* in River Omo in Omo Forest Reserve while Adetuga *et al.* (2019b) reported the presence of E. coli in Rivers Owu and Ogun in Old Oyo National Park, Southwest Nigeria. The presence of thermo-tolerant such as *Klebsiella sp* and *Enterobacter sp* observed in the study may be an indication of faecal contamination (WHO, 2017). *Enterobacter sp.* isolated from the water samples are examples of non-faecal coliforms and can be found in vegetation and soil which serves as sources by which the pathogens enters the water (Shittu *et al.*, 2008). The survival of microorganisms in water is highly influenced by many environmental factors such

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as temperature, salinity, pH, totals solids and supply of organic matter as nutrient (Pommepuy *et al.* (1992), cited in Bisi-Johnson *et al.*, 2017).

CONCLUSION

The study examined the physicochemical and microbiological characteristics of perennial waterholes in Borgu sector of Kainji Lake National Park. Seasonal variation was observed in the parameters assessed while temperature (wet season), DO, COD and total coliform counts were observed to be above the WHO permissible limit. Maintaining water quality standards in waterholes of Kainji Lake National Park is essential and required to protect drinking water resources, encourage recreational activities and provide a good enabling environment for fish and wildlife.

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CONFLICT OF INTEREST

The authors have not declared any conflict of interests.

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