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Assessment of Physicochemical and Microbiological Characteristics of Water Samples of Okomu National Park, Edo State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author AOO designed the study and wrote the protocol. Author ATA performed the statistical analysis and managed the analyses of the study. Author TVS managed the literature searches and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Water is very crucial for the survival and maintenance of most living organisms. The quality of water available for plant, animal or human use cannot therefore be compromised. This study therefore examined the physicochemical and microbiological characteristics of water samples in Okomu National Park, Edo State, Nigeria. Water samples were collected from four waterholes (three rivers and one stream) for two seasons (dry and wet) using grab sampling technique. These water samples were analysed for physicochemical [temperature, pH, total dissolved solid, electrical conductivity, total suspended solids, dissolved oxygen (DO), nitrate, chloride, phosphate, sulphate, biological oxygen demand (BOD) 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 the mean COD (both seasons) and BOD (dry season) were above the comparable WHO permissible limit while there was no significant difference in the values of all the physicochemical parameters across the seasons of sampling. *Salmonella / Shigella and Staphylococcus aureus* were observed to be absent while the total coliform and fungi counts were

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observed to be higher than the WHO permissible limit for drinking water. The detection of *Escherichia coli* in the water samples (except Arakhuan stream) is an indication of faecal contamination either of animal or human origin. There was significant difference in total heterotrophic bacteria (t=-4.936) and total coliform counts (t=-2.417) in the waters sampled. Constant monitoring of the waterholes and intensified sensitization of the surrounding communities on ecosystem conservation is needed to protect the park's ecosystems.

Keywords: Water quality; seasonal variation; anthropogenic activities; Okomu National Park; Nigeria.

1. INTRODUCTION

Water is one of the most important natural resources known to mankind. Man has depended on water resources for various purposes since time immemorial. The essentiality of water at every stage of life for living organisms (including plant and animals) and as a critical component of the environment cannot be overemphasized [1]. The conservation and sustainable use of water resources has been considered of great importance on earth [2]. Water in nature is seldomly totally pure. The uniqueness of water bodies often gets gradually deteriorated once it is engulfed with pollutant(s). Water pollution is one of the most principal environmental and public health problems in most water bodies [3]. Water can therefore be said to be polluted if there is a change in its physical, chemical and biological properties thereby restricting or preventing its use in various applications [4]. High levels of pollutants in river water systems causes an increase in biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), toxic metals such as Cd, Cr, Ni and Pb and faecal coliform and thereby making such water not potable for drinking, irrigation and unsuitable for the survival of aquatic life [5]. Despite the fact that some forms of water pollution can occur through natural processes, it is mostly as a result of anthropogenic factors. These anthropogenic factors including agricultural activities, industrial discharges and domestic wastes contribute as sources of water pollutants [6] thereby affecting the quality of water available for plant, animal and human use [7]. The availability of good quality water is an indispensable feature for preventing diseases and improving quality of life [5]. Meeting water quality expectations for streams and rivers therefore, is required to protect drinking water sources, encourage recreational activities and to provide a good environment for fish and wildlife [8]. The importance of water resources with respect to microbiological and physicochemical characteristics along with their seasonal variations (in terms of concentrations) is increasingly receiving attention in recent years. It is therefore imperative that the quality of water in waterholes in Okomu National Park be ascertained to verify their suitability for both wild animal and human use. When analyzing water quality of any water body, it is always a good practice to determine the quality of the water during low and high tide i.e. dry season and wet season. The objectives of the study were to examined the physicochemical and microbiological characteristics of water samples in Okomu National Park, Edo State, Nigeria.

2. METHODOLOGY

2.1 Study Area

Okomu National Park (ONP) previously known as the Okomu Wildlife Sanctuary is the smallest national park in Nigeria with a land area of 212 km^2. It was established by decree 46 of 1999 and lies coordinates between 6º10′-6º30′ N and 5º00′ - 5º30′ E [9]. The mean annual rainfall of the park is about 2100 mm while the mean monthly temperature is 30.2ºC. The soils of the park acidic sandy loams derived from deep deltaic and coastal sediments [10] with a gentle topography ranging from 30 m to 60 m above sea level. The park is an important refuge for forest white-throated monkey (*Cercopithecus erythrogaster*) which is an endemic species in Okomu National Park. Other endangered wildlife species of local and global concern such as the forest elephant (*Loxodonta africana cyclotis*), chimpanzee (*Pan troglodytes versus*), leopard (*Panthera pardus*) and Red-capped Mangabey (*Cercopithecus torquatus*) are also found in the park [11]. The park is also rich in tree species such as *Entandrophragma angolense, Lovoa trichilioides*, *Anopyxis klaineana*, *Nauclea diderrichii* and *Diospyros crassiflora.*

2.2 Samples Collection and Technique

Water sampling at four sampling stations (Agekpupu River, Arakhuan Stream, Lake 52 and Okomu River) was done using the grab sampling technique. Water samples were

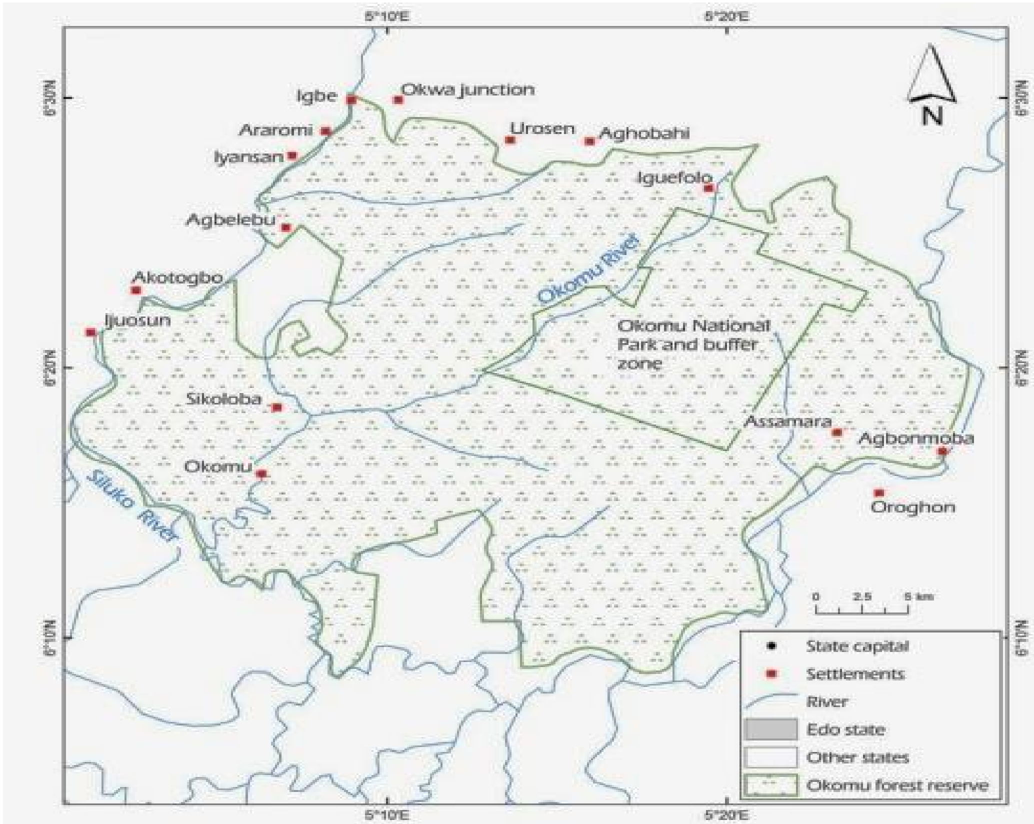

Fig. 1. Map of Okomu National Park showing the Okomu River and the surrounding settlements

Source: Field Survey, 2018

collected (from the upper, middle and lower courses of each waterhole and composited) into self-cleaned sample bottles that were adequately labelled. These water samples were 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 that were assessed.

2.3 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 determined using HM Digital Waterproof EC/TDS/TEMP Combo Meter Model COM-100 after calibration at 25ºC. 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 methods as described by APHA (2008).

2.4 Statistical Analysis

Data collected were subjected to descriptive (mean, standard deviation), inferential (T-test) statistics with statistical significance set at $\alpha_{0.05}$ and compared with WHO permissible limits. All the statistical analyses were performed with SPSS software (version 20.0).

3. RESULTS

3.1 Physicochemical Characteristics of Water Samples

The result showed that during the dry season of sampling, only the pH of Arakhuan stream (8.40) was within the WHO permissible range while those of the other streams were beyond the permissible limit. The temperature of all the water samples were within the WHO permissible limit range while EC, TDS, sulphate, phosphate, nitrate, chloride and DO were below the WHO permissible limit. The COD and BOD levels in all the water samples and TSS (in Lake 52) were above the permissible limit as shown in Table 1. Similarly, during the wet season of sampling, only the pH of Lake 52 (4.90) was below the WHO permissible range while those of the other streams with their respective temperatures were within the permissible limit range. The EC, TDS, sulphate, phosphate, nitrate and chloride levels in the water samples were below the WHO permissible limit while the DO (Arakhuan Stream = 7.80) and COD (Arakhuan Stream = 14.00; Lake 52 = 18.00) were found to be higher than the WHO permissible limit. The BOD levels of all the water samples were not detected as shown in Table 2. There was no significant difference in the values of the physicochemical parameters across the seasons of sampling (Table 3).

3.2 Microbiological Characteristics of Water Samples

The result showed that during the dry season, the heterotrophic plate counts recorded from the water samples ranged from 0.30 × 10^2 cfu/ml to 3.10 × 10^2 cfu/ml. *Staphylococcus aureus* and *Salmonella / Shigella sp* were not observed in all the water samples. Furthermore, highest fungi count of 1.80 × 10^2 cfu/ml was observed in Arakhuan Stream while the total coliform count observed in all the water samples was 1600 MPN/100 ml (Table 4). Microflora observed in the water samples include *Bacillus sp*, Enterobacter *sp*, *Flavobacterium sp* and *Escherichia coli* (except Arakhuan stream). Furthermore, in the wet season, the heterotrophic plate counts recorded from the water samples ranged from 4.00 × 10^2 cfu/ml to 8.00 × 10^2 cfu/ml while *Staphylococcus aureus* and *Salmonella / Shigella sp*. were also not observed in all the water samples. The lowest fungi count of 1.00 × 10^2 cfu/ml was observed in Agekpupu River while highest total coliform count was observed in Lake 52 (Table 5). Statistically, there was significant difference in the counts of total heterotrophic bacteria (t=-4.936) and total coliform count (t=-2.417) from the waters sampled.

4. DISCUSSION

Water is a universal solvent and while its quantity on earth remains constant, its quality changes both temporally and spatially and is highly influenced by human activities. The contamination of water is a serious environmental problem as it adversely affects the human health and the biodiversity in aquatic ecosystems [12]. The mean pH observed in the study across the seasons of sampling were within the WHO permissible limit while the high pH levels in Okomu and Agekpupu rivers during the dry season may be attributed to organic pollution and the domestic waste discharge draining into the river systems, river water intrusion as well as the flourishing photosynthetic activities of the aquatic plants as corroborated by Patra, et al. [13] and El Bouraie, et al. [14]. Adetuga, et al. [15] also reported higher values of pH during the dry seasons of sampling in Old Oyo National Park. The pH level of Lake 52 river was below the WHO permissible limit implying the non-potability of the river especially during the dry season. Ajibade, et al. [16] also had earlier reported the non-potability of river waters in Kainji Lake National Park during the dry season due to low pH values. The pH of a water body is known as one of the important factors in the determination of water quality as it affects other chemical reactions such as solubility and metal toxicity [17]. The temperature, electrical conductivity (EC) and total dissolved solids (TDS) levels in the water samples were noted to have fallen within the comparable WHO permissible limit. The low EC may be as a result of minimal land run-off which contains large amounts of cations and anions as averred by Ezzat, et al. [18]. Also, a certain level of TDS is essential for aquatic organisms and high levels of TDS may be unfavorable for aquatic life [19]. Similarly, the mean concentrations of sulphate, phosphate, nitrate and chloride were observed to fall within the WHO permissible limit. This may be due to minimal run-off from inorganic farming by the surrounding communities. The dissolved oxygen (DO) level of Arakhuan stream was observed to be higher than the comparable WHO permissible limit during the wet season. This may be attributed to low load of organic waste discharge into the stream. The high concentrations of dissolved oxygen have been reported to be very vital and important for aquatic organisms as it is required for the metabolism of aerobic organisms and organic matter decomposition [18]. Of utmost concern is the low DO levels observed in the rivers during the dry season. Though this may be attributed to high load of organic waste discharges and the microbial activity that degraded the matter leading to oxygen consumption [3], low oxygen in

Table 1. Physicochemical characteristics of water samples from Okomu National Park (Dry season, 2018)

Water stations	Coordinates	pH	Temp (ºC)	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)
Okomu River	N 06º20'28.1'' E 005º14'00.2''	9.30	26.70	13.00	7.00	70.50	0.071	0.002	0.008	7.94	2.10	72.00	9.00
Agekpupu River	N 06º24'53.8'' E 005º17'59.7''	8.70	28.70	13.00	6.00	106.00	0.400	0.003	0.063	5.96	3.20	72.00	15.00
Arakhuan Stream	N 06º20'34.9'' E 005º21'39.1''	8.40	25.70	14.00	7.00	92.70	0.023	0.003	0.004	11.91	3.10	64.00	14.00
Lake 52	N1 06º21'37.9'' E 005º19'23.9''	6.00	26.40	14.00	6.00	509.00	0.346	0.030	0.173	87.36	2.60	248.00	130.00

Note: ND – Not detected

Table 2. Physicochemical characteristics of water samples from Okomu National Park (Wet 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)
Okomu River	N 06º20'28.1'' E 005º14'00.2''	7.80	26.80	5.00	3.35	137.00	0.13	ND	ND	4.03	6.10	ND	ND
Agekpupu River	N 06º24'53.8'' E 005º17'59.7''	7.20	26.30	4.00	2.68	77.30	0.11	ND	ND	ND	7.10	ND	ND
Arakhuan Stream	N 06º20'34.9'' E 005º21'39.1''	7.10	24.60	5.00	3.35	66.50	0.14	ND	ND	ND	7.80	14.00	ND
Lake 52	N 06º21'37.9'' E 005º19'23.9''	4.90	26.90	54.00	36.2	244.00	0.14	ND	ND	1.01	ND	18.00	ND

Note: ND – Not detected

Table 3. Mean values of physicochemical parameters of water samples from Okomu National Park

Parameters	Mean values ± Standard deviation		WHO permissible limit (2011)	t-value	P-value
	Dry season (January 2018)	Wet season (June 2018)			
pH	8.10 ± 1.45	6.75 ± 1.27	6.5 – 8.5	1.401	0.211
Temp (°C)	26.88 ± 1.29	26.15 ± 1.07	25 - 30	0.868	0.419
EC (µS/cm)	17.75 ± 8.85	20.00 ± 15.34	250	-0.284	0.786
TDS (mg/l)	9.00 ± 4.70	10.25 ± 7.85	500	-0.592	0.576
TSS (mg/l)	194.55 ± 210.14	116.24 ± 100.47	-	0.562	0.594
SO_4^{2-} (mg/l)	0.21 ± 0.19	0.13 ± 0.01	400	0.838	0.434
PO_4^{3-} (mg/l)	0.01 ± 0.01	0.0 ± 0.0	5.0	1.389	0.214
NO_3^- (mg/l)	0.06 ± 0.08	0.0 ± 0.0	10	1.575	0.166
Cl^- (mg/l)	28.29 ± 39.46	1.26 ± 1.91	200	1.369	0.220
DO (mg/l)	3.00 ± 0.64	5.25 ± 3.57	7.5	-1.387	0.215
COD (mg/l)	114.00 ± 89.41	8.0 ± 9.38	7.5	2.358	0.056
BOD (mg/l)	42.00 ± 58.73	0.0 ± 0.0	2.0 - 6.0	1.430	0.203

Table 4. Microbial characteristics of water samples from Okomu National Park (Dry season, 2018)

Water holes	Coordinates	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
Okomu River	N 06º20'28.1'' E 005º14'00.2''	0.50	0.00	0.00	1.10	1600	*Bacillus sp., Escherichia coli Enterobacter sp., Flavobacterium sp. Aspergillus flavus*
Agekpupu River	N 06º24'53.8'' E 005º17'59.7''	0.30	0.00	0.00	0.70	1600	*Bacillus sp., Escherichia coli Enterobacter sp., Flavobacterium sp. Aspergillus flavus*
Arakhuan Stream	N 06º20'34.9'' E 005º21'39.1''	0.30	0.00	0.00	1.80	1600	*Bacillus sp., Enterobacter sp., Flavobacterium sp., A. flavus*

Water holes	Coordinates	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
Lake 52	N 06º21'37.9'' E 005º19'23.9''	3.10	0.00	0.00	1.10	1600	*Bacillus sp., Escherichia coli Enterobacter sp., Flavobacterium sp. Aspergillus flavus, Aspergillus niger*

Table 5. Microbial Characteristics of water samples from Okomu National Park (Wet season, 2018)

Water holes	Coordinates	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
Okomu River	N 06º20'28.1'' E 005º14'00.2''	7.00	0.00	0.00	2.00	9200	*Bacillus sp., Flavobacterium sp. Enterobacter sp.*
Agekpupu River	N 06º24'53.8'' E 005º17'59.7''	4.00	0.00	0.00	1.00	4500	*Bacillus sp., Flavobacterium sp. Fusarium sp.*
Arakhuan Stream	N 06º20'34.9'' E 005º21'39.1''	7.00	0.00	0.00	2.00	7800	*Bacillus sp., Enterobacter sp. Flavobacterium sp., Fusarium sp.*
Lake 52	N 06º21'37.9'' E 005º19'23.9''	8.00	0.00	0.00	2.00	22000	*Bacillus sp., Actinobacteria sp. Enterobacter sp., Flavobacterium sp. Escherichia coli, Penicillium sp. Fusarium sp.*

Table 6. Mean values of microbiological parameters of water samples in Okomu National Park

Parameters	Mean values ± Standard deviation		WHO permissible limit	t-value	P-value
	Dry season (January 2018)	Wet season (June 2018)			
Total Heterotrophic Bacteria count($x10^2$cfu/ml)	1.05 ± 1.37*	6.50 ± 1.73*	100 cfu/ml	-4.936	0.003
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)	1.18 ± 0.46	1.75 ± 0.50	100 cfu/ml	-1.697	0.141
Total Coliform count ($x10^2$cfu/ml)	1.60 ± 0.00*	10.86 ± 76.74*	0 per 100 ml	-2.417	0.052

*Note: * Means are significantly different at $\alpha_{0.05}$*

water negatively impacts the lives of low oxygen intolerant aquatic organisms such as fish [5]. The organic waste discharges often require oxygen for decomposition [20]. The DO is one of the most important factors for healthy and survival of aquatic organisms [12] and is critical for maintaining oxygen balance in aquatic ecosystems [21]. The Chemical Oxygen Demand (COD) levels observed in the water samples were above the comparable WHO standard particularly during the dry season. The COD defines the measure of capacity of water to consume oxygen in decomposition of organic and inorganic matters [22]. The high values obtained may be as a result of decrease in rainfall with resultant increase in concentration of electrolytes and other elements in the rivers and stream as corroborated by Raji et al. [5] with possible contributions from agricultural and industrial effluents. The Biological Oxygen Demand (BOD) of the water samples were higher than the comparable WHO reference values during the wet season. This may be as a result of decay of organic matter in the water systems [23] and is an indication of heavy pollution of the rivers as well as poor water quality [24]. The BOD has been described as an indicator of organic load in water [25].

While the microorganisms are widely distributed in nature, their abundance and diversity may be used as indicators of water quality [26]. The microbiological analysis of the water samples indicates that the total heterotrophic bacteria count (THBC) and fungi count (FC) were below the comparable WHO reference values during the seasons of sampling. Their availability in most surface water like rivers and streams has implications for environmental health as averred by Adetuga, et al. [27]. The THBC and FC were observed to be higher during the wet season and may be attributed to run-off as a result of high rainfall [25]. High surface flows during rainy seasons resulting in increase in erosion and the transport of sediment carrying bacteria into rivers are also on record [28]. The fungi species such as *Aspergillus flavus*, *Aspergillus niger* and *Fusarium* sp. observed in the study are of ecological health importance. Omonona et al. [25] also reported similar findings in their study. Furthermore, Salmonella / Shigella (enteric pathogens) and Staphylococcus aureus, seen as important indicators of the health of aquatic ecosystems [29] were not observed in the water samples. The total coliform count (TCC) was observed to be higher than the WHO permissible limit for drinking water. Adetuga, et al. [27] and Omonona, et al. [25] also reported similar findings and attributed the probable cause to more contact from animals while drinking. Coliforms generally are important among bacterial indicators that are used in water quality monitoring and assessment [30]. The higher TCC during the wet season can be attributed to excessive nutrient run-off and / or the washing off the microbes from the land during this season [21]. The presence of *Escherichia coli* in the water samples is an indication of faecal contamination either of animal or human origin as corroborated by Davies-Colley [31]. Fecal contamination of the river water can be through non-point sources (surface runoff and soil leaching), the wildlife animals and grazing livestock faeces, and also the farmyard manure used in agricultural fields. Ajibade, et al. [16] had also reported similar findings in Kainji Lake National Park in Nigeria. The presence of *Flavobacterium* sp. in the water samples may cause bloodstream infections and potentially harmful to animal and human health. The surface water including rivers and streams have been reported to be reservoirs of a spectrum of pathogenic microorganisms, including coliforms, thermotolerant coliform bacteria, Enterococcus faecalis, and Salmonella [32] and as such, microbiological quality evaluation of water is a critical parameter to measure health-associated risks.

5. CONCLUSION

The high BOD values and presence of *Escherichia coli* in the water samples as observed in the study may indicate heavy contamination of the waterholes as well as imply their non-potability while the low DO values may constitute a threat to the survival of aquatic species in the rivers and stream. It is imperative that while artificial waterholes may be provided by the park management, periodic monitoring of river water quality and effluent discharges into the rivers and stream is done while the park management take a proactive step in intensifying conservation education in the surrounding communities especially in the area of proper management of domestic raw wastes and sensitizing them on the consequence of anthropogenic activities on the park's ecosystem.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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