Assessment of some physical, chemical and biological parameters of Lake Dangana, Niger State, Nigeria

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Abstract

Ecological systems change over time due to anthropogenic and natural activities, regular monitoring is therefore necessary for identifying malignant changes and conservation of biodiversity. This study was undertaken to ascertain the health and biological diversity of Lake Dangana using both biotic and abiotic indicators. Samples for physico-chemical and biological analyses were collected monthly from four sampling stations in Lake Dangana from January to August, 2020 using standard methods. The results of physico-chemical variables were: temperature (23.5-26.5ºC), dissolved oxygen (3.96-4.13mg/l), biochemical oxygen demand (3.00-3.12mg/l), pH (6.88-7.11), conductivity (86.43-94.80µS/cm), nitrate (0.67-0.76mg/l) and phosphate (0.85-1.04mg/l). Conductivity, nitrate and phosphate varied significantly ($p<0.05$) between stations. A total of 318 individuals from 13 species and 10 families of macroinvertebrates were encountered during the study period. Hemiptera (35.52%), Coleopterans (34.59%), Odonata (22.95%), Dipterans (5.03%) and Oligochaetes (1.87%) were the dominant groups. The first two Canonical Correspondence Analysis (CCA) axes explained 87.33% of macroinvertebrate-environment relationship and pH (-0.99), BOD_5 (-0.62), nitrate (-0.61), conductivity (-0.59) and phosphate (-0.57) were the dominant structuring factors. Six bacteria species; *Bacillus* sp, *Escherichia coli, Micrococcus* sp., *Staphylococcus aureus, Klebsiella* sp and *Pseudomonas* sp. and five–fungi species; *Aspergillus fumigatus*, *A. niger*, *A. flavus*, *Penicillium* sp and *Mucor* sp. were encountered. The presence of some of these microorganisms such as *E. coli* in the lake is an indication of faecal contamination and this could endanger public health.

Keywords: Lake Dangana, *Escherichia coli*, macroinvertebrates, bacteria, fungi

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Introduction

The knowledge of physical, chemical and biological characteristics of a water body is of great essence in the determination of its productivity and usefulness (Mohammed *et al* 2020). Throughout human history, water has been of immense benefit, as a life-giving liquid; however, the same water has been reported as means of waste disposal with no proper or adequate measures to curbing the possible dangers to the end users (Adamu *et al* 2018a; Adamu *et al* 2018b). According to UN-Water (2013), access to clean and healthy drinking water is a human fundamental right, and thus it is essential to monitor water bodies that are sources of drinking water and other domestic uses. Poor water quality management remains a major health threat in most developing countries when compared to developed nations (Mohammed *et al* 2020). The degradation of water quality erodes the availability of water for humans and the ecosystem and decreases species abundance and diversity of resident communities (Iloba *et al* 2019; Mohammed *et al* 2022; Garba *et al* 2022). Changes in water quality can be associated with the spatial and temporal variation in sediment load, nutrient concentration, temperature, dissolved oxygen level and pH (Arimoro and Keke 2016).

Changes in the physico-chemical variables of the water affect the resident biota, consequently biological assessment of water bodies alternatively provides vital information on the ecological quality of aquatic ecosystems (Stevenson and Pan 1999). Many groups of organisms such as algae, macrophytes, protozoans, macroinvertebrates and fish have been used to monitor water quality (Iloba *et al* 2019; Ogbuagu *et al* 2011; Iloba *et al* 2018). According to Smith *et al* (2007), monitoring aquatic ecosystems sometimes is a very difficult task due to its complex nature as a result of the interactions between physical, chemical and biological variables. Thus, comprehensive studies that incorporate bacteria, fungi and macroinvertebrates are most likely to provide a clearer picture of the impact of human activities and the overall ecological integrity of aquatic ecosystems (Adamu *et al* 2018a, 2018b; Aydemir *et al* 2021; Garba *et al* 2022). These will serve as good indicators of water quality and could guide managers of aquatic ecosystems to make good decisions on sustainability. Studies have revealed that some surface water from lakes, streams and

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rivers may appear clean in terms of physical characteristics such as odour and taste yet be contaminated with pathogenic microorganisms (Obire *et al* 2015; Ewulonu *et al* 2019).

Among the aquatic biota employed in assessing riverine system health, macroinvertebrates are the most explored groups (Mohammed *et al* 2020; Mohammed *et al* 2021). Macroinvertebrates respond differentially to pollution, and they are easily collected from wadable and non-wadable water bodies (Namba *et al* 2020). They display varying sensitivity to pollution, with the intolerant macroinvertebrates dominating pristine systems and the tolerant macroinvertebrates increasing in polluted systems (Namba *et al* 2020). Therefore, the presence of tolerant or intolerant species could be used to predict water quality (Zhou *et al* 2020). Similarly, bacteria and fungi are indicators of the presence or absence of pathogens (Maishanu *et al* 2022) in water although they cannot accurately predict the level of contamination. The outbreak of various illness such as cholera and diarrhoea is connected with consumption of contaminated water (Amin *et al* 2019).

Water quality degradation results from a variety of substances arising from different contaminant sources such as particulate matter from air, fertilizers and pesticides from agro-allied practices, spillage from septic tanks and toxic chemical wastes from industrial processes, sewage and other urban wastes among (Ohaeri *et al* 2020). This study aims at assessing the composition, distribution pattern, abundance of macroinvertebrates, bacteria and fungi community of Lake Dangana, Lapai, Niger State, which serves as the main source of domestic water supply to nearby human communities. The study is necessitated by increased anthropogenic disturbances along the lake and its environ. It will assist managers of the lakes and other relevant authorities to manage the lake sustainably.

Material and methods

Study area

Dangana Lake is located at Lapai, Niger State, Nigeria, within longitude 6°36′29.6″E and latitude 9°02′12.02″N with elevation of 159m above sea level. The vegetation of the area comprises of grasses with few sparsely distributed trees predominated by Malaina (*Gmeilana arborea*), Locust beans (*Parkia biglobosa*) and Neem (*Azadirachta indica*), which is typical of savannah ecosystem. The climate of the area presents two distinct seasons, rainy (April-October) and dry (November-March) seasons (Mohammed and Adamu 2019).

Sampling stations

Samples for physico-chemical and biological analyses were collected from four stations in the lake monthly from January to August, 2020. Station 1 is the headwater, devoid of any anthropogenic activities. Station 2 is next to station 1 and anthropogenic activities like washing of household utensils, fetching of water for domestic use take place in this station. In station 3, various human activities such as laundry, car wash and other domestic activities occur. Station 4 has low human activities but has outlet for releasing water during high water period.

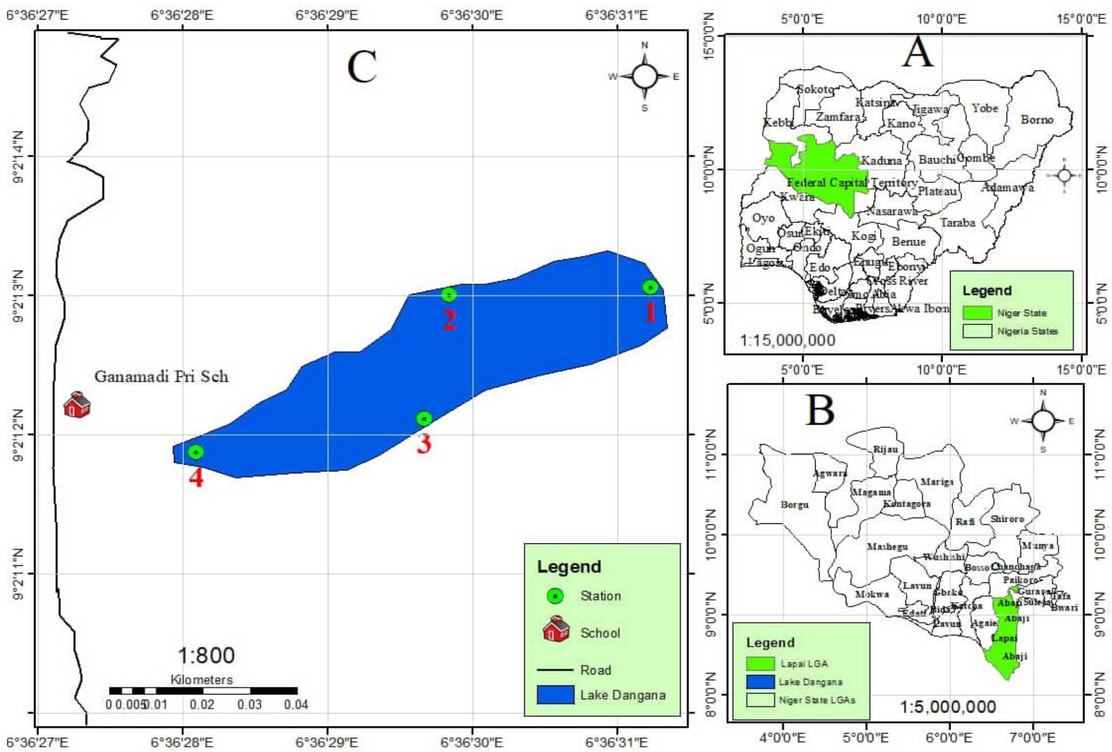

Figure 1. Map of Lake Dangana, with inserts of map of Niger State and Nigeria.

Physico-chemical parameters

Water temperature, dissolved oxygen (DO), conductivity and pH were measured *in situ* using multipurpose HANNA meter (model 1910). Biological oxygen demand (BOD_5) was determined using the Winkler-azide titration method, while nitrate and phosphate were determined using the spectrophotometric method as described by APHA (2012).

Macroinvertebrate's sampling

Kick samples of macroinvertebrates were collected using the modified kicked sampling technique (Hynes 1961) using a D-frame net (250μm mesh size) within an approximately 50m wide portion of the lake. Samples were collected from different substrata, which includes vegetation, sand and gravel biotypes. Samples collected were washed to remove attached substrate, preserved in 70% ethanol and then transported to the laboratory for further analysis.

In the laboratory, the macroinvertebrates were identified to lowest taxonomic group possible with the aid of stereoscopic microscope using the taxonomic guides of Gerber and Gabriel (2002), Day *et al* (2002), De Moor *et al* (2003) and Arimoro and James (2008).

Bacteria and fungi isolation

Water samples for microbiological analysis were collected in a sterilized 100ml plastic container from the sampling stations in the Lake. In the laboratory, the water samples were subjected to serial dilution; 1ml of the water sampled was poured into a test tube containing 9ml of distilled water. Then 1ml of the water was aseptically transferred from the first test tube to the next test tube containing distilled water up to the ninth test tube. The incubation of the sample was done using Nutrient Agar (NA). The bacteria colonies were identified by standard bacteriological procedures. Each representative colony was characterized by its macroscopic morphology; Gram stain and some biochemical tests such as catalase test, citrate test, methylred test and sugar fermentation test (Cheesbrough, 2002).

Whilst for fungi isolation, the water sample from each sampling station was placed on sterile Potato Dextrose Agar (PDA) (Accumix$^{(R)}$-Tulip Diagnostics (P) Ltd). Amended with tetracycline (100mg/kg) to prevent incubation of bacteria and inoculated at 28.00±2.00°C for 5 days before sub-culturing. Pure culture of the different fungal species isolated were morphologically characterized following established procedures of Willoughby (1994). The isolates were macroscopically studied when each colony was stained with 0.05% Trypan blue in Lacto-phenol.

Statistical analysis

The mean and standard error of each physico-chemical parameter was calculated per station; one-way analysis of variance (ANOVA) was performed to determine the differences in the mean values of the physico-chemical variables between stations and months of sampling. Ecological indices such as Simpson's dominance, Shannon-Wiener and Margalef's indices were used to determine species richness and diversity. Canonical Correspondence Analysis (CCA) was performed to determine the relationship between macroinvertebrates' abundance and physico-chemical parameters using Paleontological Statistics Software tool Pack (PAST-version 4).

Results

Physico-chemical parameters

The results of the physico-chemical parameters of the four stations of Lake Dangana showed that water temperature (23.50±29.0 to 26.65±0.74°C), dissolved oxygen (3.98±0.15 to 4.13±0.20 mg/L), biochemical oxygen demand (3.00±0.14 to 3.12±0.19mg/l) and pH (6.88±0.17 to 7.11±0.21) varied insignificantly ($p>0.05$) between the stations (Table 1). However, conductivity (86.43±8.57 to 94.80±8.54μS/cm), nitrate (0.67±0.09 to 0.68±0.08mg/l) and phosphate (0.85±0.11 to 1.04±0.12mg/l) varied significantly ($p<0.05$) among stations. All the physico-chemical parameters varied significantly between seasons ($p<0.05$).

Composition and distribution of macroinvertebrate in Lake Dangana, Lapai, Niger State

A total of 318 individuals from 13 species and 10 families of macroinvertebrates were encountered during the study period in Lake Dangana Lapai, Niger State. A total of 81, 78, 49 and 110 individuals were encountered at stations 1, 2, 3 and 4, respectively. Hemiptera (35.52%) was the most abundant group while Oligochaetes (1.87%) was the least abundant (Table 2).

Macroinvertebrates richness and diversity in Lake Dangana

The highest number of species (10), number of individuals (110) and dominance index (0.20) were observed at station 4 (Table 3). The dominance index ranged from 0.15 in station 1 to 0.20 in station 4. Similarly, the Simpson dominance index ranged from 0.80 in station 4 to 0.85 in station 1. Shannon-Wiener diversity index ranged from 1.81 in station 4 to 2.04 in station 3. The Margalef's index ranged from 1.92 in station 4 to 2.53 in station 2. The species Evenness index ranged from 0.61 in station 4 to 0.77 in station 3.

Relationship between physicochemical parameters and macroinvertebrates abundance in Lake Dangana Lapai

The first and second CCA axes accounted for 66.69% and 20.64%, respectively of macroinvertebrate-environment relationship (Figure 2). The eigenvalues for axes 1 and 2 were 0.24 and 0.07, respectively as shown in Table 4. Axis 1 was mostly influenced by nitrate (-0.61), conductivity (-0.59) and phosphate (-0.57) while axis 2 was predominantly influenced by pH (-0.99) and BOD_5 (-0.62).

Bacteria and Fungi distribution of Dangana lake Lapai Niger state

A total of six (6) species of bacteria were encountered, four gram-positive bacteria and two (2) gram negative bacteria. The gram-positive bacteria were *Bacillus* sp., *Escherichia coli, Micrococcus* sp. and *Staphylococcus aureus.* The two gram-negative bacteria recorded were *Klebsiella* sp. and *Pseudomonas* sp. Three (3) species of bacteria; *Bacillus* sp., *E. coli* and *S. aureus* were observed in station 1, whereas *Micrococcus* sp., *Bacillus* sp., *E. coli, S. aureus* and *Klebsiella* sp were present in station 2.

Table 1: Mean and standard deviation values of physico-chemical parameters of Lake Dangana, Lapai (January-August 2020)

Parameters	Stations				Probabilities ($p<0.05$)	
	Station 1	Station 2	Station 3	Station 4	Stations	Months
Water temperature (°C)	26.41±0.38	26.65±0.74	23.50±29.00	24.5±20.00	0.72	5.81E-06
DO (mg/l)	4.02±0.10	3.98±0.15	4.13±0.20	4.03±0.20	0.54	0.00
BOD_5 (mg/l)	3.00±0.14	3.08±0.18	3.12±0.19	3.08±0.18	0.37	3.40E-07
pH	6.88±0.17	7.05±0.12	6.98±0.11	7.11±0.21	0.13	1.29E-06
Conductivity (µS/cm)	86.43±8.57*	91.42±9.04	94.80±8.54	90.41±2.40	0.02	1.97E-08
Nitrate (mg/l)	0.68±0.08	0.76±0.08*	0.67±0.09	0.68±0.02	0.00	8.25E-12
Phosphate (mg/l)	0.90±0.10	1.04±0.12*	0.85±0.11	0.87±0.09	7.38E-05	3.51E-11

Mean values with asterisk (*) differs significantly across row

Table 2: Macroinvertebrates species composition and distribution in Lake Dangana Lapai, Niger State

Order	Family	Species	Code	S1	S2	S3	S4	Total	%
Hemiptera	Nepidae	*Lacocotrephes* sp	LAC	15	6	5	35	61	19.18
		Ranatra sp	RAN	10	4	6	23	43	13.52
	Hydrometridae	*Hydrometra* sp	HYD	2	1	2	0	5	1.57
	Gerridae	*Gerris* sp	GER	3	0	0	1	4	1.25
		Total						113	35.53
Odonata	Aeshnidae	*Aeshna* sp	AES	1	1	2	1	5	1.57
	Codulidae	*Epitheca* sp	EPI	2	2	0	6	10	3.14
	Coegnoridae	*Coenagrion* sp	COE	12	1	1	8	22	6.91
		Pseudogrian sp	PSE	7	12	11	6	36	11.32
		Total						73	22.95
Coleoptera	Hydrophilidae	*Hydrophylus* sp	HY	12	14	6	23	55	17.29
		Crenis sp	CRE	17	21	11	6	55	17.29
								110	34.59
Diptera	Chironomidae	*Chironomus* sp	CHI	0	12	4	0	16	5.03
Oligochaete	Hirudinidae	*Hirudina* sp	HIR	0	2	1	1	4	1.25
	Lumbriculidae	*Lumbricoides* sp	LUM	0	2	0	0	2	0.62
								6	1.87
		Grand total		81	78	49	110	318	100

Table 3: Taxa richness and diversity indices of macroinvertebrates of Lake Dangana Lapai, Niger State

Indices	S1	S2	S3	S4
Taxa (S)	10	12	10	10
Number of individuals	81	78	49	110
Dominance index	0.15	0.16	0.15	0.20
Simpson's dominance index	0.85	0.84	0.85	0.80
Shannon Weiner index	2.04	2.04	2.04	1.81
Evenness index	0.77	0.64	0.77	0.61
Margalef's index	2.05	2.53	2.30	1.92

Escherichia coli, *Klebsiella* sp., *S. aureus*, *Micrococcus* sp., *Pseudomonas* sp. and *Bacillus* sp were found in station 3. *Micrococcus* sp., *Bacillus* sp., *E. coli* and *S. aureus* were the bacteria isolates found in station 4.
The fungi isolates recorded in Dangana lake were *Aspergilus fumigatus*, *A. niger*, *A. flavus*, *Penicillium* sp and *Mucor* sp. All the fungi isolates were found in all the sampling stations of the lake as shown in Table 6.

Discussion

The observed water temperature (23.5 to 26.5ºC) in this study could be due to sampling time and vegetation nature of the Lake. Temperature is one of the most important physico-chemical indicators as it is vital in regulating aquatic organisms' physiological activities and their distribution in the habitat (Mustapha, 2008). The dissolved oxygen level in the lake was higher during the wet than dry season. which ranged between 3.96 to 4.13mg/l is an indication of a normal oxygenated water body. This could be due to increase in water volume during wet season and lower temperatures (Mustapha 2008; Mohammed *et al* 2020). The values of biochemical oxygen demand (BOD_5) obtained in this study could be due to massive flow of waste into the lake from surrounding environment during rainy season resulting in oxidative activities by microorganisms.

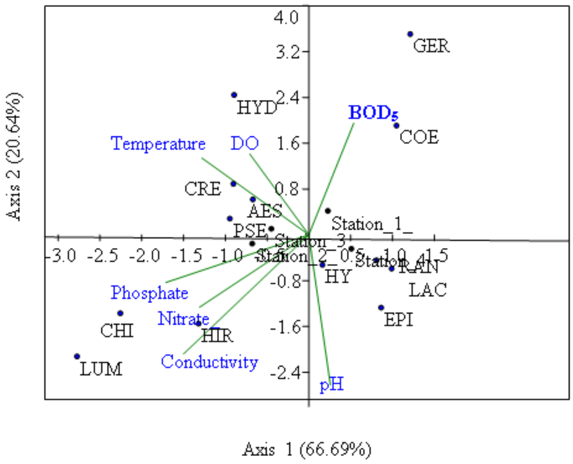

Figure 2. Biplot of the first and second CCA axis of macroinvertebrates and physico-chemical parameters of Lake Dangana, Lapai, Niger State. (The species codes used are explained in Table 2)

Table 4: Weighted intraset correlations of physico-chemical parameters and macroinvertebrates with the first two axes of canonical correspondence analysis (CCA) of Lake Dangana, Lapai, Niger State.

	Axis 1	Axis 2
Eigen value	0.24	0.07
Species variation %	69.69	20.64
Temperature	-0.10	0.19
Dissolved oxygen	-0.08	0.22
BOD	0.47	-0.62
pH	0.03	-0.99
Conductivity	-0.59	-0.45
Nitrate	-0.61	-0.41
Phosphate	-0.57	-0.27

Table 5: Bacteria species isolated from surface water in Dangana Lake, Lapai, Niger State during the sampling periods

Station	Isolates
S1	*Bacillus* sp. *Escherichia coli*, *Staphylococcus aureus*
S2	*Micrococcus* sp. *Bacillus* sp. *E. coli*, *S. aureus*, *Klebsiella* sp
S3	*E. coli*, *Klebsiella* sp, *S. aureus*, *Micrococcus* sp, *Pseudomonas* sp, *Bacillus* sp
S4	*Micrococcus* sp., *Bacillus* sp., *E. coli*, *S. aureus*

Table 6: Fungi species isolated from surface water in Dangana Lake, Lapai, Niger State during the sampling periods

Station	Isolates
S1	*Aspergillus fumigatus*, *A. flavus*, *A. niger*, *Penicillium* sp, *Mucor sp*
S2	*A. fumigatus*, *A. flavus*, *A. niger*, *Mucor* sp, *Penicillium* sp
S3	*A. flavus*, *Penicillium* sp, *A fumigatus*, *Mucor* sp., *A. niger*
S4	*Mucor* sp., *A. flavus*, *A. niger*, *Penicillium* sp., *A. fumigatus*

According to Chapman and Kimstach (2006), the biodegradation of organic materials like dry leaves fallen into water bodies exerts oxygen tension in the water and increases the biochemical oxygen demand. The pH values obtained in this study fall within the recommended range (6.0-9.0) for aquatic life (Chapman and Kimstach 2006). The values of conductivity (86.43 to 94.80µS/cm) obtained in this study were within the range for freshwater. The conductivity of water depends upon the concentration of ions and its nutrients status (Atobatele and Ugwumba 2008). The relatively high values of phosphate and nitrate in this study could be attributed to inflow of waste from the catchment area due to human activities such as washing, bathing and farming. This may also be due to the biodegradation of organic matter by bacteria. It could also be due to lower water hardness, thus less co-precipitation of phosphate and nitrate with calcium carbonate (Kolo and Ogugbuaja, 2010).

The abundance of certain groups of macroinvertebrates such as Hemiptera and Odonota in this study could be attributed to habitat structure, substrate type and vegetation cover (Arimoro *et al* 2015; Mohammed *et al* 2021; Aydemir *et al* 2021). Odume *et al* (2012) reported that vegetation nature, nutrient availability, canopy cover, and substrate type also favour diverse groups of macroinvertebrates. Similarly, surface runoff or organic materials washed into the aquatic environment also favoured the distribution of certain groups (Arimoro *et al* 2015). The diversity and abundance of Hemiptera, Odonota and Coleoptera in the lake could be due to the vegetation cover and the bottom sediment favouring their colonization. Studies have reported the presence of hemipterans in Nigeria freshwater bodies (Arimoro and Ikomi 2008; Emere and Nasiru 2009; Arimoro *et al* 2015; Edegbene *et al* 2015; Mohammed *et al* 2020). According to Arimoro and Keke (2016) and Mohammed *et al* (2020), these groups of macroinvertebrates are moderately tolerant to pollution.

The presence of dipterans and oligochaetes are indication of pollution caused by decaying organic waste in aquatic environment (Edegbene *et al* 2015). In aquatic environment, these groups are primarily found in polluted areas because they are very tolerant of pollution. The presence of these groups of invertebrates have been reported in some freshwater bodies in Nigeria (Emere and Nasiru, 2009; Dadi-Mamud *et al* 2014; Mohammed *et al* 2021).

The absence of Ephemeroptera, Trichoptera and Plecoptera is an indication of pollution and poor water quality since they are sensitive to pollution. Several studies have shown the absence or low abundance of this group in polluted freshwater bodies of Nigeria (Emere and Nasiru 2009; Edegbene *et al* 2015; Arimoro *et al* 2015; Arimoro and Keke, 2016; Iloba *et al* 2019). Lower abundance of macroinvertebrates was encountered during the wet season than in the dry season. This could be as a result of increased water volume, flowrate and surface runoff, which must have disrupted the structure of the benthos during the wet season. Previous studies (Arimoro and Ikomi 2008; Dadi-Mamud *et al* 2014; Mohammed *et al* 2020; Mohammed *et al* 2021) also observed higher abundance of macroinvertebrates during the dry season in many freshwater bodies of Nigeria. Canonical Correspondence Analysis (CCA) showed that nitrate, conductivity, phosphate and BOD_5 predominantly influenced macroinvertebrates, which further affirms the that the lake is under pollution stress.

Most of the bacteria species identified (*E. coli, Bacillus* sp., *Micrococcus* sp., *S. aureus, Klebsiella* sp. and *Pseudomonas* sp.) have been previously identified in different water bodies in Nigeria (Shittu *et al* 2008; Eze *et al* 2012; Adamu *et al* 2017; Adamu *et al* 2018a; Ayanwale *et al* 2019; Chukwuemeka *et al* 2019; Mohammed and Adamu 2019). Most of these bacteria are members of the Family Enterobacteriaceae (Rockbrand *et al* 1999; Adamu *et al* 2017). The presence of *E. coli* and other enteric pathogens such as *Pseudomonas* and *Klebsiella* species in Dangana Lake is an indication that the water is contaminated with faecal waste and other organic matters (Mohammed and Adamu 2019). It revealed that anthropogenic activities along the lake have adverse effect on the water (Obire and Aguda 2015; Ewulonu *et al* 2019). *Escherichia coli* is a known causative agent of diseases like diarrhoea and could pose some public health dangers. Although bacteria encountered bacteria such as *Bacillus* sp., *E. coli*, *Pseudomonas* sp. and *S. aureus* have been reported to be involved in the degradation of organic matter and could assist in depuration (Eze *et al* 2012; Obire and Aguda 2015; Adamu *et al* 2018a) they also cause diseases such as gastrointestinal disorders and upper respiratory infections (Singleton and Sainsbury 2001). *Escherichia coli* and *Klebsiella* species have been reported to cause pneumonia, blood stream infections, wound infections, urinary tract infections and meningitis. *Staphylococus aureus* have also been reported to cause staphylococcal food poisoning, which is characterized with excessive diarrhoea and vomiting and is known to produce enterotoxin (Obire and Aguda 2015). The presence of *Pseudomomas* species in water could be as result of discharges from immuno-compromised individuals that bath or defecate into the water. *Pseudomonas aeruginosa* have been reported to cause urinary tract infection in youth and elderly people (Ewulonu *et al* 2019).

The fungi species isolated from the lake have been reported as the causative agent of asthma, hypersensitivity pneumonitis, pulmonary mycosis (Adamu *et al* 2018b; Ewulonu *et al* 2019) and aspergillosis by *Aspergillus* species (Singleton and Sainsbury 2001; Adamu *et al* 2018b). Some of the fungi isolated had been reported by several researchers as waste degraders in aquatic environments (Ariyo and Obire, 2016; Sokolo *et al* 2018; Adamu *et al* 2018b). The presence of pathogenic bacteria and fungi indicate the need to regularly monitor the water quality of the lake. Therefore, there is a risk of being infected with a disease if water from effluent receiving lake is used without treatment especially when they occur in large numbers. Transmission of disease through contaminated water is by far the most serious source of infection and has been responsible for massive epidemics like more serious enteric diseases particularly typhoid and cholera (Bensink *et al* 1981).

Conclusion

Lake Dangana is an important water body that serves as source water for domestic use including drinking. However, the absence of pollution sensitive macroinvertebrate, especially the EPTs (Ephemeroptera-Plecoptera-Trichoptera) group and the presence of pathogenic bacteria and fungi shows that the water is polluted and could constitute public health risk. Therefore, there is need for regular monitoring of the water and for users to treat the water adequately before consumption.

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