KAMPALA INTERNATIONAL UNIVERSITY
EXPLORING THE HEIGHTS

KIU
Journal of Science, Engineering and Technology

KJSET Research Article

Surface Water Quality of a Tropical River in North-central Nigeria using Physicochemical Characteristics

[1]Mohammed Y.M., [1]Adamu K.M., [1]Ibrahim B.U., [2]Danjuma S. & [3]Amuzat A.O.

[1-]Department of Biological sciences, Ibrahim Badamasi Babangida University Lapai, Niger state, Nigeria.
[2-]Department of Crop production, Ibrahim Badamasi Babangida University Lapai, Niger state, Nigeria.
[3-]Department of Biochemistry, Ibrahim Badamasi Babangida University Lapai, Niger state, Nigeria.

Corresponding Author: yakubmohammedmanbe@yahoo.com +238064805737

Paper history:
Received 7th December 2023
Accepted in revised form 28th March 2024

Keywords
Physicochemical parameters: Anthropogenic activities; Water Quality; River Wanzum.

Abstract

Water is one of the most precious natural resources and it is essential for all form of life, despite the importance of water to human, anthropogenic activities have result to significant pressure on water bodies around the world. This study was aimed to check the water quality status of River Wanzum using physicochemical characteristics. Samples were collected and analyzed using standard methods and procedure for a period of 24 month (December 2021 to November 2023). The result of the study showed mean air temperature (24.62±0.20°C to 25.98±0.28°C), water temperature (23.99±0.42°C to 24.90±0.50°C), water depth (49.50±4.78 to 57.16±4.52cm), flow velocity (0.07±0.01 to 0.10±0.01m/s), turbidity (124.75±1.37 to 141.33±3.75 NTU), pH (6.83±0.10 to 7.01±0.11), Conductivity (68.16±6.05to 76.50±7.22 µS/cm), total alkalinity (23.50±0.83 to 24.75±1.50mg/L), total hardness (31.00±1.51 to 33.75±2.26 mg/L), dissolved oxygen (5.80±0.91 to 6.45±0.12mg/L), biochemical oxygen demand (3.70±0.18 to 4.22±0.30 mg/L), chemical oxygen demand (4.59 ± 0.14mg/L to 4.94±0.21mg/L), nitrate (0.98±0.23 to 1.17±0.28 mg/L) and phosphate (0.33±0.09 to 0.55±0.13 mg/L). Out of all the measured values, only the dissolved oxygen and air temperature indicated a significant difference ($p<0.05$), with the remaining parameters demonstrating no discernible variation between the examined stations. With the exception of dissolved oxygen, every parameter examined in this study varied considerably ($p<0.05$) between the sampling months. The year-round farming practices along the River Wanzum have resulted in a shift in physicochemical factors, which may eventually hinder the effectiveness of using river water for residential purposes.

Nomenclature and units

1.0 Introduction

The most precious natural resource that is accessible to humans is water, which is essential for life. Water bodies are used for a variety of purposes, including as a source of water for drinking, washing clothes, irrigation, and hydropower generation (Adamu *et al.*, 2021). In order for human and animal socioeconomic development to be significant in any community, there must be a sufficient and safe water supply (Mohammed *et al.*, 2020; Kılıç, *et al.*, 2020; Mohammed *et al.*, 2023). An essential resource for life, water is becoming more and more polluted as a result of modern civilization, industrialization, urbanization, rapid population growth, inadequate sanitization, and agricultural practices (Ebesi *et al.*, 2023). Human existence depends on water, which is why people choose to live close to it (Rashid *et al.*, 2018; Hosseiny *et al.*, 2021). Any body of water that is found on the surface of the earth, such as streams, creeks, rivers, wetlands, and reservoirs, is considered to be surface water (Mohammed *et al.*, 2023). The majority of the surface waters in North-central Nigeria are under pressure from pollution brought on by urbanization and population growth (Mohammed *et al.*, 2021). According to Onyegeme-Okerenta et al. (2016), land-based activities are the primary source of pollution. These activities include agricultural runoff, residential and industrial wastewater, and urban storms. The entry of those contaminants into the surface waters that flow through various towns in Nigeria poses a major threat to all three aspects of the marine realm (Iloba et al., 2018). Most of these surface waters are now subjected to an increasing pollution load from contaminated urban runoff water coming from businesses, institutions, and recreational areas like schools and hospitals, as well as from industrial, agricultural, residential, and commercial areas (Meer *et al.*, 2020). Water quality is the sum of its biological, chemical, physical, and radioactive characteristics. It's a gauge of the water's condition in respect to the requirements of a few biotic organisms and any human needs or objectives. (Iloba *et al.*, 2018). Certain factors, including turbidity, temperatures, electrical conductivity (EC), total suspended solids (TSS), pH, dissolved oxygen (DO), nitrates, nitrites, the phosphates and biochemical oxygen demand, are assessed while evaluating the physico-chemical parameters of water bodies (Chatanga et al., 2019). National and international regulations deem the water safe if these parameters are within an acceptable range for aquatic life as well as for humans to ingest (Adesakin et al., 2020). The quality standards established for drinking water are referred to as water quality standards or guidelines (Ighalo and Adeniyi, 2020). The first step toward achieving safe and consumable surface water in north central Nigeria is to analyze the water quality. An urgent need to look for alternative ways that may result in improved environmental management of fish production and aid to maintain the water body prompted this research to evaluate the Surface water physicochemical parameters of River Wanzum in Lavun Local Government Area of Niger State.

2.0 Methodology

2.1 Study area

In the Niger state's River Wanzum Manbe, the study was carried out. Within latitude 8º85068 and longitude 5º89672 is the study area. River Wanzum is situated near the rural settlements of Manbe-Tiffin and Mambe-Tako in the Niger floodplain of the Niger state's Lavun Local Government. The research location is located in North Central Nigeria's savannah region and has two distinct seasons (rainy and dry season). April through October is the wet season, and November through March is the dry season. The River provides the surrounding communities with irrigation, drinking, and washing water, as well as a possible supply of fish. The river serves as tributary for the Niger and Kaduna River as it is annually flooded by this major water bodies between the months of August and October. The vegetation of the study area reflects that of the savannah region which is characterized with few scattered trees along the bank of the river.

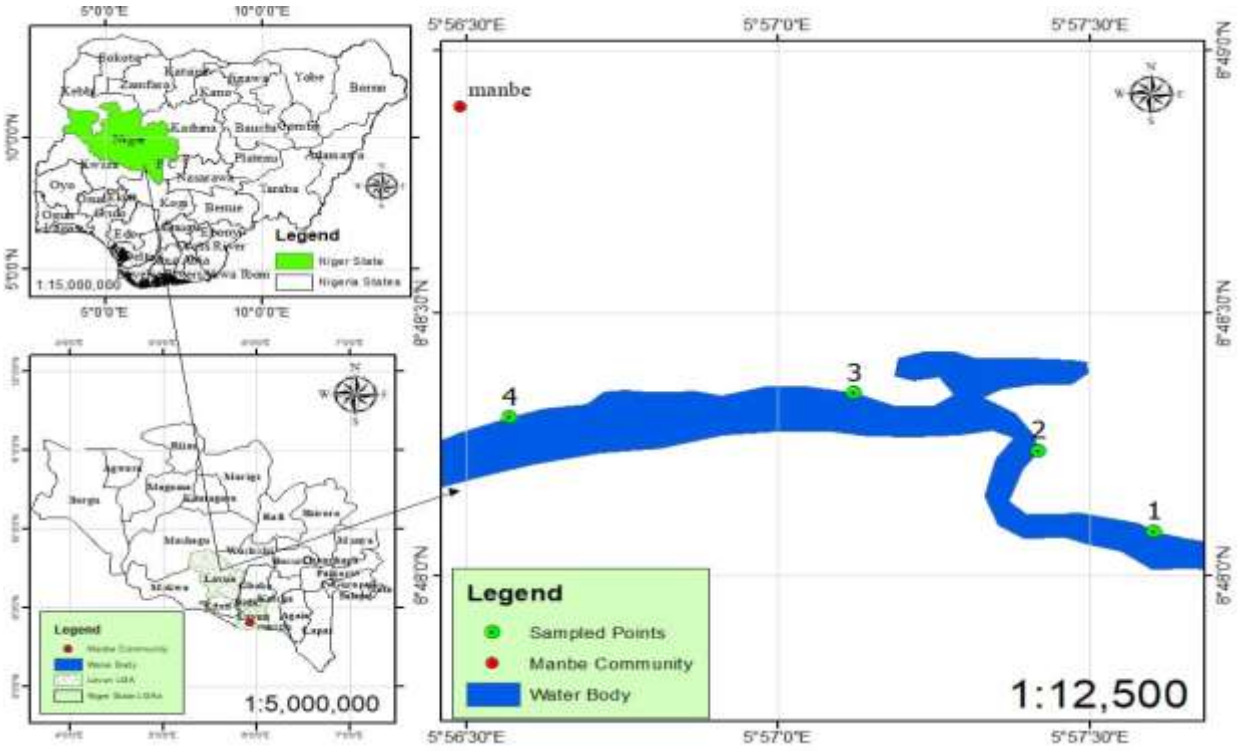

Figure 1: Map of the study area showing the sampled station of river Wanzum.

2.2 Sampling stations

Sampling station 1 is located along Mambe-Tiffin and Gbade axis. It is called Kponkparagi by the local inhabitants. This station is characterized by few anthropogenic activities, the few activities taking place in this station include, fishing and irrigation of water to farms at the bank of the river. Sampling station 2 is approximately one kilometer afar from station one (1) and it is located close to a motorable bridge along Mambe-Tiffin and Egbagi road. This station is called Mindu (Kpatayizagizhi). This station is characterized with numerous anthropogenic activities such as washing of clothes and household utensils by the women, car wash, fishing and irrigation of water to farms at the bank of the river. Sometimes sand dredging also take place at this station. Sampling station 3 is approximately one kilometer afar from station two (2) and it is one of the prominent landing sites for fishermen. This station is called Wanzum-Tachin and it is located in between Mambe-Tiffin and Mambe-Tako. This station is characterized with numerous anthropogenic activities such as bathing washing of clothes, car wash, fishing and irrigation of water to farms at the bank of the river. Sampling station 4 approximately three kilometer afar from station three (3) and it is the quiet and enclose regions of the River. This station is called Edzwanbiye by the inhabitant. The only human activity that takes place in this station is fishing.

2.3 Sample collection and determination of Physico-chemical variables

Between December 2021 and November 2023 samples were collected monthly for a duration of 24 months. This study analyzed the monthly physico-chemical data of air and water temperature, water depth, flow velocity, pH, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, electrical conductivity (EC), total alkalinity, total hardness, nitrate, and phosphate. The ambient and water temperatures were measured on-site using a mercury-in-glass thermometer. The water depth was measured in centimeters using a calibrated stick (Gordon *et al.*, 1994). Flow velocity was measured by timing a drifted ball in three trials, and the average of the trials was taken as the flow velocity of each of the sampled stations, which was measured in metres per second. The pH, conductivity and turbidity were measured using digital multipurpose machine (Hannah H1991300/1 model). Dissolved oxygen (DO), biochemical oxygen concentration (BOD_5), total hardness, total alkalinity, nitrates and phosphates were

determined using the standard methods of American public health association (APHA 2012).

2.4 Data analysis

Paleontological statistical software (PAST version 4.02) was used in this work to apply descriptive statistics (mean and standard error) to the physicochemical variables for each sampled station. A one-way analysis of variance (ANOVA) without replication was used to compare the means of all the physicochemical variables evaluated among the sampled stations and sampled months in order to look for significant differences ($p<0.05$). We in comparison the physico-chemical variables in the current investigation with those of the Federal Environment Protection Agency (FEPA) Nigeria, Standard Organization of Nigeria (SON), and World Health Organization (WHO) standards for surface and drinking water in order to ascertain the impact of anthropogenic stressors on the water quality of the studied River.

3.0 Results.

Table 1 shows the summary of mean values of physical parameters of River Wanzum, Niger State Nigeria. The result of mean air temperature ranged from 24.65±0.20°C in station 4 to 26.98±0.28°C in station 2. Mean water temperature ranged from 23.99±0.42°C in station 4 to 24.90±0.50°C in station 3. The mean water depth ranged from 49.50±4.78cm in station 2 to 57.16±4.52cm in station 3. Flow velocity mean value ranged from 0.07±0.01m/s in station 1 to 0.10±0.01 in station 3. Turbidity mean value ranged between 124.75±1.37 NTU in station 4 to 141.33±3.75 NTU in station 2. Of all the physical parameters measured, only Air temperature and turbidity showed significant difference ($p<0.05$) while the remaining parameters shows no significant difference between the sampled stations. All the physical parameters measured in this study differs significantly ($p<0.05$) among the sampling months.

Table 2 shows the summary of mean values of chemical parameters of River Wanzum, Niger State Nigeria. The pH values ranged from 6.83±0.10 in station 2 to 7.01±0.11 in station 4. Conductivity value recorded lowest mean value (68.16±6.05 µS/cm) in station 3 and highest (76.50±7.22 µS/cm) in station 2. The mean total alkalinity value ranged from 23.50±0.83mg/L in station 2 to 24.75±1.50mg/L in station 3. Total hardness mean value ranged from 31.00±1.51mg/L in station 2 to 33.75±2.26 mg/L in station 3. The mean value of dissolved oxygen varied between 5.80±0.91 mg/L at station 3 and 6.45±0.12 mg/L at station 4. The average value of biochemical oxygen demand varied between 3.70±0.18 mg/L at station 3 and 4.22±0.30 mg/L at station 2. The average chemical oxygen requirement value varied between stations 1, 4,59 ± 0.14 mg/L, and 2, 4.94 ± 0.21 mg/L. In station 2, the mean nitrate value was 0.98±0.23 mg/L, while in station 3, it was 1.17±0.28 mg/L. Station 1's mean phosphate value was 0.33±0.09 mg/L, while station 4's mean value was 0.55±0.13 mg/L. Only dissolved oxygen, out of all the chemical parameters examined, indicated a significant difference ($p<0.05$), with the other chemical values showing no discernible variation across the sampled stations. All of the chemical factors measured in this study varied significantly (p0.05) between the sampling months excepting dissolved oxygen.

Table 1: Mean values of physical parameters of sampled stations of River Wanzum, Niger State Nigeria.

Parameter	Stations				P-value		Maximum Permissible limit		
	S1	S2	S3	S4	Stations	Months	SON	FEPA	WHO
Air temperature (°C)	25.73±0.35	26.98±0.28	26.96±0.28	24.65±0.20*	0.004	5.50E-05	Ambient	40	
	(24.00-27.80)	(25.0-27.80)	(25.00-27.80)	(24.00-26.00)					
Water temperature (°C)	24.5±0.55	24.25±0.44	24.90±0.50	23.99±0.42	0.592	2.70E-05	Ambient	40	
	22.20-27.80	21.30-26.3	(22.00-27.00)	(21.20-26.40)					
Depth (cm)	51.07±5.04	49.50±4.78	57.16±4.52	50.57±4.78	0.668	1.85E-19			
	(33.00-80.80)	(33.07-77.90)	(37.00-83.00)	(34.2-77.00)					
Flow velocity (m/s)	0.07±0.01	0.09±0.01	0.10±0.01	0.09±0.01	0.33	7.01E-06			
	(0.01-0.12)	(0.01-0.12)	(0.01-0.18)	(0.01-0.13)					
Turbidity (NTU)	130.55±2.24	141.33±3.75	138.33±2.63	124.75±1.37*	0.003	0.027			
	(120-142)	(125-163)	(126-150)	(120-136)					

Note: Asterisk (*) indicates a substantial difference across rows; data are mean±S.E. with range in parenthesis.

Table 2: Mean values of chemical parameters of sampled stations of River Wanzum, Niger State Nigeria.

Parameter	Stations				P-value		Maximum Permissible limit		
	S1	S2	S3	S4	Station	Months	SON	FEPA	WHO
pH	6.99±0.13	6.83±0.10	6.90±0.12	7.01±0.11	0.5935	3.86E-09	6.5-8.5	6.0-9.0	7.0-8.5
	(6.56-7.93)	(6.39-7.56)	(6.32-7.78)	(6.38-7.56)					
Conductivity (µS/cm)	75.16±7.27	76.50±7.22	68.16±6.05	70.33±6.08	0.809	2.47E-10	1000		600
	(22.0-110.00)	(31.0-114.00)	(25.00-92.00)	(24.00-92.00)					
Alkalinity (mg/L)	24.16±1.21	23.50±0.83	24.75±1.50	23.91±0.93	0.956	2.75E-06			600
	(14.0-28.00)	(16.00-26.00)	(16.00-32.00)	(16.00-28.00)					
Total hardness (mg/L)	32.08±2.06	31.00±1.51	33.75±2.26	33.41±1.80	0.839	1.89E-08			
	(20.00-46.00)	(20.00-40.00)	(20.00±50.00)	(25.00-46.00)					
Dissolved oxygen (mg/L)	6.39±0.35	6.36±0.24	5.80±0.19*	6.45±0.12	0.003	0.309		5	5
	(4.00-8.00)	(4.00-7.20)	(5.00-7.00)	(5.80-7.20)					
Biochemical oxygen demand (mg/L)	3.75±0.25	4.22±0.30	3.70±0.18	4.02±0.16	0.686	0.028		10	5
	(3.00-5.50)	(2.00-6.10)	(3.00-5.00)	(2.90-4.80)					
Chemical oxygen demand (mg/L)	4.59±0.12	4.94±0.21	4.73±0.11	4.84-0.26	0.903	2.70E-05			
	(3.84-5.32)	(3.33-5.96)	(3.94-5.30)	(2.30-5.72)					
Nitrate (mg/L)	1.06±0.25	0.98±0.23	1.17±0.28	1.14±0.27	0.982	2.90E-05	50	20	
	(0.23-2.81)	(0.18-2.36)	(0.23-2.88)	(0.20-2.74)					
Phosphate (mg/L)	0.33±0.09	0.45±0.13	0.48±0.28	0.54±0.13	0.608	3.22E-07		5	
	(0.12-1.22)	(0.11-1.38)	(0.12-1.88)	(0.15-1.52)					

Values are mean±S.E.; range is enclosed in parenthesis; asterisks (*) indicate significant differences between rows.

3.0 Discussion

The contours of the drainage area and the amount of rainfall typically have an impact on the water level in the aquatic ecosystem. (Adamu *et al.,* 2021). Most of the physicochemical values recorded during this study reflect a typical tropical climate environment, as previously reported in other studies in Nigeria (Mohammed *et al.,* 2020; Mohammed *et al.,* 2021; Edegbene *et al.,* 2022; Adamu *et al.,* 2022; Maishanu *et al.,* 2022; Ebesi *et al.,* 2022; Adama *et al.,* 2023). The mean air temperature ranged from 24.62±0.20°C to 25.98±0.28°C and water temperature ranged from 23.99±0.42°C to 24.90±0.50°C. Temperature is one of the most important parameters in aquatic ecology as it regulates aquatic physiological behavior and distribution of aquatic organism (Mustapha, 2008). In this study a medium air and water temperature were observed which could be due to the time in which the samples were collected and the nature of vegetation around the water body. The mean water depth falls within the ranged of 49.49±4.78cm to 57.16±4.52cm which is a characteristics of shallow water body. There is rapid increase in water depth during rainy seasons as a result of rainfall and flood. The mean flow velocity ranged from 0.07±0.01 m/s to 0.10±0.01 m/s, with low flow regimes reported at the river sample point. The rainy season recorded significantly higher values than the dry season. This can be the result of rain throughout the dry season increasing the water volume, which also caused the Kaduna River to overflow. (Arimoro *et al.,* 2015). The mean value of turbidity varied from 125.22±1.76 NTU to 143.88±4.25 NTU. According to this study, the rainy season has higher turbidity values than the dry season; this could be because of the type of silt and surface runoff from stream banks (Mustapha 2008). Adam and associates (2020) Similar turbidity ranges were also noted by Mohammed et al. (2021) in their research on a few northern Nigerian water basins. Similar to this, Ibezute et al. (2016) reported that the Ikpoba River in Edo state, Nigeria, has a turbidity range of 2-468NTU. The mean value of dissolved oxygen varied between 5.80±0.19 mg/L and 6.45±0.12 mg/L. The study's measured values of dissolved oxygen were in line with the range of 0.25 to 6.39 mg/L reported by Adam et al. in 2020. in Nigeria's River Hadejia. This result is consistent with the study of Keke et al. (2015), who likewise found that surface water from the Kaduna River in Zungeru, Niger state, Nigeria, has a DO range of 3.5-8.2 mg/lEven though there was a decrease in DO values at certain points, which may have been caused by the discharge of organic waste from agricultural activities into the water body at certain times, the DO values observed in this study are characteristics of oxygenated water bodies because they may have led to biological respiration and break down processes, which in turn reduced the total amount of DO in water bodies. (Adam *et al.,* 2020; Mohammed *et al.,* 2021). Biochemical oxygen demand value ranged from 3.70±0.18 to 4.22±0.30 mg/l. The observed BOD_5 values of this study is an indication of moderately pollution across the sampling station of River Wanzum. As (BOD_5) have been reported to ascertain the level of organic pollution in water quality (Adam *et al.,* 2020). Many researchers (Ogueri, 2018; Adam *et al.,* 2020) have classified rivers using BOD_5 as follows: unpolluted (BOD_5<1.0 mg/l), moderately polluted (BOD_5 between 2-9 mg/l) and heavily polluted (BOD > 10.0 mg/l) which is an indication that that organic pollution increases bacteria decomposition aquatic environment.

The mean pH value observed ranged from 6.83±0.10 to 7.01±0.10 which fall within the recommended range of 6.5 to 8.5 by the standard organization of Nigeria (SON, 2007). The observed pH values in this study are in agreement with the findings of Raji *et al.,* (2015) and Arimoro and Keke (2016) who recorded a similar pH value from River Sokoto, Northwestern Nigeria. and Gbako River North-central Nigeria. Conductivity mean value ranged from 68.16±6.05µS/cm to 76.50±7.22 µS/cm. Conductivity of water is useful and accessible indicator of water quality as it gives the details of the ability of water to allow the passage of electricity (Mohammed *et al.,* 2021). All of the River Wanzum's measured stations had high conductivity values, which suggests that the stations may include more suspended and dissolved solid materials, which would raise the concentration of cations like calcium, magnesium, and sulfate (Mustapha, 2008). This study's conductivity range is comparable to that of Ibezute et al. (2016), who found conductivity values from Ikpoba River, Edo State, ranging from 18 to 93µS/cm. Alkalinity ranged in mean value from 23.50±0.83 to 24.75±1.09 mg/L. The moderate alkalinity observed in this study could be due to surface runoff from nearby farms and dissolution of calcium carbonate in the water column (Keke *et al.,* 2015). Similarly, Mohammed *et al.,* (2021) reported alkalinity ranged of 8.0 to 30mg/l in an urban stream Northcentral Nigeria.

Nitrate and phosphate have been used as indicators of organic pollution in most part of the globe (Arimoro *et al.,* 2015). Because the aquatic environment might become unproductive when these nutrients are depleted, they are among the environmental variables that are limited (Arimoro et al., 2015). In a river system, organic debris from plants and animals as well as sewage fertilizer are their primary sources. Eutrophication and the growth of algae are related to nitrate concentration. In this study, Nitrate mean value ranged from 1.26±0.31mg/L to 1.47±0.41mg/L**.** The high nitrate value could be probably due to increased farming activities around the sampled station of River Wanzum. Phosphate mean value ranged from 0.40±0.11 to 0.77±0.25mg/L. Phosphate value recorded in this study conforms with the findings of Adam *et al.,* (2020) in River Hadejia, Northern Nigeria. Different anthropogenic activities, farm runoff, and the breakdown of biological material into the water can all lead to high nitrate and phosphate concentration (Ibrahim et al., 2009).

5.0 Conclusion

The present study provided comprehensive information on impact of anthropogenic activities on River Wanzum using key physico-chemical parameters. The present results shows that the River is fast deteriorating, buttressing the concomitant high concentration of pollution indicating physico-chemical parameters such as BOD_5, conductivity, phosphate and nitrate. With this, it is obvious that human activities such as all year round farming activities around River Wanzum has contributed to the change of physico-chemical variables and thus could led to disabling the efficiency and utilization of river water for domestic purpose. These findings open a vista of further research for better management and consequent sustainability of the River and and its resources.

Competing interest

The authors declare no competing interest.

Authors' Contribution

This work was carried out in collaboration among all authors. MYM and AKM designed and conceptualized the study, AKM, IBU, DS and AOA supervised the study; MYM wrote the protocols and collected sample from field and performed laboratory analysis while KMA managed the data analyses and literature search of the study. All authors read and approved the final manuscript.

Acknowledgements

The Authors wished to thank the people of Manbe Community for granting us access to the water body where the study was carried out, also the authors wish to thank Mr. Ibrahim A. Isah, Mr. Zakari Mohammed and Mr Mohammed Idris Babatsu for assisting in the field during sample collection.

References

Adam, B.M., Edegbene, A.O., & Jibrin, G. (2020). Monitoring and Exploring the Spatio-temporal Variation of Physico-chemical Variables of River Hadejia, Nigeria; Using Statistical Approach. *Asian Journal of Geographical Research*, 3(1), 49-61. DOI: 10.9734/AJGR/2020/v3i130100

Adama B.S., Mohammed, Y.M., Musa, I.N., Samuel, P.O., & Saba, J.J. (2023). The Effect of Flood Regime on Water Quality and Plankton Distribution in Bosso Area, Minna, Niger State. Kampala international University; *Journal of Science, Engineering and Technology*, 02(2), 150-156. https://doi.org/10.59568/KJSET-2023-2-1-19

Adamu, K.M., Mohammed, Y.M., Ibrahim, U.F., Abdullahi, I.L., & Jimoh, Y.O. (2022). Assessment of some physical, chemical and biological parameters of Lake Dangana, Niger State, Nigeria. *The Zoologist*, 20. 133-140. http://dx.doi.org/10.4314/tzool.v20i1.17.

Adamu, K.M., Mohammed Y.M., Mohammed, H., Ebesi, E.J., & Jimoh, Y.O. (2021). Spatio-temporal Assessment of Phytoplankton and Physicochemical Parameters of Dangana Lake, Lapai, Niger State Nigeria. *Journal of Applied Life Sciences International*, 24(12), 39-48, *2021; Article no.JALSI.84650*

Adesakin, T.A., Oyewale, A.T., Bayero, U., Mohammed, A.N., Aduwo, I. A., Ahmed, P.Z., & Barje, I.B. (2020). Assessment of bacteriological quality and physico-chemical parameters of domestic water sources in Samaru community, Zaria, Northwest Nigeria. *Heliyon*, 6(8), e04773.

APHA *(American Public Health Association) 1998. Standard Methods for the Examination of Water and Wastewater*. WEF and AWWA. 20th Edition; 1998: USA

Arimoro, F.O., & Keke, U.N. (2016). The intensity of human-induced impact on the distribution and diversity of Macroinvertebrates and water quality of Gbako River, North Central Nigeria. *Energy Ecology & Environment*, 16(8), 25-36. DOI:10.1007/s40974-016-0025-8

Arimoro, F.O., Odume, N.O., Uhunoma, S.I., & Edegbene, A.O. (2015). Anthropogenic impact on water chemistry and benthic macroinvertebrate associated changes in a southern Nigeria stream. *Environmental Monitoring Assessment*, 187, 1–14.

Chatanga, P., Ntuli, V., Mugomeri, E., Keketsi, T., & Chikowore, N. V. (2019). Situational analysis of physico-chemical, biochemical and microbiological quality of water along Mohokare River, Lesotho. *The Egyptian Journal of Aquatic Research*, 45(1), 45-51.

Ebesi, E.F., Mohammed, Y.M., Iloba, K.I., Adamu, K. M., & Adama, S.B. (2022). Zooplankton community structure of a tropical lake in a Northcentral State, Nigeria. *Ruhuna Journal of Science*, 13(2), 217-230, http://doi.org/10.4038/rjs.v13i2.127

Edegbene, A.O., Abdullahi, Y., Akamagwuna, F.C., Ogidiaka, E., Osimen, E.C., & Omovoh, B.O. (2022). Are zooplankton useful indicators of ecological quality in Afrotropical ephemeral stream impacted by human activities? *Environmental Monitoring & Assessment*, 194, https://doi.org/10.1007/s10661-022-10061-4

Emere, M.C., & Nasiru, C.E. (2009). Macroinvertebrate as Indicator of the water quality of an Urbanized stream, Kaduna Nigeria. *Journal of aquatic sciences,* 7, 2-3.

Federal Environmental Protection Agency (FEPA, 1991) G*uideline and standards for Environmental pollution control in Nigeria.* Federal Environmental Protection Agency, 27, 20

Gordon, N.D., McMahon, T.A., Finlayson, B.L., (1994). *Stream hydrology, an introduction for Ecologists.* New York: John Wiley & Sons Ltd, 526Pp.

Hosseiny, S.H., Bozorg-Haddad, O., & Bocchiola, D. (2021). Water, culture, civilization, and history. In *Economical, Political, and Social Issues in Water Resources* (pp. 189-216). Elsevier.

Ibezute, A.C., Asibor, G. I., & Ibezute, G. I. (2016). Ecological Assessment of Brewery Effluent Impact on the Macrobenthic Invertebrates of Ikpoba River, Edo State, Nigeria. *International Journal of Ecosystem,* 6(3), 47-54.

Ibrahim, B.U., Auta J., & Balogun J. K. (2009). Assessment of the physicochemical parameters of Kontagora Reservoir Niger state. *Bayero Journal of pure and applied sciences,* 2(1), 64-69.

Ighalo, J.O., & Adeniyi, A.G. (2020). A comprehensive review of water quality monitoring and assessment in Nigeria. *Chemosphere,* 260, 127569.

Iloba, K.I., Akawo, O.N., & Nwaefiene, F. (2018). Diversity and Community Structure of Macroinvertebrates in Anthropogenically stressed water body in Delta state, Nigeria. *International Journal of Applied Biological Research,* 9(1), 93-106.

Keke, U.N., Arimoro, F.O., Ayanwale, A.V., & Aliyu, S.M. (2015). Physicochemical parameters and Heavy Metals content of surface water in downstream Kaduna River, Zungeru, Niger state, Nigeria. *Applied science research Journal,* 3 (2), 46-57.

Kılıç, Z. (2020). The importance of water and conscious use of water. *International Journal of Hydrology*, 4(5), 239-241.

Maishanu, F., Adamu, K.M., & Mohammed, Y.M. (2022). Anthropogenic impact on some water quality characteristics of Wupa River Federal Capital Territory, Abuja, Nigeria. *Issues in Biological Sciences & Pharmaceutical Research,* 10(3), 30-38. https://doi.org/10.15739/ibspr.22.006

Meer, B.B., Dishan, E.E., Ikima, D., & Ateh, G.O. (2020). Ecological implications of environmental contaminants on biodiversity and ecosystem services: The Nigerian Experience. *Basic Research Journal of Soil and Environmental Science*, 2(1), 1-9.

Mohammed, H., Adamu, K.M., Kasim, A.A., Mohammed, Y.M. & Dadi-Mamud, N.J. (2023). Bacteriological Analysis of Water from Emu-Stream, Kusotachin, Nigeria. *Lapai Journal of Applied and Natural Sciences,* 8(1), 38-44

Mohammed, Y. M., Arimoro, F. O., Ayanwale, A. V., Adamu, K. M., Ismail, A., Umar, M., & Kanki, H. (2020). Assessment of some physicochemical parameters of Moussa stream, Bida, Niger State Nigeria. *Journal of Public Health & Environmental Pollution,* 4(2), 020-024.

Mohammed, Y.M., Arimoro, F.O., Ayanwale, A.V., Adamu, K.M., Keke, U.N., Abubakar, M.D., & Achebe, A.C. (2021). The current state of water quality and benthic invertebrate fauna in Chikke Stream (North-Central Nigeria). *Ukrainian Journal of Ecology,* 11(3), 26-34.

Mustapha, M. K. (2008). Assessment of the Water Quality of Oyun Reservoir, Offa, Nigeria, Using Selected Physico-Chemical Parameters *Turkish Journal of Fisheries and Aquatic Sciences*, 8, 309-319

Ogueri, C., Adebayo, E.T., & Nwaiwu V.N.C. (2018). Assessment of heavy metals in fish species and some physicochemical parameters of Oguta lake, Oguta, Imo state, Nigeria. *International Journal of Hydrology*, 2(2), 116–119.

Onyegeme-Okerenta, B.M., Obia, C., & Wegwu, M. O. (2016). Physicochemical properties of water quality of Imeh, Edegelem and Chokocho communities located along Otamiri-oche River in Etche Ethnic Nationality of Rivers State, Nigeria. *Journal of Applied Sciences and Environmental Management*, 20(1), 113-119.

Raji, M.I.O., Ibrahim, Y.K.E., Tytler, B.A., & Ehinmidu, J.O. (2015). Physicochemical Characteristics of Water Samples Collected from River Sokoto, Northwestern Nigeria. *Atmospheric and Climate Sciences,* 5, 194-199.

Rashid, H., Manzoor, M.M., & Mukhtar, S. (2018). Urbanization and its effects on water resources: An exploratory analysis. *Asian Journal of Water, Environment and Pollution*, 15(1), 67-74.

Standard organization of Nigeria (SON, 2005). *Nigerian Standard for Drinking Water, Nigerian industrial standard* NS554, Lagos. 30pp.