Impact of Physicochemical Parameters and Heavy Metal Contamination on Plankton Communities in Kafin Gana Dam, Nigeria

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DOI: 10.56201/ijasmt.vol.11.no2.2025.pg26.44

Abstract

This study investigated the influence of physicochemical parameters and heavy metal concentrations on plankton communities in Kafin Gana Dam, Nigeria. Sampling was conducted from March to August 2024, covering the dry and rainy seasons. Plankton were collected using planktonic net of 55µm mesh size by hauling horizontally for five meters. Water samples were collected from four sites, and standard protocols were employed for field and laboratory analyses. One-way ANOVA and Pearson's correlation were used to analyze the data using SPSS (v.11.0.1). Results indicated that monthly mean values varied significantly across parameters: Temperature (26–30.75°C), pH (6.52–7.55), Total Dissolved Solids (79.2–96.00 mg/L), Electrical Conductivity (47.50–96.50 µS/cm), Dissolved Oxygen (5.45–8.22 mg/L), Turbidity (14.33–25.67 NTU), Calcium (12.70–60.83 mg/L), Magnesium (0.41–5.05 mg/L), Sodium (4.64–5.14 mg/L), Potassium (3.54–9.38 mg/L), and Nitrate (1.07–3.36 mg/L). Heavy metal concentrations also varied: Manganese (0.13–1.20 mg/L), Copper (0.02–0.44 mg/L), Zinc (0.12–0.61 mg/L), and Lead (0.07–0.39 mg/L). Plankton communities comprised four phytoplankton phyla (Chlorophyceae, Bacillariophyceae, Euglenophyceae, and Cyanophyceae) and three zooplankton phyla (Rotifera, Cladocera, and Copepoda). Plankton abundance was significantly higher during the dry season and in areas with minimal anthropogenic activity, while reduced abundance was observed in areas with poor water quality. Significant correlations were found between physicochemical parameters, heavy metal concentrations, and plankton abundance, highlighting the need for sustainable management practices to maintain the dam's ecological integrity.

Keywords: *Physicochemical parameters; Heavy metals; Plankton; Kafin Gana Dam.*

INTRODUCTION

Kafin Gana Dam plays a crucial role in the ecosystem and the lives of those that depend on it. The health of this vital water resource is directly linked to the well-being of its aquatic life, particularly plankton communities. Water quality is fundamental to the health of aquatic ecosystems and the organisms that inhabit them (Zaghloul *et al.*, 2020). Globally, water bodies are increasingly threatened by pollution, which adversely affects biodiversity and ecosystem services(Cazzolla Gatti, 2016). The United Nations has emphasized that approximately 1.8 billion people worldwide lack access to safe drinking water, and over 80% of wastewater is discharged untreated into the environment (Onu *et al.*, 2023).

Plankton, comprising phytoplankton and zooplankton, are critical to aquatic food webs. As primary producers, phytoplankton form the base of the aquatic food chain, providing nutrients to higher trophic levels, while zooplankton act as intermediaries in the energy transfer process (Wang *et al.*, 2024). Their abundance, diversity, and distribution are highly sensitive to changes in water quality, making them ideal bioindicators (Setyono and Himawan, 2018). For instance, pollution-tolerant taxa such as Cyanophyceae thrive in nutrient-enriched waters, while sensitive groups like Bacillariophyceae decline, signaling ecosystem degradation (Setyono and Himawan, 2018).

In aquatic ecosystems, poor water quality, often caused by physicochemical changes and heavy metal contamination, disrupts the delicate balance required to support diverse aquatic life. Heavy metals such as lead, manganese, copper, and zinc are non-biodegradable and can bioaccumulate within food webs, leading to toxic effects on aquatic organisms and humans (Sharma et al., 2024). These microscopic organisms form the base of the aquatic food web and are sensitive indicators of water quality(Amorim and Moura, 2021).

Changes in physicochemical parameters and heavy metal contamination can significantly impact plankton populations, potentially disrupting the entire ecosystem (Sharma *et al.*, 2024).

Kafin Gana Dam, located in Jigawa State, Nigeria, is an essential resource for the surrounding communities, supporting agriculture, water supply, and recreational activities. However, the dam is increasingly exposed to pollutants from agricultural runoff, livestock activities, and urbanization. Studies in other Nigerian water bodies, such as Dadin Kowa Dam (Tusayi *et al.*, 2020) and Eme River (Anyanwu *et al*., 2021), have documented significant impacts of physicochemical parameters and heavy metals on aquatic biodiversity. However, smaller water bodies like Kafin Gana Dam, which contain a substantial portion of Nigeria's aquatic biodiversity, have received limited attention. This study aimed to assess the effects of these factors on the plankton community within Kafin Gana Dam.

Materials and Methods

Study sites

Kafin Gana Reservoir is located at Kafin Gana town Birnin kudu Local Government Area of Jigawa State. Kafin Gana is located between Birnin Kudu and Dutse local government at latitude

11^0 30^0N and 9^0 21^0E. It is in Sudan savannah as ecological zone of Nigeria. The dam was established primarily for irrigation purposes. It has a surface area of 121ha while fishing and irrigation are the only secondary activities.

Four sampling sites were selected: Site A: An upstream location with minimal human interference, Site B: A midstream area near agricultural fields. Site C: A downstream section with significant urban runoff. Site D: An area close to livestock grazing zones.

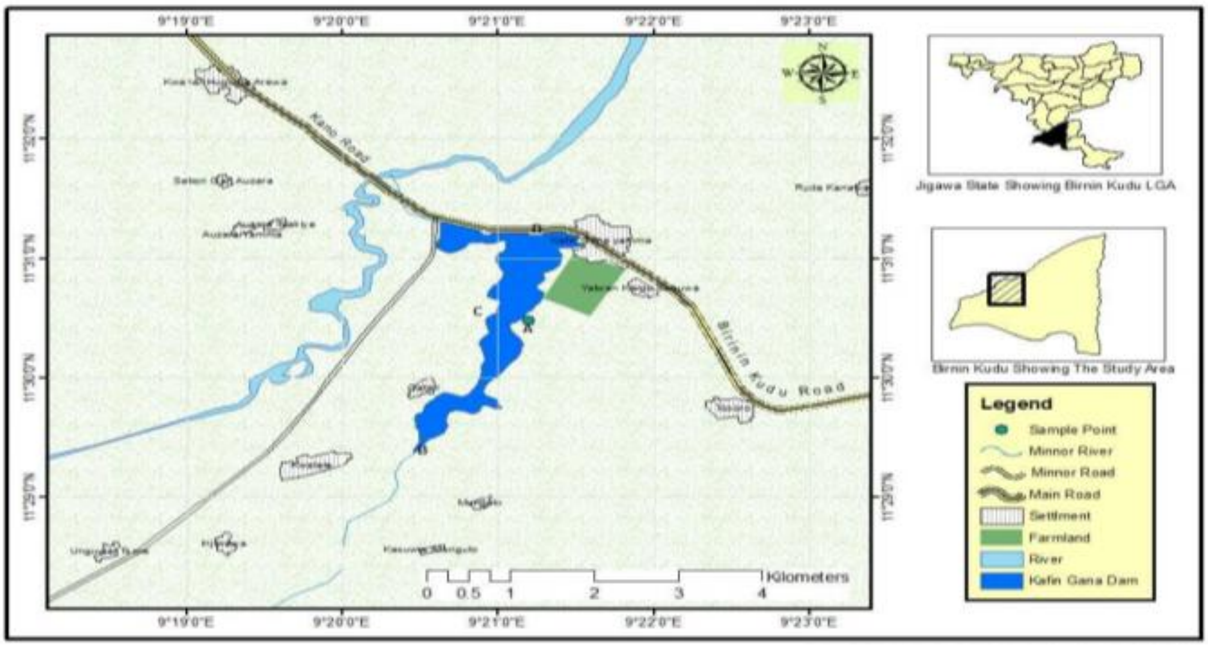

Figure 1: Map showing the Kafin Gana Dam in Birnin kudu Local Government Area, Jigawa State

Sampling

Water samples were collected from four distinct sites within Kafin Gana Dam over a six-month period (March–August 2024). Surface water samples were collected using sterilized polyethylene bottles. Samples were immediately stored in coolers at 4°C and transported to the laboratory for analysis. A plankton net (mesh size 55 µm) was used to collect phytoplankton and zooplankton samples. Samples were preserved in 4% formalin for later identification and enumeration.

Physicochemical and Heavy Metal Analysis

Temperature was measured in situ using a calibrated thermometer to ensure immediate and accurate readings. pH was determined using a pH meter, calibrated with standard buffer solutions (pH 4.0, 7.0, and 10.0) before measurement. Dissolved Oxygen (DO) were measured using the Winkler titration method, which involves chemical fixation of oxygen followed by titration to determine concentration. Turbidity was assessed using a turbidimeter, where water samples are analyzed for light scattering caused by suspended particles. Total Dissolved Solids (TDS) and Electrical Conductivity (EC) were measured with portable conductivity meters, correlating electrical conductance with ion concentrations. Heavy Metals were analyzed using Atomic Absorption Spectrophotometry (AAS) for precise quantification of metals like Pb, Mn, Cu, and Zn following the standard APHA (2017) guidelines. All measurements were cross-checked for accuracy using calibration standards.

Plankton Identification and Enumeration

The samples were collected monthly in the morning hours (between 7:00am and 9:00am) for a period of six months from each sampling station using a planktonic net of mesh size 55µm by hauling the sampler horizontally for five meters according to the method used by Umar and Abbati, (2021). Samples was transferred in 4% formalin and then transport to Federal University Dutse, Department of Fisheries and Aquaculture laboratory for identification, counting and further analysis.

Plankton samples were examined under a compound microscope. Drop count method was used and counting was done in triplicate by counting each cell as individual (Adamu *et al.*, 2021). Identification of the zooplankton to species level was done using keys described by Lynne (2004), Sanet *et al.*, (2006) and Suthers and Rissik (2009) while phytoplankton using identification keys, available literature and standard books (Bellinger and Sigee, 2010).

Statistical Analysis

One-way ANOVA was used to compare the means of various parameters between months, and Pearson's correlation analysis was used to determine the relationships between physicochemical parameters, heavy metal concentrations, and plankton abundance. Statistical analysis was performed using SPSS (v. 11.0.1). Significance was determined at $p < 0.05$.

RESULT

Table 1 summarizes the mean monthly values of the physicochemical parameters. The study revealed that temperature fluctuated significantly, with higher averages noted in the latter months of the study. The mean monthly temperature ranged from 26ºC to 30.75ºC, with higher values recorded during the dry season. This seasonal variation was attributed to increased solar radiation during the dry months. pH values ranged from 6.52 to 7.55, reflecting slightly acidic to neutral water conditions suitable for aquatic life. The pH remained within a suitable range for aquatic life but indicated slight seasonal variations. Dissolved oxygen (DO) concentrations varied between 5.45 mg/L and 8.22 mg/L, with higher values observed in less polluted sites. Total dissolved solids (TDS) and electrical conductivity (EC) values peaked during the rainy season due to increased runoff introducing dissolved ions into the dam.

Calcium and magnesium concentrations fluctuated between 12.70 mg/L and 60.83 mg/L and 0.41 mg/L and 5.05 mg/L, respectively, indicating varying levels of mineral inputs from surrounding soil erosion. Sodium and potassium concentrations were relatively stable, ranging from 4.64 mg/L to 5.14 mg/L and 3.54 mg/L to 9.38 mg/L, respectively. Nitrate levels ranged from 1.07 mg/L to 3.36 mg/L, with higher concentrations recorded during the rainy season due to agricultural runoff.

Heavy Metal Concentrations

Table 2 summarizes the mean monthly values of the heavy metals. Manganese levels varied from 0.13 mg/L to 1.20 mg/L, with elevated concentrations recorded in sites near agricultural activities. Copper ranged from 0.02 mg/L to 0.44 mg/L, while zinc levels ranged from 0.12 mg/L to 0.61 mg/L. Lead concentrations (0.07 mg/L to 0.39 mg/L) exceeded the World Health Organization's recommended limits in certain areas, highlighting potential ecological and health risks. Spatial analysis revealed that heavy metal contamination was most pronounced in areas with significant anthropogenic influence, such as agricultural runoff zones and waste disposal sites.

Table 1: Physicochemical Parameters Concentrations in Water from Kafin Gana Dam

			MONTHS				
PAR.	**MARCH**	**APRIL**	**MAY**	**JUNE**	**JULY**	**AUG.**	**P-Val.**
TEMP.(^oC)	30.75 ± 0.95^{a}	30.50 ± 0.57^{ab}	30.25 ± 0.50^{b}	29.25 ± 0.25^{bb}	28.0 ± 0.40^{c}	26.0 ± 0.40^{d}	0.001
pH	7.55 ± 0.36^{a}	7.10 ± 0.04^{ab}	6.52 ± 0.04^{d}	6.60 ± 0.04^{c}	7.10 ± 0.04^{ab}	7.07 ± 0.07^{b}	0.002
T.D.S.(mg/L)	79.2 ± 4.34^{d}	91.50 ± 4.97^{ab}	96.00 ± 3.67^{a}	91.00 ± 0.91^{b}	88.00 ± 0.40^{c}	88.25 ± 0.62^{bb}	0.031
E.C.(µS/cm)	94.25 ± 2.01^{ab}	96.50 ± 0.50^{a}	87.50 ± 1.89^{bb}	81.50 ± 2.21^{bb}	79.00 ± 1.29^{c}	47.50 ± 4.78^{d}	0.001
D.O.(mg/L)	5.45 ± 0.12^{d}	6.65 ± 0.33^{c}	7.10 ± 0.90^{b}	6.7 ± 0.64^{bb}	7.75 ± 0.44^{ab}	8.22 ± 0.12^{a}	0.020
Turb.(NUT)	14.33 ± 0.07^{d}	$14.4\pm0.14c$	14.99 ± 0.06^{bb}	16.26 ± 0.13^{b}	24.15 ± 13^{ab}	25.67 ± 023^{a}	0.001
C(mg/L)	21.20 ± 2.29^{b}	48.03 ± 7.70^{ab}	60.83 ± 4.58^{a}	15.89 ± 0.52^{bb}	12.70 ± 0.66^{d}	15.50 ± 0.40^{c}	0.001
Mg (mg/L)	$0.7.\pm0.25^{bb}$	4.92 ± 3.09^{ab}	0.57 ± 0.15^{c}	0.41 ± 0.18^{d}	1.62 ± 1.27^{b}	5.05 ± 0.08^{a}	0.104
Na (mg/L)	4.69 ± 0.21^{c}	5.11 ± 0.32^{bb}	5.12 ± 0.16^{b}	4.64 ± 0.23^{d}	5.63 ± 0.73^{a}	5.14 ± 0.11^{ab}	0.445
K (mg/L)	9.38 ± 0.33^{a}	6.74 ± 2.11^{b}	3.54 ± 0.18^{c}	5.55 ± 0.80^{bb}	5.36 ± 1.05^{d}	8.19 ± 099^{ab}	0.001
NO_3^{-} (mg/L)	1.07 ± 0.03^{d}	2.01 ± 0.98^{b}	1.65 ± 0.15^{c}	2.01 ± 0.34^{b}	2.92 ± 0.17^{ab}	3.36 ± 0.16^{a}	0.021

abcd: Means on the same row having different superscripts are significantly different = significant at P<0.05; and NS = not significant at P>0.05, ±SEM=Standard Error of means Temp. is Temperature, TDS is Total Dissolved Solids, E.C. is Electrical Conductivity, D.O. is Dissolved Oxygen, Turb. is Turbidity, C is Calcium, Mg is Magnesium, Na is Sodium, K is Potassium, $NO3^-$ is Nitrate

Table 2: Heavy metals concentration in mg/L

	MONTHS						
PARAMETERS	**MARCH**	**APRIL**	**MAY**	**JUNE**	**JULY**	**AUGUST**	**P-Value**
MANGANESE	$0.15±0.02^c$	$1.20±0.20^a$	$1.14±0.08^{ab}$	$0.13±0.02^d$	$0.18±0.04^{bb}$	$1.03±0.04^b$	0.0001
COPPER	$0.02±0.01^d$	$0.31±0.02^c$	$0.33±0.03^{bb}$	$0.44±0.02^a$	$0.33±0.05^b$	$0.40±0.03^{ab}$	0.0002
ZINC	$0.19±0.00^{bb}$	$0.15±001^c$	$0.35±0.01^{ab}$	$0.12±0.00^c$	$0.28±0.06^b$	$0.61±0.00^a$	0.0001
LEAD	$0.07±0.00^d$	$0.16±0.06^c$	$0.26±0.01^{bb}$	$0.27±0.00^b$	$0.39±0.01^a$	$0.36±0.08^{ab}$	0.0001

^{abcd}: Means on the same row having different superscripts are significantly different = significant at P<0.05; and NS = not significant at P>0.05, ±SEM=Standard Error of means the results showed considerable variation in physicochemical parameters and heavy metal concentrations across the sampling period and sites.

Plankton Community Composition

A total of 834 phytoplanktons from 4 families and 21 species were observed during the study period. The plankton samples revealed diverse communities, with phytoplankton dominated by Chlorophyceae and Bacillariophyceae.

Table 3: Community Composition of phytoplankton March to August 2024

FAMILY	SPECIE	MAR	APR	MAY	JUN	JUL	AUG	TOTAL	%
Phtoplankton									
Euglenophycaea	Euglena	18	18	12	16	8	9	81	9.7
	Phacus	8	9	7	13	5	6	48	5.8
	Stormbonas	5	3	3	---	1	--	12	1.4
	Total	**31**	**30**	**22**	**29**	**14**	**15**	**141**	**16.9**
Chlorophycaea	Chlamydomonas	15	14	17	15	12	10	83	10
	Closterium	3	11	2	5	3	2	26	3.1
	Spirogyra	21	14	10	13	11	11	80	9.6
	Volvox	10	11	8	10	10	8	57	6.8

	Oocystis	9	8	1	9	3	4	34	4.1
	Casmerium	2	11	6	--	6	4	29	3.5
	Eastrum	3	2	5	4	3	5	22	2.6
	Total	**63**	**71**	**49**	**56**	**48**	**44**	**331**	**39.7**
Cyanophycaea	Anabaena	14	12	8	11	3	8	56	6.7
	Microsystis	3	10	5	5	6	2	31	3.7
	Oscillatoria	8	3	8	11	6	6	42	5.0
	Athrospira	4	3	3	2	5	--	17	2.0
	Total	**29**	**28**	**24**	**29**	**20**	**16**	**146**	**17.5**
Bacillariophycaea	Crycotella	16	5	10	8	7	9	55	6.6
	Pinularia	10	3	3	10	5	3	34	4.1
	Aulascosera	10	7	7	8	5	6	43	5.2
	Naviculla	12	9	6	7	5	6	45	5.4
	Gyrogsima	2	3	1	--	2	1	9	1.1
	Cynatoplaura	---	---	2	2	2	--	6	0.7
	Asterionella	11	3	3	1	3	3	24	2.9
	Total	**61**	**30**	**32**	**36**	**29**	**28**	**216**	**25.9**
	Grand Total	**184**	**159**	**131**	**150**	**111**	**103**	**834**	**100**

Zooplankton diversity was also notable, with Rotifera and Copepoda showing significant representation. Table 4 illustrates the composition of phytoplankton groups in terms of abundance and diversity across sampling sites.

Table 4: Community Composition of Zooplankton March to August 2024

FAMILY	SPECIE	MAR	APR	MAY	JUN	JUL	AUG	TOTAL	%
Chladocera	Naupli	6	4	3	2	1	2	18	7.8
	Moina	4	5	5	5	4	3	26	11.3
	Bosmina	3	3	4	1	1	1	13	5.7
	Diaphanosona	5	4	3	4	4	1	21	9.1
	Total	**18**	**16**	**15**	**12**	**10**	**7**	**78**	**33.9**
Copepoda	Copepodite	4	3	5	2	2	2	18	7.8
	Cyclopodite	4	3	2	3	3	2	17	7.4
	Calanoid	3	5	4	2	2	--	16	7
	Total	**11**	**11**	**11**	**7**	**7**	**4**	**51**	**22.2**
Rotifera	Cylindrical	2	4	6	2	2	2	18	7.8
	Filina	4	6	5	3	2	1	21	9.1
	Lecane	5	5	4	5	4	4	27	11.7
	Karatella	5	3	4	3	2	2	19	8.3

	Trichocera	5	2	3	3	3	---	16	7
	Total	**21**	**20**	**22**	**16**	**13**	**9**	**101**	**43.9**
TOTAL	**Grand Total**	**50**	**47**	**48**	**35**	**30**	**20**	**230**	**100**

Seasonal and Spatial Variability

Statistical analysis indicated significant differences in plankton abundance between dry and rainy seasons. The highest diversity and abundance were recorded at Site A, whereas Site C exhibited lower values, correlating with increased metal concentrations and poor water quality.

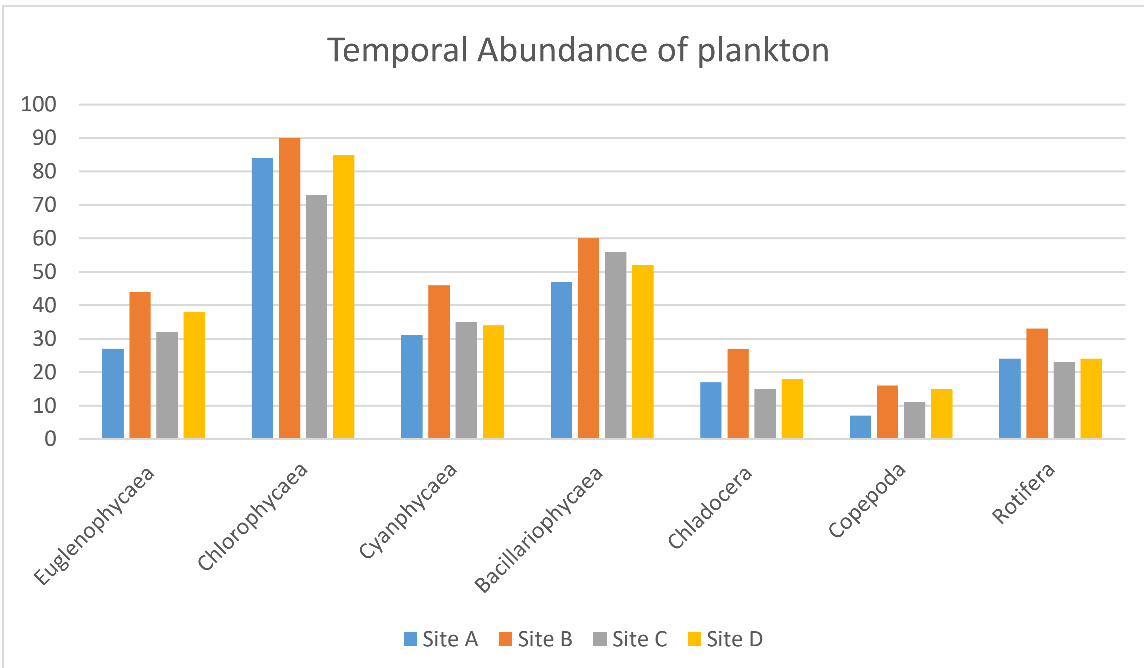

Figure 2: Temporal abundance of plankton

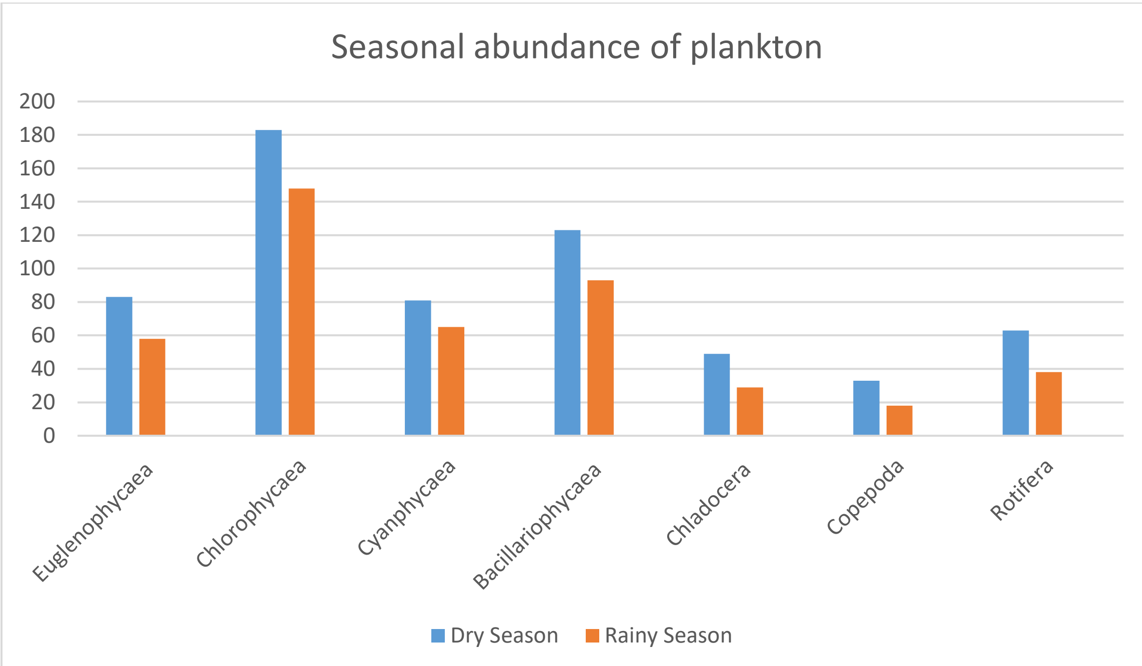

Figure 3: Seasonal abundance of plankton

Relationship between physicochemical parameters, heavy metals and plankton

Pearson's correlation analysis revealed significant correlations between specific physicochemical parameters and plankton abundance. Notably, higher dissolved oxygen and lower heavy metals correlated positively with plankton density, while turbidity and high metal concentrations showed negative correlations.

Plankton abundance was significantly influenced by both temporal and spatial factors. Higher plankton populations were observed during the dry season compared to the rainy season. Furthermore, areas with minimal anthropogenic activity exhibited higher plankton abundance compared to areas with poorer water quality.

Significant correlations were observed between physicochemical parameters, heavy metal concentrations, and plankton abundance, suggesting a strong interplay between these factors

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
A	1																				
B	0.032	1																			
C	-0.017	-0.891	1																		
D	0.962	0.088	-0.35	1																	
E	-0.855	-0.359	0.471	-0.788	1																
F	-0.953	0.095	-0.065	-0.853	0.844	1															
G	0.581	-0.39	0.611	0.486	-0.165	-0.602	1														
H	-0.448	0.262	0.081	-0.429	0.453	0.387	0.027	1													
I	-0.426	0.004	0.267	-0.242	0.695	0.626	0.024	0.315	1												

J	**-0.126**	**0.855**	**-0.854**	**-0.172**	**-0.33**	**0.094**	**-0.487**	**0.362**	**-0.355**	**1**								
K	**-0.933**	**-0.094**	**0.204**	**-0.83**	**0.931**	**0.929**	**-0.438**	**0.578**	**0.634**	**-0.041**	**1**							
L	**-0.047**	**-0.265**	**0.591**	**-0.146**	**0.347**	**-0.048**	**0.726**	**0.638**	**0.231**	**-0.194**	**0.174**	**1**						
M	**-0.542**	**-0.76**	**0.76**	**-0.508**	**0.749**	**0.416**	**-0.023**	**0.256**	**0.271**	**-0.571**	**0.66**	**0.282**	**1**					
N	**0.615**	**0.562**	**-0.565**	**0.497**	**-0.757**	**-0.561**	**0.277**	**-0.254**	**-0.403**	**0.467**	**-0.762**	**-0.024**	**-0.936**	**1**				
O	**-0.817**	**-0.434**	**0.423**	**-0.715**	**0.935**	**0.838**	**-0.329**	**0.156**	**0.657**	**-0.443**	**0.871**	**0.035**	**0.759**	**-0.824**	**1**			
P	**0.816**	**0.121**	**-0.191**	**0.729**	**-0.896**	**-0.904**	**0.277**	**-0.235**	**-0.792**	**0.234**	**-0.83**	**-0.124**	**-0.431**	**0.503**	**-0.889**	**1**		
Q	**0.75**	**0.361**	**-0.22**	**0.764**	**-0.757**	**-0.745**	**0.289**	**0.109**	**-0.422**	**0.307**	**-0.622**	**0.017**	**-0.452**	**0.425**	**-0.826**	**0.861**	**1**	
R	**0.884**	**0.021**	**-0.126**	**0.847**	**-0.897**	**-0.915**	**0.265**	**-0.442**	**-0.685**	**0.03**	**-0.862**	**-0.28**	**-0.398**	**0.426**	**-0.801**	**0.954**	**0.812**	**1**

S	**0.527**	**0.58**	**-0.781**	**0.442**	**-0.857**	**-4.498**	**-0.168**	**-0.48**	**-0.636**	**0.581**	**-0.745**	**-0.521**	**-0.88**	**0.843**	**-0.773**	**0.6**	**0.411**	**0.57**	**1**			
T	**0.97**	**0.228**	**-0.192**	**0.911**	**-0.902**	**-0.921**	**0.541**	**-0.36**	**-0.453**	**0.079**	**-0.946**	**-0.02**	**-0.705**	**0.775**	**-0.911**	**0.815**	**-0.779**	**0.833**	**0.652**	**1**		
U	**0.956**	**0.1**	**0.014**	**0.918**	**-0.748**	**-0.873**	**0.711**	**-0.319**	**-0.232**	**-0.131**	**-0.865**	**0.143**	**-0.597**	**0.688**	**-0.779**	**0.668**	**0.684**	**0.717**	**0.453**	**0.959**	**1**	
v	**0.972**	**-0.049**	**0.079**	**0.895**	**-0.778**	**-0.938**	**0.716**	**-441**	**-0.383**	**-0.197**	**-0.926**	**0.106**	**-0.526**	**0.6863**	**-0.778**	**0.727**	**0.629**	**0.778**	**0.479**	**0.954**	**0.974**	**1**

Table 5: Correlation matrix of Relationship between plankton, physicochemical parameters and heavy metals

A=Temperature B=pH, C=Total Dissolved Solids, D= Electrical Conductivity, E= Dissolved oxygen, F=Turbidity, G=Calcium H=Magnesium, I= Sodium, J=Potassium, K=Nitrate, L=Manganese, M=Copper, N=Zinc, O=Lead, P = Euglenophycaea, Q = Chlorophycaea, R= Cyanophycaea, S = Bacillariophyaea, T = Cladocera, U = Copepoda V = Rotifera

Discussion

The physicochemical parameters exhibited notable temporal and spatial variations across the six-month study period (March to August 2024), reflecting the dynamic nature of the dam's ecosystem.

The monthly mean temperature ranged from 26°C in August (rainy season) to 30.75°C in March (dry season). Elevated temperatures during the dry season corresponded to reduced cloud cover and higher solar radiation, facilitating enhanced biological activity. This aligns with findings from Adamu *et al.*, (2021) on similar water bodies in Nigeria. The pH values fluctuated between 6.52 and 7.55, indicating slightly acidic to neutral conditions. Lower pH levels during the rainy season were attributed to organic and agricultural runoff, introducing acidic compounds into the water. This is consistent with global observations on water quality dynamics in tropical freshwater systems (Hamid *et al.*, 2020).

Dissolved Oxygen (DO) levels ranged from 5.45 mg/L in August to 8.22 mg/L in March, with higher concentrations observed during the dry season. This trend was linked to lower turbidity and increased photosynthetic activity due to improved light penetration. The reduced levels during the rainy season were likely caused by increased organic decomposition from runoff, which consumes oxygen(Lao *et al.*, 2021). Turbidity values peaked at 25.67 NTU during the rainy season and were lowest at 14.33 NTU in the dry season. The elevated turbidity during the rainy season was attributed to surface runoff and sediment inflow, which significantly reduced light penetration and hindered photosynthetic activity.

Sodium concentrations remained relatively stable, showing minimal seasonal or spatial variability. Sodium plays a key role in maintaining osmotic balance in aquatic organisms. However, excessive levels can lead to stress in aquatic life(Shokr *et al.*, 2020). Its relatively low and stable concentration indicates minimal anthropogenic influence compared to other nutrients(Markich and Brown, 1998). Sodium levels in Kafin Gana Dam align with acceptable ranges for freshwater systems and are well below thresholds that could cause salinity stress.

Magnesium levels in the dam fall within acceptable limits for freshwater systems, posing no immediate threat to aquatic life. Higher values were observed during the rainy season, likely due to soil erosion and runoff introducing magnesium-rich particles into the water and Lower values in the dry season could result from reduced runoff and dilution effects. Magnesium is an essential nutrient for aquatic plant growth and serves as a cofactor for photosynthesis in phytoplankton (Lobus and Kulikovskiy, 2023). Magnesium's variability may influence phytoplankton abundance and diversity, particularly Chlorophyceae, which require magnesium for chlorophyll production (Ahmed Mohammed and Nodhy Mahran, 2022).

Calcium concentrations in Kafin Gana Dam are higher than typical levels for many freshwater systems but remain within tolerable limits for most aquatic organisms. Calcium concentrations peaked during the rainy season, likely due to increased runoff from agricultural fields and soil erosion introducing calcium carbonate. The lower levels during the dry season may reflect reduced water movement and dilution. Calcium is critical for aquatic organisms, especially invertebrates and plankton, for processes such as shell and exoskeleton formation(Brown *et al.,* 2021). Elevated calcium levels may favor the growth of certain planktonic species, such as Bacillariophyceae, which require calcium for their siliceous frustules(Saxena *et al.,* 2021).

Potassium concentrations in the dam are relatively moderate and do not pose risks to aquatic life. Higher concentrations were observed during the rainy season, potentially due to runoff carrying potassium-rich fertilizers and organic matter. Slight decreases during the dry season may reflect reduced agricultural activity and dilution. Potassium is essential for aquatic plants and phytoplankton, as it regulates osmotic balance and enzyme activation(Lobus and Kulikovskiy, 2023). Elevated potassium levels in the rainy season likely promoted phytoplankton growth, particularly Chlorophyceae, as reflected in their abundance(Mabrouk *et al.,* 2021).

Nitrate concentrations in Kafin Gana Dam are relatively low compared to eutrophic systems, indicating that the dam is not currently at risk of severe nutrient over-enrichment. Nitrate levels peaked during the rainy season due to agricultural runoff carrying nitrogen-based fertilizers (e.g., urea, ammonium nitrate) and organic waste. Lower values in the dry season reflect reduced surface runoff and lower organic decomposition rates. Nitrates are a critical nutrient for phytoplankton growth but can lead to eutrophication at elevated concentrations(Wurtsbaugh *et al.,* 2019). During the rainy season, higher nitrate levels likely favored nutrient-tolerant phytoplankton species such as Cyanophyceae, while sensitive species like Bacillariophyceae were adversely affected. Excessive nitrate levels, though still within acceptable limits, could trigger algal blooms, reducing water quality and dissolved oxygen. While concentrations remain within acceptable ranges, elevated nitrate and calcium levels during the rainy season indicate a need for monitoring to prevent long-term eutrophication and ecological degradation.

Heavy Metal Concentrations

Heavy metals in the dam's water exhibited spatial and temporal variability, with levels generally within regulatory limits of WHO and NASREA but showing concerning trends in some locations.

Manganese concentrations ranged from 0.13 to 1.20 mg/L, with elevated levels recorded during the rainy season in areas of increased runoff. The highest concentrations were observed near anthropogenic activity zones, posing potential risks to aquatic organisms. Lead levels ranged from 0.07 to 0.39 mg/L, with peak concentrations in July during the rainy season. These levels, while within some regulatory thresholds, indicate anthropogenic inputs such as agricultural runoff and urban discharge. Copper and Zinc concentrations remained relatively stable, ranging from 0.02 to 0.44 mg/L for copper and 0.12 to 0.61 mg/L for zinc. These metals were slightly elevated near agricultural zones, likely from agrochemical residues. These findings highlight potential risks to biodiversity, as metals like lead and manganese are known to bioaccumulate and exhibit toxicity at elevated concentrations, as reported by (Kulkarni *et al.,* 2018).

Plankton Community Composition

The plankton community comprised phytoplankton and zooplankton, which exhibited distinct seasonal and spatial abundance patterns.

Four phyla dominated the phytoplankton community: Chlorophyceae, Bacillariophyceae, Euglenophyceae, and Cyanophyceae. Chlorophyceae and Bacillariophyceae were most abundant during the dry season, benefiting from higher light penetration and favorable nutrient conditions. The observation of *Chlorophyceae* as the most abundant family of phytoplankton in the study is similar to the findings of Galadima *et al.;* (2021), Anyanwu *et al.*, (2021) and (Tusayi *et al.*, (2020), Auta *et al.;* (2023) stating that Chlorophycea is the dominant family in lakes and reservoirs. The greater occurrence of Chlorophyceae species in the dry season may be attributed to the shallowness of the water during this period (Obiuto *et al.,* 2022).
Cyanophyceae, indicative of poor water quality, were prevalent in areas of high turbidity and nutrient load, particularly during the rainy season.

Zooplankton included Rotifera, Cladocera, and Copepoda, with Rotifera being the most abundant group. The predominance of Rotifers in some inland water also been reported by (Suleiman *et al.*, 2021), in Katsina; Adedeji *et al.*, (2020), in Ile Ife; Idam *et al.*, (2023) in Nile and Sani et al., Furthermore, the study agrees with the findings of Abubakar (2013), in Nguru Lake, Nigeria that rotifera are the most dominant species found in the findings. Zooplankton abundance mirrored phytoplankton trends, with higher populations in the dry season due to improved feeding conditions and reduced competition.

Seasonal and Spatial Variability

Plankton abundance and diversity were significantly influenced by seasonal changes and proximity to anthropogenic activities.

Higher plankton abundance was observed during the dry season, when water quality parameters such as turbidity and dissolved oxygen were more favorable for photosynthesis and biological activity. The high abundance of plankton during the dry season agrees with Adamu *et al., (*2021) in Dangana lake Lapai, Niger State, Obiuto *et al.*, (2022) in Abia, Niger Delta, Tusayi *et al.*, (2020) in Dadin Kowa dam, Gombe State, Suleiman et al., (2021) in Ajiwa Reserviour Katsina*;* Anyanwu *et al.,* (2021)in Eme river, Ummahia and Bamaiyi *et al.;* (2021) in ABU Zaria. On contratry, the finding is not in tandem with the findings of Hameed *et al.*, (2019) in Southwestern Nigeria, Akinyemi *et al.*, (2022) in Eko-Nde reserviour Osun, and Adedeji *et al.*, (2020) in Opa Reservoir, Ile Ife, Nigeria.

Plankton populations were highest in upstream areas with minimal anthropogenic interference. In contrast, downstream sites with high turbidity and elevated heavy metal concentrations showed reduced plankton diversity, highlighting the detrimental impact of pollution.

Relationship between Parameters and Plankton Abundance

Statistical analyses revealed critical relationships between physicochemical parameters, heavy metals, and plankton abundance:

Positive Correlations: Higher dissolved oxygen levels and lower turbidity were strongly associated with increased plankton diversity and abundance ($r > 0.7$, $p < 0.05$).

Negative Correlations: Heavy metals such as lead and manganese showed significant negative correlations with plankton diversity ($r < -0.5$, $p < 0.05$), reflecting their toxic effects on aquatic organisms.

The results demonstrate how physicochemical parameters and heavy metals interplay to influence plankton communities, underscoring the need for sustainable management to preserve biodiversity and ecological balance in Kafin Gana Dam.

Conclusion

This study underscores the significant influence of physicochemical parameters and heavy metal contamination on plankton communities in Kafin Gana Dam. The observed correlations highlight the interconnectedness of water quality, heavy metal pollution, and the health of the aquatic ecosystem. The findings emphasize the urgent need for sustainable management practices, including pollution control measures, to ensure the ecological balance and long-term sustainability of the dam. Further research is warranted to investigate the long-term impacts of these factors and develop more effective strategies for protecting this valuable water resource.

Recommendations

1. Implement stringent regulations to control agricultural runoff and industrial effluents.

2. Promote community awareness programs on the impacts of water pollution.

3. Establish a long-term water quality monitoring framework to track changes and guide policy decisions.

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