

Water Quality in Relation to Phytoplankton Abundance and Diversity of Selected Reservoirs in Kazaure, Jigawa State, Nigeria

MUHAMMAD KABIRU ABUBAKAR¹, RASHIDAT SALIU², KHADIJA MOHD ALI³, JOHN OSUNG EKPO⁴, ABDULWASIU ABUBAKAR⁵, ADEKANMBI OLUFEMI S.⁶

^{1&3}*Department of Science Laboratory Technology, Hussaini Adamu Federal Polytechnic Kazaure, Jigawa State, Nigeria.*

²*NorthWest College of Health Sciences Kazaure, Jigawa State, Nigeria.*

^{4,5,6}*Benin-Owena River Basin, Obayantor, Edo State, Nigeria*

Abstract- *This study investigates the composition of phytoplankton species as bio-indicators of water quality in Wawan Rafi Reservoir and Kazaure, Jigawa State, Nigeria. A total of 962 and 1262 organisms/litre were recorded for Kazaure Reservoir and Wawan Rafi Reservoir respectively. The composition of forty (40) and thirty nine (39) phytoplankton genera distributed into 5 and 4 classes were also tabulated for Kazaure Reservoir and Wawan Rafi Reservoir respectively, with Bacillariophyta accounting for a greater abundance and Euglenophyta and Pyrrophyta having the least abundant species. The population distribution presented in percentages indicated the occurrence of Phytoplankton taxa in order of Chlorophyta>Bacillariophyta>Cyanophyta>Euglenophyta. Following Palmer (1980) organic pollution, 10 pollution tolerant genera comprising of Nitzschia sp., Synedra sp., Navicula sp., Scenedesmus sp., Ankistrodesmus sp., Oscillatoria sp., Melosira sp., Chlorella sp., Pandorina sp. and Phacus sp were identified for both Reservoir. The collective Pollution Index (PI) value of 35 and 39 were calculated for both reservoir. According to Palmer (1980), a pollution index greater than or equal to 20 indicates high organic pollution. Therefore, the pollution index value of 35 and 39 of both Reservoirs indicates enriched water with high organic pollution. Although, eutrophication was not observed in the reservoir, however, the results shows a transiting move from oligotrophic state to eutrophic state of both reservoir.*

Keys words: *Wawan Rafi, phytoplankton, Spatial and clean water*

I. INTRODUCTION

The rapid development of infrastructure, including railway systems and campsites, poses significant environmental challenges, particularly in aquatic

ecosystems. The construction activities associated with these developments can drastically alter limnological parameters and disrupt aquatic habitats. The main environmental problems associated with reservoirs are: eutrophication, inorganic pollution, sedimentation, siltation, over exploitation, biodiversity loss, habitat change, aquatic plant infestation and introduced species. Environmental factors like physical and chemical components have been reported in various studies to significantly influence the wellbeing of aquatic species, including plankton (Banerjee et al., 2022). Similarly, according to Abubakar (2026), physical and chemical conditions of aquatic environments determine the occurrence, diversity and density of both flora and fauna in any given environment, which could vary according to the season of the year.

The word phytoplankton consist of all the photoautotrophic microorganisms in aquatic food webs (Schreier, 2019). Lüring, (2021), described phytoplankton as photosynthetic microorganisms adapted to inhabit partly or continuously in open water. They inhabit in the sunlight surface of almost all ocean and freshwater. Phytoplankton serves as the food web base, providing an essential ecological function for all the aquatic life (Updhyay et al., 2021). They are vital as substantial organic carbon source at the bottom of these systems. They account for half photosynthetic activity on earth, thus the plant area unit responsible for lot more the gas gift within earth's atmosphere – half of the entire quantity created by all flora. Previous research has highlighted the sensitivity of freshwater ecosystems to anthropogenic activities.

Zhu et al. (2024) emphasized that alterations in land use and development can lead to significant shifts in water quality parameters, including temperature, pH, and nutrient concentrations, which can directly affect plankton communities. For instance, García-Ávila et al. (2025) demonstrated that changes in nutrient loading from construction runoff can lead to phytoplankton blooms, thereby altering the trophic dynamics of the aquatic system. In Nigeria, studies have documented the effects of urbanization and agricultural practices on water bodies but comprehensive assessments focusing on the construction of railways and campsites remain limited. The assessment of Heavy Metals Bioaccumulation by Tissues of *Ipomea batatas* and *Manihot esculenta* irrigated with water from Kazaure Reservoir by Abdullah et al. (2015), the Physico-Chemical and Phytoplankton analyses of Kazaure Reservoir by Abubakar et al. (2015), and the Physio-Chemical properties of the same Reservoir by Oladeji (2020) feared that such alterations could have a detrimental effect on phytoplankton because they are primary producers and the foundation of the food chain in an aquatic environment. This study aims to assess the impacts of railway and campsite construction on the limnological characteristics and phytoplankton composition of Kazaure Dam and Wawa Rafi Dam in Jigawa State. Understanding these impacts is crucial

for the sustainable management of water resources and biodiversity in the region.

II. MATERIALS AND METHODS

Study Area

Kazaure Reservoir which was formerly called Muhammad Ayuba Reservoir, is a freshwater source that was constructed between 1974 and 1975. This reservoir is located at the coordinates of 12°39'10"N and 8°24'43"S. Positioned between the old and new neighbourhoods of Kazaure, known as Cikin Gari and Kanti. The dam is an artificial water body linked by a modern bridge that was completed in 2008. The earthen and concrete structure of the reservoir stands 15.65 meters tall with a total capacity of 299,500 cubic meters. Its widest base reaches 730.67 meters, stretching a length of 2,346 meters, while encompassing an area of 116 hectares (Galadima et al., 2021). The Wawan Rafi Dam on the other hand measures 986 meters in length and has a maximum base width of 716.54 meters. The water provided by this dams are utilized for various household activities such as agriculture, fishing, and leisure pursuits. Figure 1 illustrates the description of the sample location.

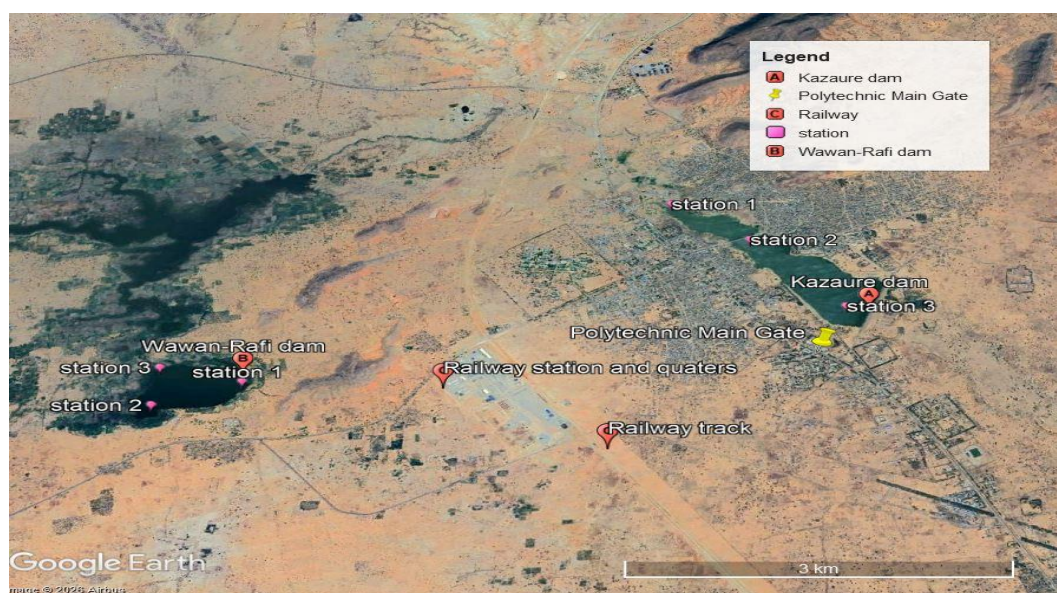


Fig. 1 Google Map of Kazaure and Wawan Rafi Dams

Sample Collection

Three sampling sites were designated as station 1, 2 and 3.

For Kazaure Dam:

Station 1 – This site is the water inlet of the reservoir, where water from Katsina River enters the reservoir. The water is within a narrow pathway. There are limited agricultural activities around this site.

Station 2 – This site is the middle of the reservoirs with dense volume of water. It is characterised by agricultural and fishing activities with pungent and rotten fish smell due to fishing and allied activities at the location.

Station 3 – This site is the water outlet of the reservoir. It is characterised by various anthropogenic activities including washing of cars, bathing, laundry and animals' activities.

For Wawan Rafi Dam:

Station 1 & 2 – This site are characterised by agricultural and fishing activities.

Station 3 – This site is characterised by various anthropogenic activities including bathing and animals' activities.

Samples for the analyses were taken from Kazaure and Wawan Rafi Dams in triplicate from each sampling stations between 8:00 and 10:00 am for a period of 4 months (May – August 2026) cutting across the wet and dry seasons.

The examination of phytoplankton species, both in qualitative and quantitative terms, involved filtering 30 liters of water samples through a plankton net that had a mesh size of 25 micrometers. The samples were treated with Lugol's solution for preservation and then stored in a cooler with ice cubes at a temperature close to 4 degrees Celsius, ensuring they were shielded from light before being transported back to the laboratory at Hussaini Adamu Federal Polytechnic Kazaure for analysis. All samples were made ready for observation under an inverted microscope (Motic BA410 Compound Binocular Microscope, China) that was outfitted with a Moticom 10.0 camera. The counting of

phytoplankton was performed using a random transect located at the top or bottom of the counting chamber, according to Nannette (2012).

Identification and enumeration of phytoplankton cells were conducted based on established reference materials, specifically: Jorgensen et al. (2005) and Rosen and Amand (2015). The quantities of phytoplankton (number of individuals per litre) were determined by applying the dilution factors used during the preparation of the samples in accordance with (Nannette, 2012).

$$\text{Cells/L} = \frac{\text{cells counted} \times 1 \times 1000\text{mL}}{\text{slide volume concentration factor L}}$$

Concentration Factor = volume factor/concentrated amount
Volume Factor = concentrated amount + amount decanted

Palmer Index presented a categorization of pollution that utilized 20 types of phytoplankton, which were categorized based on their tolerance to various degrees of organic pollution present in the water, and these are referred to as bio-indicator species. Each of these types was assigned a score index factor. Based on Palmer's Algal Pollution criteria, score index values ranging from 0 to 10 suggest an absence of organic pollution, values between 10 and 15 indicate moderate pollution, scores from 15 to 20 imply likely high organic pollution, and values greater than 20 are classified as confirmed high organic pollution, as illustrated in Table 1.

Table 1. Palmer Index of phytoplankton.

Genus	Pollution Score Index
Anacystis (Microcystis)	1
Closterium	1
Cyclotella	1
Gomphonema	1
Lepocinclis	1
Melosira	1
Micractinium	1
Pandorina	1
Phormidium	1
Ankistrodesmus	2
Phacus	2
Stigeoclonium	2
Synedra	2

Chlorella	3
Navicula	3
Nitzschia	3
Chlamydomonas	4
Oscillatoria	4
Scenedesmus	4
Euglena	5

III. RESULTS AND DISCUSSION

Table 1 and Table 2 revealed the Phytoplankton species abundance and diversity in Kazaure Reservoir and Wawan Rafi Reservoir. The composition of forty (40) and thirty nine (39) phytoplankton genera distributed into 5 and 4 classes was tabulated for Kazaure Reservoir and Wawan Rafi Reservoir respectively, with Bacillariophyta accounting for a greater abundance and Euglenophyta and Pyrrophyta having the least abundant species. The total of 962 and 1262 organisms/litre were recorded for Kazaure Reservoir and Wawan Rafi Reservoir respectively. Following Palmer (1980) organic pollution, 10 pollution tolerant genera comprising of *Nitzschia* sp., *Synedra* sp., *Navicula* sp., *Scenedesmus* sp., *Ankistrodesmus* sp., *Oscillatoria* sp., *Melosira* sp., *Chlorella* sp., *Pandorina* sp. and *Phacus* sp were identified for both Reservoir. The collective Pollution Index (PI) value of 35 and 39 were calculated for both reservoir. The current study contributed to the knowledge of the taxonomic composition and abundance of phytoplankton species in Kazaure and Wawan Rafi Reservoirs. According to Palmer (1980), a pollution index greater than or equal to 20 indicates high organic pollution. Therefore, the pollution index value of 35 and 39 of both Reservoirs indicates enriched water with high organic pollution. Similar findings were reported by Yusuf (2020). The composition of *Synedra* sp., *Navicula* sp. (Bacillariophyta), *Coelastrum* sp., *Cosmarium* sp., (Chlorophyta), *Microcystis aeruginosa*, *Nostoc* sp., *Gomphosphaeria* sp., *Oscillatoria* sp. (Cyanophyta), *Mallomonas* sp., *Straurastrum* sp. (Euglenophyta) in all the sampled stations of Kazaure Reservoir and *Gyrosigma* sp., *Gomphonema* sp., *Synedra* sp., *Navicula* sp. (Bacillariophyta), *Coelastrum* sp., *Cosmarium* sp., *Planktosphaeria* sp., *Mougeotia* sp., *Mougeotia* sp. (Chlorophyta), *Oscillatoria* sp.,

Microcystis aeruginosa, *Nostoc* sp., *Gomphosphaeria* sp. (Cyanophyta), *Mallomonas* sp., *Straurastrum* sp., *Phacus* sp. (Euglenophyta) in all the sampled stations of Wawan Rafi Reservoir indicated enriched water with organic pollution. The presence of these species is attributed to their ability to adapt to a wide range of environmental changes from anthropogenic influences. This trend is observed to be common in many African fresh water bodies especially in Nigerian Reservoirs as documented in the work of Atobatele (2013).

One of the observed dominant specie, *Navicula* sp (Bacillariophyta) in both wet and dry season in both reservoir was reported to be as a result of physiological and behavioural flexibility of these species which can accommodate environmental stresses better than most fast growing species (Abubakar, 2026). The phytoplankton community abundance can be a useful indicator of the trophic conditions of lake zones (Bilbao and Seoane, 2024). *Cosmarium* (Charophyta), and *Gomphonema* & *Diatoma* (Bacillariophyta), which were found dominant in the present study are generally found in oligotrophic waters. Although, the presence of polluted species such as *Navicula* (Bacillariophyta) and *Ankistrodesmus* (Charophyta) in high density shows that the reservoirs are transiting from Oligotrophic to Eutrophic state. Uneven distribution of phytoplankton was observed across studied stations. The study revealed the abundance of *Microcystis*, *Oscillatoria*, *Nostoc*, *Navicular*, *Pediastrum*, *Tetraspora* and *Diatoma* in Station 1 and Station 3 of Kazaure Reservoir and Wawan Rafi Reservoir respectively. This is as a result of high inflow of nutrients into the reservoirs from various pollutants generating activities characterising the Station. This finding is of great concern because the presence of these species poses potential health risks to the inhabitants. Hameed (2019) also reported these notable bio-indicator phytoplankton species in Nigerian fresh water body. Ayoade and Aderogba (2020) cautioned that these species are capable of producing cyanotoxins which can cause serious illness in humans and animals in general. Observation of these species revealed the need for continuous bio-monitoring and control of organic pollution in the reservoir.

The population distribution presented in percentages indicated the occurrence of Phytoplankton taxa in order of Chlorophyta>Bacillariophyta>Cyanophyta>Euglenophyta (Figure 1 and 2). This corroborate the findings of Abubakar and Ohiare (2020) who reported same trend in the same Reservoir with Bacillariophyta accounting for greater population. The trend of Phytoplankton population distribution in this study also corroborates with that of many fresh water bodies studied in Nigeria by Abubakar and Abubakar (2013), Ahmad and Indabawa (2015) and Suleiman and Ibrahim (2019). Ewebiyi (2015) attributed this trend to the fact that sensitive species disappear as the water becomes polluted while tolerant ones survive pollution stress. The total phytoplankton distribution revealed seasonal variation influenced by railway systems/campsites construction and irrigation activities around the Reservoirs. The abundance of Chlorophyta & Bacillariophyta (May, June & August), Bacillariophyta (July) in Kazaure Dam and Chlorophyta (May, June, July & August) in Wawan Rafi Dam as shown in Figure 3 and 4, revealed variation. The finding is attributed to the impact of Temperature and Turbidity as an important seasonal parameter that controls the biological processes of phytoplankton communities. Biological monitoring using phytoplankton attributes showed that the water condition was good. This is one of the advantages of using algae as a biological indicator, as it can detect traces of contamination that cannot be detected by chemical analysis.

According to several studies, abundance of cyanobacteria genera is favoured by water temperature (Paerl and Paul, 2012). Thus, the odour problems experienced in Kazaure Reservoir during sampling particularly in dry season are partly attributed to the occurrence of *Anabaena* sp., *Oscillatoria* sp and *Microcystis* sp., which are associated with odour problems and are capable of releasing geosmin/2-MIB even at very low cell densities. Chinyama *et al.* (2016) made similar observation and associated odour

problems in fresh water bodies to cyanotoxin production in Vaal dam. Al-Hassany (2012) attributed high values during dry season to the reduction in the rate of water flow of a reservoir which allows the sparse plankton already present to multiply before it is swept away. It is worthy to note that the significant variation in the number of Chlorophyta species recorded during rainy season, than dry season is an indication that more species could survive changes in nutrients and increase in water volume which varies with season.

IV. CONCLUSION

This condition of the water encourages the growth and distribution of phytoplankton taxa. There were forty (40) and thirty nine (39) phytoplankton species from Kazaure Reservoir and Wawan Rafi Reservoir respectively representing four (5) major taxa; Bacillariophyta, Chlorophyta, Cyanophyta, Euglenophyta and Pyrrophyta. Although, eutrophication was not observed in the reservoir, however, the results shows a transiting move from oligotrophic state to eutrophic state of both reservoir. Therefore pollution indices may deteriorate further. The presence of *Anabaena* sp. and *Microcystis* sp. were not reassuring signs of good water conditions and is linked to odour problems related to gaseous release from metabolic activities. The study suggests the need to control or treatment of effluent from within the railway construction sites into the Reservoir. In addition, farmers should be sensitized on careful selection of fertilizer and washing using detergents to reduce high organic pollution of the Reservoir. Water authorities should monitor the potential blooms of species of phytoplankton (*Oscillatoria* sp. and *Peridinin* sp.) already present in the reservoirs during specific months of the study period. These species are associated with water pollution and potential toxin producers (neurotoxins). It is important to pay more attention to environmental monitoring than chemical indicators according to Pinilla-Cortés and Moreno-Gutiérrez (2019).

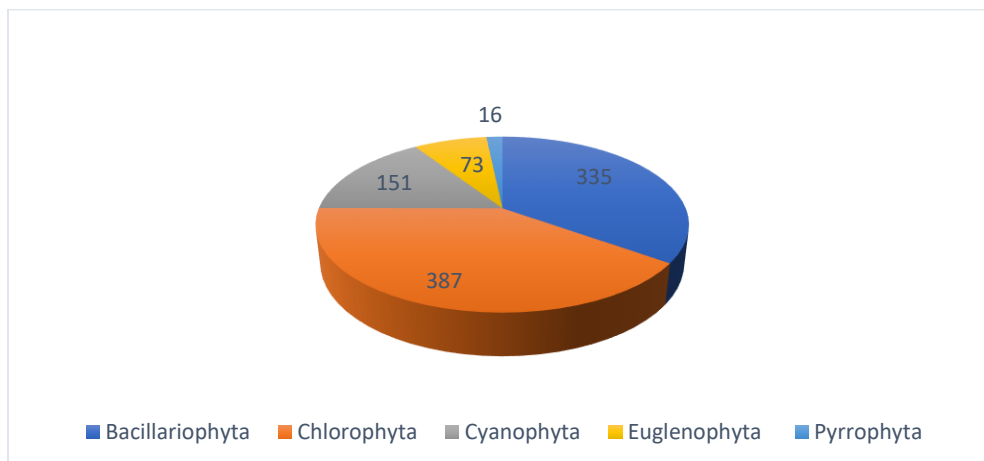


Figure 1 illustrates the population distribution of the five (5) phytoplankton taxa observed in Kazaure Dam.

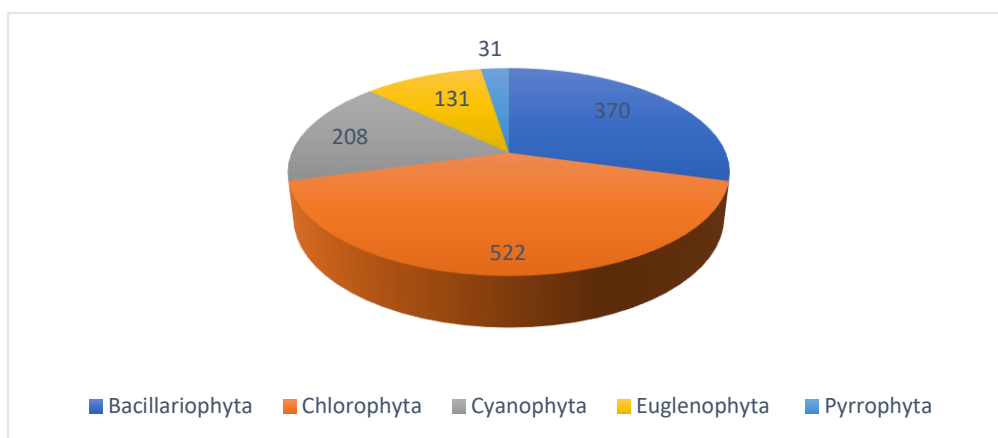


Figure 2 illustrates the population distribution of the five (5) phytoplankton taxa observed in Wawan Rafi Dam.

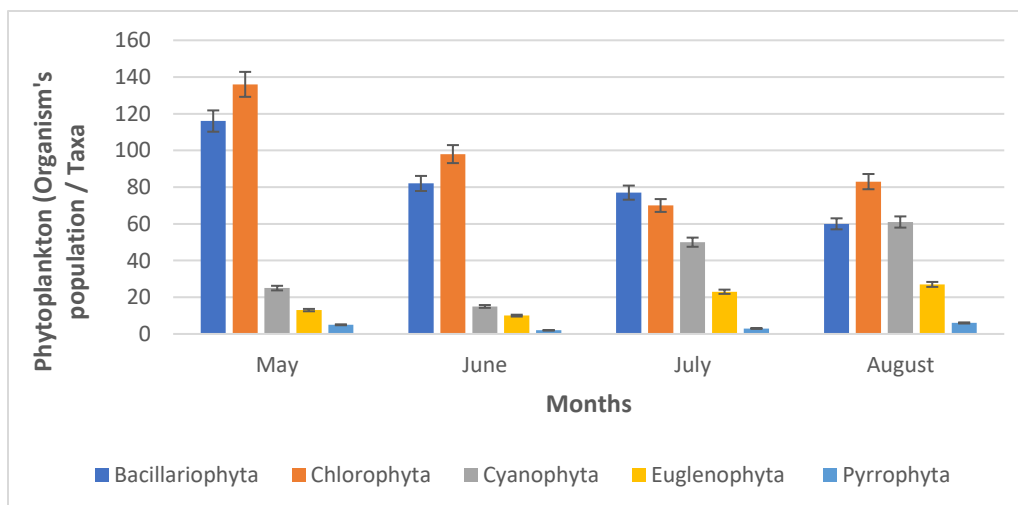


Figure 3. Distribution of Phytoplankton Species across the Months at Kazaure Reservoir

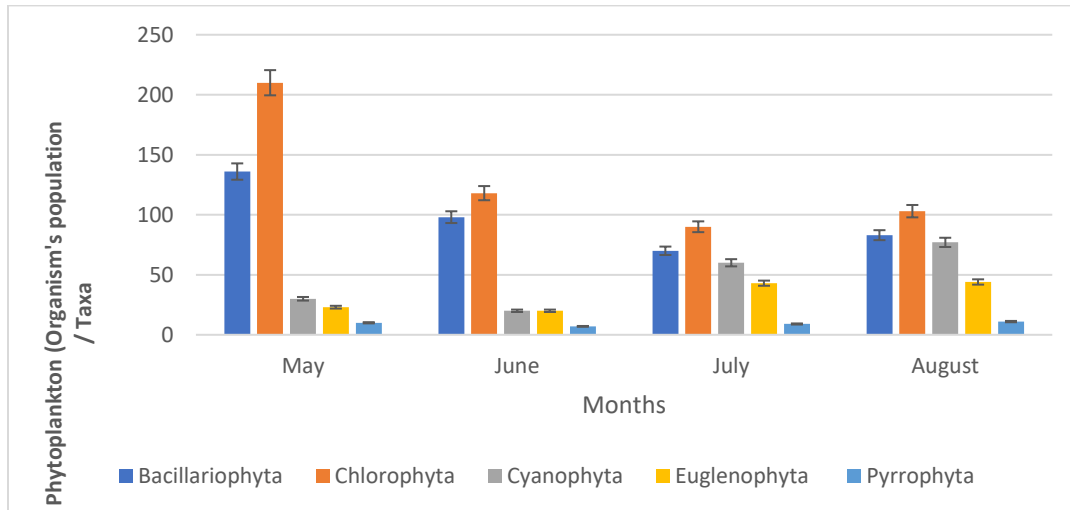


Figure 4. Distribution of Phytoplankton Species across the Months at Wawan Rafi Reservoir

Table 1. Phytoplankton Species Composition and Abundance in Kazaure Reservoir, Jigawa State, Nigeria

Taxa	PI Value	SITES			Total Org/l	Abundance (%)
		1	2	3		
Bacillariophyta						
Asterionella sp		23			23	2.39
Diatoma vulgare		21			21	2.18
Melosira sp.	1	11			11	1.14
Cymbella cistula		10			10	1.04
Gyrosigma sp.		12	28		40	4.16
Gomphonema gracile.			12	6	18	1.87
Gomphonema sp.	3	36	19		55	5.72
Meridionsp.		16			16	1.66
Nitzschia sp.	2			7	7	0.73
Synedra sp.	3	11	16	11	38	3.95
Synedra ulna		17		9	26	2.7
Navicula sp.	4	26	38	6	70	7.28
Chlorophyta						
Scenedesmus quadricauda	4			20	20	2.08
Coelastrium sp.		8	2	28	38	2.91
Ulothrix zoonata				8	8	0.83
Cosmarium sp.		14	15	16	45	4.68
Pediastrum sp.		35		13	48	4.99
Planktosphaeria sp.		23		7	30	3.12
Ankistrodesmus sp.	3	25		25	50	5.2
Tetraedron acutum		12			12	1.25
Chlorella vulgaris	5	6		2	8	0.83
Desmidium grevillei				23	23	2.39
Mougeotia sp.				4	4	0.42
Pandorina sp.	1			12	12	1.25
Tetraspora sp				20	20	2.08
Tetraspora gelatinosa		22			22	2.29

Sphaerocystic sp		34			34	3.53
Sphaerocystis schoeteri		13			13	1.35
Cyanophyta						
Microcystis aeruginosa		18	12	6	36	3.74
Nostoc sp.		10	4	6	20	2.08
Gomphosphaeria sp.		10	6	8	24	2.49
Anabaena sp.			6		6	0.62
Oscillataria putrid	5	11	6	10	27	2.81
Oscillataria splendida		23	4		27	2.81
Oscillataria lanterbornii				11	11	1.14
Euglenophyta						
Mallomonas spp		16	5	2	23	2.39
Straurastrum sp		13	9	5	27	2.81
Phacus sp.	2	18	5		23	2.39
Pyrrophyta						
Peridinium sp.		13	3		16	1.66
	35	460	237	265	962	100.00

Table 2. Phytoplankton Species Composition and Abundance in Wawan Rafi Reservoir, Jigawa State, Nigeria

Taxa	PI Value	SITES			Total Org/l	Abundance (%)
		1	2	3		
Bacillariophyta						
Asterionella sp		29		12	41	3.25
Diatoma vulgare		41		23	64	5.07
Melosira sp.	3	21		8	29	2.3
Cymbella cistula		10		3	13	1.03
Gyrosigma sp.		10	6	11	27	2.14
Gomphonema gracile.			2	6	8	0.63
Gomphonema sp.	4	16	9	9	34	2.69
Meridionsp.		16		11	27	2.14
Nitzschia sp.	2			7	7	0.55
Synedra sp.	3	17	6	11	34	2.69
Synedra ulna		17		9	26	2.06
Navicula sp.	4	36	8	16	60	4.75
Chlorophyta						
Scenedesmus quadricauda	4			25	25	1.98
Coelastrum sp.		8	2	21	31	2.46
Ulothrix zoonata		6		8	14	1.11
Cosmarium sp.		27	11	26	64	5.07
Pediastrum sp.		45		13	58	4.6
Planktosphaeria sp.		32	3	8	43	4.41
Ankistrodesmus sp.	4	31		27	58	4.6
Tetraedron acutum		9			9	0.71
Chlorella vulgaris	5	9		5	14	1.11
Desmidium grevillei		19		13	32	2.54
Mougeotia sp.		1	1	4	6	0.48
Pandorina sp.	2	23		12	35	2.77
Tetraspora sp		16		20	36	2.85

Tetraspora gelatinosa	42	11	32	85	6.74
Sphaerocystic sp		9		9	0.71
Sphaerocystis schoeteri		3		3	0.24
Cyanophyta					
Microcystis aeruginosa	28	12	16	56	4.44
Nostoc sp.	11	4	6	21	1.66
Gomphosphaeria sp.	6	6	8	20	1.58
Anabaena sp.		6		6	0.48
Oscillataria putrid	5	13	6	30	2.38
Oscillataria splendida	21	4	9	34	2.69
Oscillataria princeps	10	8	2	20	1.58
Oscillataria lanterbornii	9	1	11	21	1.66
Euglenophyta					
Mallomonas spp	19	5	21	45	3.57
Straurastrum sp	15	9	25	49	3.88
Phacus sp.	3	19	5	37	2.93
Pyrrophyta					
Peridinium sp.	13	3	15	31	2.46
	39	645	140	477	1262
					100.00

Acknowledgements

The authors are thankful to Tertiary Education Trust Fund (TETFUND) and Federal Government of Nigeria for the grant that saw this research through. The authors are also thankful to Hussaini Adamu Federal Polytechnic, Kazaure for paving the way to access the fund. The authors are gratefully acknowledging the help from Engr. Dr. Bashir Ahmad Danzomo (Ag. Rector Hussaini Adamu Federal Polytechnic, Kazaure), Mal. Ahmad Nasiru (Dean School of Science and Technology, Hussaini Adamu Federal Polytechnic, Kazaure) and Dr. Adekanmbi Olufemi S. of Benin-Owena River Basin for their encouragement during the preparation of this article.

REFERENCES

- [1] Abdullah, S.A., Lawan, J., Fowotade, S. A. and Abdu, H. (2015). Assessment of Heavy Metal Bioaccumulation by Tissues of Ipomoea Batatas and Manihot Esculenta Irrigated with water from Muhammad Ayuba Reservoir, Kazaure. *Proceedings of 18th International Conference on Plant and Environmental Sciences*, 2(2).
- [2] Abubakar, M. K. (2026). *BIOLOGICAL PROCESSES AND HEALTH-RELATED MECHANISMS*. Halic Publishing House Istanbul, Türkiye. Pp. 81-101.
- [3] Abubakar, M. K. and Ohiare, A. A. (2020). COMPARATIVE PLANKTON SURVEY AND PHYSICO-CHEMICAL ASSESSMENT OF TWO PONDS IN KANO METROPOLIS, NIGERIA. *Eurasian Journal of Analytical Chemistry*. 13(3): 193-206.
- [4] Abubakar, M. M., and Abubakar, J. Y. (2013). Seasonal dynamics of the phytoplankton in relation to environmental variables in Nguru Lake, North eastern Nigeria. *Journal of Biodiversity and Environmental Sciences (JBES)*: 3(1): 88-94.
- [5] Abubakar, M.K., Muhammad, M.A., Anas.A. and Ibrahim, S. (2015). Phytoplankton Survey and Physico-Chemical Assessment of Kazaure Dam, Nigeria. *Proceedings of The IRES 3rd International Conference*, Dubai, UAE, 34-37.
- [6] Ahmad, H. K., and Indabawa, I. I. (2015). A study of Algal species of Kano River, Tamburawa, Kano State, Nigeria. *Bayero Journal of Pure and Applied Sciences*, 8(1): 42-49.
- [7] Al Hassany, J. S., Zahraw, Z., Murtadeh, A., Ali, H. and Sulaiman, N. (2012). Study of the effect of Himreen dam on the phytoplankton diversity in Dyala River, Iraq. *Journal of Environmental Protection*, 3:940-948.

- [8] American Public Health Association (APHA, 2017). *Standard methods for the examination of water and wastewater*. American Public Health Association (APHA): Washington, DC, USA, 21.
- [9] Atobatele, O.E. (2013). Pelagic Phytoplankton Succession Pattern in a Tropical Freshwater Reservoir (Aiba Reservoir, Iwo, Osun state, Nigeria). *Bioremediation, Biodiversity and Bioavailability*, 7(1): 81-84.
- [10] Ayoade, A., and Aderogba, A. (2020). Spatial and temporal distribution of plankton in a tropical reservoir, southwestern Nigeria. *Egyptian Journal of Aquatic Biology and Fisheries*, 24(5):161-181.
- [11] Banerjee, D., Chatterjee, S. and Nath, S. (2022). Aquatic Physicochemical Parameters and Their Possible Impact on Freshwater Bodies. *Applied Ecology and Environmental Sciences*. 10(6), 360-367. [Science and Education Publishing](#)
- [12] Bilbao, J. and Seoane, S. (2024). Response of the phytoplankton community to the cessation of wastewater discharges in the urdaibai estuary (SE Bay Of Biscay) based on PIGMENTUM analysis of HPLC pigments. *Marine Environmental Research*, 200: 106668.
- [13] Chinyama, A., Snyman, J., Ochieng, G. M., and Nhapi, I. (2016). Occurrence of cyanobacteria genera in the Vaal Dam: implications for potable water production. *Water SA*, 42(3): 415-420. [Water SA](#)
- [14] Ewebiyi, F. O., Appah, J., and Ajibade, G. A. (2015). Taxonomy, distribution and diversity of phytoplankton in some water bodies in Kaduna metropolis.
- [15] Mufida, B. H. (2024) *BADEGGI JOURNAL OF AGRICULTURAL RESEARCH AND ENVIRONMENT*, 2024, 06(01), 54 - 63 59.
- [16] García-Ávila, F., García-Pizarro, E., Malla-Aguilar, G., Sánchez-Cabrera, C., Cadme-Galabay, M., Valdiviezo-Gonzales, L. and Cabello-Torres, R. (2025). Influence of nutrients on aquatic vegetation and trophic status of lakes: analysis of eutrophication and mitigation. *Results in Engineering*, Volume 27, 106381, ISSN 2590-1230. [ScienceDirect](#)
- [17] Hameed, I. O., Adeniyi, I. F., Adesakin, T. A., and Aduwo, A. I. (2019). Phytoplankton diversity and abundance in relation to physico-chemical parameters of Ifewara Reservoir, Southwestern Nigeria. *World News of Natural Sciences*, 24.
- [18] Jorgensen, S. E., Löffler, H., Rast, W. and Straskraba, M. (2005). *Lake and Reservoir Management*. Elsevier, Netherlands. pp. 43-366.
- [19] Lüring, M. (2021). Grazing resistance in phytoplankton. *Hydrobiologia* 848, 237–249. [Springer](#)
- [20] Nannette Huber (2012). *Estuaries - Phytoplankton Protocol*. Pp. 1-8.
- [21] Oladeji, S.O. (2020). Evaluation of physicochemical parameters in wastewater from Muhammad Ayuba dam in Kazaure, Jigawa state, Nigeria. *Archives of Agriculture and Environmental Science*, 5 (4): 482-488.
- [22] Paerl, H. W. and Paul, V. J. (2012). Climate change: links to global expansion of harmful cyanobacteria. *Water research*, 46(5): 1349-1363. [ScienceDirect](#)
- [23] Palmer, C.M. (1969). Composite rating of algae tolerating organic pollution. *Journal of Phycology* 5(1):78-82. [Wiley](#)
- [24] Rosen, B. H., and St. Amand, A. (2015). *Field and laboratory guide to freshwater cyanobacteria harmful algal blooms for Native American and Alaska Native Communities*: U.S. Geological Survey Open-File Report, Virginia.
- [25] Schreier, J. E. (2019). Dynamics of Bacteria and Phytoplankton in the Surface Ocean, Editor(s): J. Kirk Cochran, Henry J. Bokuniewicz, Patricia L. Yager, *Encyclopedia of Ocean Sciences* (Third Edition), Academic Press, Pages 546-552, ISBN 9780128130827, <https://doi.org/10.1016/B978-0-12-409548-9.11236-9>.
- [26] Suleiman, U. F., and Ibrahim, S. (2019). Spatial and temporal patterns of phytoplankton composition in Zobe Reservoir, Dutsinma, Katsina State, Nigeria. *Bayero Journal of Pure and Applied Sciences*, 12(1): 51-56.
- [27] Updhyay, D., Shukla, K., Mishra, A., Shukla, S. (2025). Freshwater Phytoplankton: The Significant Ecosystems Services Provider in

- Aquatic Environment. In: Gupta, J., Verma, A. (eds) *Green Equilibrium. Green Energy and Technology*. Springer, Singapore. [Springer](#)
- [28] Yusuf, Z. H. (2020). Phytoplankton as bioindicators of water quality in Nasarawa reservoir, Katsina State Nigeria. *Acta Limnologica Brasiliensia*, 32. [SciELO](#)
- [29] Zhu, Y., Gao, J., Zhao, H., Deng, S., Lin, M., Wang, N., Liu, M., Hu, S., & Luo, L. (2024). Land Use Impact on Water Quality and Phytoplankton Community Structure in Danjiangkou Reservoir. *Diversity*, 16(5), 275. [MDPI](#)