Plankton Composition and Distribution in Some Selected Rivers Within Ilorin, Kwara State, North Central Nigeria

Abisola Majeed, Habeeb Tajudeen, Olagbile Grace, Aladetohun Damilola, Abia Nse-abasi, Adebajo Ruth, Olatunbosun Samuel, Aje Lydia, Azeez Bimpe Suliyat, Abass Toba Anifowoshe*

Department of Zoology, University of Ilorin, Ilorin, Nigeria

Email: anifowoshe.at@unilorin.edu.ng

ABSTRACT

This study assessed the changes in plankton abundance and physicochemical properties in three different rivers (Agba, Oyun, and Asa) in Ilorin, Kwara State, Nigeria. About 250 mL of water samples collected were collected into properly labeled zooplankton and phytoplankton glass containers and preserved in formalin and Lugol's iodine solution, respectively, and the physicochemical parameters were all measured. About 61 phytoplankton species from three classes were identified. Bacillariophyceae (diatoms and desmids) were found to be the most abundant class, accounting for 63.93%, followed by Cyanophyceae (22.95 %), and finally Chlorophyceae (14.95 %). In the Agba, Asa, and Oyun Rivers, a total of 20 zooplankton species were identified. Protozoa accounted for 15% of the zooplankton found in the three rivers, followed by crustacea (50%). The pH of the water was determined to be between 6.40 and 6.80, with a mean temperature of 25.50°C and 26.90°C. Heavy metals like magnesium had the greatest mean values in the Agba, Oyun, and Asa Rivers. Human activities, particularly those related to agriculture, are a key contributor to the problem. This study will give information on river plankton distribution, potential health problems, and river water treatment strategies. However, more studies on monthly sampling and comparison with other rivers within the states will be necessary.

Keywords: plankton abundance, physicochemical parameter, Nigeria, rivers

INTRODUCTION

Water is vital in man's daily activities. According to Dudgeon (2019), freshwater covers less than 1% of the Earth's surface, constituting only 0.03% of the total volume of all water, which is the main water source used by humans. Fifty-five percent of that water originates from polluted reservoirs, rivers, streams, and lakes. Only 1% of freshwater available for drinking, agriculture, and home use is free of contamination (Awomeso et al., 2020). Rivers are the site of the greatest biological diversity and human activity (Odulate et al., 2017). Human activities generally pollute river water. Plankton's reliance on water quality is analogous to human reliance on air quality. In the same way that air pollution affects humans, water pollution affects all aquatic life.

Water quality affects the survival and well-being of all aquatic organisms in an environment. Aquatic quality is defined as the physical, hydrological, chemical, and biological qualities of water and its interactions (Odulate et al., 2017). The water quality parameters are generally measured according to their physical, chemical, and biological properties. (Halim et al., 2018). Due to the persistent and intense chemical, biological, and physical agents that contaminate water bodies, human activities can occasionally be harmful to aquatic organisms' health, leading to genetic changes and carcinogenesis in aquatic organisms, especially fish (Anifowoshe et al., 2020). There are many riverine towns in Kwara State, Nigeria, where fishing is very active, notably near Moro, Oyun, Asa, and Apodu (Oladipo et al., 2018). Our previous studies have shown the physicochemical parameters of many of these rivers in great detail, and the pollution effects of these rivers are well-documented (Anifowoshe et al., 2018; 2019; 2020; 2022). However, information on plankton composition and distribution across of many of these rivers is sparse.

Plankton (phytoplankton and zooplankton) are the primary and secondary producers in aquatic ecosystems and are the most commonly measured biological parameters. Phytoplankton play a critical role in primary production, nutrient cycling, and food web and are used in assessing the degree of pollution or as indicators of pollution of different water bodies due to their very sensitive nature and response to changes in their environment (Dauda et al., 2021). Just as phytoplankton rely on water quality characteristics, especially nitrates and phosphates, for growth, reproduction, and survival, so do all consumer aquatic organisms (zooplankton, aquatic invertebrates, fish larvae, etc.). Zooplankton are tiny critters that are essential in all aquatic food webs. Also vital in the transport of energy from primary producers of phytoplankton to higher trophic levels, they feed on phytoplankton. It is possible that negative changes in physicochemical characteristics could impair plankton yield, causing issues for all aquatic life (such as dissolved oxygen depletion at night or oversaturation during the day, food shortage, competition for food, stress, and mortality). Zooplankton are one of the important biotic components and a sensitive indicator of water quality, vital for maintaining overall ecosystem productivity and stability of the food web (Kumari et al., 2022). Parameters such as temperature and pH as well as dissolved oxygen are also measured. Plankton yield is affected by changes in physicochemical factors.

Water quality varies due to changes in component concentrations flowing into the water body. Although rivers are man's most vital freshwater source yet, sewage, industrial waste, and numerous human activities degrade river water and affect their physicochemical qualities (Va et al., 2021). In this study, we compared the heavy metal composition, physicochemical parameters, and plankton compositions in three rivers in Ilorin, Kwara State, Nigeria. The main objectives of this are to

i. identify species of plankton present and distribution in the three water bodies.
ii. regularly provide and analyze data on water body physicochemical parameters.
iii. provide data on heavy metal levels in Oyun, Agba, and Asa River water bodies and sediments.

MATERIALS AND METHODS

Description of the Site

Three different locations were sampled for this study—the Agba, Asa, and Oyun Rivers.

The Asa River is located near the Unity Road exit of the industrial estate in Ilorin, Nigeria (8°28'N, 4°38'E to 8°31'N, 4°40'E). Shopping centers, a hospital, banks, a car park, and a mini-market for the selling of fresh vegetables and fish are all located along the river's edge. The Asa River is the largest body of water in Ilorin; it flows from Asa Dam to the southern end of the industrial estate, then northwards through the residential and commercial districts of the city (Anifowoshe et al., 2022).

The Oyun River is located in the Oyun area (08°30' N and 08°15' E) along with the Joint Admission and Matriculation Board (JAMB) office in the Ilorin East Local Government Area of Kwara State. It serves as a source of water for local enterprises as well as general municipal needs. The river is also used for subsistence and commercial fishing, as well as agriculture.

The Agba River is a 326,000-km^2 river with two springs as its source. Approximately one-third of the Ilorin metropolitan is served by the river. The study region is focused at roughly 4°35' E and 8°28' N in Ilorin, Kwara State. The Agba River is one of Ilorin's main sources of drinkable water. It is at Gaa Akanbi, Ilorin, Kwara State, on Agba Dam Road. On the river's edge are residential houses, schools, hotels, and St. Mary's School (Busari et al., 2014).

Sampling Collection and Procedures

Plankton

Water samples were collected from three rivers—Agba, Asa, and Oyun from April to June 2018 using a 25-cm-diameter net of 76-μm mesh size. The net was towed vertically over a distance of 2 m on the water surface due to the shallowness of the river. Two hundred fifty milliliters of water samples collected were put into properly labeled zooplankton and phytoplankton plastic containers and preserved in 25 ml of 10% formalin and 2.5 ml of Lugol's iodine solution, respectively. The sample was subsequently taken to the laboratory at the Department of Zoology, University of Ilorin, Ilorin, Nigeria, for investigation. In the lab, a drop of each water sample was placed on a microscope's glass slide and covered with a coverslip for identification and enumeration, with plankton identified at different magnifications (×40 and ×100) under a light microscope (Plutzer & Törökné, 2012). Using appropriate keys and checklists, the total numbers per species were recorded.

Physiochemical parameters

The Hanna Multiparameter Instrument H198125 was used to measure pH, conductivity, and total dissolved solids (TDS). The device was calibrated, then readings from the sample were collected. Before the next sample reading, the probe was washed twice with clean water and rinsed with 70% ethanol.

Determination of total hardness

The total hardness of the water samples was evaluated using the ethylenediaminetetraacetic acid (EDTA) titration method (WHO/M/26. R1, 1999), which involved mixing 50 ml of the well-mixed sample with 1–2 ml PH 10 buffer and a pinch of Eriochrome Black T indicator. After that, the contents were titrated with 0.01 M EDTA until the wine red solution became blue.

Determination of biological oxygen demand

The biochemical oxygen demand (BOD) level is calculated by comparing the dissolved oxygen (DO) level of a water sample obtained immediately with the DO level of a water sample incubated for 5 days in a dark cupboard. The difference between the two levels is an approximation of the BOD level since it represents the amount of oxygen necessary for the breakdown of any organic material in the sample.

Heavy Metal Analysis

Water sampling

Water samples were collected by lowering precleaned plastic bottles into the bottom of the water body, 30 cm deep, and allowed to overflow before withdrawing.

Sediment sampling

An Ekman Bottom Grab was used to obtain sediment samples from each of the three sampling locations. Each location provided composite sediment samples, which were delivered in labeled polyethylene containers. At the point of sediment collection, the polythene bags were rinsed with water samples before the sediment samples were placed inside. In preparation for digestion and heavy metal analysis, sediment samples were air-dried and sieved with a 0.5-mm sieve. The sediment sample is protected from decomposition by drying the materials, which also maintains a stable reference value. An inductively coupled plasma-atomic emission spectrometer was used to evaluate the metal content of the digested silt samples (Optima 4100 DV ICP-OES model).

Statistical Analysis

The graphical image was created with Microsoft Excel. The descriptive statistics were calculated using SPSS 25.0, statistical software for the social sciences. The one-way analysis of variance was performed to evaluate the differences, and the Duncan multiple range test was employed to determine statistical significance at $p < 0.05$. The mean and standard deviation were computed.

RESULTS

Plankton Abundance

Diatoms (Bacillariophyceae)

Asterionella sp., *Cymbella* sp., *Synedra, Melosira* sp., *Pinnularia* sp., *Nitzschia* sp., *Cyclotella* sp., *Tabellaria* sp., and *Stauroneis* sp. are all representatives of diatoms recorded at the sampling locations. The highest (18.03%) and lowest (8.20%) relative abundance were recorded in the Asa and Agba Rivers, respectively (Table 1).

Green algae (Chlorophyceae)

Green algae were represented by *Characium* sp., *Scenedesmus* sp., *Ankistrodesmus* sp., *Zygnema* sp., *Protococcus* sp., *Pediastrum* sp., and *Bulbochaete* sp. The Oyun River recorded the highest abundance (8.20%) of green algae, and the lowest (1.64%) was recorded in the Asa River (Table 1). The Agba River had an abundance of 3.28%.

Table 1. Numerical Abundance of Plankton in Each of the Sampling Locations

Sampling Location	Plankton	No. of Individuals Observed	Relative Abundance (%)
	Phytoplankton		
Oyun	Green algae	5	8.20
Agba		2	3.28
Asa		1	1.64
Total		8	13.12
Oyun	Blue-green algae	1	1.64
Agba		1	1.64
Asa		12	19.67
Total		14	22.95
Oyun	Diatoms	8	13.11
Agba		5	8.20
Asa		11	18.03
Total		25	39.34
Oyun	Desmids	1	1.64
Agba		3	4.92
Asa		11	18.03
Total		15	24.59
	Zooplankton		
Oyun	Protozoa	3	15
Agba		3	15
Asa		3	15
Total		9	45
Oyun	Crustacean	3	15
Agba		6	30
Asa		1	5
Total		10	50
Oyun	Miscellaneous	—	—
Agba	invertebrates	1	5
Asa		—	—
Total		1	5

Blue-green algae (Cyanophyceae)

Cyanophyceae was represented by *Anabaena* sp. (Fig. 1A), *Spirulina* sp. (Fig. 1B), *Oscillatoria* sp., and *Phormidium* sp. The highest abundance (19.67%) of Cyanophyceae was recorded in the Asa River (Table 1). The Oyun and Agba Rivers recorded an abundance of 1.64%.

Desmids

Closterium sp. (Fig. 1C), *Spirotaenia* sp. (Fig. 1D), *Gonatozygon* sp., *Netrium* sp., *Docidium* sp. (Fig. 1E), and *Pleurotaenium* sp. were representatives of desmids at each sampling location. Desmids had their highest (18.03%) and lowest (1.64%) abundance recorded in the Asa and Oyun Rivers, respectively, while the Agba River had an abundance of 4.92% (Table 1).

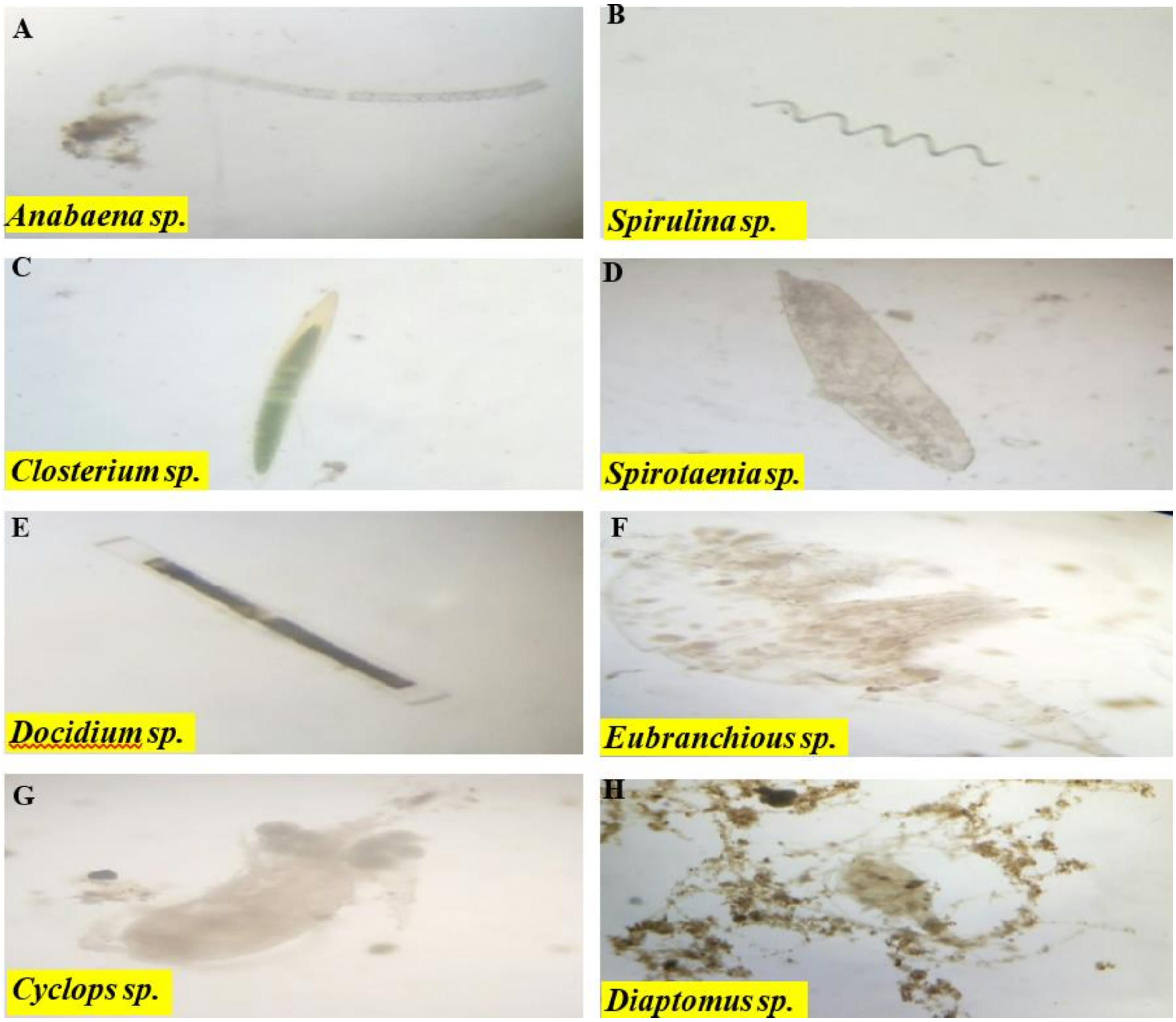

Figure 1. Representative of planktons in the three rivers.

Protozoa

Protozoa was represented by *Chlamydomonas* sp., *Gonium* sp., *Mallomonas* sp., *Nalteria* sp., *Mayorella* sp., *Loxodes* sp., *Trinema* sp., and *Spirostomum* sp. The three sampling locations (Oyun, Agba, and Asa Rivers) recorded the same (15%) abundance (Table 1).

Crustacean

Eubranchipus sp. (Fig. 1F), *Mysis/Neomysis* sp., *Cyclops* sp. (Fig. 1G), *Acroprus* sp., *Diaptomus* sp. (Fig. 1H), and *Canthocamptus* sp. are all representatives of crustaceans in the sampling locations. The highest abundance (30%) was in the Agba River, and the lowest abundance (5%) was recorded in the Asa River (Table 1).

Other invertebrates

The freshwater sponge was the only representative of Porifera, found in the Agba River. About 5% abundance was recorded in the Agba River (Table 1).

Physiochemical parameters

The temperature values ranged from 25.50 to 25.70°C in the Agba River, 26.50 to 26.80°C in the Oyun River, and 26.70 to 26.90°C in the Asa River (Fig. 2A). The mean values recorded from each river were as follows: Agba River = 25.60 ± 0.14°C, Oyun River = 26.80 ± 0.14°C, and Asa River = 26.65 ± 0.21°C.

The highest and lowest ranges of pH were 6.70 to 6.80 in Agba and 6.40 to 6.53 in Oyun, respectively. The range recorded at the Asa River was 6.60 to 6.80 (Fig. 2B). The mean values recorded from each river were as follows: Agba River = 6.70 ± 0.07, Oyun River = 6.46 ± 0.09, and Asa River = 6.70 ± 0.14.

The total hardness values ranged from 68.10 to 68.12 mg/L in the Agba River, 70.08 to 70.09 mg/L in the Oyun River, and 60.21 to 60.22 mg/L in the Asa River (Fig. 2C). The mean values recorded from each river were as follows: Agba River = 68.11 ± 0.01 mg/L, Oyun River = 70.08 ± 0.01 mg/L, and Asa River = 60.21 ± 0.01 mg/L.

Turbidity values ranged from 5.47 to 5.48 mg/L in the Agba River and 5.10 to 5.12 mg/L in the Oyun River. The Asa River recorded the highest range of 6.00 to 6.01 mg/L of turbidity (Fig. 2D). The mean values recorded from each river were as follows: Agba River = 5.47 ± 0.01 mg/L, Oyun River = 5.11 ± 0.01 mg/L, and Asa River = 6.00 ± 0.01 mg/L.

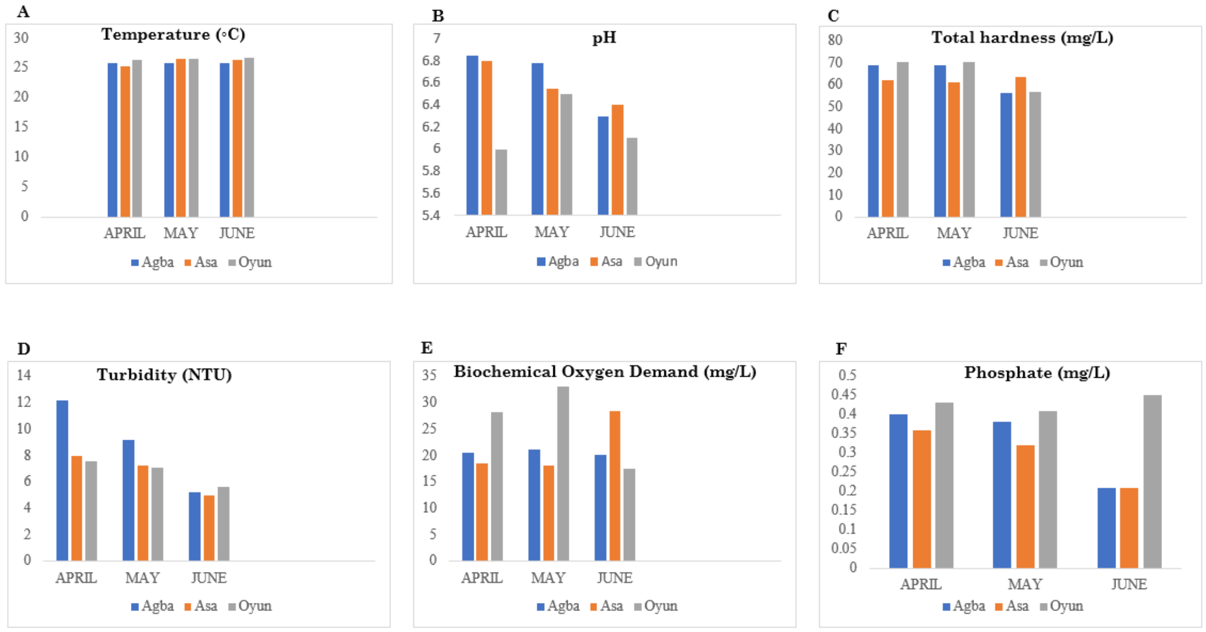

Figure 2. Physicochemical parameters of the water samples from the three sites between April and June.

The mean values of BOD recorded were 20.16 ± 0.02 mg/L in the Agba River, 30.19 ± 0.02 mg/L in the Oyun River, and 18.01 ± 0.01 mg/L in the Asa River. The BOD ranges from 30.18 to 30.21 mg/L in the Oyun River, and the lowest range is from 18.01 to 18.02 mg/L in the Asa River. The Agba River had a range of 20.14 to 20.18 mg/L (Fig. 2E).

The mean values of phosphate range from 0.34 ± 0.01 in the Agba River, 0.38 ± 0.01 in the Oyun River, and 0.30 ± 0.01 in the Asa River. Phosphate had its highest ranges from 0.37 to 0.39 mg/L in the Oyun River and 0.30 to 0.31 mg/L in the Asa River and 0.34 to 0.35 mg/L in the Agba River (Fig. 2F).

The DO values ranged from 72.46 to 72.50 mg/L in the Agba River, 156.00 to 158.00 mg/L in the Oyun River, and 109.00 to 110.00 mg/L in the Asa River (Table 2). The mean values recorded for the Agba, Oyun, and Asa Rivers were 72.48 ± 0.02, 157.00 ± 1.41, and 109.50 ± 0.00, respectively.

The mean values of TDS recorded were 137.00 ± 0.70 mg/L in the Agba River, 118.05 ± 1.34 in the Oyun River, and 235.00 ± 0.70 in the Asa River. TDS had its highest and lowest ranges of 235.00 to 236.00 mg/L in the Asa River and 117.10 to 119.00 mg/L in the Oyun River, respectively. The Agba River had a range of 137.00 to 138.00 mg/L (Table 2).

The nitrate values ranged from 6.01 to 6.02 mg/L in the Agba River and 4.34 to 4.35 mg/L in the Oyun River. The Asa River recorded a range value of 6.07 to 6.10 mg/L. The mean values recorded for the Agba, Oyun, and Asa Rivers were 6.01 ± 0.01, 4.34 ± 0.01, and 6.08 ± 0.02, respectively (Table 2).

Table 2. Physicochemical Parameters in the Water of the Oyun, Agba, and Asa Rivers

Parameters (mg/L)	Sampling Location	Mean ± SD (mg/L)	Minimum (mg/L)	Maximum (mg/L)
Dissolved oxygen	Agba	72.48 ± 0.02	72.46	72.50
	Oyun	157.00 ± 1.41	156.00	158.00
	Asa	109.50 ± 0.0	109.00	110.00
Total dissolved solids	Agba	137.00 ± 0.70	137.00	138.00
	Oyun	118.05 ± 1.34	117.10	119.00
	Asa	235.50 ± 0.70	235.0	236.00
Nitrate	Agba	6.01 ± 0.01	6.01	6.02
	Oyun	4.34 ± 0.01	4.34	4.35
	Asa	6.08 ± 0.02	6.07	6.10
Chloride	Agba	50.11 ± 0.01	50.10	50.12
	Oyun	66.06 ± 0.38	65.08	67.04
	Asa	56.09 ± 0.01	56.09	56.10
Chemical oxygen demand	Agba	28.76 ± 0.48	28.42	29.10
	Oyun	16.71 ± 0.41	16.42	17.00
	Asa	23.74 ± 0.93	23.08	24.40
Conductivity (µs/cm)	Agba	80.00 ± 0.00	80.00	80.00
	Oyun	81.50 ± 0.70	81.00	82.00
	Asa	82.00 ± 0.00	82.00	82.00

The chloride values ranged from 50.10 to 50.12 mg/L in the Agba River, 65.08 to 67.04 mg/L in the Oyun River, and 56.09 to 56.10 mg/L in the Asa River. The mean values recorded for the Agba, Oyun, and Asa Rivers were 50.11 ± 0.01, 66.06 ± 0.38, and 56.09 ± 0.01, respectively (Table 2).

The mean values of COD were 28.76 ± 0.48 mg/L in the Agba River, 16.71 ± 0.4 mg/L in the Oyun River, and 23.74 ± 0.93 mg/L in the Asa River. The COD values recorded at the Agba and Oyun Rivers ranged from 28.42 to 29.10 mg/L and 16.42 to 17.00 mg/L, respectively. The range value for the Asa River was recorded at 23.08 to 24.40 mg/L (Table 2).

The conductivity values ranged from 80.00 to 80.00 µs/cm in the Agba River, 81.00 to 82.00 µs/cm in the Oyun River, and 82.00 to 82.00 mg/L in the Asa River. The mean values recorded for the Agba, Oyun, and Asa Rivers were 80.00 ± 0.00 µs/cm, 81.50 ± 0.70 µs/cm, and 82.00 ± 0.00 µs/cm, respectively (Table 2).

Heavy Metal Analysis

The highest range (0.05 to 0.08 mg/L) of copper was recorded in the Oyun River, and the lowest range (0.02 to 0.03 mg/L) was recorded in the Agba River. The Asa River had a range of 0.03 to 0.04 mg/L. The mean values recorded were 0.02 ± 0.03 in the Agba River, 0.06 ± 0.01 in the Oyun River, and 0.03 ± 0.01 in the Asa River (Table 3).

Zinc had its highest range in the Oyun River from 0.14 to 0.17 and lowest range in the Agba River from 0.06 to 0.08. The Oyun River had a range of 0.17 to 0.17. The mean values recorded were 0.07 ± 0.00 in the Agba River, 0.15 ± 0.01 in the Oyun River, and 0.16 ± 0.00 in the Asa River (Table 3).

Nickel was absent in the Agba River. The mean values recorded from Agba, Oyun, and Asa were 0.00 ± 0.00, 0.01 ± 0.00, and 0.01 ± 0.01, respectively. The Oyun and Asa Rivers recorded a range of values of 0.01 to 0.01 and 0.00 to 0.01, respectively (Table 3). However, lead was absent in the three rivers.

The mean values of iron recorded were 0.10 ± 0.02 in the Agba River, 0.22 ± 0.03 in the Oyun River, and 0.26 ± 0.01 in the Asa River. Iron had its highest range in the Asa River from 0.25 to 0.27 and its lowest range in the Agba River from 0.18 to 0.21. The Oyun River had a range of 0.20 to 0.25 (Table 3).

Table 3. Heavy Metals in Sediments of the Oyun, Agba, and Asa Rivers

Metals (mg/L)	Sampling Location	Mean ± SD (mg/L)	Minimum (mg/L)	Maximum (mg/L)
Copper	Agba	0.02 ± 0.03	0.02	0.03
	Oyun	0.06 ± 0.01	0.05	0.08
	Asa	0.03 ± 0.01	0.03	0.04
Zinc	Agba	0.07 ± 0.00	0.06	0.08
	Oyun	0.15 ± 0.01	0.14	0.17
	Asa	0.16 ± 0.00	0.17	0.17
Nickel	Agba	0.00 ± 0.00	0.00	0.00
	Oyun	0.01 ± 0.00	0.01	0.01
	Asa	0.01 ± 0.01	0.00	0.01
Lead	Agba	0.00 ± 0.00	0.00	0.00
	Oyun	0.00 ± 0.00	0.00	0.00
	Asa	0.00 ± 0.00	0.00	0.00
Iron	Agba	0.10 ± 0.002	0.18	0.21
	Oyun	0.22 ± 0.03	0.20	0.25
	Asa	0.26 ± 0.01	0.25	0.27
Magnesium	Agba	2.25 ± 0.01	2.24	2.26
	Oyun	2.12 ± 0.02	2.11	2.14
	Asa	2.36 ± 0.02	2.34	2.38
Chromium	Agba	0.00 ± 0.00	0.00	0.00
	Oyun	0.00 ± 0.00	0.00	0.00
	Asa	0.00 ± 0.00	0.00	0.00
Aluminum	Agba	0.00 ± 0.00	0.00	0.00
	Oyun	0.00 ± 0.00	0.00	0.00
	Asa	0.00 ± 0.00	0.00	0.00
Cobalt	Agba	0.00 ± 0.00	0.00	0.00
	Oyun	0.00 ± 0.00	0.00	0.00
	Asa	0.00 ± 0.00	0.00	0.00
Manganese	Agba	0.01 ± 0.00	0.01	0.01
	Oyun	0.12 ± 0.03	0.10	0.15
	Asa	0.05 ± 0.01	0.04	0.06

Magnesium had its highest range in the Asa River (2.34 to 2.38) and lowest range in the Oyun River (2.11 to 2.14). The Agba River had a range of 2.24 to 2.26. The mean values recorded were 2.25 ± 0.01 in the Agba River, 2.12 ± 0.02 in the Oyun River, and 2.36 ± 0.02 in the Asa River (Table 3).

Manganese had its highest range in the Oyun River from 0.10 to 0.15 and lowest range in the Agba River from 0.01 to 0.01. The Asa River had a range of 0.04 to 0.06. The mean values recorded were 0.01 ± 0.00 in the Agba River, 0.12 ± 0.30 in the Oyun River, and 0.05 ± 0.01 in the Asa River

Water quality is not a static state of a system, nor can it be defined by a single parameter measurement. Water quality is influenced by a variety of chemical, physical, and biological factors. These factors give a broad picture of water pollution, while others allow for more precise tracking of pollution sources. Free-floating unicellular, colonial, or filamentous organisms that develop photoautotrophically in aquatic settings are referred to as phytoplankton. They provide the basis of food chains and food webs that directly sustain zooplankton, fish, and certain aquatic mammals (Dey, 2021). Phytoplankton abundance and species composition in tropical lakes and reservoirs exhibit distinct yearly biological features (Usman et al., 2016). The availability of nutrients, temperature, light intensity, and temperature all influence phytoplankton succession in open lakes (Usman et al., 2016). The phytoplankton community's species makeup is an effective bioindicator of water quality (Geethu & Balamurali, 2018). During the study period, 61 phytoplankton species from three classes were identified. Bacillariophyceae (diatoms and desmids) were found to be the most varied class, accounting for 63.93% of the total, followed by Cyanophyceae (22.95%), and Chlorophyceae (14.95%). The maximum production of phytoplankton is obtained when the physiochemical factors are at the optimum level (Khellou et al., 2018). With

(Table 3). pH had its highest range in the Agba River from 6.30 to 6.70 and lowest range in the Oyun River from 6.10 to 6.50. The Asa River had a range of 6.40 to 6.60. The mean values recorded were 6.50 ± 0.28 in the Agba River, 6.30 ± 0.28 in the Oyun River, and 6.50 ± 0.14 in the Asa River (Table 3). However, chromium, aluminum, and cobalt were absent in the three rivers (Table 3).

DISCUSSION

24 species, diatoms were the most abundant category (Table 1). Desmids came in second with 15 species, followed by Cyanophyceae and Chlorophyceae, which had 14 and 8 species, respectively. Phytoplankton-nutrient relationships are widely used by lake managers to access eutrophication and set nutrient targets (Zębek & Szymańska, 2017). Diatoms react rapidly to environmental changes by shifting their community composition due to eutrophic conditions as reported by Hilaluddin et al. (2020). The presence of diatoms in the three rivers indicated that the environment was eutrophic. Nitzschia (blue-green algae) blooms are a good sign of pollution. Oscillatoria, Nitzschia, and Cymbella were discovered to be good water pollution indicators. This is proof that areas with higher concentrations of the above-mentioned phytoplankton were polluted. According to Adedeji et al. (2018), phytoplankton such as *Microcystis* sp., *Anabaena* sp., and *Oscillatoria* sp. are known indicators of pollution. Phosphates and nitrates are the most significant nutrients, as they promote phytoplankton growth in the surface light layers. Because these areas were subjected to higher nitrate pollution, significant amounts of Nitzschia and nitrogen-fixing phytoplankton (Anabaena) were found in the Agba and Asa Rivers.

Zooplankton are excellent pollution indicators and may exhibit the effects of even low levels of chemical pollution in a body of water (Adadu et al., 2019). They are mostly minute protozoans, rotifers, cladocerans, and copepods (Balkhande & Kulkarni, 2018).

Zooplankton species are cosmopolitan in their clean freshwater habitat and are also found in industrial and municipal wastewaters. In the Agba, Asa, and Oyun Rivers, a total of 20 zooplankton species were found. Protozoa accounted for 15% of the zooplankton found in the three rivers, followed by crustacea (50%) and a freshwater sponge (5%), the only species classified as miscellaneous invertebrates (Table 1). Mustapha (2009) found 14 different zooplankton genera in Oyun Reservoir, including rotifers (eight), cladocera (three), and copepods (three). Rotifera and the genus *Brachionus* have been identified as the most dominant zooplankton group in Nigerian aquatic ecosystems (Adedeji et al., 2019). Rotifers' dominance is due to their opportunistic nature and ability to reproduce throughout a wide temperature range (Fishar et al., 2019). *Asterionella* absorption is greatest between pH 6 and 7, which explains why it is found in the Oyun River, which has a pH range of 6.40 to 6.53. *Scenedesmus*, *Ankistrodesmus*, and other green algae (Chlorophyta) found in the Oyun River reveal that they have a high tolerance for phosphates, with a range of 0.37 to.39 mg/L. Diatoms (39.34%), desmids (24.59%), blue-green algae (22.95%), and green algae (22.95%) have the highest phytoplankton density (13.12%).

According to Ustaoğlu & Tepe (2019), water temperature is one of the most essential indicators for water quality and ecological research. The temperature of the water influences the solubility of salts and gases. In this experiment, the water temperature ranged from 25.50°C to 26.90°C. The mean temperature values of the water samples do not differ significantly, and they also fall within the normal temperature range that supports adequate surface water quality, which is between 0 and 30°C. These temperatures were within the range established by the Federal Ministry of Environment for agricultural purposes in Nigeria (Aliyu et al., 2017). The prevalence of nitrates in surface water is largely due to human activities, particularly those related to agriculture. The nitrate concentration was found to be between 4.34 and 6.10 mg/L. This allows us to see that the nitrate levels obtained are lower than the acceptable criteria, which are below the value allowed by the World Health Organization standard of 50 mg/L as reported by Mamadou et al. (2019). Intensive agricultural activity may be to blame for this pollution (the studied regions are known for their agricultural vocation). The chloride concentration in this investigation fluctuated between 50.10 and 67.04 mg/L. The presence of both allochthonous and autochthonous organic materials could explain the elevated chloride concentration (Reshi et al., 2021).

The pH of river water samples was slightly below neutral (Tables 2 and 3), although these values are within the acceptable range of 6.0–8.5, indicating good water quality (Khound & Bhattacharyya, 2018). When pollution results in higher algal and plant growth (e.g., from increased temperature or excess nutrients), pH levels may increase. The scent and taste are caused by BOD and COD, according to reports. The COD typically comprises all, or almost all, of the BOD, as well as several additional chemical requirements. The significantly high mean COD levels were significantly higher than the permitted amounts for unpolluted surface water quality, which were above the limits of 20 mg/L for water bodies and, therefore, could be classified within the range of polluted waters (Aliyu et al., 2017). Omoboye et al. (2022) reported that moderately polluted rivers may have a BOD value in the range of 2 to 8 mg/L. The elevated BOD levels are most likely related to the discharge of domestic wastes, particularly defecation operations, as well as poorly conducted agriculture activities near the river banks, as observed during the research site assessment. Magnesium had the greatest mean values (mg/L) in the Agba, Oyun, and Asa Rivers, respectively, of 0.250.01, 2.120.02, and 2.360.02. (Table 3). For the metals determined, there were significant disparities found across each sample type.

Freshwater environments have seen significantly larger biodiversity reductions than terrestrial ones. If existing trends in human water consumption do not change, species losses will undoubtedly continue at their current rates. Corrective steps should be implemented to avoid catastrophic ecological collapse. Furthermore, as long as biodiversity is a significant natural resource in economic, cultural, artistic, scientific, and educational aspects, the protection and management of freshwater ecosystems are vital to the interests of the entire humanity. These findings may expose individuals who rely on these rivers' water for household purposes such as cooking, bathing, cleaning, and even drinking or for agricultural purposes such as fishing and farming to public health hazards. It is so advised that public education programs and campaigns be developed to educate the public on the dangers of dumping untreated wastes and effluents into bodies of water in order to improve their personal actions and attitudes. Proper treatment is also required if the river is to be used for potable, household, or industrial reasons.

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