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Full Length Research Article

PHYSICOCHEMICAL CHARACTERISTICS AND PHYTOPLANKTON COMMUNITY STRUCTURE OF ADOFI RIVER, NIGERIA

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ABSTRACT
This study assessed the physicochemical characteristics and phytoplankton community structure of the Adofi River, Nigeria, across three sampling stations over a twelve-month period. Standard analytical procedures and microscopic examination were employed to determine water quality parameters and phytoplankton composition, abundance, and diversity, with spatial variations evaluated using one-way ANOVA. Most physicochemical parameters showed no significant spatial variation (one-way ANOVA, $p > 0.05$), except sulphate ($p < 0.05$), while temperature (26–30 °C), dissolved oxygen (5.47–6.50 mg/L), and moderate BOD_5 levels (2.28–2.95 mg/L) indicated low organic pollution and generally good water quality with limited eutrophication; additionally, 2,653 phytoplankton individuals comprising 117 species, 37 families, 9 classes, and 6 divisions were recorded, with Ochrophyta (46.63%) and Charophyta (38.94%) dominating, and Cyanobacteriophyta (7.95%) increasing downstream. Overall, the dominance of diatoms and charophytes reflects favorable ecological conditions, while the presence of pollution-tolerant taxa at low abundance suggests early but non-critical nutrient enrichment, indicating that the Adofi River remains in good ecological condition but requires continuous monitoring to prevent future degradation.

Keywords: Adofi River; Physicochemical parameters; Phytoplankton diversity; Water quality; Nutrient dynamics; Ecological assessment.

INTRODUCTION

Freshwater ecosystems are indispensable to ecological sustainability and human development, particularly in developing countries such as Nigeria, where rivers serve as primary sources of domestic water supply, irrigation, fisheries, transportation, and waste disposal. However, rapid urbanization, agricultural intensification, and industrial expansion have significantly altered the physicochemical integrity of many inland water bodies (United Nations Environment Programme, 2021; World Health Organization, 2019). In the Niger Delta region, increasing anthropogenic pressures have heightened concerns regarding the ecological health and long-term sustainability of river systems (Edegbene et al., 2020; Nwankwoala, 2021). One such river receiving growing scientific attention is the Adofi River in Delta State, whose water quality has been influenced by surrounding industrial and human activities.

Physicochemical characteristics—including temperature, hydrogen ion concentration (pH), dissolved oxygen (DO), biochemical oxygen demand (BOD), electrical conductivity, total dissolved solids (TDS), turbidity, and nutrient concentrations (nitrate and phosphate)—are fundamental indicators used in evaluating freshwater quality. Variations in these parameters often reflect both natural processes and anthropogenic inputs (World Health Organization, 2019; Food and Agriculture Organization, 2020). Changes in these indicators can signal pollution from agricultural runoff, industrial discharge, and domestic waste, thereby affecting aquatic life and human health (Ezenwaji et al., 2022; Olalekan et al., 2021)

Recent assessments of the Adofi River using multivariate statistical techniques and Water Quality Index (WQI) models have revealed spatial and seasonal fluctuations in key water quality parameters, with some sections categorized as having poor to very poor water quality status (Akawo et al., 2025). Elevated nutrient concentrations and conductivity at certain sampling stations were attributed to industrial effluent discharge and surface runoff, indicating a measurable human impact on the river system. Similarly, Akporido et al. (2018) reported that effluents entering the Adofi River significantly altered its physicochemical properties, emphasizing the need for sustained monitoring and regulatory oversight.

Beyond chemical assessments, biological components—particularly phytoplankton—play a critical role in determining freshwater ecosystem health. Phytoplankton constitute the primary producers in aquatic environments, forming the base of food webs and driving nutrient cycling and oxygen production. Because of their rapid response to environmental changes, phytoplankton communities are widely recognized as reliable bioindicators of water quality. Changes in nutrient enrichment, pH, turbidity, and dissolved oxygen levels often result in shifts in phytoplankton composition, abundance, and diversity. Studies by Anyanwu et al. (2021) and Amoda et al. (2025) conducted in other Nigerian rivers have demonstrated strong correlations between physicochemical parameters and phytoplankton community structure. For example, Anyanwu et al. (2021) found that nutrient concentrations and dissolved oxygen significantly influenced phytoplankton diversity patterns in a southeastern Nigerian river system. Likewise, Amoda et al. (2025) reported that increased nutrient loading promoted the dominance of certain algal taxa, particularly members of Bacillariophyceae and Chlorophyceae, highlighting the ecological consequences of nutrient enrichment.

Although comprehensive phytoplankton data specific to the Adofi River remain limited, the documented variability in its physicochemical properties suggests potential implications for primary productivity and aquatic biodiversity. Variations in parameters such as pH, dissolved oxygen, temperature, and nutrient concentrations significantly influence phytoplankton composition and productivity in freshwater ecosystems (Ogunfowokan et al., 2019; Nwankwo & Akinsoji, 2021). Given the sensitivity of phytoplankton assemblages to changes in water chemistry, integrating physicochemical analysis with phytoplankton assessment provides a more holistic evaluation of river health (Mustapha, 2018; Ekwu & Sikoki, 2020). Such integrated studies

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are particularly important in the Niger Delta, where freshwater systems are subjected to continuous environmental stress from industrial activities, agricultural runoff, and domestic waste discharge, all of which can alter nutrient dynamics and biological communities (Aghoghovwia et al., 2022; Izonfuo & Bariweni, 2023). Therefore, investigating the physicochemical characteristics and phytoplankton composition of the Adofi River is essential for understanding the river's ecological status and informing sustainable water resource management strategies. Establishing baseline data on water quality parameters alongside phytoplankton diversity will contribute to environmental monitoring efforts, guide pollution control policies, and enhance conservation planning in southern Nigeria.

MATERIALS AND METHODS

Description of Study Area.

River Adofi is a first-order river that flows from Ejeme-unor in the Aniocha South local government of Delta State, through Ejeme-aniogor in the Aniocha South Local Government area to Utagba-Uno. It swings south-eastwards to Ossissa, where it joins the Ase River in Delta State, Nigeria. The river is vital to the surrounding communities, as it is the only river draining the area.

To ensure adequate coverage of the river system and account for spatial variations in environmental conditions, sampling was conducted at three strategically selected points: the communities of Umudike, Ogbe-Etiti, and Umueze in the Ossissa clan, designated as Stations 1, 2, and 3, respectively, as shown in Figure 1. The selection of these sites was based on their distinct ecological characteristics, levels of human activity, and position along the river continuum.

Umudike (Station 1) was chosen to represent the upstream section of the river, characterized by minimal human interference, thereby serving as a baseline for assessing natural water quality conditions. Ogbe-Etiti (Station 2), located in a more densely populated and actively used area, was selected to reflect moderate anthropogenic influence, including domestic use and agricultural activities that may contribute to nutrient inputs and physicochemical changes. Umueze (Station 3), positioned downstream, was selected to represent a zone of cumulative impact, where inputs from upstream activities are likely to converge, potentially resulting in higher levels of nutrients and pollutants.

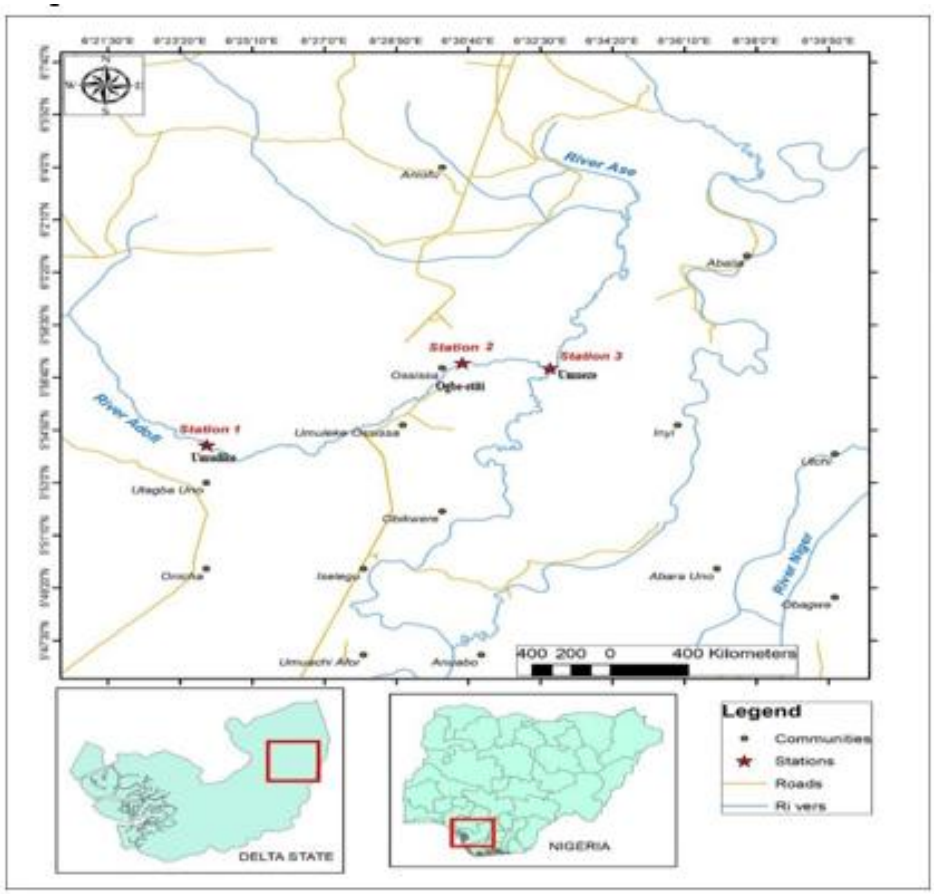

Figure 1: Map showing the river course of River Adofi at Ossissa

Sampling Method

Water samples and plankton in the different stations were collected at monthly intervals for twelve (12) months between 7.30 am and 11.00 am, and analyzed for physico-chemical parameters and plankton composition, distribution, and diversity.

Analysis of water samples from River Adofi followed standard procedures as described by APHA (2017) and Bartran and Balance (1996).

Determination of physico-chemical parameters
At each sampling station, some physicochemical parameters were determined in situ. Samples that could not be measured in situ were collected in a 5 mL container.

Temperature (°C)

Air Temperature
Air temperature was measured with the use of the calibrated mercury-in-glass thermometer (10-100) ◦C. At the sampling stations, the thermometer was held at the tip in the air and observed for 2 minutes while monitoring the mercury rise. Temperature readings were taken after the mercury level stabilized and were measured in degrees Celsius(^{0}C).

Water Temperature
Water temperature was also measured with the use of the calibrated mercury-in-glass thermometer (10 – 100) ◦C. The thermometer was inserted directly into the water until the mercury level was covered, then left for 2 minutes to stabilize. The reading was taken while the tip of the thermometer remained inside the water and recorded in degrees Celsius (^{0}C).

Dissolved oxygen (DO)
Dissolved oxygen was determined using "The modified Winkler's method". Water samples were collected by immersing 250ml reagent bottles in the river, allowing them to fill with water, and then stoppering them firmly under the water surface to avoid air bubbles. The oxygen in the sample was immediately fixed, by adding 1ml of Winkler's solution A (Manganese sulphate) followed by 1ml of Winkler's solution B (Alkaline-iodide-azide solution) to the bottle, and a brown precipitate was formed. The resulting brown floc was dissolved in the laboratory by adding 1 mL of concentrated H2SO4, forming a yellowish-brown solution. 50 mL of the treated sample was transferred into a conical flask on a white surface. This was titrated with 0.025N (6.25g/l) sodium thiosulphate until the sample developed a pale-yellow color. Then two (2) drops of starch solution were added, and titration continued until the blue color disappeared to a colorless endpoint, as confirmed by comparison with a reagent blank under consistent lighting conditions.

Biochemical Oxygen Demand (mg/l):
The determination of BOD5 (Biochemical Oxygen Demand) was performed according to the APHA (1998) method. In the field, dedicated reagent bottles were prepared specifically for the BOD5 analysis. Water samples were collected by immersing reagent bottles in the river, allowing them to fill with water, and then stoppering them firmly under the water surface to avoid air bubbles. These bottles were filled with water samples and securely sealed in black polythene bags to prevent algal growth. They were then transported to the laboratory and stored in a dark cupboard.
After a period of five (5) days, the samples were retrieved from storage and treated with Winkler's solution A (Manganese (II) Sulphate) and B (Potassium Iodide) for fixation. The dissolved oxygen procedure was repeated to determine the remaining oxygen levels, indicating the amount of oxygen consumed by microorganisms. The final BOD5 value was calculated using the following formula:

$$BOD5 = DO1 - DO5\ (mg/l)$$

DO_1 = Initial dissolved oxygen at the first day
DO_5 = dissolved oxygen value after 5 days

Total Dissolved Solids (TDS): This was determined by evaporation. A clean evaporating dish was heated to 105°C for 1 hour and then stored in a desiccator. The preheated evaporating dish was weighed, and 100 mL of the properly mixed water sample was poured through filter paper into the evaporating dish. The sample was evaporated to dryness in an evaporating oven, with temperatures set at least 2˚C below the boiling point. The evaporated sample was dried for one (1) hour, then allowed to cool in a desiccator, and afterward, the sample was taken and recorded. The total solids content of the water sample was calculated using the formula below.

$$Total\ dissolved\ solids\ (TDS) = \frac{(A-B)X\ 1000}{Vol.of\ sample\ used}$$

Where,
A = weight of dried residue + dish
B= weight of the dish

Hydrogen ion concentration (pH).
During each sampling occasion, pH determination was carried out using a battery-operated pH meter that has been calibrated with the pH 4-8 buffer solution. The pH meter's probe was immersed in the water sample before the meter was turned on to initiate the pH measurement. The pH value was recorded, ensuring accuracy to the nearest 0.1 pH unit.

Conductivity
A conductivity meter was used to determine the conductivity of Adofi River water samples. The probe of the meter was standardized by inserting it into a solution of 0.01 mol-1 potassium chloride, ensuring there were no air bubbles attached. The conductivity meter was then switched on. The probe was rinsed in distilled water and mopped dry with blotting paper. The conductivity of the water sample was determined by inserting the probe into a beaker containing the water sample to a depth of 2cm, ensuring the probe was at least 1cm from the bottom and sides of the beaker. The conductance of the water sample was read off directly from the display on the conductivity meter, and recorded in micros meter per centimetre (µS/cm).

Turbidity
A turbidity meter was used to measure dissolved solids at each sampling site, expressed in nephelometric turbidity units (NTU).

Nitrate
The nitrate concentration was determined using the ultraviolet spectrophotometric method (APHA, 1998). Initially, a standard nitrate solution ranging from 0 to 350 µg was prepared and used to generate a standard curve. To remove the color from the water sample, 4 mL of aluminum hydroxide suspension was added to 100 mL of the sample. Subsequently, 1 ml of 0.1 M hydrochloric acid was introduced to 50 ml of the clarified water sample. The optical density of the solution was measured at 220 nm. Using the standard curve measured in mg/L, the optical density was converted to its nitrate equivalent.

Sulphate
100 mL of the sample was placed into a 250 mL Erlenmeyer flask. Then 5mL of conditioning reagent was added, and the solution was mixed together using a stirrer. One spoonful of barium chloride crystal was added, then stirred for one minute. The solution was poured into the absorption cell of a photometer, and its turbidity

was measured every 30 seconds for about 4 minutes. The concentration of sulphates in the sample was determined with the calibration curve prepared from blanks.

Cyanide

The determination of cyanide was carried out using a known amount of the sample suspected of containing cyanide. Concentrated sulfuric acid was added to the sample to release cyanide ions. Sodium nitroprusside, which reacts with cyanide to form a colored complex (typically pink to red), was introduced. The color change in the solution, which indicates the presence of cyanide, was observed. The color intensity was measured using a spectrophotometer or visually compared with standards of known cyanide concentrations. The cyanide concentration in the sample was calculated using a calibration curve or standard method provided by the reagent manufacturer.

Phosphate

The determination of phosphate was carried out using the stannous chloride method as described in APHA (1998). A drop of phenolphthalein indicator was added to 100 ml of the sample; if no color change was observed, further dilution was not necessary. To each sample, 4 ml of ammonium molybdate reagent (1) and 0.5 ml or 10 drops of stannous chloride reagent were added after thoroughly mixing the two reagents together. This mixture will result in a blue color. The mixture was allowed to stand for 11 minutes to allow for color development. Subsequently, the absorbance of the solution was measured using a Gallenkamp Bausch and Lamb spectrophotometer at 690 nm, with a distilled water blank.

To prepare a standard phosphate calibration curve, the transmittance of serially diluted standard phosphate solutions was measured using a procedure similar to that for nitrate determination. The phosphate concentration of the water sample, measured in mg PO4-P, was read from the prepared phosphate standard calibration curve.

Samples Collection

Collection of Water Samples

Water samples were collected from the three (3) stations in 2-liter containers cleaned thoroughly. The sampling cans were rinsed using a water sample before filling the sample for physicochemical. The samples were collected at depths 30cm below the water surface to avoid air bubbles and covered under water to avoid trapping atmospheric oxygen in the bottle at different sampling points.

Collection of Plankton Samples

Plankton samples were collected within a period of twelve (12) months from the river using a plankton net of mesh size 55 µm by towing the plankton net extensively against the current. The plankton samples were preserved in 4% formalin before microscopic examination. For microscopic examination and identification, 1 or 2 drops sub sample was placed on a slide and placed on the stage of a digital microscope. Drawing and counting were done from one end to the other by moving the slide from side to side. Each plankton sampled was snapped, and identification to the lowest taxonomic level was done. Identification of plankton species was based on established guides and taxonomic references, including Needham and Needham (1962) Guide to the Study of Freshwater Biology, Prescott (1978) How to Know the Freshwater Algae, APHA (2017) Standard Methods for the Examination of Water and Wastewater, and Bellinger and Sigee (2010) Freshwater Algae: Identification and Use as Bioindicators.

Data Analysis

With the aid of Past 4.05 statistical software, Principal component analysis (PCA), was applied to physical (air and water temperature and depth) and chemical (conductivity, pH, alkalinity, dissolved oxygen, sulphate, nitrates, cyanide, and total phosphorus) and plankton abundance to evaluate the variations that exist between the various sampling stations in the Adofi river. A One-way ANOVA was applied to physicochemical parameters to assess variation among stations. Turkey's pairwise analysis was used to determine the points of these variations, if present. Microsoft Excel 2013 was used to plot simple line graphs and bar charts showing fluctuations in measured parameter values.

Diversity Indices

The diversity indices were measured by calculating the following index;

Shannon-Weiner diversity, H:

$H = -\sum Pi \ln Pi,$
$where\ Pi = ni / N$
Where,
Ni is the total number of individual Species
H is Shannon-Weaver Species diversity

Simpson Evenness measure, E

$E = D/Dmax$
Where,
D = Simpson's diversity index
D_{max} =maximum possible value of Simpson's index. D_{max} =1/S,

Species Richness, (Margalef) $d = \frac{s-1}{InN}$
Where,
where S is the total number of species,
N is the total number of individuals of all the species.

Simpson's index of Dominance (D):
D = Σ (pi)2
Where pi is the proportion of important value of the ith species (pi = ni/N, ni is the importance value of the ith species, and N is The importance value of all the species.

$$Relative\ Abundance\ (\%) = \frac{Number\ of\ individuals\ of\ a\ specie}{Total\ number\ of\ individuals\ of\ all\ specie}\ x\ 100$$

$$\%A = \frac{n}{N}\ x\ 100$$

Where:
N= total individuals of a particular species
N = total individuals of all species combined

RESULTS

Station 1 (Umudike): This is the point located on longitude 5.914, and latitude 6.465, about ten (10m) meters before the River Adofi bridge at Ossissa, on the Kwale /Ogwashi-ukwu expressway. The flow of the river is fast in this portion, shallow, and highly transparent. Activities in this region include occasional laundering

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of clothes, fetching water for drinking, swimming, and fishing. The station is characterized by emergent, submerged, and floating vegetation, amongst which are *Pistia* sp*., Azolla africana, and Nymphacea lotus;* the submerged plants *include Vossia cuspidata, Ludiogia* sp*., Salvinia nymphelluda, Hydroles glabra, Echinochloa stagnina, Echinochloa pyramidalis, Oryza barthi, Phragmites karka, Polygonum lanigerum, Leersia virginica, Leersia oryzoides, and Pyereus lanceotus.* This is the main channel of the river, characterized primarily by rapid-water zones. This is the main channel of the river, characterized primarily by rapid-water zones. The water body is relatively narrow when compared to other sampling sites.

Station 2 (Ogbe-etiti): This is a backwater region cut off from the main water channel by dense aquatic vegetation. The station has very visible lush green emergent, submerged, and floating vegetation. It is deeper than the upper region (Umudike) of the river and is located at longitude 5.928 and latitude 6.484. The distance from this station to station one (1) is 1 kilometer. The vegetation here consists of floating plants such as *Pistia sp., Azolla africana, and Nymphacea lotus*. This station is subject to increased human interaction, as the fermentation of cassava, anchoring canoes, fishing, fetching water for drinking, and swimming are among the noticeable activities taking place here.

Station 3 (Umueze): This is the deepest of the three stations, and it is located at longitude 5.950 and latitude 6.509, about two (2) kilometers away from the mouth of the river, where it empties into the Ase River. Although like Station 2, it is a backwater zone with numerous vegetation types. The vegetation here consists of floating plants such as Pistia sp., Azolla africana, and Nymphaea lotus, while Raffia palm occurs as part of the emergent vegetation. The water is used for drinking, washing, swimming, anchorage, cassava fermentation, and as a site of religious activities for local folks who worship the river deity. The riparian zone and adjoining land are used for agricultural activities, serving as farmland for local cassava farmers

Physico-Chemical Parameters**.**

Table 1: A summary of the results of the physico-chemical parameters of the sampled stations, showing sample means ± standard deviation, F-value, and p-value.

Parameters	STATION 1	STATION 2	STATION 3	F-value	p-value
Air Temp. (°C)	28.25±1.1382 (27–30)	29±1.2792 (27–31)	29.5±1.3817 (27–32)	2.944	0.06663
Water Temp (°C)	27.16667±1.1146 (26–29)	27.91667±1.2401 (26–30)	28.16667±1.1934 (26–30)	2.319	0.1142
pH	7.11±0.4884 (5.98–8.02)	7.181667±0.3554 (6.54–8.01)	6.875833±1.2645 (5.97–7.8)	0.469	0.6297
D.O (mg/L)	6.5±1.7960 (5–11.4)	6.025±1.7473 (4.4–10.8)	5.470833±2.053 (3.2–11.6)	0.9024	0.4154
B.O.D (mg/L)	2.896667±1.1340 (1–4.6)	2.95±1.2817 (1.2–5.8)	2.275833±1.2873 (1–6)	1.103	0.3439
Cond. (µS/cm)	19.05±8.2695 (10–35.8)	17.0825±9.2635 (0.09–30.3)	19.21±11.7239 (10–38.4)	0.1724	0.8424
TDS (mg/L)	4.633333±1.4075 (3.1–7)	3.930833±1.4514 (1.8–6.22)	3.209167±1.5508 (1.05–6)	2.812	0.07455
Nitrate (mg/L)	0.472±0.3455 (0.15–1.52)	0.4803333±0.3338 (0.025–1.23)	0.3473333±0.1139 (0.22–0.56)	0.8198	0.4493
Sulphate (mg/L)	37.73333±12.916 (20–60)	27.85833±8.2622 (10–40)	23.025±8.6986 (10–40.7)	6.509	0.00414
Phosphate (mg/L)	0.1885833±0.091 (0.043–0.4)	0.2105±0.1128 (0.042–0.42)	0.1836667±0.1051 (0.024–0.4)	0.2214	0.8026
Ammonia (mg/L)	0.02825±0.0584 (0.001–0.21)	0.005833333±0.0026 (0.001–0.009)	0.00625±0.0037 (0.001–0.013)	1.725	0.1938
Cyanide (mg/L)	0.004018333±0.116 (0.25–0.648)	0.004248333±0.1869 (0.225–0.918)	0.00356±0.1989 (0.11–0.837)	0.4977	0.6124
Alkalinity (mg/L)	55.43333±24.7438 (26–92)	51.175±21.0029 (28–88)	39.62333±15.9184 (24–64)	1.844	0.1742
Calcium (mg/L)	13.1±11.8064 (4–45)	12.985±11.4611 (5.8–45)	11.06083±8.0721 (3.6–27.8)	0.1406	0.8693
Magnesium (mg/L)	8±4.4540 (3–16.3)	6.953333±3.8137 (3–15)	8.165±4.7175 (1.88–15.8)	0.274	0.762

Air and water temperatures exhibited typical tropical patterns, with mean air temperatures ranging from 28.25 to 29.5 °C and water temperatures from 27.17 to 28.16 °C across stations. Seasonal variation was evident, with higher values during the dry season; however, no significant spatial differences were detected ($p > 0.05$). These conditions are consistent with tropical freshwater systems and are suitable for sustaining aquatic biota.

The river maintained near-neutral pH conditions (6.88–7.19), although occasional acidic deviations were observed, particularly at Station 3. Despite these fluctuations, spatial differences were not significant ($p > 0.05$), suggesting overall stability in hydrogen ion concentration and favorable conditions for aquatic organisms.

Dissolved oxygen concentrations (5.47–6.50 mg/L) were within acceptable ecological limits and showed seasonal peaks during the rainy season, likely due to increased aeration and surface runoff. Correspondingly, moderate BOD_5 values (2.28–2.95 mg/L) indicate relatively low organic pollution. Both parameters exhibited no significant spatial variation ($p > 0.05$), reflecting a generally well-oxygenated system with limited organic loading.

Electrical conductivity (17.08–19.21 µS/cm) and total dissolved solids (3.21–4.63 mg/L) were low across all stations, indicating minimal mineralization and low ionic content. Spatial differences in these parameters were not significant ($p > 0.05$), suggesting a limited influence of dissolved inorganic substances and relatively unimpacted water chemistry.

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Nutrient concentrations were generally low to moderate, with nitrate, phosphate, and ammonia showing no significant spatial variation ($p > 0.05$), indicating limited nutrient enrichment and low risk of eutrophication. In contrast, sulphate exhibited significant spatial variation ($p < 0.05$), likely reflecting localized inputs or underlying geological influences.

Cyanide concentrations were very low (0.0036–0.0043 mg/L) and consistent across stations ($p > 0.05$), falling within acceptable limits for natural waters. Similarly, alkalinity (39.62–55.43 mg/L) exhibited a moderate buffering capacity with no significant spatial variation. Calcium and magnesium concentrations were also uniformly distributed ($p > 0.05$), indicating stable hardness characteristics across the river system.

Overall, the physicochemical profile of the Adofi River suggests a relatively stable and minimally impacted freshwater system, with most parameters remaining within acceptable ecological limits. The absence of significant spatial variation across most parameters highlights the homogeneity of the river system, while localized variation in sulfate underscores the influence of site-specific factors.

Table 2: Distribution and Abundance of Phytoplankton Identified and Reported in Adofi River

DIVISION	FAMILY	SPECIES	Station 1	Station 2	Station 3	Total	% Abundance
Ochrophyta	Achnanthaceae	*Achnanthes delicatula*	2			2	0.08
	Achnanthidiaceae	*Achnanthidium minutissimum*	1			1	0.04
	Fragilariaceae	*Asterionella Formosa*	2		2	4	0.15
	Asterionellaceae	*Asterionella hassallii*			1	1	0.04
	Aulacoseiraceae	*Aulacoseira granulate*			12	12	0.45
	Aulacoseiraceae	*Aulacoseira sp.*	20			20	0.75
	Aulacoseiraceae	*Aulacoseira thwaitesii*	28		38	66	2.49
	,	*Bacillariophyta (diatoms)*		1		1	0.04
	Chaetocerotaceae	*Bacteriastrum furcatum*	1			1	0.04
	Hemiaulaceae	*Ceratula bergonii (?)*	3			3	0.11
	Chaetocerotaceae	*Chaetoceros radicans*		1		1	0.04
	Cymbellaceae	*Cymbella lanceolata*		5	10	15	0.57
	Cymbellaceae	*Cymbella sp.*	2	7	9	18	0.68
	Cymbellaceae	*Cymbella cymbiformis*		14		14	0.53
	Naviculaceae	*Diadesmis confervacea*	99	11	18	128	4.83
	Naviculaceae	*Diadesmis sp.*	14			14	0.53
	,	*Diatom sp.*	2			2	0.08
	Hemiaulaceae	*Eucampia zodiacus*	55			55	2.07
	Fragilariaceae	*Fragilaria crotonensis*	93	17	51	161	6.07
	Fragilariaceae	*Fragilaria javanica*	1			1	0.04
	Fragilariaceae	*Fragilaria lyngbyei*	16	9	34	59	2.22
	Fragilariaceae	*Fragilaria pectinalis*			52	52	1.96
	Fragilariaceae	*Fragilariaforma javanica*	37	42	35	114	4.30
	Fragilariaceae	*Fragilariopsis kerguelensis*	2			2	0.08
	Fragilariaceae	*Frickia sp.*	2			2	0.08
	Fragilariaceae	*Gaillonotia formica*		2		2	0.08
	Leptocylindraceae	*Leptocylindrus danicus*	38		5	43	1.62
	Melosiraceae	*Melosira moniliformis*		120	33	153	**5.77**
	Melosiraceae	*Melosira sp.*	36			36	1.36
	Naviculaceae	*Navicula ambigua*			1	1	0.04
	Naviculaceae	*Navicula reinhardtii*		12	1	13	0.49
	Bacillariaceae	*Pseudo-nitzschia sp.*	30	30	49	109	4.11

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DIVISION	FAMILY	SPECIES	Station 1	Station 2	Station 3	Total	% Abundance
	Naviculaceae	*Pinnularia viridis*	2	2		4	0.15
	Rhizosoleniaceae	*Rhizosolenia robusta*			4	4	0.15
	Rhopalodiaceae	*Rhopalodia gibba*		4		4	0.15
	Skeletonemataceae	*Skeletonema costatum*	1			1	0.04
	Fragilariaceae	*Synedra superba*	2			2	0.08
	Fragilariaceae	*Tabellaria sp.*	13			13	0.49
	Fragilariaceae	*Tabellaria fenestrata*	8	7		15	0.57
	Fragilariaceae	*Tabellaria flocculosa*	6	6	10	22	0.83
	Fragilariaceae	*Tabellaria javanica*	25			25	0.94
	Thalassionemataceae	*Thalassionema nitzschioides*	6	24	7	37	**1.40**
	Thalassionemataceae	*Thalassionema nitzschioides*	3			3	0.11
	Triceratiaceae	*Triceratium favus*			1	1	0.04
Sub-total			***550***	***314***	***373***	***1237***	***46.63***
Chlorophyta	Oedogoniaceae	*Bulbochaete sp.*	5			5	0.19
	Chlorellaceae	*Chlorella vulgaris*		5		5	0.19
	Chlamydomonadaceae	*Carteria diesing*			12	12	0.45
	Chlamydomonadaceae	*Chlamydomonas reinhardtii*			8	8	0.30
	Dunaliellaceae	*Dunaliella salina*	1			1	0.04
	Volvocaceae	*Eudorina pectinatum*	10			10	0.38
	Oedogoniaceae	*Oedogonium fragile*	1			1	0.04
	Oedogoniaceae	*Oedogonium succinum*	4			4	0.15
	Oedogoniaceae	*Oedogonium succicuum*			7	7	0.26
	Oedogoniaceae	*Oedogonium grande Kütz.*		11		11	0.41
	Scenedesmaceae	*Tetradesmus lagerheimii*	1			1	0.04
	Dinobryaceae	*Dinobryon sertularia*			3	3	0.11
Sub-total			***22***	***16***	***30***	***68***	***2.56***
Cyanobacteriophyta	Aphanizomenonaceae	*Anabaena sphaerica*	8			8	0.30
	Oscillatoriaceae	*Oscillatoria bornetii*			1	1	0.04
	Oscillatoriaceae	*Oscillatoria princeps*	16	67	42	125	4.71
	Aphanizomenonaceae	*Raphidiopsis raciborskii*			3	3	0.11
	Oscillatoriaceae	*Spirulina gomontii*		5		5	0.19
	Oscillatoriaceae	*Spirulina major*			69	69	2.60
Sub-total			***24***	***72***	***115***	***211***	***7.95***
Dinoflagellata	Ceratiaceae	*Ceratium gravidum*		2		2	0.08
	Ceratiaceae	*Ceratium tripos*	7	4	1	12	0.45
	Gymnodiniaceae	*Gymnodinium aeruginosum*		2		2	0.08
	Gymnodiniaceae	*Gymnodinium fuscum*			2	2	0.08
	Kareniaceae	*Karenia brevis*		1		1	0.04
Sub-total			***7***	***9***	***3***	***19***	***0.72***
Euglenophyta	Euglenaceae	*Lepocinclis spirogyra*		2		2	0.08
	Euglenaceae	*Lepocinclis spirogyroides*			3	3	0.11

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DIVISION	FAMILY	SPECIES	Station 1	Station 2	Station 3	Total	% Abundance
	Euglenaceae	*Phacus longicauda*		12		12	0.45
	Euglenaceae	*Strombomonas acuminata*	2	1		3	0.11
	Euglenaceae	*Strombomonas deflandrei*			3	3	0.11
	Euglenaceae	*Trachelomonas oblonga*		30		30	1.13
	Euglenaceae	*Trachelomonas volvocina*			2	2	0.08
	Chaetocerotaceae	*Chaetoceros furcellatus*		30		30	1.13
Sub-total			***2***	***75***	***8***	***85***	***3.20***
Charophyta	Phymatodocidaceae	*Phymatodocis nordstedtiana*	3			3	0.11
	Desmidiaceae	*Arthrodesmus convergens*		1		1	0.04
	Closteriaceae	*Closterium incurvum*	51			51	1.92
	Closteriaceae	*Closterium lineatum*	8			8	0.30
	Closteriaceae	*Closterium lunula*		7		7	0.26
	Closteriaceae	*Closterium moniliferum*		2		2	0.08
	Closteriaceae	*Closterium pseudolunula*	2			2	0.08
	Closteriaceae	*Closterium striolatum*		11		11	0.41
	Closteriaceae	*Closterium venus*	2			2	0.08
	Desmidiaceae	*Cosmarium botrytis*		1		1	0.04
	Desmidiaceae	*Cosmarium turpinii*	10			10	0.38
	Desmidiaceae	*Desmidium swartzii*	1			1	0.04
	Desmidiaceae	*Euastrum pectinatum*	14			14	0.53
	Desmidiaceae	*Gonatocerus kinahanii*	14		30	44	1.66
	Desmidiaceae	*Gonatozygon kinahanii*	18			18	0.68
	Desmidiaceae	*Hyalotheca dissii*	4			4	0.15
	Desmidiaceae	*Hyalotheca mucosa*		13		13	0.49
	Desmidiaceae	*Micrasterias apiculata*	52	2	15	69	2.60
	Desmidiaceae	*Micrasterias americana*		3	9	12	0.45
	Desmidiaceae	*Micrasterias conferta*	3			3	0.11
	Desmidiaceae	*Micrasterias furcata*	2		2	4	0.15
	Desmidiaceae	*Micrasterias mahabuleshwarensis*	4		3	7	0.26
	Desmidiaceae	*Micrasterias radiata*	4		3	7	0.26
	Desmidiaceae	*Micrasterias sp.*			10	10	0.38
	Desmidiaceae	*Micrasterias thomasiana*		8		8	0.30
	Mougeotiaceae	*Mougeotia genuflexa*	1	4	1	6	0.23
	Mougeotiaceae	*Mougeotia sphaerocarpa*	1	11		12	0.45
	Mougeotiaceae	*Mougeotiopsis calospora*	5	23		28	1.06
	Desmidiaceae	*Pleurotaenium bimaculoides*			12	12	0.45
	Desmidiaceae	*Pleurotaenium coronatum*	1		5	6	0.23
	Desmidiaceae	*Pleurotaenium convergens*	14			14	0.53
	Desmidiaceae	*Pleurotaenium trabecula*	11		8	19	0.72
	Desmidiaceae	*Pleurotaenium subcoronatatum*		5		5	0.19

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DIVISION	FAMILY	SPECIES	Station 1	Station 2	Station 3	Total	% Abundance
	Zygnemataceae	*Spirogyra communis*	42	44	39	125	4.71
	Zygnemataceae	*Spirogyra dubia*	6	17	39	62	2.34
	Zygnemataceae	*Spirogyra karnalae*	108	12	15	135	5.09
	Zygnemataceae	*Spirogyra porticalis*	112	9	138	259	9.76
	Zygnemataceae	*Spirogyra sp.*	1			1	0.04
	Desmidiaceae	*Staurastrum grandiosum*	8			8	0.30
	Desmidiaceae	*Staurastrum tirdium*	1			1	0.04
	Desmidiaceae	*Staurodesmus glaber*			4	4	0.15
	Zygnemataceae	*Zygnema pectinatum*	24			24	0.90
Sub-total			***527***	***173***	***333***	***1033***	***38.94***
Total			1132	659	862	2653	100

The taxonomic composition, spatial distribution, and relative abundance of phytoplankton recorded at three sampling stations along the Adofi River vary among stations. A total of 2,653 phytoplankton individuals belonging to six divisions—Ochrophyta, Chlorophyta, Cyanobacteriophyta, Dinoflagellata, Euglenophyta, and Charophyta—were identified, indicating a relatively rich and diverse phytoplankton community in the river as presented in Table 2. Such diversity generally reflects heterogeneous microhabitats, varying nutrient gradients, and adequate light penetration along the river course.

Ochrophyta was the most dominant division, contributing 1,237 individuals (46.63%) of the total phytoplankton abundance. This group was represented mainly by diatom families such as Fragilariaceae, Naviculaceae, Melosiraceae, Cymbellaceae, and Aulacoseiraceae. Species including *Fragilaria crotonensis*, *Diadesmis confervacea*, *Melosira moniliformis*, *Pseudo-nitzschia* sp., and *Aulacoseira thwaitesii* were particularly abundant.

Charophyta comprised 1,033 individuals (38.94%), making it the second-most abundant division. This group was largely represented by desmids and filamentous green algae, especially members of the families Zygnemataceae and Desmidiaceae. The genus *Spirogyra* showed remarkable dominance, with *Spirogyra porticalis* (9.76%), *S. karnalae* (5.09%), and *S. communis* (4.71%) contributing significantly to total abundance.

Cyanobacteriophyta accounted for 211 individuals (7.95%), with *Oscillatoria princeps* and *Spirulina major* being the most abundant species. Although cyanobacteria were not dominant, their noticeable presence—particularly at Stations 2 and 3—may indicate localized nutrient enrichment, possibly from runoff or anthropogenic inputs.

Chlorophyta recorded 68 individuals (2.56%). The relatively low abundance of this group may suggest competitive exclusion by diatoms and charophytes, which were better adapted to the prevailing flow and nutrient conditions.

Euglenophyta contributed 85 individuals (3.20%), with species such as *Trachelomonas oblonga* and *Phacus longicauda* being more prominent at Station 2.

Dinoflagellata were the least abundant group, with only 19 individuals (0.72%).

Spatial Distribution Across Stations

Station 1 recorded the highest total phytoplankton abundance (1,132 individuals), followed by Station 3 (862 individuals) and Station 2 (659 individuals). The higher abundance at Station 1 may be attributed to favorable hydrological and nutrient conditions, while variations among stations reflect local environmental differences, including flow velocity, nutrient inputs, and anthropogenic influences

Table 3: Diversity Indices of Phytoplankton in Adofi River

	Stn 1	Stn 2	Stn 3
Taxa_S	6	6	6
Individuals	1132	659	862
Dominance_D	0.4537	0.3216	0.3556
Simpson_1-D	0.5463	0.6784	0.6444
Shannon_H	0.9076	1.342	1.179
Evenness_e^H/S	0.4131	0.6381	0.5417
Brillouin	0.8971	1.322	1.164
Menhinick	0.1783	0.2337	0.2044
Margalef	0.7111	0.7703	0.7397

Table 3 summarizes key ecological diversity indices used to describe the structure, richness, dominance, and evenness of phytoplankton communities at the three sampling stations (Stations 1–3) in the Adofi River. These indices provide insight into how individuals are distributed among taxa and the relative stability of the phytoplankton assemblage across stations.

Species richness (Taxa_S) was the same at all stations (S = 6), indicating that each station supported phytoplankton from the same number of major taxonomic groups. However, total abundance differed considerably, with Station 1 recording the highest number of individuals (1,132), followed by Station 3 (862) and Station 2 (659). This suggests spatial variation in productivity and/or environmental conditions that influence phytoplankton growth, rather than differences in taxonomic presence.

The Dominance index (D) was highest at Station 1 (0.4537), indicating that a few taxa contributed disproportionately to total

abundance at this station. In contrast, Station 2 showed the lowest dominance (0.3216), suggesting a more balanced distribution of individuals among taxa. This pattern is corroborated by the Simpson diversity index (1–D), which was highest at Station 2 (0.6784), followed by Station 3 (0.6444), and lowest at Station 1 (0.5463). Higher Simpson values reflect greater diversity and lower dominance, confirming that Station 2 supported the most diverse phytoplankton assemblage.

The Shannon–Wiener index (H') ranged from 0.9076 at Station 1 to 1.342 at Station 2, with Station 3 recording an intermediate value (1.179). These relatively low-to-moderate values suggest moderate phytoplankton diversity across the river, with Station 2 again exhibiting the highest diversity. The Brillouin index followed a similar trend, reinforcing the conclusion that Station 2 had a more evenly structured community with less dominance by a few taxa.

Evenness (e^H/S) and Equitability (J) values further illustrate differences in community structure. Station 2 recorded the highest evenness (0.6381) and equitability (0.7492), indicating a more uniform distribution of individuals among taxa. Station 1 had the lowest evenness (0.4131) and equitability (0.5065), suggesting that certain phytoplankton groups were highly dominant at this station. Station 3 showed intermediate values, reflecting moderate balance in species distribution.

Menhinick and Margalef indices, which emphasize species richness relative to the number of individuals, were highest at Station 2 and lowest at Station 1. Despite equal numbers of taxa, these results reflect differences in individual abundance, with Station 2 exhibiting comparatively higher richness per individual and, therefore, a more stable and less crowded community.

DISCUSSION

The phytoplankton assemblage of the Adofi River exhibited moderate species diversity and high abundance, indicating generally favorable conditions for primary productivity and ecosystem functioning. Although species richness was uniform across stations (S = 6), total abundance varied considerably, with Station 1 recording the highest number of individuals (1,132), followed by Station 3 (862) and Station 2 (659). Diversity indices further clarified community structure: the Shannon–Wiener index (H') ranged from 0.91 to 1.34, while Simpson's diversity index (1–D) ranged from 0.55 to 0.68, indicating low-to-moderate diversity typical of tropical freshwater systems under moderate environmental control.

Diatoms (Ochrophyta) and charophytes were the dominant groups, consistent with observations from other Nigerian freshwater ecosystems where these taxa thrive under stable, well-oxygenated conditions (Amoda et al., 2025; Iloba, 2018). The dominance of genera such as *Fragilaria*, *Melosira*, and *Diadesmis* reflects a community structured around efficient primary producers adapted to flowing water conditions. Unlike previous studies on the Adofi River that focused mainly on physicochemical parameters (Akawo et al., 2025; Iloba et al., 2019), this study provides a novel contribution by integrating phytoplankton community structure as a biological indicator of ecosystem health, thereby offering a more holistic understanding of river functionality.

The observed phytoplankton composition reflects underlying physicochemical conditions within the river. The dominance of diatoms and the presence of *Spirogyra* spp. suggest moderate nutrient availability, good light penetration, and near-neutral pH, conditions typically associated with relatively unpolluted freshwater systems. These findings align with earlier reports indicating that stable diatom communities are often linked to moderate anthropogenic influence and effective natural self-purification processes (Iloba, 2018).

Spatial variations in abundance and diversity indices further indicate environmental heterogeneity across stations. For instance, Station 2 exhibited the highest diversity (H' = 1.34; Simpson = 0.68) and evenness (J = 0.75), suggesting a more balanced and stable habitat. In contrast, Station 1 showed higher dominance (D = 0.45) and lower evenness, indicating that a few taxa disproportionately contributed to total abundance, possibly due to localized environmental conditions favoring specific groups.

Ecologically, Shannon index values below 1.5 and moderate Simpson values generally indicate mesotrophic conditions, while highly eutrophic or polluted systems often show very low diversity dominated by a few tolerant taxa. Thus, the observed indices suggest that the Adofi River is not yet ecologically stressed but lies within a moderately productive range.

Despite generally favorable conditions, there is evidence of localized anthropogenic influence within the river system. The gradual increase in Cyanobacteriophyta downstream suggests nutrient enrichment likely arising from agricultural runoff and domestic waste inputs, a pattern consistent with other Nigerian rivers experiencing moderate human pressure (Olatunji, 2025; Anyanwu et al., 2022). However, cyanobacteria remain relatively low in dominance, indicating that nutrient levels have not yet reached thresholds associated with harmful algal blooms or severe eutrophication.

The backwater environment (Station 2), while exhibiting the highest diversity, may also reflect localized organic inputs that enhance nutrient availability without causing ecological imbalance. In more heavily impacted systems, such conditions would typically lead to dominance by pollution-tolerant taxa such as Cyanophyceae and Chlorophyceae (Adamu et al., 2024). The absence of such dominance in the Adofi River suggests that current nutrient enrichment is in its early stages and has not yet disrupted ecological stability.

Overall, the phytoplankton community structure indicates a resilient freshwater ecosystem capable of maintaining functional balance despite moderate anthropogenic pressures. However, the emerging presence of indicator species associated with nutrient enrichment highlights the need for continued monitoring to prevent progression toward eutrophic conditions.

Conclusion

This study provides a comprehensive assessment of the physicochemical characteristics and phytoplankton community structure of the Adofi River, thereby contributing valuable insight into the ecological condition of a tropical freshwater system subjected to both natural environmental controls and moderate anthropogenic influences. The results indicate that most measured physicochemical parameters remained within internationally recommended standards for freshwater ecosystems, suggesting that the Adofi River currently maintains generally good water quality. However, observable spatial and seasonal variations in nutrient concentrations, sulphate levels, and biochemical oxygen demand highlight the influence of agricultural runoff, domestic activities, and catchment-scale processes.

The Adofi River exhibits a gradient of ecological conditions. The

upstream reach is productive and diatom-dominated, while downstream reaches show early signs of nutrient enrichment. A distinct backwater site (station 2) is impacted by point-source organic waste.

Phytoplankton composition further supports these observations, indicating a moderately balanced ecosystem with no evidence of severe ecological stress. However, the low abundance of pollution-tolerant species, especially in downstream sections, indicates early signs of nutrient enrichment rather than severe eutrophication.

To sustain the current ecological status of the Adofi River, regular monitoring of water quality and plankton dynamics is recommended, along with implementing management strategies to control nutrient inputs from agricultural and domestic sources. Such measures will help prevent further ecological deterioration and ensure the long-term health of the river system.

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