Sigma J Eng Nat Sci, Vol. 44, No. 5, pp. 3055–3066, October, 2026

Sigma Journal of Engineering and Natural Sciences
Web page info: https://sigma.yildiz.edu.tr
DOI: 10.14744/sigma.2026.2143

Research Article

Assessing the water quality of a rural South-Eastern Nigeria river using water quality assessment indices

Emeka Donald ANYANWU[1,*], Sharmine Akter SIMU[2], Onyinyechi Gladys ADETUNJI[1], Amarachi Grace STEPHEN[1]

[1]*Department of Zoology and Environmental Biology, Michael Okpara University of Agriculture, Umudike, 440109, Nigeria*
[2]*Department of Environmental Sciences, Jahanagirnagar University, Dhaka, 1342, Bangladesh*

ARTICLE INFO

Article history
Received: 28 December 2024
Revised: 27 February 2025
Accepted: 05 May 2025

Keywords:
Anthropogenic Activities; Indices; Limits; Season; Water Quality

ABSTRACT

Poor or no regulatory framework and lack of public awareness in developing countries leads to the misuse of surface water bodies to the detriment of aquatic organisms. This study evaluated a river in rural South-east Nigeria to determine its capacity to sustain diverse aquatic organisms from May to October 2023. The study was carried out in three stations using standard methods and four (4) water quality assessment indices. Sixteen (16) physicochemical parameters were evaluated vis-a-vis national standard. The results were: temperature (25.2–27.0), pH (5.6–7.8), turbidity (0.1-1.7NTU), dissolved oxygen (3.2–6.4mg/l), total suspended solids (1.0-3.1mg/l), biochemical oxygen demand (1.0-2.7mg/l), chloride (39.2-80.7mg/l), chemical oxygen demand (5.2-22.3mg/l), phosphate (0.01-0.04mg//l), ammonia-nitrogen (0.12–0.42mg/l), nitrate (0.02-0.08mg/l), sulphate (0.01-0.04mg/l), sodium (0.40-1.21mg/l), potassium (0.08-0.45mg/l), calcium (1.42-2.77mg/l) and magnesium (0.66-2.10mg/l). Dissolved oxygen, ammonia, pH and total suspended solids did not conform to regulatory standards. The indices results were: Water Quality Index (37.90-39.96), Comprehensive Pollution Index (0.24-0.25), Organic Pollution Index (1.06-1.34) and River Pollution Index (2.00-2.75). The indices showed that the river was not adversely polluted. The physicochemical parameters and indices were influenced more by season and less by anthropogenic activities. It can be concluded that the river is still suitable to support aquatic life. However, the observed anthropogenic activities like sand mining, disposal of solid wastes and wastewater discharges from local industries into the river could negatively affect the quality of the water if not checked. Future studies in the river will be anchored on this study as the community develops further.

Cite this article as: Anyanwu ED, Simu SA, Adetunji OG, Stephen AG. Assessing the water quality of a rural South-Eastern Nigeria river using water quality assessment indices. Sigma J Eng Nat Sci 2026;44(5):3055–3066.

***Corresponding author.**
*E-mail address: ekadon@yahoo.com

This paper was recommended for publication in revised form by Editor-in-Chief Ahmet Selim Dalkilic

Published by Yıldız Technical University Press, İstanbul, Turkey
© Author. This is an open access article under the CC BY-NC license (http://creativecommons.org/licenses/by-nc/4.0/).

INTRODUCTION

Every living thing depends on water for life and all human activities are directly or indirectly related to water. Rivers, mostly fresh, are one of the most vital life-sustenance systems on earth; they influence natural events in both aquatic and terrestrial ecosystems [1]. They are also home to different types of aquatic organisms. Water quality is very important in determining the composition, numbers and spread of organisms living in water. Consequently, water quality degradation can negatively affect the biodiversity of the aquatic community. Water quality degradation can result from natural processes and anthropogenic activities, which could be influenced by season. However, anthropogenic activities are the major source of pollution in water bodies [2-6]. River water quality degradation is increasingly becoming a global environmental issue [7]. Rural areas like Ohiya community are not spared. Cottage industries and enterprises are springing up to boost their economies, with potentials for negative environmental footprints. The determination of quality status of a waterbody is by analysing its physicochemical characteristics in relation to local and international frameworks for regulating water quality. Determination of the quality includes rapid interpretation of data, which will help to understand the dynamics and influence of natural and anthropogenic activities on the waterbody [8]. However, when the parameters involved are many, interpretation of the water quality could be challenging. Therefore, there is need to apply some indices to help deduce the status of the water. Some indices for assessing the quality status of waterbodies have been developed and used in recent times. However, this study applied Organic Pollution Index (OPI), Comprehensive Pollution Index (CPI), Water Quality Index (WQI) and River Pollution Index (RPI). Ahi is an important rural river used by Ohiya community, Umuahia for different domestic purposes (including drinking during the dry season) and waste disposal, which could negatively affect the quality for other purposes. Studies on such small rural rivers that could sustain diverse aquatic organisms are often overlooked by researchers. The increasing human population, activities around the community due to its nearness to city centre and location of the city's mechanic village and motor spare parts market necessitated this study because of their potential impact on the river. To the best of our knowledge, the river has not been previously assessed. Hence, the objective of this study is to evaluate the status of Ahi River to determine its capacity to sustain diverse aquatic organisms by applying some indices of water quality.

MATERIALS AND METHODS

Description Study Location

Ahi lotic system is a freshwater body situated within Ohiya community in Umuahia, Southeast Nigeria (Fig. 1). The community is fast growing due its closeness to the city centre and host to the city's mechanic village and vehicle spare parts market. It is a forth order River that discharges into Imo River basin. The study area experiences

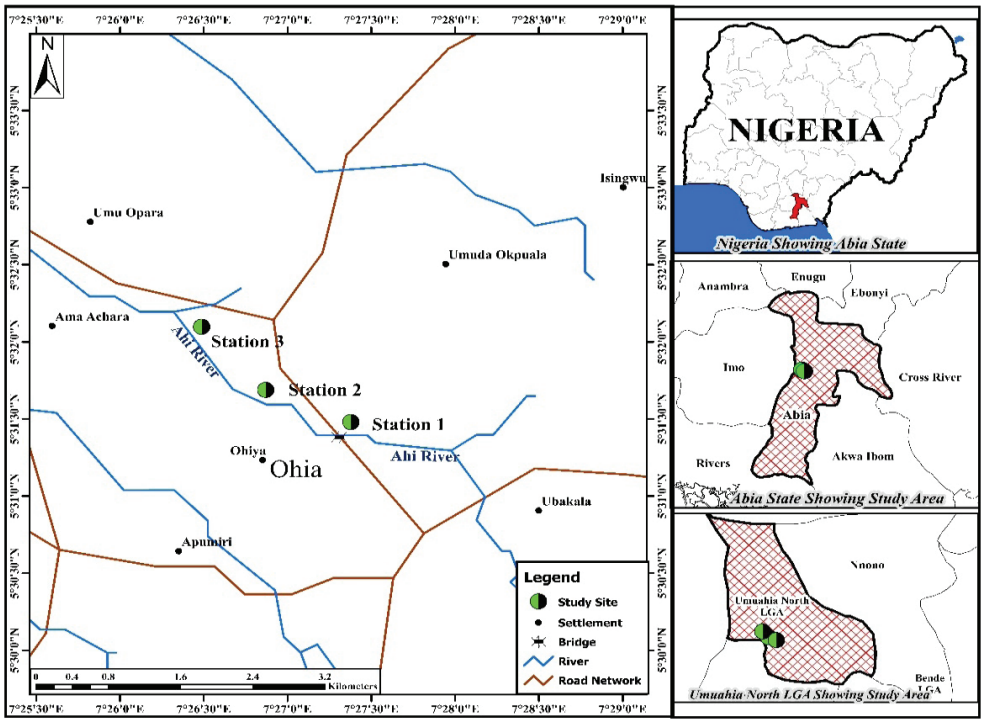


Figure 1. Map of Ahi River, Ohiya, Umuahia, Nigeria showing the sampling stations.

high temperatures (29.00-31.00°C), annual mean rainfall (≈ 4000mm), and high relative humidity (>70%); characteristic of sub-equatorial zone [9]. Two major seasons namely; wet season (usually from May to October) and dry season (usually from November to April) prevail over the study area with rainfall peaks often occurring July and September each year. However, a break usually exists in between late July and Mid-August referred to as "August Break". Station 1 (upstream) is adjacent to a road. Laundry and traditional worship activities are the majors activities observed around the station. Runoff from the upper section of the community discharges into the station. Station 2 (midstream) is located about a distance of 0.97 km after station 1. Wastewaters from solid wastes dumped around the station are washed into the station via runoff. Sand mining, food processing, bathing and washing also occur in the station. Station 3 (downstream) sited within a gully is about a distance of 1.83 km away from station 2. Minimal human activities were observed due to the difficult terrain. Periodic activities like bathing and washing were noted. Also, some cottage industries discharge their wastewaters into the river around station 3.

Sampling Protocol and Analyses

The water sampling was done in Ahi River monthly from May to October 2023. Water sampler was used to collect the samples, transferred into 1litre plastic bottles and sent to the laboratory preserved with ice for analysis. Determination of the physicochemical parameters was based on standard analytical methods [10]– pH was determined with Jenway 550 Portable pH meter while turbidity was determined with Jenway 6035 Portable Turbidimeter. Total suspended solids was measured using Gravimetric Method. Dissolved oxygen was evaluated in-situ hand-held Dissolved Oxygen Meter (Jenway Model 970) while biochemical oxygen demand (BOD_5) was measured with Winkler Method (Azide Modification). Chemical oxygen demand was measured with Open Reflux Method. Nitrate and ammonia-nitrogen were measured by Thermo Scientific Orion AquaMate 8100 UV-Vis Spectrophotometer while phosphate was determined with Stannous Chloride Method. Sulphate and chloride were determined by Turbidimetric and Argentometric Methods respectively, while the cations (potassium, sodium, calcium and magnesium were quantified with UNICAM Solaar 969 atomic absorption spectrometer.

Application of Water Quality Indices

Water quality index

Weighted Arithmetic Mean Water Quality Index (WAMWQI) is a commonly employed tool by researchers to deduce the status of waterbodies for different purposes [11, 12]. Thirteen parameters - sulphate, sodium, potassium, calcium, magnesium, chloride, pH, phosphate, dissolved oxygen, ammonia-nitrogen, biochemical oxygen demand, turbidity, chemical oxygen demand, and nitrate were used. Equation 1 described by Brown et al. [13] was used to estimate the index.

$$WQI = \frac{\sum Q_i w_i}{\sum w_i} \quad (1)$$

Where, Qi represent the water quality rating of each water quality parameter, and Wi ($\sum Wi = 1$) represent the unit weight of each water quality parameter. The quality rating scale (Qi) was calculated for each parameter with Equation 2 below:

$$Qi = \frac{100\,(C_i - V_0)}{S_i - V_0} \quad (2)$$

Ci = the determined concentration of each parameter in the water sample; S*i* = the acceptable limit of each parameter based on National Environmental (surface and groundwater quality control) Regulations [14]. V_0 = the optimal value for each parameter is 0 while pH is 7 and DO is 14.6 mg/L.

Equation 3 was used to estimate W*i* (unit weight) for each parameter:

$$Wi = K/Si \quad (3)$$

$$\text{Where } K = \frac{1}{\sum\langle\frac{1}{S_i}\rangle}$$

Comprehensive pollution index (CPI)

Comprehensive pollution index (CPI) gives the arithmetic mean by adding up all the single factor indices. This method determines the pollution status of rivers as well as the water quality changing trend [15]. CPI was calculated using the equation proposed by Jiang et al. [16]:

$$CPI = \frac{1}{n}\sum_{i=o}^{n} PI_i \quad (4)$$

Where, CPI stands for Comprehensive Pollution Index, *n* represents the total number of water characteristics evaluated while PIi represent the pollution index number (*i*).

The calculation of PI_i was done with equation 5:

$$PI_i = \frac{C_i}{S_i} \quad (5)$$

Where, *Ci* represent the mean concentration of the water characteristics evaluated, *Si* represent the acceptable limit for each water characteristic based on Nigeria environmental standard [14]. The same 13 water parameters used for WQI were also used in the determination of CPI.

River pollution index (RPI)

This index is a simplified integrated instrument used for determining of the pollution status of a river [17]. The individual parameters used in the determination of this index was converted into any of four index scores (S*i* = 1,

3, 6, 10). Dissolved oxygen, biochemical oxygen demand, total suspended solids and ammonia-nitrogen are the four water characteristics used in determining this index. RPI is the arithmetic mean of the index scores in relation to the parameters presented in Table 1. The calculation of RPI was by equation 6 according to Chen et al. [17].

$$RPI = \frac{1}{n}\sum_{i=1}^{4} S_i \quad (6)$$

With the index scores represented as Si while RPI values ranged between 1 and 10.

Organic pollution index (OPI)

Organic pollution level of any waterbody can be deduced with OPI and its modifications [18]. The calculation was done with parameters like chemical oxygen demand, nitrate, phosphate, ammonia-nitrogen, and biochemical oxygen demand based on the equation by Boluda et al. [19].

$$OPI = \frac{\sum\left(\frac{C_i}{C_{mi}}\right)}{n}$$

Where, Ci represent the mean concentration of each water characteristic, Cmi represents the acceptable limit for each characteristic while n represent all the water characteristic evaluated. Water with OPI value > 1 is considered polluted [19].

Data Analysis

The resultant data was summarized with Microsoft Excel package. Significant differences between the stations were determined with single-factor ANOVA. The relationships between water characteristics were deduced using Pearson correlation coefficient.

RESULTS

Spatio-Temporal Trend

The results of physico-chemical parameters evaluated in Ahi River were summarized and shown in Table 2. In all the evaluated parameters, the spatial differences were not significant ($p>0.05$).

The temperatures of the water were moderate; ranging from 25.2 to 27.0°C. Station 2 had the lowest value in June 2023 while stations 1 and 2 had the maximum concentrations in May 2023. Station 3 had water temperatures that were generally low (Fig. 2a).

The water pH ranged from 5.6 to 7.8; representing moderate acidic to slight alkaline conditions with most values within 6.5 – 8.5 prescribed by NESREA [14]. The acidic values outside the acceptable limit were observed in May and June 2023. However, in the 3 station, the pH increased with increased precipitation (Fig. 2b). Station 3 had the least pH concentration in June 2023 while station 1 had the maximum concentration in September 2023.

Turbidity had values ranging from 0.1 to 1.7 NTU that were within the regulatory standard of 5 NTU prescribed by NESREA [14]. Station 3 had the least concentration in June 2023 and the maximum was in August 2023 at station 2 (Fig. 2c).

Total Suspended Solids (TSS) varied from 1.0 to 3.1 mg/l. The values did not conform to regulatory standard (0.25 mg/l) prescribed by NESREA [14]. Station 3 had the least concentration in June 2023 and station 1 had the maximum concentrations in May and July 2023 (Fig. 2d).

The concentrations of Dissolved Oxygen (DO) were between 3.2 and 6.4 mg/l. Only one value observed in station 3 (June 2023) conformed to regulatory standard (>6 mg/l) prescribed by NESREA [14]. However, all the stations had increased values in that month (Fig. 2e). Station 1 had the least concentration in October 2023 and station 3 had the maximum concentration in June 2023 (Fig. 2e).

The biochemical oxygen demand concentrations (1.0 - 2.7 mg/l) were in line with the regulatory standard (3 mg/l) prescribed by NESREA [14] with the least and maximum concentrations observed in stations 1 and 3 in June 2023 respectively. The BOD concentrations generally increased with precipitation in all the stations (Fig. 2f).

Chemical Oxygen Demand (COD) varied from 5.2 to 22.3 mg/l. The regulatory standard (30 mg/l) prescribed by NESREA [14] was maintained. Station 3 had the least concentration in June 2023 and station 1 had the maximum concentration in September 2023 (Fig. 2g).

Chloride concentrations varied from 39.2 to 80.7 mg/l. The regulatory standard (300 mg/l) prescribed by NESREA

Table 1. Parameters and classes used in River Pollution Index (RPI) determination [17]

Parameters/Ranks	Good	Less polluted	Moderately polluted	Highly polluted
DO (mg/L)	>6.5	4.6-6.5	2.0-4.5	<2.0
BOD5 (mg/L)	<3.0	3.0-4.9	5.0-15	>15
TSS (mg/L)	<20	20-49	50-100	>100
NH_3-N (mg/L)	<0.5	0.5-0.9	1.0-3.0	>3.0
Index scores (Si)	1	3	6	10
Sub-index	<2	2.0 - 3.0	3.1 - 6.0	>6.0

Table 2. Summarized results of the water quality characteristics evaluated in Ahi River, Southeast Nigeria

Parameters	Station 1	Station 2	Station 3	P- Value	NESREA [14]
Water Temperature (°C)	26.3±0.17	26.1±0.25	25.9±0.07	F = 0.96	-
	(25.9-27.0)	(25.2–27.0)	(25.6–26.0)	P > 0.05	
pH	6.85±0.31	6.85±0.32	6.81±0.87	F = 0.00	6.5-8.5
	(5.7–7.8)	(5.7–7.7)	(5.6–7.7)	P > 0.05	
Turbidity (NTU)	0.88±0.12	0.80±0.20	0.65±0.17	F = 0.47	5
	(0.3–1.1)	(0.2–1.7)	(0.1–1.4)	P > 0.05	
Total Suspended	2.70±0.16	2.35±0.27	2.07 ± 0.27	F = 1.23	0.25
Solids (mg/l)	(2.1–3.1)	(1.3-3.0)	(1.0–2.7)	P > 0.05	
Dissolved Oxygen (mg/l)	3.93±0.29	3.97±0.30	4.80±0.38	F = 0.40	>6
	(3.2 – 5.2)	(3.4–5.2)	(3.8–6.4)	P > 0.05	
Biochemical Oxygen	1.77±0.26	1.97±0.17	2.20±0.23	F = 0.97	3
Demand (mg/l)	(1.0–2.6)	(1.5–2.4)	(1.2–2.7)	P > 0.05	
Chemical Oxygen	15.13±1.88	12.92±1.60	11.5±1.95	F = 1.01	30
Demand (mg/l)	(10.2–22.3)	(7.4–17.3)	(5.2–18.4)	P > 0.05	
Chloride (mg/l)	64.17±4.04	59.77±3.76	56.17±4.27	F = 0.99	300
	(55.1–80.7)	(47.2–75.3)	(39.2–70.1)	P > 0.05	
Phosphate (mg/l)	0.03±0.00	0.02±0.00	0.02±0.00	F = 0.62	3.5
	(0.02–0.04)	(0.01-0.03)	(0.01 – 0.03)	P > 0.05	
Ammonia-N (mg/l)	0.28±0.03	0.25±0.04	0.21±0.03	F = 1.11	0.05
	(0.19–0.42)	(0.15–0.38)	(0.12–0.28)	P > 0.05	
Nitrate-N (mg/l)	0.05±0.00	0.05±0.00	0.04±0.00	F = 0.72	9.1
	(0.03–0.8)	(0.03–0.6)	(0.02–0.05)	P > 0.05	
Sulphate (mg/l)	0.03±0.00	0.02±0.00	0.01±0.00	F = 1.30	100
	(0.02–0.04)	(0.01–0.04)	(0.01–0.03)	P > 0.05	
Sodium (mg/l)	0.72±0.05	0.71±0.11	0.61±0.07	F = 0.52	120
	(0.53–0.92)	(0.44–1.21)	(0.40–0.82)	P > 0.05	
Potassium (mg/l)	0.21±0.03	0.22±0.06	0.17±0.05	F = 0.41	50
	(0.11–0.30)	(0.08–0.45)	(0.08–0.37)	P > 0.05	
Calcium (mg/l)	2.20±0.12	2.11±0.17	1.84±0.15	F = 1.62	180
	(1.80–2.66)	(1.59–2.77)	(1.42–2.45)	P > 0.05	
Magnesium (mg/l)	1.40±0.17	1.33±0.20	1.15±0.21	F = 0.43	40
	(0.89–2.10)	(0.72–1.87)	(0.66–1.97)	P > 0.05	

NESREA [14] = National Environmental (surface and groundwater quality control) Regulations.

[14] was maintained. Station 3 had the least concentration in July 2023 and station 1 had the maximum concentration in May 2023 (Fig. 2h).

The phosphate values were low (0.01 -0.04 mg//l) and followed the regulatory standard (3.5 mg/l) prescribed by NESREA [14]. Station 3 had the least concentrations in June and July 2023 and station 1 had the maximum concentration in September 2023 (Fig. 2i).

Ammonia-nitrogen concentrations varied from 0.12 to 0.42 mg/l. The regulatory standard (0.05 mg/l) prescribed by NESREA [14] was surpassed by all the concentrations. Station 3 had the least concentration in October 2023 and station 1 had the maximum concentration in May 2023 (Fig. 2j).

The nitrate values were low (0.02 - 0.08 mg/l) and conformed to the regulatory standard (9.1 mg/l) prescribed by NESREA [14]. Station 3 had the least concentration in October 2023 and station 1 had the maximum concentration in May 2023. The values decreased from May to October 2023 especially as the rains increased in all the stations except for stations 2 and 3 in August 2023(Fig. 2k).

Sulphate concentrations were also low (0.01 - 0.04 mg/l) and met the regulatory standard (100 mg/l) prescribed by NESREA [14]. Stations 2 and 3 had the least concentrations

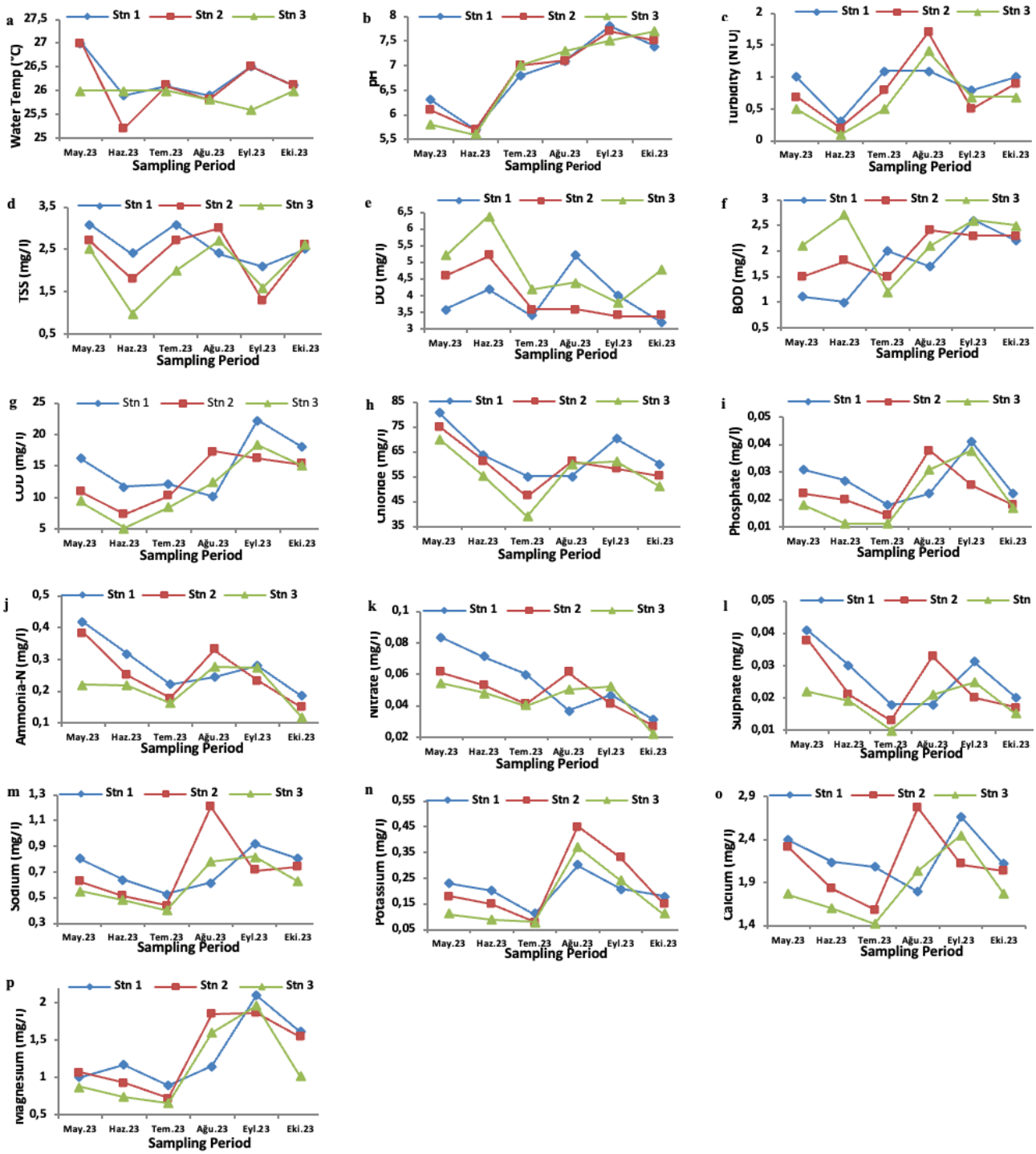


Figure 2. Spatiotemporal variations of the parameters (a: Water Temp., b: pH, c: Turbidity, d: TSS, e: DO, f: BOD, g: COD, h: Chloride, i: Phosphate, j: Ammonia-nitrogen, k: Nitrate, l: sulphate, m: sodium, n: Potassium, o: Calcium, p: Magnesium).

in July 2023 and stations 1 and 2 had the maximum concentrations in May 2023 (Fig. 2l).

The sodium concentrations were also low (0.40 - 1.21 mg/l) and met the regulatory standard (120 mg/l) prescribed by NESREA [14]. Station 3 had least concentration in July 2023 and station 2 had the maximum concentration in August 2023 (Fig. 2m).

The potassium concentrations were also low (0.08 - 0.45 mg/l) and conformed to the regulatory standard (50 mg/l) prescribed by NESREA [14]. Stations 2 and 3 had the least

Table 3. Values of water quality assessment indices and their categories (Brown et al. [13], Yang et al. [15], Chen et al. [17], Helal et al. [18])

Indices	Station 1	Station 2	Station 3	Water Quality Categories*
Water Quality Index	37.90	39.04	39.96	0-25 (Excellent), 26-50 (Good), 51-75 (Poor), 76-100 (Very Poor) and >100 (Inappropriate for intended use)
Comprehensive Pollution Index	0.24	0.24	0.25	<0.20 (Clean), 0.21-0.40 (Sub clean), 0.41-0.70 (slightly polluted), 0.71-1.00 (moderately polluted), 1.01-2.00 (heavily polluted) and ≥ 2.01 (severely polluted)
Organic Pollution Index	1.34	1.22	1.06	Excellent = 0.0-4, Good = 0.0-1.0, Slightly Polluted = 1.0-4.0, Heavily polluted = 4.0-5.0
River Pollution Index	2.75	2.75	2	Good = <2, Less polluted = 2.0-3.0, Moderately polluted = 3.1-6.0, Highly polluted = >6.0

concentrations in July 2023 and station 2 had the maximum concentration in August 2023 (Fig. 2n).

The calcium values were also low (1.42 - 2.77 mg/l) and conformed to the regulatory standard (180 mg/l) prescribed by NESREA [14]. Station 3 had the least concentration in July 2023 and station 2 had the maximum concentration in August 2023 (Fig. 2o).

The magnesium values were also low (0.66 - 2.10 mg/l) and conformed to the regulatory standard (40 mg/l) prescribed by NESREA [14]. Station 3 had the least concentration in July 2023 and station 1 had the maximum concentration in September 2023 (Fig. 2p).

Correlation analysis showed that pH had significant positive correlation with BOD (0.941), EC with TDS (1.000), sulphate with EC and TDS (0.895), DO with potassium (0.800), calcium with COD (0.851) and sodium (0.874) in station 1. In station 2, pH had significant positive correlation with COD (0.830), EC with TDS (0.995), sulphate with EC (0.917), TDS (0.889) and calcium (0.801), sodium with turbidity (0.844), potassium (0.891) and calcium (0.916), calcium with potassium (0.857) and BOD with COD (0.834). In station 3, COD had significant positive correlation with pH (0.819), sodium (0.817) and calcium (0.816), potassium with turbidity (0.879) and sodium (0.839), calcium with sulphate (0.806) and sodium (0.946) and EC with TDS (0.995). However, a few negative correlations were observed. DO with pH (-0.973) and COD (-0.806) in station 2 and DO with pH (-0.808) in station 3.

Water Quality Assessment Indices

The four (4) assessment indices showed slight spatial deviations in the quality status of the river water (Table 3). Water quality index (WQI) values ranged between 37.90 and 39.96 and indicated that the quality of the water was good. The comprehensive pollution index (CPI) ranged between 0.24 and 0.25 and within sub clean category. Station 3 had the maximum levels of WQI and CPI.

Organic pollution index (OPI) showed that the water was polluted; having OPI > 1 in all stations while river pollution index (RPI) indicated less pollution with values falling within 2.0 – 3.0. The maximum levels of OPI and RPI were observed in station 1 and stations 1 and 2 respectively.

DISCUSSION

Season (precipitation) and to a lesser extent anthropogenic activities were the major influencers of the conditions observed in the river. Most of the quality characteristics had moderate values or within acceptable limits suitable to sustain aquatic life. The water temperatures were moderate. Rainfall event during sampling in June 2023 could be responsible for the lowest temperature value observed in station 2 while late dry season effect before the onset of wet season could have influenced the highest values observed in May 2023 for stations 1 and 2. Atmospheric and water temperatures are usually influenced by seasonal patterns [20]. However, location could be responsible for the generally low temperature observed in station 3. The station was located in a deep gully with thick vegetation, which reduced insolation getting to the river. Variations in water temperatures do occur with time within a particular watershed and control aquatic ecosystem health [21]. Odo et al. [22] presented 24.0 – 29.0° C in Akor River, Ikwuano while Anyanwu et al. [23] presented 22.7°C – 24.1°C in Anya stream, Umudike in previous studies in the region.

Most of the pH values were within the regulatory standard. Rainfall event during sampling in June 2023 could be the reason for the acidic pH observed in the 3 stations. Runoff from rainfall events can introduce some allochthonous materials that could reduce the pH of the river [24]. The pH values generally increased in all the stations as the rains increased; attributable to dilution. Huang et al. [25] observed higher pH during the wet season due to dilution of solute concentrations as the river receives more runoff. pH is among the important environmental variable restricting the distribution of species in aquatic ecosystem [26]. The pH levels were in agreement with with related studies. For example, Anyanwu and Umeham [3] presented 4.30 – 6.30 in Eme River, Umuahia, 5.50 – 7.00 was presented by Anyanwu et al. [12] for Ikwu River, Umuahia, Odo et

al. [22] presented 4.60 – 6.60 in Akor River, Ikwuano and 6.00 – 6.60 was presented by Anyanwu et al. [23] in Anya stream, Umudike.

The turbidity values were low and within the regulatory standard. Rainfall event during sampling in June 2023 could be responsible for low turbidity values observed in the 3 stations especially station 3. The elevated levels observed in stations 2 and 3 may be as a result of concentration during the August break. The break also known as short dry season usually result in increased concentrations of some physicochemical parameters because of reduced rainfall and water flow, high temperatures and associated evaporation and transpiration. Anyanwu et al. [23] and Akhere and Kadiri [27] also presented their highest turbidity values in August. Related studies in the region showed that 0.30 – 2.20 NTU was presented by Anyanwu et al. [12] for Ikwu River, Umuahia, Odo et al. [22] presented 0.20 – 1.50 NTU in Akor River, Ikwuano and 0.20 – 3.20 NTU was presented by Anyanwu et al. [23] in Anya stream, Umudike. However, relatively higher values (0.5 – 9.4 NTU) were presented in Eme River, Umuahia by Anyanwu and Umeham [3] due to intensive sand mining activities.

All the Total Suspended Solids (TSS) values exceeded the acceptable limit and not suitable for aquatic life. Rainfall event during sampling in June 2023 could be responsible for the least concentration observed in station 3; attributable to dilution. However, late dry season effect in May 2023 and allochthonous input from runoff in July 2023 could be responsible for the highest values in station 1. This trend of low and high values was also observed in the 3 stations; suggesting similar related influence. Odo et al. [22] presented 0.60 – 4.20 mg/l in a related study in Akor River, Ikwuano. High TSS in the waters can negatively affect water quality and aquatic organisms. It can limit the primary productivity of phytoplankton by reducing light penetration into the water [28]. The feeding organs of filter-feeders could be blocked by elevated TSS levels leading to reduction in the efficiency of feeding and growth [29]. Damage to eggs and gills, larvae mortality and high mortality among juveniles have also been associated elevated TSS [29].

Dissolved oxygen (DO) concentrations were lower than regulatory standard except for station 3 in June 2023 and not suitable to support some sensitive aquatic organisms. The high DO values observed in June in the three stations; could be re-aeration caused by rainfall event during sample collection. Chowfin et al. [30] observed that turbulence caused by rainfall events can lead to aeration and rise in dissolved oxygen concentrations of waterbodies. Reduced photosynthetic activities occasioned by high turbidity and total suspended solids could be responsible for the observed decrease in DO values in all the stations as the rains increased especially in station 1 in October 2023 [28]. DO concentrations above 5 mg/L will be required to sustain diverse aquatic organisms and boost aquaculture productivity [31]. Related studies in the region showed that DO values of 1.60 – 6.10 mg/l was presented in Eme River, Umuahia by Anyanwu and Umeham [3], 1.50 – 6.00 mg/l was presented by Anyanwu et al. [12] in another rural river in Umuahia, Odo et al. [22] presented 3.40 – 6.80 mg/l in Akor River, Ikwuano and 3.50 – 7.50 mg/l was presented by Anyanwu et al. [23] in Anya stream, Umudike.

The biochemical oxygen demand (BOD) concentrations conformed to regulatory standard. Though a trend was observed in all the stations – the concentrations went up as the rainfall increased; suggesting allochthonous introduction via runoff. Low allochthonuous input and dilution following rainfall event during sample collection in June led to the least concentration observed in station 1. Stations 2 and 3 had high values in June 2023; attributed to anthropogenic activities. Station 3 received wastewaters from palm oil production and cassava processing facilities and pig farm while wastewaters from refuse dumps around station 2 and sand mining activities contribute to the high BOD levels [1-6]. Related studies in the region showed that BOD values of 0.80 – 4.30 mg/l was presented in Eme River, Umuahia by Anyanwu and Umeham [3], 0.30 – 3.00 mg/l was presented by Anyanwu et al. [12] in another rural river in Umuahia, Odo et al. [22] presented 1.20 – 2.40 mg/l in Akor River, Ikwuano and 0.50 – 2.20 mg/l was presented by Anyanwu et al. [23] in Anya stream, Umudike.

Chemical Oxygen Demand (COD) values conformed to regulatory standard. The concentrations also increased as the rains increased as observed in BOD. Dilution from rainfall event during sample collection could be responsible for the decreased concentrations observed in the 3 stations particularly station 3 in June 2023. However, the high value observed in station 3 in September 2023 is attributable to allochthonous input from runoff as the rains increased [32]. Related studies in the region showed that COD values of 1.60 – 24.00 mg/l was presented by Anyanwu et al. [12] in another rural river in Umuahia, 0.80 – 34.40 mg/l was presented by Anyanwu et al. [23] in Anya stream, Umudike, However, relatively higher values (5.20 – 69.60 mg/l) were presented in Eme River, Umuahia by Anyanwu and Umeham [3] and 28.00 – 491.00 mg/l was presented in Akor River by Odo et al. [22].

Chloride, ammonia-nitrogen, phosphate and sulphate exhibited a similar trend. Chloride had moderate concentrations that conformed to regulatory standard. Dilution could have contributed to the low concentrations observed in the 3 stations (particularly in station 3) in July 2023. However, the high concentrations observed in the 3 stations (May 2023) particularly in station 1, could be due to concentration caused by late dry season. Related studies in the region showed that chloride values of 5.20 – 69.60 mg/l were presented in Eme River, Umuahia by Anyanwu and Umeham [3], 30.90 – 88.60 mg/l was presented by Anyanwu et al. [23] in Anya stream, Umudike, However, relatively higher values (35.50 – 141.80 mg/l) were presented by Anyanwu et al. [12] in another rural river in Umuahia.

Ammonia-nitrogen values exceeded the regulatory standard and may not be suitable for some sensitive organisms.

Station 3 had the least concentration in October 2023; attributable to dilution [25] because of the high intensity of rain observed in month. The high concentrations observed in May 2023 for stations 1 and 2 was due to concentration caused by late dry season. Some water parameters tend to concentrate during dry season because of reduction in rainfall and discharge, high temperatures and associated evaporation and transpiration. Elsewhere in Nigeria, Ogbeibu and Oriabure [33] presented concentrations of 0.033 mg/l to 0.43 mg/l in Benin River, Edo State. High concentration of ammonia can be fatal to aquatic organisms because it is difficult for them to excrete completely, which will result in toxic accumulation in the internal tissues and blood [34]. Soler et al. [35] described ammonia as a common pollutant in aquatic ecosystems; capable of causing physical damage, behaviour alteration and even death in fish.

Phosphate had low concentrations that conformed to regulatory standard. Dilution contributed to the least concentrations observed in June and July 2023 for station 3 [25]. General reduction in concentration was observed in all the stations from May 2023. Station 1 had the maximum concentration in September 2023; attributed to allochthonous input as the rains increased. Shou et al. [36] observed that the quantity of nutrients (phosphate and nitrate) bearing pollutants in water generally increase as the intensity of rainfall increase. Related studies in the region showed that phosphate concentration of 0.40 – 4.60 mg/l was presented in Eme River, Umuahia by Anyanwu and Umeham [3], 0.02 – 0.35 mg/l was presented by Anyanwu et al. [12] in another rural river in Umuahia, Odo et al. [22] presented 0.36 – 3.12 mg/l in Akor River, Ikwuano and 0.02 – 0.60 mg/l was presented by Anyanwu et al. [23] in Anya stream, Umudike.

Nitrate also had low concentrations that conformed to regulatory standard. Dilution was responsible for the low concentrations observed in October 2023 (particularly in station 3) while effects of late dry season contributed the high concentrations observed in May 2023 (especially in station 1). Nitrate exhibited a completely different trend; decreasing from May to October 2023 in all the stations; attributable to reduced environmental input and dilution. Related studies in the region showed that nitrate concentrations of 1.10 – 5.60 mg/l was presented in Eme River, Umuahia by Anyanwu and Umeham [3], 0.11 – 1.42 mg/l was presented in another rural river in Umuahia by Anyanwu et al. [12], Odo et al. [22] presented 0.24 – 2.15 mg/l in Akor River, Ikwuano and 0.07 – 3.01 mg/l was presented by Anyanwu et al. [23] in Anya stream, Umudike.

Sulphate also had low concentrations that conformed to regulatory standard. Dilution contributed to the least concentrations observed in July 2023 for stations 2 and 3 and dry season effect was responsible for the highest concentrations observed in May 2023 for stations 1 and 2. Related studies in the region showed that sulphate concentrations of 0.10 - 0.90 mg/l was presented in Eme River, Umuahia by Anyanwu and Umeham [3], 0.02 – 0.42 mg/l was presented by Anyanwu et al. [12] in another rural river in Umuahia, Odo et al. [22] presented 0.09 – 0.85 mg/l in Akor River, Ikwuano and 0.04 – 0.33 mg/l was presented by Anyanwu et al. [23] in Anya stream, Umudike.

Complete absence of the cations in aquatic systems will restrict the development and distribution of some invertebrates [33]. Sodium, potassium and calcium exhibited a similar trend; suggesting related environmental and anthropogenic influence. All their values were well within their respective limits. Dilution contributed the least concentrations observed in July 2023 in stations 2 and 3 while August break effect contributed to the maximum concentration observed in August 2023 for station 2. Related studies in the region showed varying values for the cations. Sodium concentration of 0.20 – 1.10 mg/l was presented in Eme River, Umuahia by Anyanwu and Umeham [3], 011 – 0.33 mg/l was presented in another rural river in Umuahia by Anyanwu et al. [12], Odo et al. [22] presented 0.22 – 2.10 mg/l in Akor River, Ikwuano and 0.07 – 0.31 mg/l was presented by Anyanwu et al. [23] in Anya stream, Umudike, For potassium, values of 0.02 – 0.40 mg/l was presented in Eme River, Umuahia by Anyanwu and Umeham [3], 0.05 – 0.18 mg/l was presented in another rural river in Umuahia by Anyanwu et al. [12], Odo et al. [22] presented 0.09 – 0.91 mg/l in Akor River, Ikwuano and 0.01 – 0.12 mg/l was presented by Anyanwu et al. [23] in Anya stream, Umudike while for calcium, the concentrations were 1.00 – 4.60 mg/l presented by Anyanwu and Umeham [3] in Eme River, Umuahia, 0.48 – 1.07 mg/l was presented in another rural river in Umuahia by Anyanwu et al. [12], 0.72 – 6.44 mg/l was presented by Odo et al. [22] in Akor River, Ikwuano and 0.41 – 1.44 mg/l was presented by Anyanwu et al. [23] in Anya stream, Umudike. However, magnesium concentrations were equally low and conformed to regulatory standard but exhibited a different trend. Dilution also contributed to the least concentration observed in July 2023 for station 3 as the case of sodium, potassium and calcium. However, allochthonous input from runoff as the rains increased contributed to the maximum concentration observed in September 2023 for station 1. Previous studies within the state showed that magnesium concentrations of 0.20 – 1.50 mg/l was presented in Eme River, Umuahia by Anyanwu and Umeham [3], 0.28 – 0.87 mg/l was presented in another rural river in Umuahia by Anyanwu et al. [12], Odo et al. [22] presented 0.51 – 4.32 mg/l in Akor River, Ikwuano while 0.24 – 0.88 mg/l was presented by Anyanwu et al. [23] in Anya stream, Umudike.

All the positive and negative correlation coefficient values were close to one; an indication of strong relationship [37, 38]. The strong positive association observed among a number of parameters in the 3 stations suggests a common source of influence [37]. The spatio-temporal distribution pattern of the parameters indicated that season was the source of influence. However, the few negative correlations in stations 2 and 3 suggest interplay between season and anthropogenic activities.

Water Quality Assessment Indices

The outcome of water quality index (WQI) and comprehensive pollution index (CPI) suggests that the river quality was not negatively influenced by human activities and season especially precipitation. This is because a greater number of the parameters assessed conformed to their regulatory standards. However, the highest values of WQI and CPI observed in station 3 could have been influenced by low mean pH value and high mean BOD value.

The outcome of organic pollution index (OPI) and river pollution index (RPI) suggested slight pollution; which aligned with WQI and CPI. This variation could be attributed to two parameters (TSS and NH_3-N) that the exceeded their respectively acceptable limits with high margins in the 3 stations. The high OPI and RPI values observed in station 1 and stations 1 and 2 respectively were also a reflection of higher values of TSS and NH_3-N in the stations.

CONCLUSION

This study assessed the status of a rural lotic system to determine its suitability to sustain diverse aquatic organisms. Being the first of its kind, it will serve as baseline for future studies as the community develops further. Evaluation of sixteen parameters with four different water assessment indices contributed to the study's novelty. The parameters conformed to regulatory standards except for ammonia-nitrogen, dissolved oxygen, pH, and total suspended solids. The indices showed that the river was not adversely polluted. The physicochemical characteristics and indices were generally influenced by effect of season and anthropogenic activities to a lesser extent, which reflected in the spatial and temporal variations. It can be concluded that the river is still suitable to support aquatic life. However, some of the anthropogenic activities observed like sand mining, disposal of solid wastes and discharge of wastewaters from cottage industries into the river could negatively affect the quality of the water if not checked.

ACKNOWLEDGEMENTS

The study map was produced by Mr. Utibe Usanga of Department of Geography, University of Uyo, Uyo, Nigeria.

AUTHORSHIP CONTRIBUTIONS

Concept and Supervision: EDA; Field Evaluation: EDA, OGA and AGS; Data analysis and interpretation: EDA, SAS; Manuscript writing: EDA, SAS, OGA and AGS. The final version of the manuscript was approved by the authors.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declared that there is no competing interests among the authors.

ETHICS

There are no ethical issues with the publication of this manuscript.

STATEMENT ON THE USE OF ARTIFICIAL INTELLIGENCE

Artificial intelligence was not used in the preparation of the article.

REFERENCES

[1] Kamboj N, Kamboj V. Water quality assessment using overall index of pollution in riverbed-mining area of Ganga-River Haridwar, India. Water Sci 2019;33:65–74. [CrossRef]

[2] Izah SC, Bassey SE, Ohimain EI. Impacts of cassava mill effluents in Nigeria. J Plant Anim Ecol 2018;1:14–42. [CrossRef]

[3] Anyanwu ED, Umeham SN. Identification of waterbody status in Nigeria using predictive index assessment tools: a case study of Eme River, Umuahia, Nigeria. Int J Energy Water Resour 2020;4:271–279. [CrossRef]

[4] Cao ST, Tran HP, Le HTT, Bui HPK, Nguyen GTH, Nguyen LT, et al. Impacts of effluent from different livestock farm types (pig, cow, and poultry) on surrounding water quality: a comprehensive assessment using individual parameter evaluation method and water quality indices. Environ Sci Pollut Res Int 2021;28:1–14. [CrossRef]

[5] Lokman NA, Ithnin AM, Yahya WJ, Yuzir MA. A brief review on biochemical oxygen demand (BOD) treatment methods for palm oil mill effluents (POME). Environ Technol Innov 2021;21:101258. [CrossRef]

[6] Indirani P, Sekar RRJ, Ponmurugaraj N. Impact of solid waste disposal on water quality in the selected stations of Thamiraparani River Basin at Kanyakumari District, Tamilnadu. Int J Food Sci Nutr 2022;11:2255–2266.

[7] United Nations Environment Programme (UNEP). Freshwater: globally, 3 billion people at health risk due to scarce data on water quality. Nairobi: United Nations Environment Programme; 2021. Available at: https://www.unep.org/news-and-stories/story/globally-3-billion-people-health-risk-due-scarce-data-water-quality. Accessed November 3, 2026.

[8] Effendi H. River water quality preliminary rapid assessment using pollution index. Procedia Environ Sci 2016;33:562–567. [CrossRef]

[9] Nwankwo C, Nwankwoala HO. Gully erosion susceptibility mapping in Ikwuano Local Government Area of Abia State using GIS techniques. Earth Sci Malays 2018;2:08–15. [CrossRef]
[10] American Water Works Association (AWWA). Standard methods for the analysis of water and wastewater. 23rd ed. American Water Works Association, Water Environment Federation, American Public Health Association; 2017.
[11] Tokatli C. Application of water quality index for drinking purposes in dam lakes: a case study of Thrace Region. Sigma J Eng Nat Sci 2020;38:393–402.
[12] Anyanwu ED, Jonah UE, Adetunji OG, Nwoke OB. An appraisal of the physicochemical parameters of Ikwu River, Umuahia, Abia State in South-eastern, Nigeria for multiple uses. Int J Energy Water Resour 2023;7:221–228. [CrossRef]
[13] Brown RM, McClelland NI, Deininger RA, O'Connor MF. A water quality index crashing the psychological barrier. In: Thomas WA, editor. Indicators of environmental quality. Environmental Science Research. Vol. 1. Springer; 1972. p. 173–182. [CrossRef]
[14] Nigeria Environmental Standard and Regulatory Enforcement Agency (NESREA). Guidelines and standards for environmental pollution control in Nigeria. Abuja: NESREA; 2011. p. 12–28.
[15] Yang Y, Huang X, Wu X, Liu C, Zhao S, Zhu X. The spatiotemporal variations characteristic and pollution evaluation of water quality in Qujiang River, China. Appl Water Sci 2023;13:32. [CrossRef]
[16] Jiang HH, Zhu JP, Liang DH, Wu ZL. The relationship between comprehensive pollution index assessment and water quality type distinguishing. Environ Monit China 1999;15:46–48. [In Chinese].
[17] Chen YC, Yeh HC, Wei C. Estimation of river pollution index in a tidal stream using kriging analysis. Int J Environ Res Public Health 2012;9:3085–3100. [CrossRef]
[18] Helal MH, Abd El-Gawad HS, Mohamed SK, Aiffiy MI. Pollution indices and ecological evaluation for wastewater in industrial areas. Egypt J Chem 2022;65:1323–1339.
[19] Boluda R, Quintainilla JF, Bonilla JA, Seaz E, Goman M. Application of the microtox test and pollution indices to the study of water toxicity in the Albufera Natural Park (Valencia, Spain). Chemosphere 2002;46:355–369. [CrossRef]
[20] Gizińska J, Sojka M. How climate change affects river and lake water temperature in Central-West Poland-a case study of the Warta River Catchment. Atmosphere 2023;14:330. [CrossRef]
[21] Bonacina L, Fasano F, Mezzanotte V, Fornaroli R. Effects of water temperature on freshwater macroinvertebrates: a systematic review. Biol Rev Camb Philos Soc 2022;98:191–221. [CrossRef]
[22] Odo SN, Odo MK, Anyanwu ED, Ikechukwu PI. Spatial and temporal variations of physical-chemical parameters of the Akor River in Ikwuano local government of Abia State, Nigeria. Limnol Freshw Biol 2022;2022:1217–1228. [CrossRef]
[23] Anyanwu ED, Nwoke OB, Adetunji OG, Paul OC. Assessing the water quality of a rural multipurpose stream, Southeast, Nigeria. J Mater Environ Sci 2022;13:1414–1424.
[24] Ojok W, Wasswa J, Ntambi E. Assessment of seasonal variation in water quality in River Rwizi using multivariate statistical techniques, Mbarara Municipality, Uganda. J Water Resour Prot 2017;9:83–97. [CrossRef]
[25] Huang GZ, Hsu TC, Yu CK, Huang JC, Lin TC. Dilution and precipitation dominated regulation of stream water chemistry of a volcanic watershed. J Hydrol 2020;583:124564. [CrossRef]
[26] United States Environmental Protection Agency (USEPA). pH - Causal Analysis/Diagnosis Decision Information System (CADDIS). 2024. Available at: https://www.epa.gov/caddis/ph. Accessed November 3, 2026.
[27] Akhere MA, Kadiri MO. Physicochemical characteristics of a tropical seasonal water body: Ikoro Stream, Edo State, Nigeria. J Appl Sci Environ Manag 2023;27:911–918. [CrossRef]
[28] Vonshak A, Laorawat S, Bunnag B, Tanticharoen M. The effect of light availability on the photosynthetic activity and productivity of outdoor cultures of Arthrospira platensis (Spirulina). J Appl Phycol 2014;26:1309–1315. [CrossRef]
[29] Bilotta GS, Brazier RE. Understanding the influence of suspended solids on water quality and aquatic biota. Water Res 2008;42:2849–2861. [CrossRef]
[30] Chowfin A, Gluvakovic N, Gayh U. Effect of rainfall on water parameters in recreational lakes in Heidelberg, Germany. IgMin Res 2024;2:121–126. [CrossRef]
[31] Dong X, Qin JG, Zhang XM. Fish adaptation to oxygen variations in aquaculture from hypoxia to hyperoxia. J Fish Aquacul 2011;2:23–28.
[32] Kamarudin MKA, Wahab NA, Bati SNAM, Toriman ME, Saudi ASM, Umar R, et al. Seasonal variation on dissolved oxygen, biochemical oxygen demand and chemical oxygen demand in Terengganu River Basin, Malaysia. J Environ Sci Manag 2020;23:1–7. [CrossRef]
[33] Ogbeibu AE, Oriabure PA. Assessment of the water quality of the Benin River, Southern Nigeria, prior to the seaport development project. J Water Resour Prot 2023;15:597–610. [CrossRef]
[34] United States Environmental Protection Agency (USEPA). Aquatic life criteria - ammonia. 2024. Available at: https://www.epa.gov/wqc/aquatic-life-criteria-ammonia. Accessed November 3, 2026.

[35] Soler P, Faria M, Barata C, García-Galea E, Lorente B, Vinyoles D. Improving water quality does not guarantee fish health: effects of ammonia pollution on the behaviour of wild-caught pre-exposed fish. PLoS One 2021;16:e0243404. [CrossRef]

[36] Shou CY, Tian Y, Zhou B, Fu XJ, Zhu YJ, Yue FJ. The effect of rainfall on aquatic nitrogen and phosphorus in a semi-humid area catchment, Northern China. Int J Environ Res Public Health 2022;19:10962. [CrossRef]

[37] Simu SA, Uddin MJ, Majumder RK, Kashem MA. Water quality analysis by multivariate statistical analysis in Gazipur Industrial Area, Bangladesh. Int J Mod Res Eng Technol 2018;3:23–32.

[38] Kothari V, Vij S, Sharma SK, Gupta N. Correlation of various water quality parameters and water quality index of districts of Uttarakhand. Environ Sustain Indic 2021;9:100093. [CrossRef]