IMPACT OF ANTHROPOGENIC ACTIVITIES ON THE PHYSICOCHEMICAL QUALITY AND POLLUTION STATUS OF OGUTA LAKE

*Okereafor, U. H[1]., Onyeizu, U. R[1]., Anene, A[3]., Ogbuji, V. A[2].
[1] Department of Environmental management and toxicology, Michael Okpara university of Agriculture, Umudike
[1] Department of Plant Science and biotechnology, Michael Okpara university of Agriculture, Umudike
[2] Department of Animal science and Fisheries, Abia state university, Uturu

Abstract
This study comprehensively assessed the physicochemical characteristics, heavy metal concentrations, Water Quality Index (WQI), and Pollution Load Index (PLI) of Oguta Lake across dry (February–April) and wet (May–July) seasons. Physicochemical parameters such as pH (5.43–6.02), conductivity (11.57–24.72 µS/cm), total dissolved solids (5.71–12.39 mg/L), and dissolved oxygen (5.50–6.28 mg/L) were mostly within or near FAO/WHO limits, though acidity (10.80–20.05 mg/L) and chemical oxygen demand (COD) levels (18.40–238.60 mg/L) frequently exceeded recommended limits, indicating organic pollution. Heavy metals including lead (0.068–0.23 mg/L), cadmium (up to 0.02 mg/L), mercury (up to 0.03 mg/L), and nickel (up to 0.39 mg/L) surpassed permissible limits, demonstrating contamination from anthropogenic activities. The WQI ranged from 100.56 to 203.91 in the dry season (mean = 143.78) and surged between 340.19 and 572.15 during the wet season (mean = 459.54), categorizing the water quality from moderately polluted at the dry season to critically polluted at the wet season. PLI values followed a similar pattern, increasing from 0.179–1.128 in the dry season (mean = 0.709) to 1.447–2.767 in the wet season (mean = 2.070), reflecting heightened pollution loads with rains. These seasonal dynamics emphasize the impact of increased runoff and anthropogenic discharge during the wet period, threatening the lake's ecological sustainability and water usability. The study advocates integrated watershed management and pollution control strategies, especially targeting wet season inflows, to safeguard Oguta Lake's environmental and socio-economic functions.
Keywords: Oguta Lake, Physicochemical properties, WQI, PLI
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INTRODUCTION

The availability of good water is an indispensable feature for preventing disease and improving quality of life, however, Pollution of water ways by organic discharges in Nigeria is presumably a serious threat posed to the Nigerian inland waters (Kigbu and Mohammed, 2013). The notable point source arise from the dumping of untreated and partially treated sewage into the river (Ogbugu and Olajide, 2002), brewery effluents into the river (Ogbeibu and Ezerunara, 2002), discharge of biodegradable wood waste from sawmill located along the river Nwankwo (2006) which are introduced into aquatic ecosystem as direct discharge from industrial plants or as surface run-off from municipal and Agricultural fields. These wastes cause ecological degradation with the attendant severe adverse consequence on the aquatic biota (Kigbu and Mohammed, 2013).

Water quality refers to the chemical, physical and biological characteristics of water (Diersing, 2009). It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose (Johnson *et al.*, 1997). Another general perception of water quality is that of a simple property that tells whether water is polluted or not. In fact, water quality is a complex subject, in part because water is a complex medium intrinsically tied to the ecology of the Earth. The parameters for water quality are determined by the intended use (domestic, agricultural or industrial). Environmental water quality, also called ambient water quality, relates to water bodies such as lakes, rivers, and oceans. The water quality standards for most surface waters significantly vary as a result of different environmental conditions, ecosystems, and human uses that's intended (Diersing, 2009). Substances that are toxic and elevated levels of microorganisms can present a health hazard in water for other purposes of water use, such as irrigation, swimming, fishing, rafting, boating, and most industrial uses. These conditions has the potential to adversely affect wildlife that live on the water, either for drinking or as a habitat. Recent water quality laws specifies the need for the protection of fisheries and recreational use and requires a minimum, retention of current quality standards.

Heavy metals have been defined as naturally occurring elements that have high atomic weight and a density that is at least five times greater than that of water. They are known to be persistent, they bio-accumulative, and are toxic micro-pollutants according to Dickman and Leung (2018). Their several applications have led to their wide spread in the environment raising public health concerns globally over their potential adverse effects on human health and the environment (Dissanayake and Chandrajith, 2019). Duan *et al.* (2010) poised that the

concentration of heavy metals in an organism is the product of equilibrium between the concentration of the metal in an organism's environment and its rate of ingestion and excretion. Oguta Lake, which is the largest natural freshwater lake in southeastern Nigeria, serves as a potential resource for drinking water, fishing activity, transportation means, agriculture, and tourism. The lake receives water from three major tributaries, Utu, Awbana, and Njaba Rivers, the practice of poor sanitation, runoff from agricultural lands, activities that are oil-related, and effluent that are discharged from surrounding communities pose a major threat to the lake's ecological balance.

Irrespective of the ecological and socio-economic importance of the lake, there has only been a hand full research carried out to assess the quality of Oguta Lake. The lack of baseline and monthly monitoring data on the lake's quality has left a significant knowledge gap, thus preventing the effective management and conservation effort of the lake. As a result, there is an urgent need to investigate the seasonal changes in the water quality of the lake, in order to create a management practices that is sustainable and ensure that the integrity of Oguta Lake is safeguard.

Materials and methods
Study area
Oguta Lake is situated in Oguta local government Area of Imo State; it constitutes the largest natural lake in Imo State, South East Nigeria. It is located between latitude 5° 42' 24''N and longitude 6° 47' 33''E and has a maximum depth of 8m and a mean depth of 5.5 and water surface area that varies from1.8km^2 in dry season to 2.5km^2 at the peak of the rainy season. The length of the shoreline is approximately 10km (Nfor and Akaegbobi, 2012). The region is located within the equatorial rain forest, with an average annual rainfall of 3,100mm. Oguta Lake increases in size during the rainy season when it receives overflow and floodwaters from its tributaries (Utu, Awbuna and Njaba River), although river Utu is seasonal, taking its source from river Orashi (an outlet of Oguta Lake), and normally empties into Oguta during the high tide. Oguta Lake drains into Orashi, a

main river on the east- bank flood plain of the Niger and which conveys river Niger's flood waters directly into Niger delta.

Collection of samples
Water samples was collected at 11 points downstream from 5 km upstream of breweries using 2-litre-sterilized plastic bottles following standard method described by American Public Health Association, (1992) and transported to the laboratory for further analysis. Samples were collected monthly for a total of six months representing dry (February, March and April) and wet (May, June and July) season,

Physicochemical Parameter of water samples
The pH of the water samples was determined using the Hanna microprocessor pH meter. It was standardized with a buffer solution of pH range between 4-9. Conductivity and total dissolve solid (TDS) was done using a Jenway conductivity/TDS meter (4510 model). The turbidity of the water samples was done following the nephelometric method for turbidity determination as described by EPA (1993). Phosphate was determined by the molybdate spectrophotometric method described by APHA (1998). Nitrate was determined by the spectrophotometric sodium salicylate method, chloride was determined by titrating with silver nitrate solution using potassium chromate indicator, total hardness was determined by the EEDTA complexiometric method using CaCO$_3$ as standard, bicarbonate content of the water samples were determined using the titrimetric method using dilute hydrochloric acid and methyl orange indicator, dissolved oxygen (DO) was determined using DO probe, while chemical oxygen demand COD) was done following the open reflux titrimetric method as described by APHA (1998)

The concentrations of the heavy metals (Zn, Pb, Cd, Fe, Ni and Hg) in the study water samples were determined directly using a Varian Atomic Absorption Spectrophotometer (Perkin Elmer Analyst AA 200 equipped with a high sensitivity nebulizer) as described by (Fu et al., 2014). Water Quality Index (WQI) was calculated by using the Weighted Arithmetic Index method as described by (Cude, 2001).

Table 1: Grades of Water Quality Index (WQI) and status of water quality (Modified from Ramakrishniah et al., 2009)

Water quality index level	Description
< 50	Excellent
50 – 99	Good
100 – 199	Poor
200 – 299	Very poor
> 300	Unsuitable

The pollution load index (PLI) of the samples was obtained as a contamination factor (CF) of each metal with respect to the natural background value in the water (Angulo, 1996: Usero, *et al*. 2000) by using Equations below:

CF = Csample / Cbackground

PLI =[CF1 × CF2 × CF3 ×. . .× CFn]1/n

where, CF: contamination factor, n = number of metals = 5; Csample: mean metal concentrate of polluted soils; Cbackground: mean natural background value of that metal. E

Results

Table 2: Physicochemical properties of Oguta Lake water samples in dry and wet season

Parameters	Dry season			Wet season			FAO/WHO limit
	Feb	Mar	Apr	May	June	July	
pH	5.43	5.63	5.58	6.02	5.69	5.62	65-8.5
Conductivity	24.72	21.18	20.29	18.43	11.57	11.71	500
TDS	12.39	10.61	11.50	8.57	5.71	6.00	500
DO	5.58	5.60	6.14	6.28	5.50	6.16	>5
Turbidity	16.19	12.38	16.44	20.05	22.84	24.77	25
Acidity	12.37	10.80	13.11	20.05	15.64	18.13	4.5–8.0
PO4	0.13	0.10	0.20	0.34	0.58	0.47	0.1
SO4	2.08	1.43	1.80	3.94	4.75	3.79	250
Cl	6.81	10.15	15.11	19.70	18.12	26.89	250
NO3	10.44	8.63	10.06	12.68	18.20	17.27	50
Bicarbonate	14.62	2.00	9.32	11.36	21.75	17.18	<300
Total hardness	4.09	4.61	15.59	19.96	14.77	24.00	<500
COD	18.40	40.70	135.50	168.00	238.60	211.90	<10

Table 2 presents the results of the physicochemical properties of Oguta Lake water samples collected at dry (February, march and April) and wet (May, June and July) season. The result showed that pH values ranged from 5.43 to 5.58 during the dry season and between 5.62 and 6.02 in the wet season. Conductivity measured from February to July varied between 11.57 µS/cm during the wet season and 24.72 µS/cm during the dry season. Higher values were recorded during the dry season than the wet season. The TDS values ranged between 12.39 mg/L in early dry months and fell to about 5.71-6.00 mg/L during wet months. These values are far below the guideline threshold of 500 mg/L. DO values measured were between 5.50 mg/L and 6.28 mg/L throughout both seasons, all above the guideline value of >5 mg/L for healthy aquatic life. Turbidity increased from about 12.38-16.44 NTU during dry months to between 20.05-25.77 NTU in the wet season, with July readings (24.77 NTU) approaching but not exceeding the FAO/WHO limit of 25 NTU. Acidity was observed to range from approximately 10.80 to 13.11 in dry season, rising to 15.64-20.05 in wet season. These values exceed the given guideline range of 4.5-8.0. Phosphate concentrations increased from 0.10-0.20 mg/L in the dry season to about 0.34-0.58 mg/L in the wet season, with the wet months exceeding the guideline level of 0.10 mg/L. Values of sulphate content ranged from 1.43 mg/L to 4.75 mg/L, all well below the guideline limit of 250 mg/L. Chloride concentrations were observed between 6.81 mg/L and 26.89 mg/L, increasing in wet months, yet remaining well below the 250 mg/L guideline. Nitrate concentrations increased from 8.63-12.68 mg/L in dry months to 17.27-18.20 mg/L in wet months. All measured values remained below the guideline limit of 50 mg/L as NO_3^-. Bicarbonate values varied between 2.00 mg/L and 21.75 mg/L, all well below a guideline of <300 mg/L. Total hardness was found to range between approximately 4.09 mg/L and 24.00 mg/L, extremely soft water, far below the guideline of <500 mg/L. COD values rose from about 18.40-135.50 mg/L in the dry season to 168.00-211.90 in the wet season all exceeding the guideline of ≤10 mg/L by substantial margins.

Table 3: Heavy metal concentration of Oguta Lake water samples in dry and wet season (mg/l)

Parameters	Dry season			Wet season			FAO/WHO limit
	Feb	Mar	Apr	May	June	July	
Pb	0.068	0.079	0.120	0.15	0.20	0.23	0.01
Cd	0.000	0.008	0.008	0.01	0.01	0.02	0.01
Hg	0.002	0.006	0.010	0.01	0.02	0.03	0.006
Zn	0.304	0.351	0.488	0.67	0.88	1.07	5

| Fe | 0.516 | 0.766 | 0.965 | 1.37 | 1.74 | 2.34 | 5 |
| Ni | 0.046 | 0.090 | 0.137 | 0.20 | 0.31 | 0.39 | 0.02 |

Table 3 presents the result of the heavy metal concentration of Oguta Lake water samples collected at dry (February, march and April) and wet (May, June and July) season. There was a gradual, but consistent increase in the heavy metal concentration from February to July. The result rec0orded in this study showed that the lead (Pb) concentrations in the water samples ranged from 0.068 mg/L (February) to 0.23 mg/L (July), consistently exceeding the FAO/WHO guideline of 0.01 mg/L. Cadmium (Cd) was below detection in February but increased to 0.02 mg/L in July, surpassing the 0.01 mg/L guideline during late wet months. Mercury (Hg) concentrations increased from 0.002 mg/L (February) to 0.03 mg/L (July), exceeding the 0.006 mg/L threshold in wet months. Zinc (Zn) values ranged 0.304–1.07 mg/L, remaining below the 5 mg/L guideline. Iron (Fe) concentrations (0.516–2.34 mg/L) were within the 5 mg/L guideline but displayed a clear wet-season surge. Nickel (Ni) values (0.046–0.39 mg/L) surpassed the FAO/WHO limit (0.02 mg/L) all through the sampling duration, peaking in July.

Table 4 WQI for each month (wet and dry season) for Oguta Lake

Season	Month	Oguta Lake
	Feb	126.86
Dry mean	Mar	100.56
	Apr	203.91
	Mean	143.78
	May	340.19
Wet mean	June	572.15
	July	466.27
	Mean	459.54

The WQI values during the dry months range from 100.56 in March to 203.91 in April, with a mean of 143.78 for February, March, and April (Table 4). These values indicate a water quality status that is moderately to heavily polluted, because commonly accepted WQI classifications rate values above 100 as showing significant pollution and unsuitability for sensitive uses such as drinking without treatment. The values rise sharply during the wet season, starting from 340.19 in May and peaking at 572.15 in June, before slightly dropping to 466.27 in July. The mean value during these months is 459.54. These very high values indicate critically polluted water quality in Oguta Lake during the wet season.

Table 4: the Pollution Load Index (PLI) Oguta Lake water at wet and dry season

Month	Oguta Lake
Feb	0.179
Mar	0.821
Apr	1.128
Dry Mean	0.709
May	1.447
June	1.996
July	2.767
Wet Mean	2.070

PLI values for the dry months start at 0.179 in February, increased to 0.821 in March, and exceed unity (1.128) in April, producing an average PLI of 0.709 during the dry season. A notable escalation in PLI values occurred in the wet season, starting at 1.447 in May and rising sharply to 1.996 in June, and peaking at 2.767 in July. The result showed a linear increase in the pollution load of Oguta Lake throughout the sampling period (Feb-July)

DISCUSSION
From the result of the physicochemical properties of the Oguta Lake water (Table 4.1), the lowest pH value (5.43) was recorded in February. This indicates strong acidity, which was slightly ameliorated but not corrected in later months. This acidity suggests that Oguta Lake is subject to acidifying influences. The slight increase toward May suggests some dilution effect or buffering, but given low alkalinity the buffer capacity is limited, and pH remains outside safe limit. Comparatively, Okorondu and Anyadoh-Nwadike (2015) reported similar acidic conditions in Oguta Lake with pH values approximating 5.7 in some stations, confirming that acidity is a historical characteristic of this system. Likewise, Verla *et al*.

(2022) observed pH values below the optimal range in parts of Oguta Lake especially during dry months.

These low conductivity values imply minimal dissolved salt load and suggest limited mineral dissolution, saline intrusion, or anthropogenic salt contributions. The decline in conductivity in wet months reflects dilution by rainfall and increased inflows with lower ion content. Such low conductivity is a favourable trait for potable water in terms of taste and salinity, but combined with low buffering (low bicarbonate, low hardness) may render the lake sensitive to acidification and chemical perturbations. In comparison, Verla *et al*. (2022) also reported low conductivity in Oguta Lake, although values in some near-shore or impacted stations were higher. Low TDS recorded in this study is consistent with the conductivity trend and indicates that Oguta Lake is very low in dissolved mineral and salt content. Low TDS is advantageous for taste and human consumption, but the low levels of dissolved constituents may reduce buffer capacity and contribute to instability of water chemistry with environmental changes Tiga Reservoir exhibited TDS of tens to over a hundred mg/L during various seasons, according to Adamu *et al*. (2024). Oguta Lake's TDS is therefore in the lower range compared to many regional water bodies.

All the dissolved oxygen values recorded during the sampling period were above the guideline value of >5 mg/L for healthy aquatic life. These values indicate that, at sampling times, the lake surface water was adequately oxygenated. The consistently acceptable DO suggests that despite organic inputs, the lake has managed to maintain aerobic conditions, at least in surface layers. Okoro *et al*. (2021) showed that in many tropical lakes DO often declines in dry periods due to stagnation or elevated temperatures. The high turbidity value recorded in the wet season compared to the dry season suggests that increased rainfall and runoff contribute suspended solids, soil erosion, and possibly re-suspension of sediments during wet months, causing higher turbidity. In dry months, lower runoff and calmer water reduce particle load. Atobatele and Ugwumba (2020) recorded much higher turbidity during heavy rains and storm events, often exceeding recommended limits in Aiba Reservoir studies. Verla *et al*. (2022) also observed elevated turbidity in Oguta Lake's impacted stations during rainy season. Elevated turbidity implies increased potential for pathogen transport, reduced water clarity (affecting photosynthesis), and challenges for water treatment if the water is used for domestic supply.

The acidity of Oguta Lake increased during wet season compared to the dry season, this reflects that acidity inputs (from runoff, surface soil leaching, organic matter) intensified during wet months. The baseline (dry season) acidity already exceeded guideline thresholds, indicating persistent acidification pressure. Okorondu and Anyadoh-

Nwadike (2015) reported similar problematic acidity in Oguta Lake, confirming that acidification has been ongoing. The elevated acidity, together with low pH and low bicarbonate, suggests that the lake has low buffering, and is vulnerable to further acidic inputs; this could influence metal speciation, biological processes, and human uses.

The observed seasonal increase in PO_4 indicates that its inputs from agricultural runoff, detergents, domestic wastewater, or erosion are elevated during rain periods. The dry season's lower phosphate suggests that except for background and possibly point sources, nutrient loading is less severe. Umeoka (2024) reported phosphate values that were lower in certain spatial zones but similarly variable with season in Oguta Lake. Other Nigerian lake studies (Okoro et al., 2021) also showed elevated PO_4 during wet season, but sometimes not as high as in this study. Elevated phosphate is a key driver of eutrophication, causing algal blooms, reducing water quality, and possibly leading to oxygen depletion during senescence and decay of algae. The sulphate levels all through the study months were well below the guideline limit of 250 mg/L. This indicate that sulphate pollution is minimal. The modest increases during wet months likely represent natural runoff and mineral dissolution. There appears to be no obvious anthropogenic sulphate burden. Literature indicates similar low sulphate in many inland freshwater systems in Nigeria without industrial sulphate sources (e.g., Verla *et al*., 2022). Thus, sulphate does not represent a significant risk under current the conditions. The increasing of chloride in the wet months compared to the dry months suggests that runoff or perhaps waste leakage contributes Cl^-, especially during rains. Nevertheless, the low absolute levels imply chloride is not presently a major water-quality concern for Oguta Lake. Verla *et al*. (2022) found higher chloride in stations closer to human settlements, suggesting spatial heterogeneity. Thus sampling location is likely an important factor in observed Cl values.

All measured nitrate values in this study remained below the guideline limit of 50 mg/L as NO_3^-. The seasonal trend points to increased fertilizer runoff, domestic or septic effluent, or decomposition inputs during wet season. Although values are under the limit for nitrate (NO_3^-), if the measurement were expressed as nitrate-nitrogen (NO_3-N), parts of the dataset might approach or exceed stricter health guidance. Umeoka (2024) reported spatially variable nitrate with some elevated values during wet season, but rarely breaching limits. Other lakes in tropical regions display similar seasonal nitrate increases as reported by Adamu *et al*. (2024). Elevated nitrates contribute to eutrophication and may pose health risks where drinking water is untreated. These low bicarbonate values recorded in this study indicate limited buffering capacity of the lake water. Such weakness in alkalinity exacerbates susceptibility to pH fluctuations and to

acidification from both natural and anthropogenic sources. In Aiba Reservoir, bicarbonate-equivalent alkalinity is much higher in many months (Atobatele and Ugwumba, 2020). In Oguta Lake, studies by Verla *et al*., 2022 and Umeoka, 2024 have shown spatial zones with somewhat higher alkalinity, often associated with inflows or sediment interaction. The Oguta Lake water was found to be extremely soft, as the values obtained were far below the guideline of <500 mg/L. Water of such low hardness contains minimal calcium and magnesium ions. It usually does not pose health risks but may contribute to corrosion of pipes or infrastructures; also, some aquatic organisms require certain hardness levels for optimal physiological functioning. Aiba Reservoir studies reported higher hardness values in many months (Atobatele and Ugwumba, 2020). In Oguta Lake, Verla *et al*. (2022) reported greater hardness in zones near mineral soils or human-altered catchments. The persistently low hardness in these samples suggests that the sampling locations might be relatively distant from such inputs or that dilution is strong.

All COD values recorded in this study exceeded the WHO limit of ≤10 mg/L by substantial margins. This marked elevation of COD especially in wet months indicates severe organic pollution. Likely sources include runoff (vegetative waste, agricultural residues), domestic wastewater, possibly market or industrial discharges. The baseline dry-season value already significantly exceeded the guideline, indicating that organic pollution is not solely a wet-season phenomenon. Okorondu and Anyadoh-Nwadike (2015) reported elevated organic load but not to the magnitude observed in this data; Adebayo *et al*. (2017) also recorded high COD values in certain stations but fewer months exceeding very high levels. The magnitude in this study suggests occasional or sustained inputs of organic matter that overwhelm natural oxidation capacity.

From the result of the heavy metal concentration of Oguta Lake water samples, the gradual increase of lead (Pb) into the wet season implies augmented mobilization of Pb-bearing particles through storm-water runoff and soil leaching. Similar seasonal Pb enrichment was observed in the Karnaphuli River, Bangladesh, where monsoonal flows intensified metal loading (Ali *et al*., 2020). Nwadiaro and Ogbuagu (2019) also reported comparable wet-season Pb peaks in Oguta Lake, attributing them to agricultural effluents and informal battery recycling in surrounding settlements. Elevated Pb poses risks of bioaccumulation in fish tissues and neurological effects in humans upon consumption (FAO/WHO, 2011). Cadmium (Cd) surpassed the maximum permissible limit by WHO/FAO during late wet months. Cadmium often originates from phosphate fertilizers and discarded electronic waste (Chukwu and Nwankwo, 2020). Comparable wet-season Cd exceedances were recorded in Warri River waters by Idowu *et al*. (2022). Even low Cd levels are

concerning, as chronic exposure may lead to kidney dysfunction and skeletal damage. Mercury concentration exceeded the threshold in wet month, suggesting increases pollution rate as a result of run-off and erosion. Mobilization may occur through atmospheric deposition or re-suspension of contaminated waters during high flows (Zhao *et al*., 2021). Similar trends were noted by Adesuyi *et al*. (2021) in Lagos Lagoon, where Hg spikes coincided with rainy-season runoff. Though the zinc (Zn) concentration of the water sample all through the sampling period was below the 5 mg/L guideline. Nonetheless, the near fourfold increase from dry to wet season suggests substantial anthropogenic inputs, possibly from galvanized roofing, automotive debris, and agricultural chemicals within Oguta's catchment. Singh *et al*. (2022) reported analogous Zn patterns in the Gomti River (India), linking seasonal increases to fertilizer wash-off and urban runoff. While Zn is an essential micronutrient for aquatic organisms, elevated concentrations can disrupt gill function in fish and inhibit primary productivity (Ogbeibu *et al*., 2021). The moderate but rising Zn levels in Oguta Lake therefore hint at early signs of nutrient-metal imbalance. Similar to zinc, the iron (Fe) concentration of the samples were within the 5 mg/L guideline but displayed a clear wet-season surge. Iron mobilization is likely driven by weathering of ferruginous bedrock, soil erosion, and organic matter decomposition. Similar Fe elevations during wet periods were documented by Ogbeibu *et al*. (2021) in tropical rivers and by Ali *et al*. (2020) in South Asian basins. Though Fe is essential for aquatic biota, excessive dissolved iron can cause taste and staining issues in drinking water and smother benthic habitats when precipitating as ferric hydroxide. Nickel level in the water samples surpassed the FAO/WHO limit (0.02 mg/L) year-round, peaking in July. Sources include metal plating wastes, burning of fossil fuels, and discarded alloys (Nwadiaro and Ogbuagu, 2019). Elevated Ni levels can induce respiratory stress and reduced reproduction in fish and pose carcinogenic risks to humans upon chronic exposure.

The drastic increase in the WQI from the dry to the wet season reflects typical tropical lake pollution dynamics. During the wet months, rainfall enhances the transport of nutrients (e.g., phosphorus and nitrogen), organic matter, and suspended solids into the lake. This influx results in elevated turbidity, chemical oxygen demand (COD), and concentrations of potentially toxic substances, all of which contribute to the poor water quality scores. The peak in June could correspond to the period of highest rainfall intensity and surface runoff, transporting more pollutants from both agricultural lands and domestic sources into the lake. Although July shows a slight decrease, the values remain critically high, indicating ongoing pollutant inputs and insufficient natural attenuation within the lake system.

PLI values below 1, such as those in February and March, suggest relatively low pollution loads during these months, implying that the lake water quality was moderately impacted. However, the rise to 1.128 in April indicates a transition towards moderate pollution levels, possibly coinciding with the onset of increased land runoff or pollutant discharge as seasonal conditions begin to shift. The wet season mean of 2.070 denotes a considerable pollution load, well above the threshold of 1 that demarcates pollution presence. These higher values correspond with enhanced surface runoff during heavy rains, leading to elevated inputs of nutrients, organic matter, sediments, and potentially toxic substances such as heavy metals from agricultural, domestic, and urban sources. This seasonal increase reflects typical patterns in tropical freshwater systems subjected to intensified pollutant mobilization during rainy months. The PLI values obtained for Oguta Lake reflect significant anthropogenic influence and align with findings from similar Nigerian and tropical freshwater bodies. For instance, Ezeh *et al*. (2021) documented PLI values ranging from 0.8 to 2.5 in Niger Delta estuaries, attributing elevated wet season values to runoff enriched with agricultural fertilizers and urban effluents. Similarly, Emeka *et al*. (2023) reported PLI values exceeding 2 during the wet season in Cross River sediments, emphasizing the role of seasonal precipitation in delivering pollutants.

CONCLUSION
The seasonal evaluation of Oguta Lake water quality revealed significant variations linked to hydrological and anthropogenic factors. While parameters like pH and dissolved oxygen largely remained within acceptable limits, elevated acidity and COD values consistently exceeded guidelines, signaling organic pollution. Crucially, heavy metals such as lead, cadmium, mercury, and nickel surpassed FAO/WHO limits across both seasons, underscoring persistent contamination that poses ecological and public health risks.

The Water Quality Index articulated a generally moderate pollution status during the dry season (mean WQI = 143.78), escalating to critical pollution levels in the wet season (mean WQI = 459.54). This trend was mirrored in the Pollution Load Index, with wet season values (mean PLI = 2.070) indicative of intensified pollutant influxes beyond safe thresholds. Elevated wet season indices correspond with increased runoff, bringing sediment, nutrients, and contaminants into the lake from agricultural and urban sources.

These findings resonate with prior studies on tropical lakes, which document elevated pollutant loads during rainy seasons due to enhanced terrestrial inputs. The critical condition during the wet months necessitates urgent intervention through sustainable watershed management to reduce pollutant inflows and restore the lake's ecological integrity.

Efforts should include comprehensive monitoring of physicochemical and heavy metal parameters, enforcement of pollution control regulations, community engagement for sustainable practices, and investment in treatment infrastructure. Such strategies are imperative to maintain Oguta Lake as a valuable environmental resource supporting biodiversity, fisheries, and livelihoods.

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