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Original Research

Assessment of Temporal Variation of Water Quality Parameters and Ecotoxic Trace Metals in Southern Nigeria Coastal Water

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Abstract

This study investigated the temporal variations of water quality parameters and ecotoxic trace metal contamination in the Opuroama River over a year, with a focus on providing baseline data for regulating water and fisheries resources in the area. Metal concentrations in sediment, water, and four aquatic organisms were analyzed for cadmium (Cd), chromium (Cr), nickel (Ni), and lead (Pb) using atomic absorption spectrophotometry. Metal concentration in *C. amnicola* occurred in the order: Cr>Cd>Ni>Pb, *U. tangeri*: Cr>Pb>Cd>Ni, *T. fuscatus*: Cr>Pb>Ni>Cd, *P. monodon*: Pb>Cr>Ni>Cd, while in sediment, the order was Cr>Pb>Cd>Ni, and water occurred in the order: Cr>Pb>Ni>Cd. Results showed temporal variations in water physicochemical parameters, with Cd and Ni concentrations within 0.003 mg/L, and 0.02 mg/L reported as set standard limits for aquatic ecosystems except for Cd in December, which exceeded permissible limits. Pb concentrations were below the threshold of 0.01 mg/L from January to May but progressively increased and exceeded limits from June to December. Cd had the highest mean concentration in sediment and the least in water and aquatic organisms, while Ni had the highest mean concentration in *U. tangeri* and water and the lowest in *T. fuscatus* and *P. monodon*. Pb had the highest concentration in water and the lowest in *C. amnicola*, while *U. tangeri* had the highest mean Cr

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value. The study suggests potential health risks to humans and the environment from the presence of potentially toxic elements in the studied media.

Keywords: toxic metals, shellfish, bioaccumulation, physicochemical parameters

Introduction

In many parts of the world, including Nigeria, the discharge of pollutants into aquatic systems is a widespread problem [1, 2]. The belief that these systems have an unlimited capacity to absorb waste is unfortunately not accurate, as heavy metal pollution and other forms of contamination can have serious and long-lasting impacts on the health of these ecosystems and the species that depend on them [3]. Environmental pollution is a serious issue in the Niger Delta region of Nigeria and many other countries around the world, due to the release of harmful substances from oil spills, gas flaring, and industrial activities [4]. Oil spills and gas flaring release harmful substances such as hydrocarbons and toxic chemicals into the environment, contaminating the soil and water sources [5]. This pollution can have negative impacts on the health of local communities, endangering wildlife and the ecosystem [6]. The discharge of toxic chemicals from industrial activities also contributes to the pollution problem, as these chemicals can accumulate in the environment and have long-lasting impacts [7]. Despite efforts to address the problem, oil spills and gas flaring continue to occur, and the discharge of toxic chemicals from industrial activities is also a concern [5]. The widespread pollution in the Niger Delta region of Nigeria has had significant impacts on the environment and local communities [8].

Heavy metal pollution in the Niger Delta region of Nigeria has been reported to have severe impacts on the aquatic environment and human health. These metals have been found in elevated levels in sediments, water bodies, and wildlife in areas such as Port Harcourt and Warri [9, 10]. The sources of these pollutants are largely attributed to the petroleum exploration and exploitation industries. Toxic metals such as cadmium, lead, and mercury are toxic to aquatic organisms and can cause reproductive failure, death, and damage to the food chain [11-17]. This has a significant impact on the aquatic life and ecosystem, as well as the health of those who depend on it for their livelihoods and sustenance. In addition, heavy metal pollution can have long-lasting impacts on the environment, as these substances can persist in the sediment and water for many years. This can lead to continued exposure of the local population to toxic pollutants, further exacerbating the problem [18]. The accumulation of heavy metals in the sediments can lead to difficulty for aquatic flora to grow and further sediment degradation [19]. Human exposure to heavy metals can cause serious health problems, including neurological damage, reproductive failure, and cancer [20]. These health impacts can have long-lasting effects on individuals and communities, leading to decreased quality of life and increased healthcare costs. In addition, heavy metal pollution can persist in the environment for many years causing ongoing exposure and health risks to the local population [12].

When they accumulate in the sediments, they can continue to contaminate the water and sediments for long periods of time [21, 22]. This can lead to a decline in the abundance and diversity of aquatic species, as well as harm to the food chain and overall health of the ecosystem. The presence of heavy metals in the sediments can also lead to the release of these toxic substances back into the water column, perpetuating the cycle of pollution and harm to aquatic life [23]. This is because contaminated sediments can release heavy metals back into the water through natural processes such as erosion or bioturbation. This can further contaminate the water and harm aquatic species, leading to a decline in the overall health of the ecosystem. This may also lead to a decline in the abundance and diversity of aquatic species, harm to the food chain and overall health of the ecosystem, and perpetuation of the cycle of pollution [24].

The study aimed to assess and report the variation in the water quality parameters and toxic metals contamination in the Opuroama River over a year to provide baseline data for regulating water and fisheries resources in the area. The sources of pollution in the investigated area are well known, but not their impact on pollution. The study area was chosen due to its significance as a source of livelihood for the local communities and potential contamination by human activities.

Materials and Methods

Study Area

The Opuroama water settlement in Nigeria is a crucial source of water for the Asaro-Toru Local Government Area and the city of Port Harcourt (Fig. 1). The creeks system consists of the main channel and associated feeder creeks linking other communities like Te-ama, Sangama, Abala-ama, Degema, Krakrama and other riparian communities. Many communities in the area rely on the river for their food, agriculture, and recreation, making it a vital resource [25]. Artisanal fishing is common in many coastal communities around the world and provides a vital source of food and income for local populations [26]. The river is home to abundant fish species, including silver catfish and tilapias. The abundance of these species highlights the importance of the Opuroama River as a fishery resource

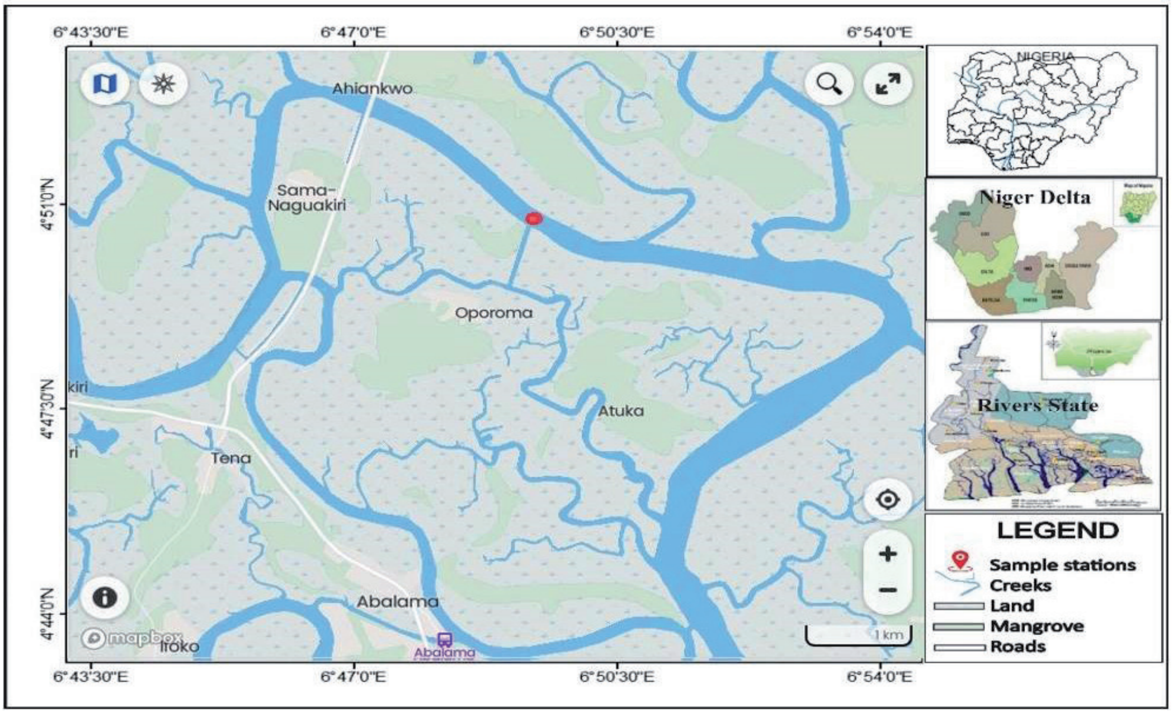

Fig. 1. Map showing the coordinates of sampling area, 4°48`14.8"N 6°50'17.9"E.

for the local population and underscores the need for effective management and protection of this valuable resource.

The fishery resource in the river is exploited in a subsistence artisanal manner, providing a source of food and income for the local population. The Opuroama River is also subjected to various sources of pollution, including industrial effluent discharge and domestic sewage inputs, which can have significant impacts on the health and productivity of the river [26]. It is important to regulate these activities to protect the river and ensure it remains a valuable resource for the local community.

Description of Sampling Points

The sampling area is located after the community effluent mixes with the receiving water body. It serves as a major shipping route for crude oil and other cargoes, and leads to many other communities. Other activities observed include sand dredging activities, illegal bunkering discharges, domestic, human, animal, and plastic waste disposal, and discharges of runoff laden with petroleum product residues.

Collection of Samples

Sampling Procedure

The sampling station is situated at 4°48`14.8"N 6°50'17.9"E was selected and was at least 1000 meters apart along the Opuroama creek. Based on the peculiarities and features observed around the study area of this creek, sampling station was selected within the creek to reflect different activities in the areas. A total of twenty representative samples were obtained within a sampling period of January to December 2017 to provide for statistical variation. The healthy species were collected from each creek. Samples collected for analysis include water, sediment, and biota. The sites were geo-referenced using a handheld global positioning system (GPS) receiver unit (Magellan GPS 315) to generate geographic coordinates of the sampling area.

Physico-Chemical Parameters

The assessment of various physicochemical parameters is generally considered to set guidelines and categorize the physicochemical water quality. *In-situ* analysis was carried out for most of the physicochemical parameters for the surface of Opuroama Creek. The temperature, salinity, conductivity, Total Suspended Solid (TSS), hydrogen ion concentration (pH), and Total Dissolved Solids (TDS) of the water were measured using an in-situ Handheld Multi-meter (Milwaukee Model pH600 and Laboratory Benchtop meter 860033-model). Dissolved Oxygen (DO) was measured using a Milwaukee Dissolved oxygen meter (MW 600 Model). Biochemical Oxygen Demand (BOD) was determined by the 5-day BOD test (APHA, 2005). Chemical Oxygen Demand (COD) was determined using the Closed Reflux Method 5220C with a higher concentration of potassium dichromate solution. All parameters determined were methods recommended by APHA 2340C (1995) standards. These were done in triplicates and the values were recorded.

The Cadmium (Cd), Chromium (Cr), Nickel (Ni), and Lead (Pb) were determined at standard wavelength using the GBC-Avanta PM SN A6600 Atomic Absorption Spectrophotometer (AAS).

Bioaccumulation Factor Calculation

Bioaccumulation factor (BAF) is defined as the ratio between the concentration of the analysed metal in the studied fish and the concentration of the same metal in water or to the sediment. It was calculated using the following formula:

BAF = Concentration of metals in shellfish (mg/kg) /Concentration of metals in water (mg/kg).

BAF = Concentration of metals in shellfish (mg/kg) /Concentration of metals in sediment (mg/kg).

Fish with bioaccumulation values of greater than 1 for one or more heavy metals can be considered as strong accumulators of the corresponding metals [27].

Statistical Analysis

Data was analysed using a one-way ANOVA and Duncan's multiple range and results were tested statistically significant differences at 0.05.

Results and Discussion

Variability in Physicochemical Properties of Water Quality

Physicochemical properties of Opuroama creek variation were compared with the national (Department of Petroleum Resources) and international (World Health Organisation and Environmental Protection Agency) standards for environmental regulation and the results in different months were recorded in Tables 1 and 2. The present investigation reveals that the temperature varied from a minimum 26.4±1.22 in Feb to maximum 30.4±1.64 in October. The temperature values were significantly different ($P<0.05$) from the mean values obtained in February, November, and December, but no temporal variability between these values and the ones observed in March, May, and August ($P>0.05$). It is the most important factor which influences the chemical, biochemical and biological characteristic of the aquatic system [28].

Because most of the chemical and biochemical reactions are influenced by the pH it is of great practical importance [29]. The adverse effect of most of the acids appear below 5 and of alkalis above the pH 9.5. The pH values were significantly higher in May to August and lowest value 5.9 in October. The values observed in this investigation suggest the creek water were within the recommended standards. The dissolved oxygen (DO) values range from a minimum of 2.8 mg/L (July) to maximum of 4.5 mg/L (Dec.). DO means concentrations showed no significant difference ($P>0.05$) across the sampling months except for the value recorded in July, which was significantly different ($P<0.05$) from others excluding in June, August and October. DO play an important role in determining DO in an aquatic body [30]. Some researchers have reported low DO in other aquatic ecosystems, and it was attributed to high organic content in the water bodies occasioned by discharges of wastewater, sewage, oil spills, and other domestic wastes [31-33] but differed from higher DO values reported by Ertas et al. [34] attributed to having being affected by temperature, pressure and dissolved salts in the water body.

The salinity concentrations obtained in this study indicated the concentrations generally were within the nationally and internationally recommended limits for freshwaters. The temporal salinity level revealed that the mean concentrations in July showed significant variation ($P<0.05$) with other months except for values observed in June, August, and October. The low salinity

Table 1. Physicochemical parameters showing standard deviation and range.

Parameters	Max. values	Min. values	Mean values	± SD	WHO (2011)	EPA (2017)	DPR (2002)
Temp.	29.8	27.1	28.2	0.51	24.8-30	27 – 30	22.32-25
pH	6.9	6.2	6.6	0.16	6.5-8.5	6.5 - 8.5	6.5-8.5
DO	4.3	3.6	4	0.35	6	7.5	5
Salinity	13.2	10.7	11.9	0.52	120	-	600
BOD	2.7	2.4	2.5	0.34	10	5 – 7	10
Cond	29.6	23.7	26.6	1.58	400	200-1000	-
TDS	23.4	15.5	19.6	1.74	2000	1000 – 2000	2000
TSS	119.1	94.5	106.5	4.79	500-1000	30	30
COD	76.6	60.1	69.5	2.28	40	-	10

Note: *World Health Organization (WHO) *Environmental Protection Agency (EPA)
*Department of Petroleum Resources (DRP)

Table 2. Temporal variation of the physicochemical parameters.

Stations	Temp.	pH	DO	Salinity	BOD	Cond	TDS	TSS	COD
Jan	29.3 ± 0.67^{a}	6.2 ± 0.16^{ab}	3.9 ± 0.81^{a}	12.9 ± 1.27^{a}	1.9 ± 0.71^{b}	27.1 ± 0.20^{ab}	24.4 ± 6.09^{a}	122.6 ± 17.6^{a}	75.0 ± 4.9^{ab}
Feb	26.4 ± 1.22^{b}	6.9 ± 0.39^{a}	4.4 ± 1.02^{a}	10.1 ± 0.27^{b}	1.8 ± 0.44^{b}	23.1 ± 1.64^{c}	17.1 ± 1.85^{b}	95.7 ± 6.0^{b}	55.2 ± 7.1^{b}
March	27.4 ± 0.89^{ab}	6.4 ± 0.00^{ab}	3.9 ± 0.72^{a}	11.6 ± 1.24^{ab}	1.9 ± 0.64^{b}	22.7 ± 2.66^{c}	17.8 ± 1.45^{b}	102.0 ± 5.3^{a}	71.9 ± 6.4^{ab}
April	29.4 ± 1.51^{a}	6.1 ± 0.20^{ab}	4.0 ± 0.61^{a}	12.1 ± 1.60^{a}	2.3 ± 1.09^{ab}	25.6 ± 3.17^{b}	18.9 ± 2.0^{b}	116.9 ± 12.0^{a}	73.3 ± 2.6^{ab}
May	27.2 ± 1.28^{ab}	6.9 ± 0.13^{a}	3.9 ± 0.80^{a}	10.6 ± 0.72^{b}	1.9 ± 0.53^{b}	21.3 ± 1.58^{c}	17.3 ± 2.23^{b}	94.7 ± 1.2^{b}	58.7 ± 7.2^{b}
June	28.9 ± 0.40^{a}	6.9 ± 0.41^{a}	3.4 ± 0.64^{ab}	12.7 ± 1.66^{a}	2.8 ± 0.49^{a}	26.9 ± 3.15^{b}	19.0 ± 3.14^{b}	102.7 ± 5.6^{a}	71.0 ± 1.0^{ab}
July	30.2 ± 1.15^{a}	6.6 ± 0.73^{ab}	2.8 ± 0.34^{b}	13.9 ± 2.11^{a}	3.2 ± 1.07^{a}	30.4 ± 4.99^{a}	22.0 ± 5.73^{a}	112.0 ± 5.0^{a}	76.7 ± 3.5^{ab}
August	27.9 ± 0.79^{ab}	7.1 ± 0.14^{a}	3.7 ± 0.50^{ab}	11.4 ± 0.75^{ab}	2.8 ± 0.20^{a}	24.2 ± 2.32^{b}	17.0 ± 1.51^{b}	90.7 ± 9.4^{b}	64.7 ± 1.7^{b}
Sept	28.0 ± 1.20^{a}	6.5 ± 0.35^{ab}	4.2 ± 0.59^{a}	11.7 ± 1.03^{ab}	3.1 ± 0.58^{a}	30.9 ± 4.18^{a}	23.6 ± 9.26^{a}	111.0 ± 16.0^{a}	73.7 ± 4.7^{ab}
Oct	30.4 ± 1.64^{a}	5.9 ± 0.46^{b}	3.6 ± 0.78^{ab}	13.8 ± 1.45^{a}	3.5 ± 1.19^{a}	35.3 ± 7.08^{a}	28.2 ± 14.76^{a}	125.0 ± 13.3^{a}	81.3 ± 6.1^{a}
Nov	26.7 ± 1.35^{b}	6.9 ± 0.32^{a}	4.3 ± 0.94^{a}	10.5 ± 0.67^{b}	3.0 ± 0.47^{a}	26.3 ± 0.50^{b}	10.5 ± 9.08^{c}	97.0 ± 16.3^{b}	61.7 ± 5.9^{b}
Dec	26.6 ± 0.74^{b}	6.9 ± 0.23^{a}	4.5 ± 1.12^{a}	11.4 ± 0.75^{ab}	1.7 ± 0.48^{b}	24.9 ± 0.68^{b}	18.9 ± 2.31^{b}	108.0 ± 9.3^{a}	70.6 ± 4.7^{ab}

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

concentrations observed across the sampling months were in conformity with values reported previously in other aquatic ecosystems adduced to be freshwater [26, 35, 36]. The dry season brings about a reduction in water inflow and increased evaporation, thereby increasing water salinity levels [36]. The findings of this study did not align with this assertion as many months adjudged rainy seasons had higher values than the core dry season, and this could be due to anthropogenic disturbance during these months. The biological oxygen demand (BOD) values range from 1.7±0.48 mg/L (Dec) to a maximum of 3.5±1.19 mg/L (Oct.). The average BOD concentrations observed across the sampling months revealed data obtained in January, February, March, May, and December were significantly different ($P<0.05$) from those obtained in July-November except for April, with no statistical difference ($P>0.05$). It has been used as a measure of the amount of organic materialism an aquatic solution which support the growth of microorganism [31]. BOD values observed in this study suggest there were discharges of organic substances into the Opuroama creek, which may have affected the DO levels and increased the BOD concentrations. The BOD concentrations recorded in this study were comparable with the BOD values previously reported in the New Calabar river and Isaka-Bundu waterfront respectively [33, 37].

Conductivity is one vital water parameter that measures the ability of natural water to carry the electric current because of dissolved ionized solids, mobility of ions, and concentration of ions in standards for drinking water and aquatic life [38, 39]. The values of conductivity obtained across the sampling months showed higher mean concentrations were observed in July, September and October which were significantly different ($P<0.05$) from other months except January (Table 2). The low conductivity observed in this investigation was indicative that Opuroama creek had low dissolved solids. Coincidentally, the value of conductivity recorded in July, September, and October, known as rainy seasons in Southern Nigeria, was higher when compared with the other months (Table 2). This affirmed the assertion that large sea water flows into the freshwater ecosystem during rainy seasons [40]. Conversely, Okey-Wokeh et al. [31] and Onajake et al. [37] reported higher conductivity during the dry seasons when there was high evaporation due to an increase in sunlight intensity.

The total dissolved solids (TDS) are the measure of total inorganic salts and other substances that are dissolved in water, and their level influences water density and freshwater organisms and reduces the solubility of gases [41]. The major contributory ions to TDS are magnesium, calcium, carbonate, bicarbonate, chloride, and potassium [42]. The mean TDS concentrations observed across the months showed the data obtained in January were significantly different ($P<0.05$) from other sampling months except for July and September. The average TDS concentration obtained across the months were within the national and international limits recommended for domestic water use [39, 43]. Total suspended solids (TSS) are a known pollution indicator and its elevation beyond the threshold in this study could be attributed to the impacts of anthropogenic disturbance on the creek. Similar result was previously reported in Opuroama creek [44]. The highest temporal average TSS concentration (125±13.3) was recorded in October, which showed no statistical difference ($P<0.05$) from others except for values observed in February, May, August, and November

Table 3. Mean concentrations of trace metals across the different medium.

Samples	Cd	Ni	Pb	Cr
C. amnicola	0.168±0.17 ^{b}	0.003±0.00^{ab}	0.002±0.00 ^{e}	0.208±0.13 ^{b}
U. tangeri	0.112±0.11 ^{c}	0.004±0.00 ^{a}	0.282±0.28 ^{c}	0.612±0.47 ^{b}
T. fuscatus	0.001±0.00 ^{d}	0.002±0.00 ^{b}	0.015±0.01 ^{d}	0.608±0.31^{b}
P. monodon	0.001±0.00 ^{d}	0.002±0.00 ^{b}	0.321±0.29 ^{b}	0.004±0.00 ^{e}
Sediment	0.224±0.22^{a}	0.003±0.00^{ab}	0.260±0.23 ^{c}	0.506±0.31^{c}
Water	0.001±0.00 ^{d}	0.004±0.00 ^{a}	0.595±0.45 ^{a}	0.085±0.08 ^{a}

that was lower with observable significant differences (P<0.05) (Table 2). The minimum chemical oxygen demand (COD) data obtained showed no significant difference was observed from other months except for February, May, August, and November. The COD value usually surpasses BOD concentrations because organic substances that are biochemically degraded and others, which can be oxidized, are all included in biochemical oxygen demand [28]. Similar COD values were reported by Davies and Efekemo [44] in Opuroama Creek, opined to have been caused by sewage, household and other waste discharges from residents around the creek. Opuroama creek, with elevated COD concentrations observed across the months, depicts a water body under threat of organic pollution.

Test of Significance of the Observed Correlation Coefficients

The significance of the observed correlation coefficients has been tested by using Pearson's correlation. Water temperature showed a negative correlation with pH (r = -0.713;<0.01) and DO (r = -0.756;<0.01), but positively correlated with salinity (r = 0.937;<0.01), COD (r = 0.804;<0.01), TSS (r = 0.744;<0.01), TDS (r = 0.726), conductivity (r = 0.704) and BOD (r = 0.539). pH correlated positively with DO (r = 0.183;<0.01), but negatively with salinity (r = -0.672;<0.01), BOD (r = -0.214;<0.01), conductivity (r = -0.603;<0.01), TDS (r = -0.7.13;<0.01), TSS (r = -0.903;<0.01) and COD (r = -0.787;<0.01). DO correlated negatively with salinity (r = -0.742;<0.01), BOD (r = -0.512), conductivity (r = -0.388), TDS (r = -0.348), TSS (r = -0.208) and COD (r = -0.454). Salinity showed significant positive correlation with BOD (r = 0.496), conductivity (r = 0.749), TDS (r = 0.772), TSS (r = 0.775) and COD (r = 0.898). BOD correlated positively with conductivity (r = 0.790), TDS (r = 0.279), TSS (r = 0.225) and COD (r = 0.443). Conductivity showed a significant positive correlation with TDS (r = 0.714), TSS (r = 0.716) and COD (r = 0.756). TDS correlated positively with TSS (r = 0.808) and COD (r = 0.770). TSS showed significant correlation with COD (r = 0.853;<0.01).

From the correlation analysis, it was revealed temperature correlated inversely with DO and pH,

Table 4. Mean distribution of trace metals across the month (January to December).

Months	Cd	Ni	Pb	Cr
Jan	0.001±0.00 ^{b}	0.001±0.00 ^{c}	0.001±0.00 ^{f}	0.010±0.00 ^{cd}
Feb	0.001±0.00 ^{b}	0.001±0.00 ^{c}	0.009±0.00 ^{e}	0.010±0.00 ^{cd}
Mar	0.001±0.00 ^{b}	0.001±0.00 ^{c}	0.007±0.00 ^{e}	0.010±0.00 ^{cd}
Apr	0.001±0.00 ^{b}	0.001±0.00 ^{c}	0.001±0.00 ^{f}	0.009±0.00 ^{d}
May	0.001±0.00 ^{b}	0.001±0.00 ^{c}	0.009±0.00 ^{e}	0.008±0.00 ^{d}
Jun	0.001±0.00 ^{b}	0.001±0.00 ^{c}	0.015±0.01^{d}	0.007±0.00 ^{d}
Jul	0.001±0.00 ^{b}	0.001±0.00 ^{c}	0.016±0.01^{d}	0.012±0.00 ^{c}
Aug	0.001±0.00 ^{b}	0.001±0.00 ^{c}	0.020±0.01^{d}	0.016±0.00 ^{c}
Sept	0.002±0.00 ^{b}	0.004±0.00 ^{b}	0.037±0.01^{c}	0.034±0.00 ^{b}
Oct	0.002±0.00 ^{b}	0.006±0.00 ^{b}	0.043±0.01 ^{c}	1.063±0.50 ^{b}
Nov	0.001±0.00 ^{b}	0.008±0.00 ^{b}	2.513±0.87 ^{a}	1.638±0.92 ^{a}
Dec	1.00±0.48 ^{a}	0.011±0.00 ^{a}	0.268±0.28 ^{b}	1.230±0.45 ^{a}

and this supports the assertion that an increase in temperature reduces dissolved Oxygen solubility in water [28, 32]. Temperature correlated positively with salinity, conductivity, COD, TSS, and BOD, and this reveals that an increase in temperature will result in significant rises in these parameters [23, 42]. The pH values showed weak correlations with DO but significantly correlated with salinity, conductivity, TSS, TDS, and COD. This affirms the assertion that water pH is dependent on conductivity, TDS, and salinity, which are key pollution indicators in freshwater [32, 33].

Distribution of Potentially Toxic Metals across the Month

Potentially toxic metals are frequently released in the aquatic environments either from natural or anthropogenic sources, causing undue stress to aquatic inhabitants as a result of the persistent, toxic, and bio-accumulative nature of these metals. The results in Table 4 indicated the monthly mean distribution of potentially toxic metals showed the value of Cd observed in December was significantly different (P<0.05) from other months. Cd is a non-essential element known for its toxic and carcinogenic effects, and even in low concentrations, it has been marked as a source of concern in water and other media [45]. The values of Ni revealed mean concentration recorded in December showed significant differences from values obtained in other months. The low Ni occurrence in Opuroama creek was expected as it affirmed the assertion that Ni naturally occurs in water and foodstuff in minute concentrations since its elevated form could be toxic and carcinogenic [46]. In this study, the distribution of metals across the sampling months revealed the concentrations of Cd and Ni reported as set standard limits for aquatic ecosystems except for Cd in December, which exceeded permissible limits [38]. The results obtained in this study aligned with the findings previously reported by Okey-Wokeh and Wokeh [47] in Mini-Ezi stream, Niger delta.

Maximum Pb concentration was significantly different (P<0.05) from values obtained in all other months. The Pb concentrations across the months indicated there were low values below the threshold of 0.01 mg/L from January-May, while the concentrations showed a progressive increase that was above limits imposed by national and international regulatory agencies from June-December. This increase could be attributed to illegal crude refining activities and other anthropogenic influences around the creek. Pb is a non-essential and nutritionally useless metal, which is potentially hazardous to most forms of life, and its presence in aquatic ecosystem, even in minute forms, poses significant risks to consumers, leading to physiological, biological, and behavioural dysfunction in man and animals [48]. The highest mean Cr concentration was observed in November which showed no statistical difference from the value obtained in December but was significantly different (P<0.05) from data obtained in other months. high Cr concentrations, which were above the 0.05 mg/L stipulated limit, were observed from October through December, being the core dry season in Southern Nigeria. Higher Cr values within these months could be traced to the concentration factor [47]. Similar reports were documented in the past by other researchers in different aquatic ecosystems in Niger delta [49, 50]. The Cd value showed negative correlation with Ni (r = -0.097), Pb (r = -0.054) but correlated positively with Cr (r = 0.261). Ni correlated positively with Pb (r = 0.253), while it showed negative correlation with Cr (r = -0.172). Pb correlated positively with Cr (r = 0.253).

Bioaccumulation Factor/Tissue Contamination of Toxic Metals in the Shellfishe

The results in Table 5 showed that *C. amnicola* had the highest accumulation of Cd and *P. monodon* had the lowest accumulations. Similarly, the trend for Ni accumulation was the same as for Cd. For Pb accumulation, *P. monodon* had the highest accumulation and *C. amnicola* had the lowest accumulations, respectively. Regarding Cr accumulation, *U. tangeri* had the highest contamination while *P. monodon* had the least contamination. Finally, the tissue concentration of the trace metals contamination in the shellfish with reference to water followed this sequence: *U. tangeri*> *T. fuscatus*>*C.amnicola*>*P. monodon*. In the environmental assessment, the bio-accumulation factor (BAF) was used as an ecological tool to measure the number of contaminants present in living organisms. This study used the BAF values to compare the concentration

Table 5. Tissue concentration of the trace metals with reference to water and sediment by the shellfishes.

Medium	Sediment				Water			
	Cd	Ni	Pb	Cr	Cd	Ni	Pb	Cr
C. amnicola	168	0.75	0.003	2.45	0.75	1	0.008	0.411
U. tangeri	112	1.0	0.474	7.20	0.5	1.333	1.085	1.209
T. fuscatus	1.0	0.5	0.025	7.153	0.0045	0.667	0.058	1.202
P. monodon	1.0	0.5	0.540	0.047	0.0045	0.667	1.235	0.008

NB: Concentration in (mg kg-1)

of heavy metals in sediment to their concentrations in fish. From the results in Table 5, the concentration of the toxic metals with reference to sediment shows that the tissue of *C. amnicola* recorded the highest Cd and Ni accumulation *P. monodon* had the least accumulations. Higher Pb accumulation was observed in *P. monodon* while *C. amnicola* recorded the lowest accumulation respectively. The accumulation of Cr in tissue of the shellfishes recorded the highest contamination in *U. tangeri* and the least was recorded in tissue of *P. monodon*.

Based on the results of the study, the concentration of potentially toxic metals in the various shellfish species with reference to water has shown a ranking of the different shellfish species based on their accumulation of the metals. The variations in the contamination levels of potentially toxic metals in the different shellfish species may be attributed to several factors such as species-specific differences [51]. Different species of shellfish may have different physiological and biochemical characteristics [52], which can affect their ability to accumulate metals. *C. amnicola* may have a higher ability to accumulate Cd than other species because of its feeding behavior, habitat, or metabolic processes [53]. Boquete et al. [54] reported that habitat differences could also have an impact on the variation in accumulation. The concentrations of metals in the water, sediment, and seafood may vary depending on the location where the samples were collected [52]. Shellfish from areas with higher metal pollution may have higher accumulation levels than those from cleaner areas [55]. Although, Rashida et al. [56] stated that the size and age of the shellfish could also play a large role because larger and older shellfish may have higher metal accumulation levels than smaller and younger ones. This is because older shellfish may have had more exposure to metal-contaminated water and food over their lifespan.

Conclusions

In conclusion, this study revealed that the physicochemical parameters of water at Opuroama creek showed significant temporal variations in various physical and chemical parameters in water over a 12-month period which could be attributed to human activities in the area. The study found that the concentration of potentially toxic elements varied across different media. The study provided information about the potential toxicity of different shellfish species, which can be useful in assessing the safety of consuming these shellfish. Therefore, in order to safeguard human health and aquatic fauna from toxic accumulation, routine check and monitoring of the aquatic environment should be of great importance to environmental practitioners and other critical stakeholders.

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Conflict of Interest

The authors declare no conflict of interest.

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