

Integrated Assessment of Heavy Metal Concentrations and Current Pollution Status: A case study of Nworie River, Southeastern Nigeria

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**Integrated Assessment of Heavy Metal Concentrations and Current Pollution
Status: A case study of Nworie River, Southeastern Nigeria**

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Abstract

The study assessed Heavy Metal Concentrations and the current pollution status of Nworie River in Imo State, Nigeria. Water sample were collected from the river and analysed for heavy metals using Atomic Absorption Spectrophotometer. The level of heavy metal pollution was assessed using single pollution indices; Contamination factor (Cf) and Ecological risk factor (Er). The findings from this work was used to checkmate the previous works done on this river on heavy metal pollution level. Cadmium (0.014mg/l), Mercury (0.001mg/l) and Chromium (0.03mg/l) were all found to be below WHO/FMEnv standard for good water. Lead (0.05mg/l) and iron (0.71mg/l) were found to be above the standard value and this attributed to the littered presence of dredging material found along the river banks. The results revealed that mercury recorded the highest Cf 0.60 during the dry season at Umezuruike, while the highest Er 3.52 was recorded at Egbada. During the rainy season, mercury also recorded the highest Cf 0.056 and the highest Er 2.24 at Akanchawa. The results from the physico-chemical parameters and heavy metal showed that the river is negatively adversely polluted and this is aided by the result from the calculated water quality index and composition, abundance and distribution of the phytoplankton observed. Thus there is need for regular monitoring of the river and also provide ways to reduce the rate of contamination and illegal dumping of wastes along the watersheds.

Keywords: Heavy Metals, Pollution Status, Nworie River, Imo State

Introduction

Rivers are among the most vital components of the natural environment, providing water for domestic, agricultural, industrial, and recreational uses while sustaining diverse ecosystems and human livelihoods. At the same time, they often serve as conduits for toxic heavy metals and other contaminants, posing significant ecological and public health risks [1,2]. However, rapid urbanization, industrialization, and population growth have contributed to a global decline in river water quality [3-5]. Rivers are increasingly contaminated by pollutants from a variety of anthropogenic sources, including untreated sewage, agricultural runoff, and industrial effluents. These pollutants alter key physicochemical characteristics of water, such as pH, dissolved oxygen (DO), turbidity, and heavy metal concentrations, thereby degrading water quality and threatening aquatic ecosystems [6-10].

Nworie River is one example of a body of water that experiences environmental degradation due to human influence. Although the river has undergone pollution, it continues to be a vital source of water especially during disruptions of the municipal water supply system. Population increase in the Owerri metropolis of Imo State has led to an increase in the amount of waste produced, and some of this ends up in the river through various means of disposal. There are several institutions and business centers located on both sides of the river that largely pollute the river. These include the effluents and wastes from Federal Medical Centre (FMC), Alvan Ikoku Federal College of Education (AIFCE), Holy Ghost College, and many hotels in the municipality. Moreover, anthropogenic activities such as washing, bathing, and other domestic purposes pollute the river. Considering the importance of the river for drinking, fishing, and other domestic purposes, the Imo State Government in cooperation with Niger Delta Development Commission (NDDC) carried out the process of dredging in order to enhance the environment of the river by dealing with problems related to eutrophication, sedimentation, and pollution. However, the process of dredging involves the removal of sediments, riverbank soils, and riparian vegetation, the disposal of dredged sediments taking place on the banks of the river [11]. The process of dredging can lead to a number of negative environmental impacts such as acidification, water pollution, death of fish and plants [11]. Apart from that, the disturbance of sediments due to dredging can result in re-suspension of pollutants including heavy metals [12].

Heavy metals are one of the most persistent environmental contaminants owing to their non-biodegradable properties, toxicity, and ability to accumulate in aquatic organisms and sediment. The sources of heavy metals in the aquatic environment include not only natural weathering processes but also anthropogenic sources such as industrial effluents, agricultural runoff, sewage, and urban storm waters [11,13,14]. Once released into the aquatic system, heavy metals are distributed in the water column, suspended particulate

material, and sediments where they can stay for a long time. Accumulation of heavy metals in aquatic organisms is of considerable ecological and public health hazard due to their biomagnifications via the food web, which can adversely affect fish, wildlife, and humans [15-17]. In order to quantify the level of contamination with heavy metals, different pollution indices have been formulated as useful tools for environmental evaluation purposes. Pollution indices offer a quantitative approach towards contamination and also make it easy to communicate pollution levels to scientists, environmental managers, and decision-makers [18]. Pollution indices can be categorized into single and integrated indices. Single indices are those that assess contamination by individual metals such as the contamination factor (Cf), ecological risk factor (Er), and enrichment factor (Ef). Integrated indices are those that assess the combined impacts of different metals. Some of the integrated indices include the Pollution Index Sum (PIsum), Pollution Index Average (PIavg), and Nemerow Pollution Index (PINemerow) [19, 20]. These pollution indices have gained popularity for evaluating pollution of sediments and water.

Several studies have investigated the environmental quality of the Nworie River. Mgbudem et al. [21] studied the toxic of Heavy Metals of Public Health Importance in Surface Water from Nworie River. Okere et al. [13] evaluated Heavy Metal Risks of Otamiri and Nworie River. Umunnakwe et al. [11] assessed water quality using the Water Pollution Index to determine the levels of dissolved organic and inorganic substances. Although these studies have provided valuable information on the river's condition, continuous monitoring is necessary because pollution levels and contaminant distributions are dynamic and may change with increasing anthropogenic activities and environmental disturbances.

Therefore, the present study aims to assess the current pollution status of the Nworie River by determining the concentrations and spatial variations of selected heavy metals and evaluating their implications for the river's environmental quality. The findings are expected to provide updated baseline information for environmental monitoring and support sustainable management and conservation of the river ecosystem.

Materials and Methods

Study Area

This study was carried out along Nworie River, located in Owerri, Imo State, Nigeria, from January 2022 to January 2023. The Nworie River is a major tributary of the Otamiri River covering an approximate length of 9.2 km (Figure 1).

Owerri, the state capital and biggest city of Imo State, lies in south eastern Nigeria in about 5°29'00" N and 7°02'00" E latitudinal coordinates. The climate in the area is tropical with two distinct seasons; the rainy season extending from April to October and the dry season stretching from November to March.

The amount of annual rainfall is in the range of 1,700 mm and 2,500 mm with most of the rain falling between March and October. Temperature is generally quite stable all year round with the highest temperatures ranging between 28°C to 35°C and the lowest between 19°C and 24°C.

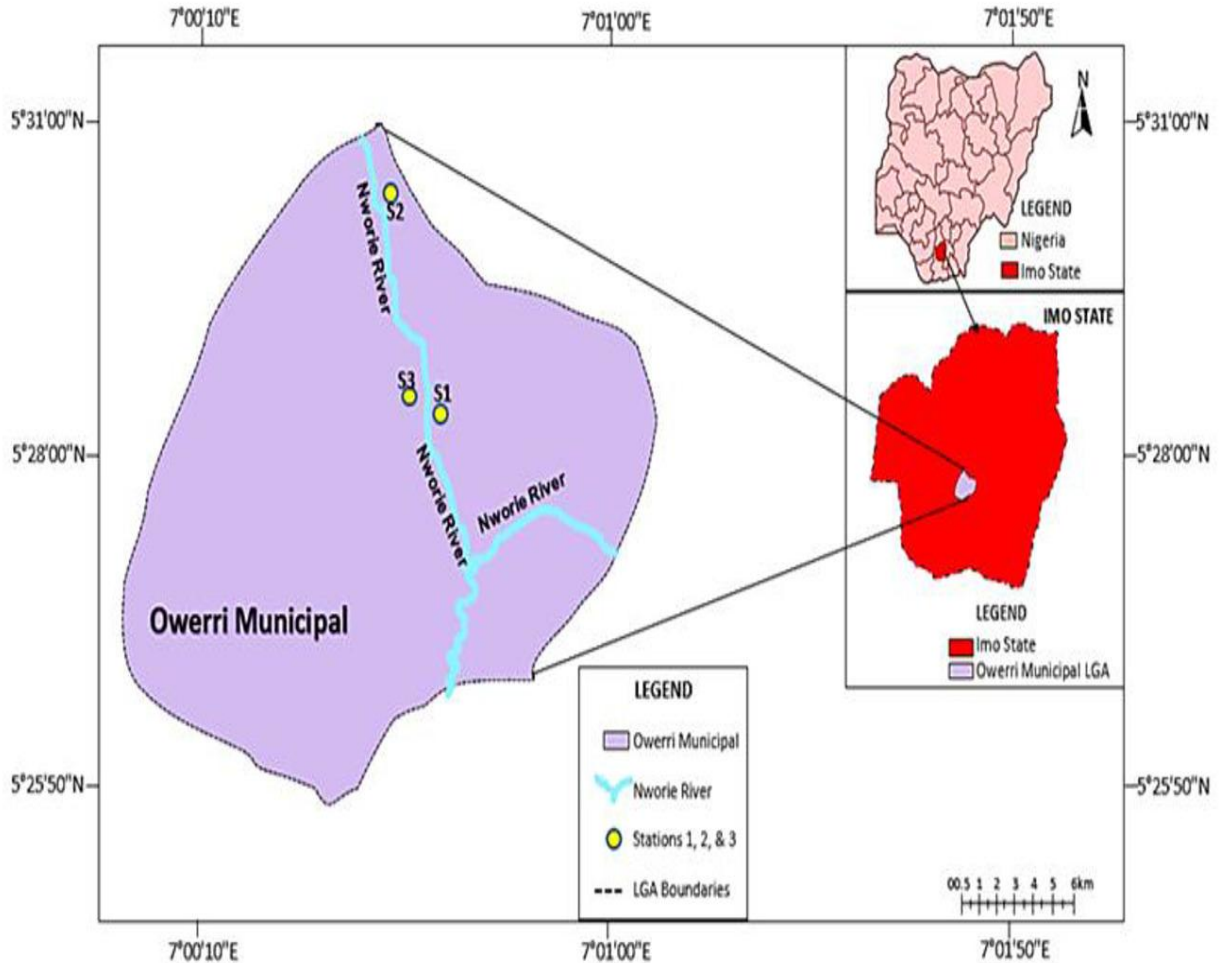


Figure1: Map showing Nworie River

Source: [22]

Sampling

Sampling was done on a monthly basis between January 2022 to January 2023 during both dry and rainy seasons. There were three sampling stations located along the lower part of the river; Egbeada Bridge (upper station), Umezuruike Hospital Bridge (middle

station), and Akachanwa Bridge (lower station). The geographical coordinates of each sampling site were determined using GPS and Google Maps (figures 2-4).

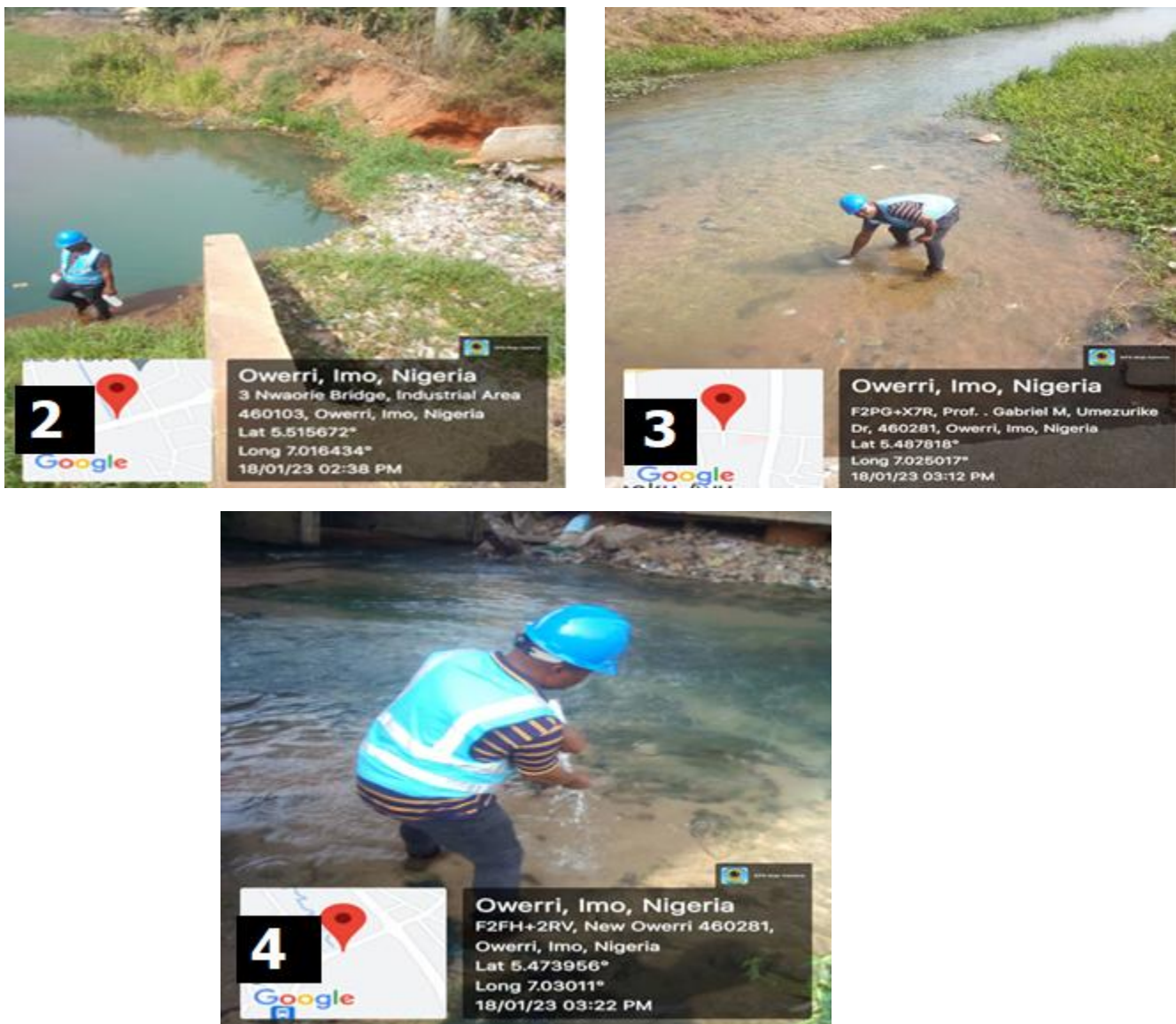


Figure 2-4: Google Map of Point 1 (Egbeada), Point 2 (Umezuruike) and Point 3 (Akanchawa)

Water Sampling, Treatment and Preservation for Heavy Metal Analysis

Bottles used for sampling purposes were first preconditioned using a metal-free non-ionic detergent solution (Citranox) followed by thorough rinsing using distilled water. Water samples were collected from each sampling point by dipping the bottles about 10 cm beneath the water surface and collecting 0.5 liters of water in each bottle. The samples were immediately acidified with 10% nitric acid (HNO_3), then kept in an ice bath and taken to the laboratory. The samples were later filtered using Whatman No. 1 filter paper and kept in refrigeration at 4°C.

Digestion of Water for Heavy Metal Analysis

Each of the water samples was then subjected to filtration using Whatman filter paper through a 100 mL aliquot. The filtrate was acidified using 2 mL of concentrated nitric acid (HNO_3) and 5 mL of concentrated hydrochloric acid (HCl). The resulting mixture was heated in an electric hot plate until almost dried. The resulting dry material was then dissolved in a 100 mL volumetric flask using deionized water. This resulted solution was then subjected to analysis for heavy metal content using Atomic Absorption Spectrophotometer (AAS) according to USEPA [22] standard method.

Heavy Metal Analysis Using Atomic Absorption Spectrophotometer (AAS)

Heavy metal contents were determined using Atomic Absorption Spectrophotometer (AAS). Standard metal solutions were made and used to set up the spectrophotometer prior to analysis of samples. Before digestion, each water sample was well mixed by shaking. A 100 ml portion of the water sample was pipetted in a 250 ml beaker, and 5 ml of concentrated nitric acid was added. This was boiled till the volume decreased to about 20 ml and again 5 ml of nitric acid was added and the mixture boiled till there was no residue left. After cooling, the digest was poured in a 100 ml volumetric flask and diluted to volume with metal free distilled water. The AAS was switched on and left to warm up to the desired conditions. Operating conditions such as resonance wavelength, type of flame, type of fuel, lamp current, and slit width were selected for each metal. Hollow cathode lamps for the specific metals were set up and calibration of the instrument was done with the help of standard solutions. Calibration curves were drawn by recording the absorbances of each standard solution aspirated in the flame. Subsequently, the digested water samples were aspirated through the capillary tube into the flame, and the absorbance readings were recorded for the determination of heavy metal concentrations.

Determination of pollution levels using (Single Indices Calculations)

The level of heavy metal pollution in the Nworie River was assessed using single pollution indices. These indices evaluate the contamination status of individual metals and included the contamination factor (C_f) and ecological risk factor (Er). The calculated

indices were used to assess the degree of heavy metal contamination and the associated ecological risks at the sampled locations.

Contamination Factor (Cf)

The level of heavy metal contamination was evaluated using the Contamination Factor (Cf), as proposed by Håkanson [24]. The contamination levels were classified according to the following criteria [24,25]. $Cf < 1$: Low contamination, $1 \leq Cf < 3$: Moderate contamination, $3 \leq Cf < 6$: Considerable contamination, $Cf \geq 6$: Very high contamination. The contamination factor was calculated using the following equation:

$$Cf = \frac{C_{\text{metal}}}{C_{\text{background}}}$$

where

C_{metal} is the measured concentration of the heavy metal in the water sample, and $C_{\text{background}}$ is the corresponding background or baseline concentration.

Ecological Risk Factor (Er).

The ecological risk factor incorporates both the contamination level (Cf) and the toxic-response factor (Tr), thereby providing a more comprehensive assessment of the potential ecological impact of heavy metals [24]. The calculated Er values were compared with the ecological risk categories proposed by Håkanson [24] and further applied by Shin and Lam [26]. The ecological risk factor was interpreted using the following classification: $Er < 40$: Low ecological risk, $40 \leq Er < 80$: Moderate ecological risk, $80 \leq Er < 160$: Considerable ecological risk, $160 \leq Er < 320$: High ecological risk, $Er \geq 320$: Very high ecological risk

It is calculated as:

$$Er = Tr \times Cf$$

where

Tr is the toxic-response factor of a specific heavy metal and
Cf is the contamination factor.

Ecological Risk Index (ERI)

The Ecological Risk Index (ERI), also referred to as the Potential Ecological Risk Index (RI), is used to evaluate the combined ecological risk posed by multiple heavy metals in an ecosystem. This index considers both the contamination levels and the toxicities of individual metals, making it a valuable tool for assessing the overall ecological risk and potential for heavy metal accumulation within the environment. The ERI was calculated using the equation proposed by Håkanson [24] and adopted by Taiwo et al. [27]. The overall ecological risk was classified as follows: $ERI (RI) < 150$: Low ecological risk, $150 \leq ERI (RI) < 300$: Moderate ecological risk, $300 \leq ERI (RI) < 600$: Considerable ecological risk, $ERI (RI) \geq 600$: Very high ecological risk [24].

$$ERI(RI) = \sum Eri = \sum (Tri \times Cfi)$$

where

Eri is the ecological risk factor of the heavy metal,

Tri is its toxic-response factor, and

Cfi is its contamination factor.

Data Analysis

Data collected were subjected to analysis of variance (ANOVA). Mean separations were done using fisher LSD at 0.05% probability. Two mean value were subjected to studentized-t-test using statistical analytical system (SAS) software, version 8.0.

Results

Table 1 presents the concentrations of heavy metals in water samples collected from the Nworie River during the dry season. Mercury concentration was highest at Point 3 (downstream) compared to the other sampling points. Overall, the concentrations of the heavy metals analyzed exceeded the Federal Ministry of Environment (FMEnv) permissible limits for water quality. Lead concentration was highest at Point 1 (upstream), whereas arsenic and chromium recorded their highest concentrations at Point 3 (downstream). Nickel was not detected at Egbeada (Point 1) and Umezuruike Hospital (Point 2) but was detected at Point 3 at the FMEnv permissible limit. Chromium concentrations were highest at Point 3 (0.65 mg/L), followed by Point 2 (0.10 mg/L), with the lowest concentration recorded at Point 1 (0.06 mg/L). Mercury concentrations exceeded the FMEnv permissible limit at all sampling points, although the lowest value was observed at Point 2 (0.015 mg/L). Cadmium concentration was highest at Point 2 and lowest at Point 1. Table 2 shows the heavy metal concentrations in water samples collected during the rainy season. All the analyzed metals exceeded the FMEnv permissible limits except chromium, which remained within the acceptable limit at Point 1 (0.03 mg/L) and Point 2 (0.04 mg/L). The highest concentrations of all the analyzed metals were recorded at Point 3 (downstream), followed by Point 2 (midstream), while Point 1 (upstream) recorded the lowest concentrations. Lead had the highest concentration among all the metals analyzed, followed by mercury, whereas nickel had the lowest concentration. Unlike the dry season, nickel was detected at all sampling points during the rainy season, although its concentrations remained below the FMEnv permissible limit. Table 3 summarizes the concentrations of heavy metals in water from the Nworie River from 2010 to the present across the three sampling points. Cadmium concentrations remained below the permissible limit throughout the study period except in 2013, when it increased to 0.077 mg/L. Lead concentrations recorded in the current

study were higher than those reported in previous studies, although they remained below the FMEnv/WHO permissible limits. Zinc concentrations ranged from 0.4 to 1.3 mg/L between 2010 and the present and remained below the permissible standard. Zinc concentration was highest at Akanchawa (Point 3), followed by Umezuruike Hospital (Point 2), with the lowest concentration recorded at Egbeada (Point 1). Overall, Akanchawa (Point 3) recorded the highest concentrations for most of the heavy metals analyzed in the current study. Iron concentrations exceeded the permissible limits at Points 2 and 3. Contamination factors (C_f) and Ecological risk factors (Er) values obtained for heavy metals pollutants in Nworie River at Egbeada (Point 1) in both dry and rainy seasons are shown in Table 4. Mercury had the highest C_f and Er value in both seasons, with C_f and Er values of 0.088 and 3.52, respectively, in the dry season, and 0.040 and 1.60, respectively, in the rainy season. On the other hand, Chromium had the lowest C_f and Er values, with C_f and Er values of 0.001 and 0.002, respectively, in the dry season, and 0.0001 and 0.0002, respectively, in the rainy season. Table 5 presents the heavy metal pollution concentration determined through the contamination factor (C_f) and ecological risk factor (Er) of Nworie River at Umezuruike (Point 2) in the dry and rainy seasons. Mercury was the heavy metal that showed the highest C_f and Er during the dry and rainy seasons with a C_f value of 0.060 and 2.40, and Er value of 0.044 and 1.76 for the dry and rainy seasons, respectively. In the dry season, the lowest C_f and Er values were registered by Chromium with a value of 0.001 and 0.0002, respectively. Contamination factor (C_f) and ecological risk (Er) factor of the heavy metals in Nworie River, Akanchawa (Point 3) for the dry and rainy seasons are given in Table 6. The highest contamination and ecological risk factors were recorded for mercury, where the C_f and Er values were 0.072 and 2.88, respectively, in the dry season while the values were 0.056 and 2.24, respectively, in the rainy season. On the other hand, the lowest contamination and ecological risk factors were recorded for chromium, where the C_f and Er values were 0.001 and 0.003, respectively, in the dry season while the values were 0.003 and 0.006, respectively, in the rainy season. Figures 5-7 illustrate the seasonal variation in heavy metal concentrations during the dry and rainy seasons at the three sampling locations: Egbeada (Point 1, upstream), Umezuruike Hospital (Point 2, midstream), and Akanchawa (Point 3, downstream). Figure 8 presents the historical trend of heavy metal concentrations in water collected from Egbeada (Point 1) between 2010 and the present. Mercury, chromium, and arsenic were not detected in previous studies but were detected in the current study at concentrations of 0.011 mg/L, 0.003 mg/L, and 0.003 mg/L, respectively. Cadmium, iron, and zinc remained below the WHO/FMEnv permissible limits throughout the study period. Lead concentrations were below the permissible limit in all years except 2013, when a concentration of 0.81 mg/L was recorded. Figure 9 shows the heavy metal concentrations in water samples collected from Umezuruike Hospital (Point 2) from 2010 to the present. Mercury was not detected in studies conducted between 2010 and 2013 but was detected in 2019 and in the current

study. Arsenic was absent in previous studies but was detected in the current study at a concentration below the permissible limit. Lead concentration was below the permissible limit in 2010 but increased from 2013 onward. Iron concentrations exceeded the permissible limit in 2010, 2013, and the current study but remained below the standard in 2019. Figure 10 presents the heavy metal concentrations in water samples collected from Akanchawa (Point 3) from previous studies to the present. Arsenic and chromium were not detected in earlier studies but were detected in the current study at concentrations below the WHO/FMEnv permissible limits. Lead and zinc concentrations exceeded the permissible limits in most of the study years but were not detected in 2019. Iron concentration exceeded the permissible limit but remained lower than the value reported in 2019. Mercury was absent in earlier studies but exceeded the permissible limit in 2019.

Table 1: Heavy metal analysis in water from Nworie River during Dry season

Parameters	FMEnv Standard	Nworie River						Test
		Egbeada point1 N5.515671 ⁰ E7.016434 ^o		Umezuruike Hospital point2 N5.487818 ^o E7.025017 ^o		Akanchawa point 3 N5.473956 ⁰ E7.03011 ^o		
		RUN 1	RUN 2	RUN 1	RUN 2	RUN 1	RUN 2	
Mercury, mg/l Hg	0.001	0.021	0.023	0.017	0.014	0.018	0.018	AAS
Cadmium, mg/l Cd	0.05	0.011	0.013	0.021	0.021	0.019	0.017	AAS
Arsenic, mg/l As	0.01	0.003	0.003	0.018	0.016	0.056	0.059	AAS
Chromium, mg/l Cr	0.05	0.006	0.006	0.009	0.011	0.064	0.059	AAS
Nickel, mg/l Ni	0.02	ND	ND	ND	ND	0.002	0.001	AAS
Lead, mg/l Pb	0.05	0.082	0.081	0.064	0.062	0.053	0.050	AAS

Table 2: Heavy metal analysis in water from Nworie River during Rainy season

Parameters	FMEnv Standard	Nworie River						Test
		Egbeada point1 N5.515671 ⁰ E7.016434 ^o		Umezuruike Hospital point2 N5.487818 ^o E7.025017 ^o		Akanchawa point 3 N5.473956 ⁰ E7.03011 ^o		
		RUN 2	RUN 1	RUN 2	RUN 1	RUN 2	RUN 2	
Mercury, mg/l Hg	0.001	0.011	0.009	0.011	0.011	0.014	0.014	AAS
Cadmium, mg/l Cd	0.05	0.014	0.013	0.017	0.017	0.023	0.021	AAS
Arsenic, mg/l As	0.01	0.03	0.03	0.09	0.10	0.28	0.28	AAS
Chromium, mg/l Cr	0.05	0.03	0.04	0.04	0.04	0.24	0.26	AAS
Nickel, mg/l Ni	0.02	0.01	0.01	0.01	0.01	0.02	0.01	AAS
Lead, mg/l Pb	0.05	0.55	0.56	0.68	0.68	0.76	0.77	AAS

Table 3: Results of Heavy metals in water from Nworie River from 2010 to Date

Heavy Metals	WHO/ FME _{env} Standard	NWORIE RIVER											
		EGBEADA POINT1				UMEZURIKE HOSPITAL POINT2				AKANCHAWA POINT 3			
		2010	2013	2019	Current	2010	2013	2019	Current	2010	2013	2019	Current
Mercury, mg/l Hg	0.001	-	-	ND	0.001	-	-	0.268	0.011	-	-	0.268	0.014
Cadmium, mg/l	0.05	0.02	0.016	ND	0.014	0.04	0.043	0.14	0.017	0.06	0.077	0.18	0.023
Arsenic, mg/l As	0.01	-	-	-	0.003	-	-	-	0.009	-	-	-	0.028
Chromium, mg/l	0.05	BDL	ND	-	0.003	BDL	ND	-	0.004	BDL	ND	-	0.024
Lead, mg/l Pb	0.05	0.02	0.08	ND	0.055	0.03	0.16	0.070	0.068	0.08	0.13	0.068	0.076
Zinc, Zn	5	0.7	0.81	ND	0.31	0.4	0.95	ND	0.72	0.6	0.84	ND	1.3
Iron, Fe	0.3	0.29	0.34	0.09	0.71	0.48	0.55	0.20	0.42	1.62	0.72	0.20	0.35

Key:

2010 Umunnakwe and Nnaji,

2013 Nwagbara et al.,

2019 Agudozie et al.,

ND Not detected

Table 4: Heavy metal pollution levels using contamination factor and ecological factor for Nworie river (Egbada point 1) raining and dry season

	Dry Season				Rainy Season			
Heavy Metals	Cf	Level of pollution	Er	Level of pollution	Cf	Level of pollution	Er	Level of pollution
Mercury	0.088	LCF	3.52	LER	0.04	LCF	1.60	LER
Cadium	0.012	LCF	0.36	LER	0.014	LCF	0.42	LER
Arsenic	0.002	LCF	0.02	LER	0.002	LCF	0.02	LER
Chromium	0.001	LCF	0.002	LER	0.0001	LCF	0.0002	LER
Lead	0.061	LCF	0.07	LER	0.007	LCF	0.035	LER
Zinc	0.001	LCF	0.001	LER	0.001	LCF	0.001	LER
Iron	0.004	LCF	-	LER	0.002	LCF	-	LER

Table 5: Heavy metal pollution levels using contamination factor and ecological factor for Nworie river (Umezuruike point 2) raining and dry season

	Dry Season				Rainy Season			
Heavy Metals	Cf	Level of pollution	Er	Level of pollution	Cf	Level of pollution	Er	Level of pollution
Mercury	0.60	LCF	2.40	LER	0.044	LCF	1.76	LER
Cadium	0.021	LCF	0.63	LER	0.017	LCF	0.51	LER
Arsenic	0.001	LCF	0.01	LER	0.007	LCF	0.007	LER
Chromium	0.0001	LCF	0.0002	LER	0.0004	LCF	0.008	LER
Lead	0.001	LCF	0.005	LER	0.007	LCF	0.035	LER
Zinc	0.0003	LCF	0.0003	LER	0.006	LCF	0.006	LER

Table 6: Heavy metal pollution levels using contamination factor and ecological factor for Nworie river (Akanchawa point 3) raining and dry season

	Dry Season				Rainy Season			
Heavy Metals	Cf	Level of pollution	Er	Level of pollution	Cf	Level of pollution	Er	Level of pollution
Mercury	0.072	LCF	2.88	LER	0.056	LCF	2.24	LER
Cadium	0.018	LCF	0.54	LER	0.022	LCF	0.66	LER
Arsenic	0.004	LCF	0.04	LER	0.018	LCF	0.18	LER
Chromium	0.001	LCF	0.002	LER	0.003	LCF	0.006	LER
Lead	0.001	LCF	0.005	LER	0.011	LCF	0.055	LER
Zinc	0.005	LCF	0.005	LER	0.007	LCF	0.007	LER

Key: Cf- Contamination Factor LCF - Low Contamination Factor
LER – Low Ecological Risk Erⁱ -Ecological Risk Factor

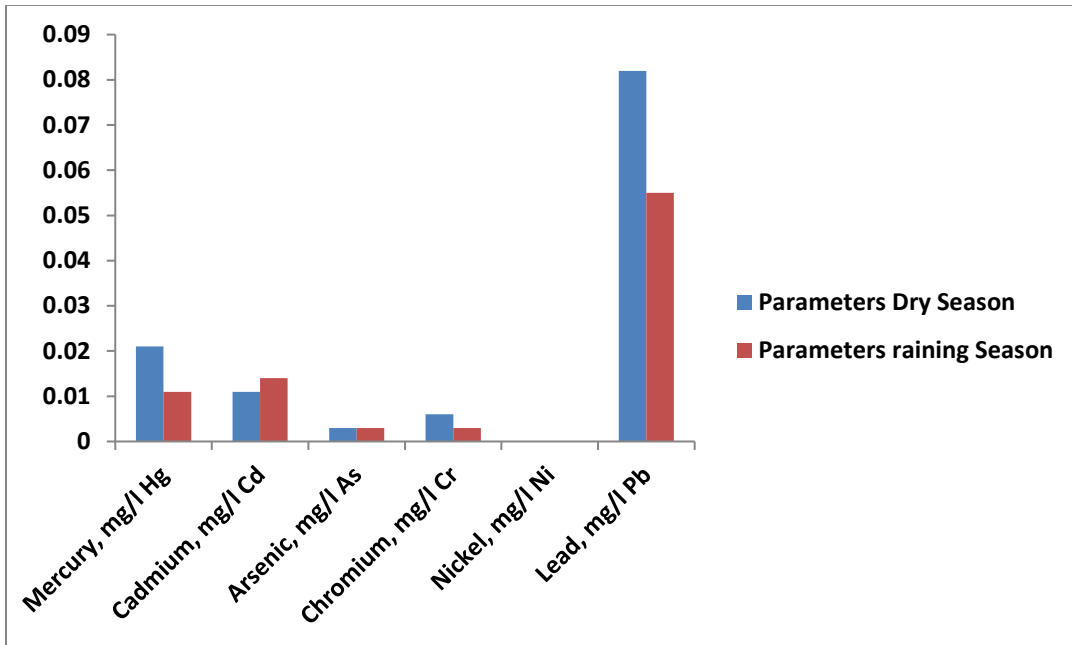


Figure 5 showing parameters of dry and wet season Egbeada point 1 (upstream)

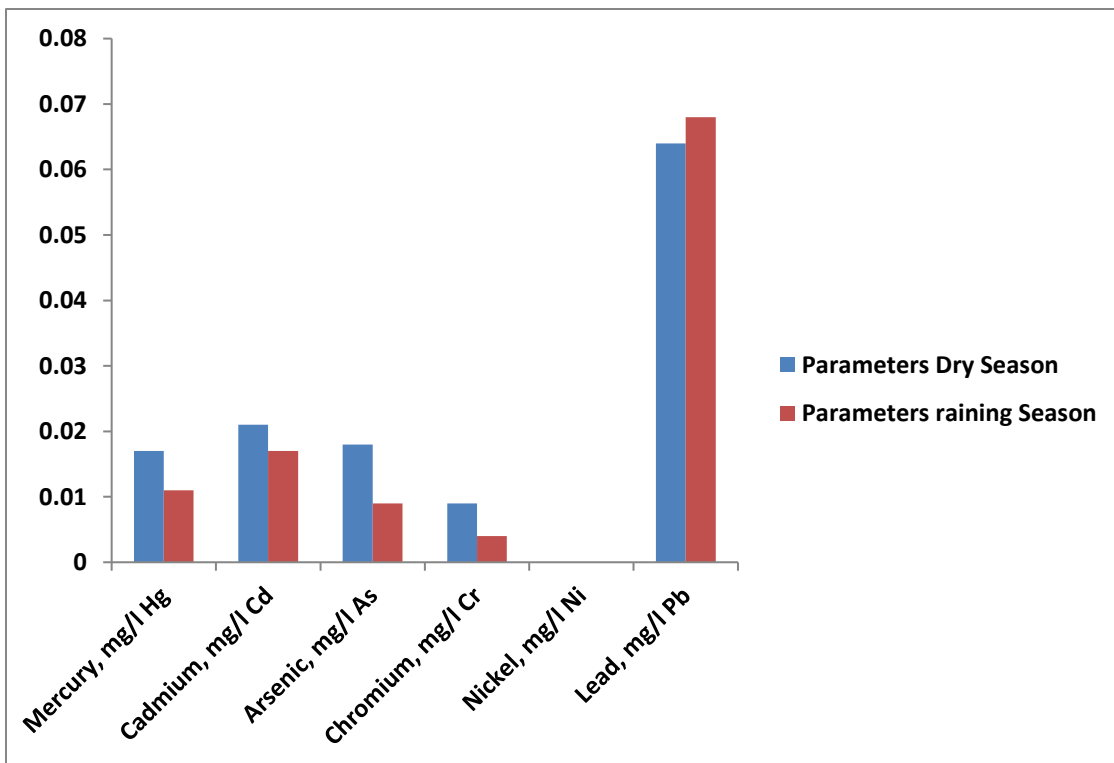


Figure 6: showing parameters of dry and wet season Umezuruike hospital point 2 (mid stream)

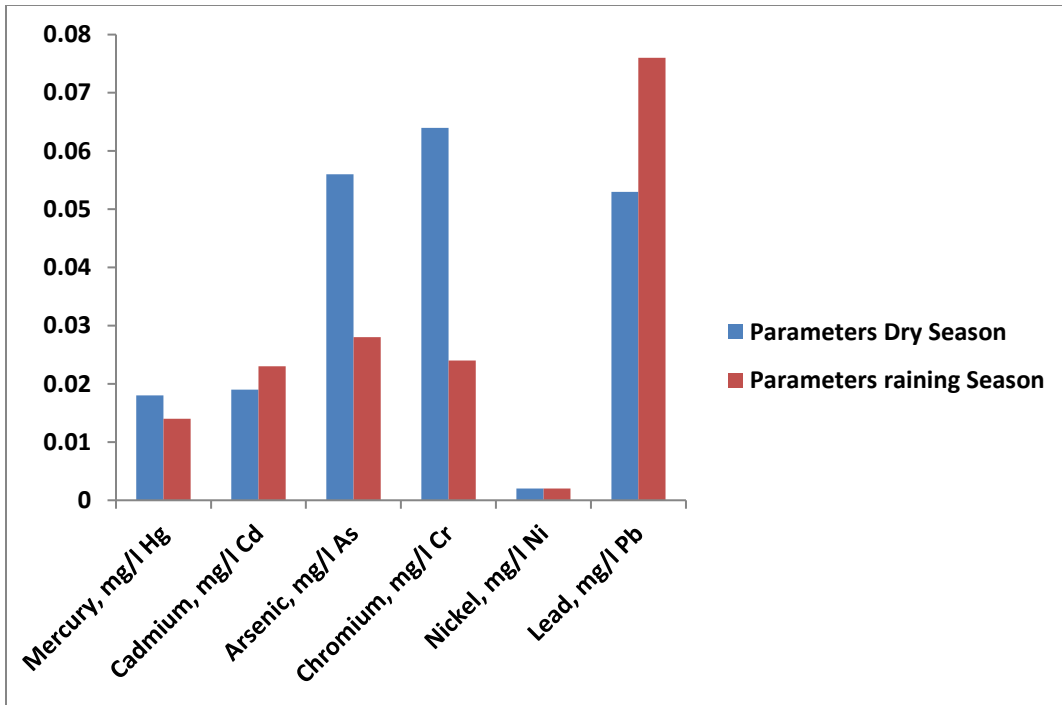


Figure 7 showing parameters of dry and wet season Akanchawa point 3 (downstream)

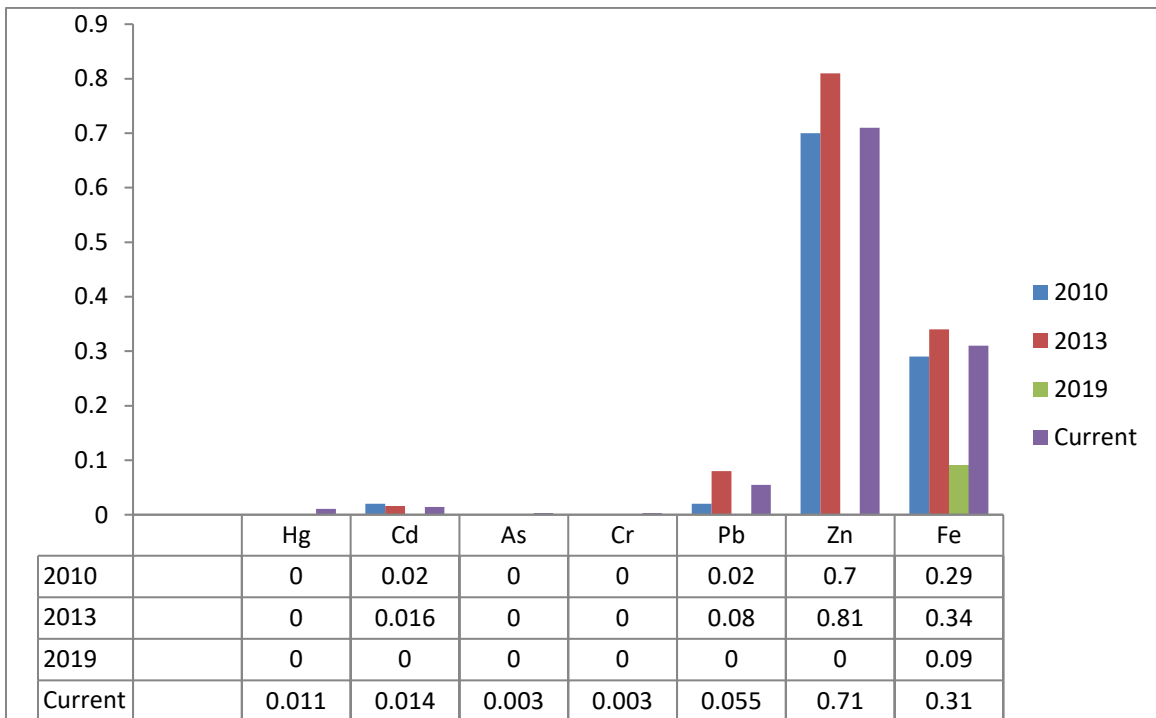


Figure 8: Heavy metals in Nworie River (Egbada Point 2) compared to previous works

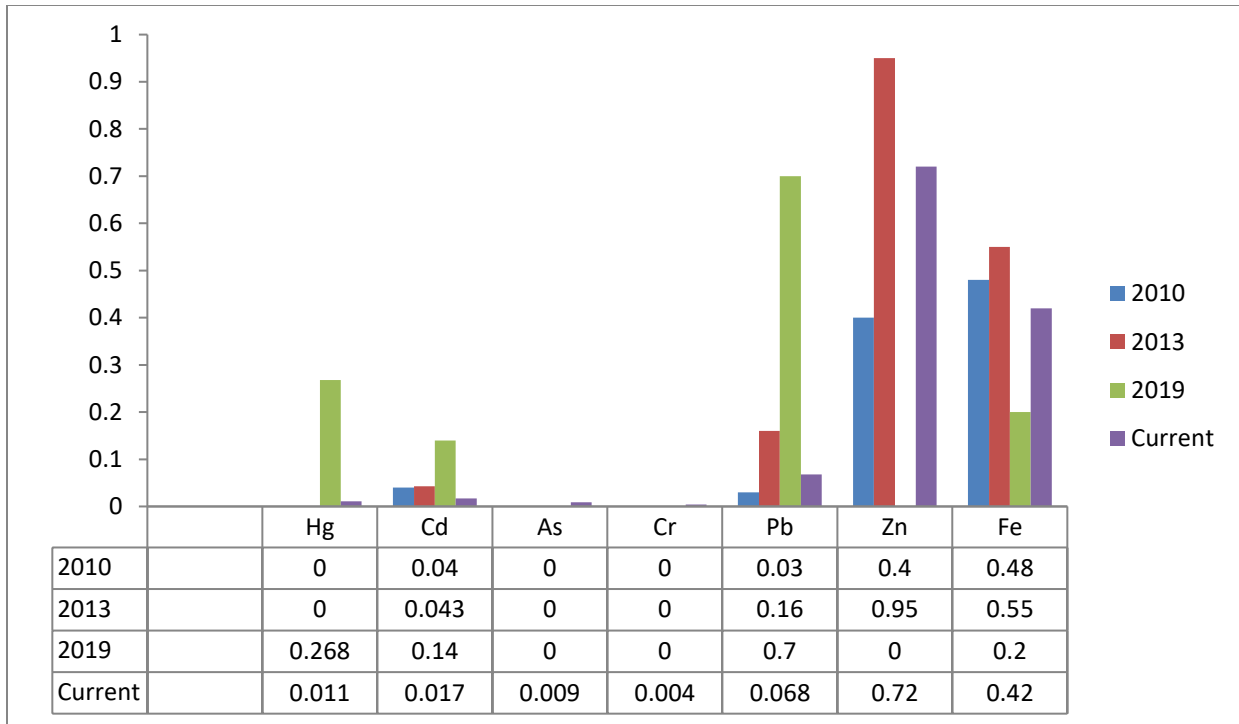


Figure 9: Heavy metals in Nworie River (Umezuruike Point 2) compared to previous works

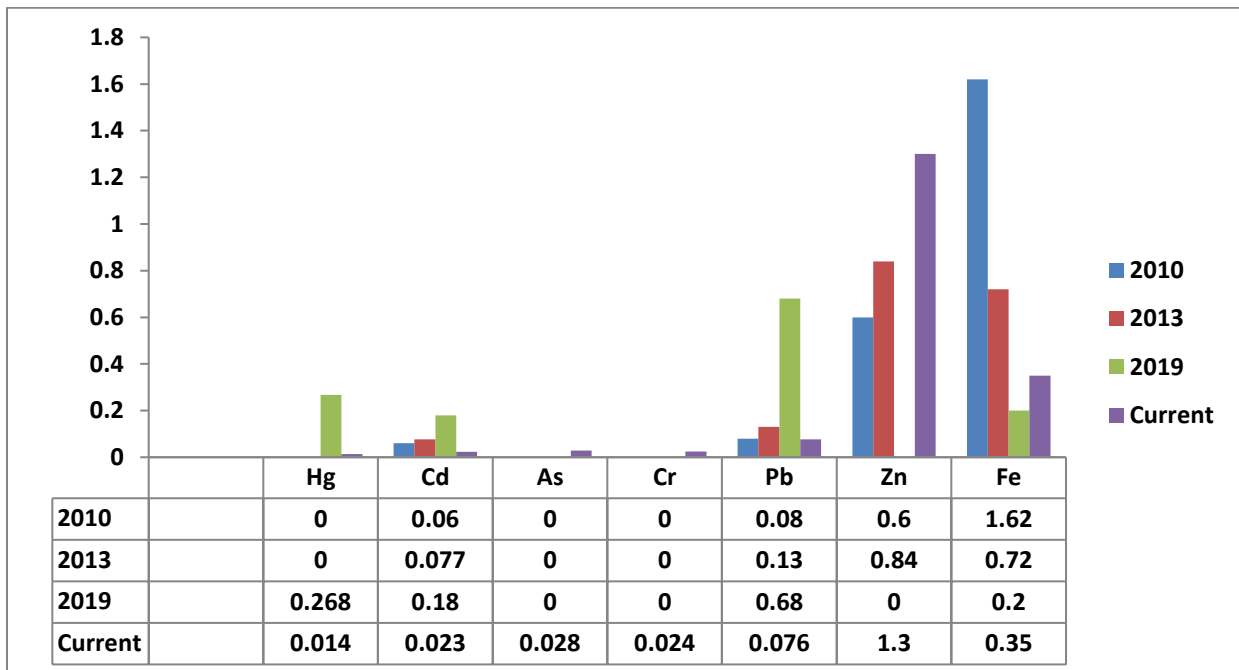


Figure 10: Heavy metals in Nworie River (Akanchawa point 3) compared to previous works

Discussion

The results of this study revealed varying concentrations of heavy metals in the Nworie River during both the dry and rainy seasons. Among the metals analyzed, mercury was the most significant contaminant, with concentrations exceeding the permissible limits for drinking water at all sampling stations in both seasons. During the rainy season, the highest mercury concentration (0.014 mg/L) was recorded at Akachanwa, while the highest concentration during the dry season (0.021 mg/L) was observed at Egbeada. These findings are consistent with those of Okere et al [13], Umunnakwe et al. [11], who also reported the presence of mercury in the Nworie River. However, unlike earlier studies in which mercury was not detected, the current findings indicate elevated concentrations above the recommended limits. The increased mercury levels may be attributed to the direct discharge of industrial effluents and mining-related wastes into the river, as several industrial activities are located along the river corridor and release untreated wastes into the water. Cadmium concentrations observed in this study were comparable to those reported in previous studies on the Nworie River. Earlier findings indicated that cadmium concentrations at sampling Points 1 and 2 were below the permissible limit, whereas Point 3 exceeded the recommended standard. The elevated concentration at Point 3 may be attributed to the infiltration of landfill leachates into the river, as reported by Turner [28]. Cadmium contamination in aquatic environments is commonly associated with the disposal of cadmium-containing products and landfill runoff. The proximity of a landfill site to Point 3 likely contributed to the increased cadmium concentration observed. Cadmium pollution in surface water and groundwater poses serious ecological and public health concerns because prolonged exposure can lead to bioaccumulation and adverse effects in living organisms through the food chain [13]. Arsenic concentrations recorded in this study ranged from 0.002 to 0.009 mg/L, remaining below the WHO permissible limit for drinking water. Although arsenic is naturally present in the Earth's crust and widely distributed in the environment, its inorganic forms are highly toxic. Similarly, chromium concentrations ranged from 0.02 to 0.04 mg/L and remained below the recommended permissible limits. Chromium enters aquatic systems primarily through the weathering and leaching of rocks and soils. In addition, dredging activities along the Nworie River may have contributed to chromium mobilization by disturbing riverbanks and removing vegetation, thereby increasing sediment transport into the river [13]. Lead concentrations in this study exceeded the WHO/FMEnv permissible limits for drinking water [29]. The elevated lead levels may be associated with dredging activities, particularly the improper disposal of excavated materials along the riverbanks. Abandoned dredging equipment and pipelines observed within the river channel may also contribute to lead contamination through corrosion. According to USEPA/USAGE [30], lead contamination in water is enhanced under acidic conditions and in water with low mineral content. Similar observations were reported by Umunnakwe et al. [11], who attributed elevated lead concentrations in the Nworie River to the presence of dredging machinery. Zinc concentrations recorded in this study were below the WHO/FMEnv recommended limit of 5 mg/L for drinking water. Although the concentrations did not exceed permissible levels, elevated zinc concentrations can impart a metallic taste and a milky or turbid appearance to water. Zinc contamination in aquatic environments is commonly associated with the corrosion of galvanized metals and the disposal of solid wastes containing trace amounts of zinc, lead, and cadmium. Iron

concentrations exceeded the WHO/FMEnv permissible limits for drinking water. This may be attributed to the corrosion of iron-based dredging materials and equipment left within the river channel. Elevated iron concentrations can discolor water, giving it a reddish-brown appearance and an unpleasant metallic taste. Overall, the results suggest that dredging activities have significantly influenced the heavy metal composition of the Nworie River by increasing the concentrations of several metals, thereby reducing water quality [13]. The contamination factor (C_f), which compares present heavy metal concentrations with background (pre-anthropogenic) levels, indicated considerable to high mercury contamination across the three sampling stations, with C_f values of For dry season 0.088, 0.60, and 0.072, for rainy season 0.4, 0.044, and 0.056. Chromium exhibited the lowest contamination factor at all sampling points. It should be noted that contamination factor values depend on the selected background concentration. Consequently, a metal may exhibit a relatively low contamination factor despite having a high measured concentration. Therefore, low contamination factor values should not be interpreted as an absence of pollution or environmental risk.

Conclusion

The assessment of heavy metals revealed that mercury, arsenic and chromium were detected in this study and within WHO standard but not detected in previous studies and this attributes to high level of solid wastes disposed into this river. Comparison of the present findings with previous studies indicates a gradual deterioration in the water quality of the Nworie River, largely driven by poor waste management practices within Owerri and its surrounding communities. To mitigate further degradation, environmental protection laws should be strictly enforced to prevent indiscriminate dumping of refuse into waterways and drainage systems, with appropriate penalties imposed on offenders. Regular monitoring of the river's physicochemical characteristics and heavy metal concentrations is essential to detect changes in water quality, protect aquatic ecosystems, and safeguard public health. Furthermore, potentially polluting activities, including indiscriminate waste disposal, agricultural practices involving agrochemicals, and mechanic workshops, should be restricted within the Nworie River watershed to ensure the long-term sustainability of the river and its ecological functions.

Abbreviations

AAS	Atomic Absorption Spectrophotometer
AIFCE	Alvan Ikoku Federal College of Education
C_f	Contamination factor
Er	Ecological Risk Factor
FMC	Federal Medical Centre
FMEnv	Federal Ministry of Environment
GPS	Global Positioning System
LCF	Low Contamination Factor
LER	Low Ecological Risk
NDCC	Niger Delta Development Commission
USEPA	United States Environmental Protection Agency
WHO	World Health Organization

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Author Contribution

FUN, CMUA and CAI conceptualized the study and designed the study. JII and TCM participated in fieldwork and data collection. JII performed the data analysis and interpreted the data. IJI prepared the first draft of the manuscript, reviewed by all the authors. All authors contributed to the development of the final manuscript and approved its submission.

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Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation

Declarations

Ethical Approval

Not applicable

Consent for publication

Figures 2-4 was the Researcher (Corresponding author) pictures. So the Journal have my consent

Competing interests

The authors declare no competing interests.

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