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Utilisation of biotic and abiotic components in the ecological assessment of the Ossiomo River, Edo State, Nigeria

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Fish (*Gymnarchus niloticus*) and sediment samples were used as bioindicators of heavy metal contamination in the ecological assessment of the Ossiomo River. These samples were collected monthly (August 2021 to January 2022) and analysed for heavy metal content using standard methods. Results from this study showed that both the sediment and fish were contaminated with heavy metals. Heavy metal concentration profile of Fe > Zn > M n > Cu > Pb > Cr > Cd was observed in the sediment. Bioaccumulation factor (BAF) for heavy metals in *G. niloticus* were > 1, with an order of Cd > Zn > Mn > Cu > Cr > Fe > Pb (gills); Cu > Cd > Zn > Cr > Mn > Fe > Pb (liver), and Mn > Zn > Cu > Cr > Fe > Cd > Pb (muscles). The pollution load index (PLI) values across the three study stations indicate that there is heavy metal pollution of the sediment (PLI > 1). Potential ecological risk index (PERI) assessment showed that stations 1 and 3 exhibited considerable ecological risk (300 < RI ≤ 600), while station 2 indicated a very high ecological risk (RI > 600). There is a need for periodic water quality assessment and monitoring of human and industrial activities within the Ossiomo River catchment area in order to forestall further deposition of more pollutants into the river and protect public health.

Keywords: ecological risk assessment, heavy metals, *Gymnarchus niloticus*, pollution index, the Ossiomo River

INTRODUCTION

Increasing industrialisation, especially in developing nations, has seen primary exploitation of the environment for economic gains at the detriment of environment. The increasing discharge of wastewater from urban settlements and runoffs from agricultural farmlands where inorganic fertilisers and pesticides are used into inland surface water bodies has caused deleterious impact on the aquatic biota (Maina, 2013; Obaidy et al., 2013; Egun and Oboh, 2023). Heavy metals, which are also referred to as metalloids, are products from natural and numerous anthropogenic

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activities, and are toxic to the environment (Ali et al., 2019). Heavy metals are deposited into the aquatic environment as constituents ofeffluent/waste discharge, surface runoffs, water transportation activities, and atmospheric depositions (Hamuna, Wanimbo, 2021). The main route of heavy metals into aquatic ecosystems is the deposition of surface runoff from their watershed and direct deposit from industrial waste. In Nigeria, heavy metals are reported in various water bodies and their concentrations are traceable to waste discharged into receiving water bodies such as rivers, streams, and lakes runoff from agricultural land and recreational activities (Adebayo, 2017; Kumari et al., 2018).

Sediment is an essential component of aquatic ecosystems. It serves as habitat for diverse aquatic organisms at various stages of their development, provides substrate for organism nutrition and deposits of fertile silts on flood plains after naturally occurring floods, and acts as deposit sink for many hazardous chemicals (Adebayo, 2017). Variations in environmental conditions and hydrogeochemical processes in the aquatic ecosystem have been reported to influence the ability of the sediment to act as a sink for the bioaccumulation pollutants (Islam et al., 2018; Lee et al., 2020). Focal examination of river beds for the presence of heavy metals in the sediment is because of their persistent and non-degradable nature, the potential for bioaccumulation in the food chain, and the ability to be remobilised into the water phase with alterations of the physicochemical conditions (Ezemonye et al., 2009; Ekeanyanwu et al., 2011; Palumbo-Roe et al., 2012).

Aquatic environments are natural sinks to pollutants, including heavy metals which can have detrimental environmental implications that may manifest through bio-magnification up the food chain (Islam et al., 2018). Also, within the aquatic food chain, the presence of heavy metals has been reported to cause a wide spectrum of debilitating effects ranging from molecular alterations, disruption of physiological development, and loss of aquatic fauna (Fernandes et al., 2008; Egun et al., 2023). In Nigeria, inland freshwater bodies have always been a vital component in human growth and sustainable development (Egun, Ogiesoba-Eguakun, 2018; Egun, Oboh, 2021; Egun, Oboh, 2023). The assessment of heavy metal contents in the sediments and aquatic organisms has been regarded as significant indicators of heavy metal contamination in freshwater systems (Rashed, 2001). The functions and services of the aquatic ecosystem of the Ossiomo River to surrounding rural communities and the increasing influx of pollutants from the watershed has necessitated this study, which is an ecological assessment of the Ossiomo River using biotic (*Gymnarchus niloticus*) and abiotic (sediment) indicators to ascertain the pollution status of the aquatic ecosystem. The biotic indicator, *G. niloticus*, was chosen for this study due to the abundance of the species, its common consumption by the surrounding communities, and its commercial value.

MATERIAL AND METHODS

Description of the study area. The study was carried out on a stretch of the Ossiomo River in Ologbo community, Edo State (Latitude 6°30'–6°32'0"N, longitude 5°39'–5°40'30"E). The river is a tributary of the Benin River and stretches over a distance of 250 km within Edo and Delta states in Southern Nigeria (Fig. 1) (Ikhuoriah, Oronsaye, 2016). The lithostratigraphic unit of the study area is the Benin formation, which is composed of sandstone and coarse sand. The predominant anthropogenic activity within the watershed are commercial agriculture and processing of farm produce. The Ossiomo River lies within the tropical rainforest belt of Nigeria, with mean temperature of 30°C (Okumagba, Ozabor, 2014).

Collection of samples. Six fresh adult-sized samples of *G. niloticus* (Fig. 2) were harvested monthly (August 2021 to January 2022) from designated fishing points along the river with the assistance of artisanal fishermen using drag nets. Fish samples were properly identified using taxonomic guides (Idodo-Umeh, 2003). They were packed in polyethylene bags and preserved in ice blocks before transported to

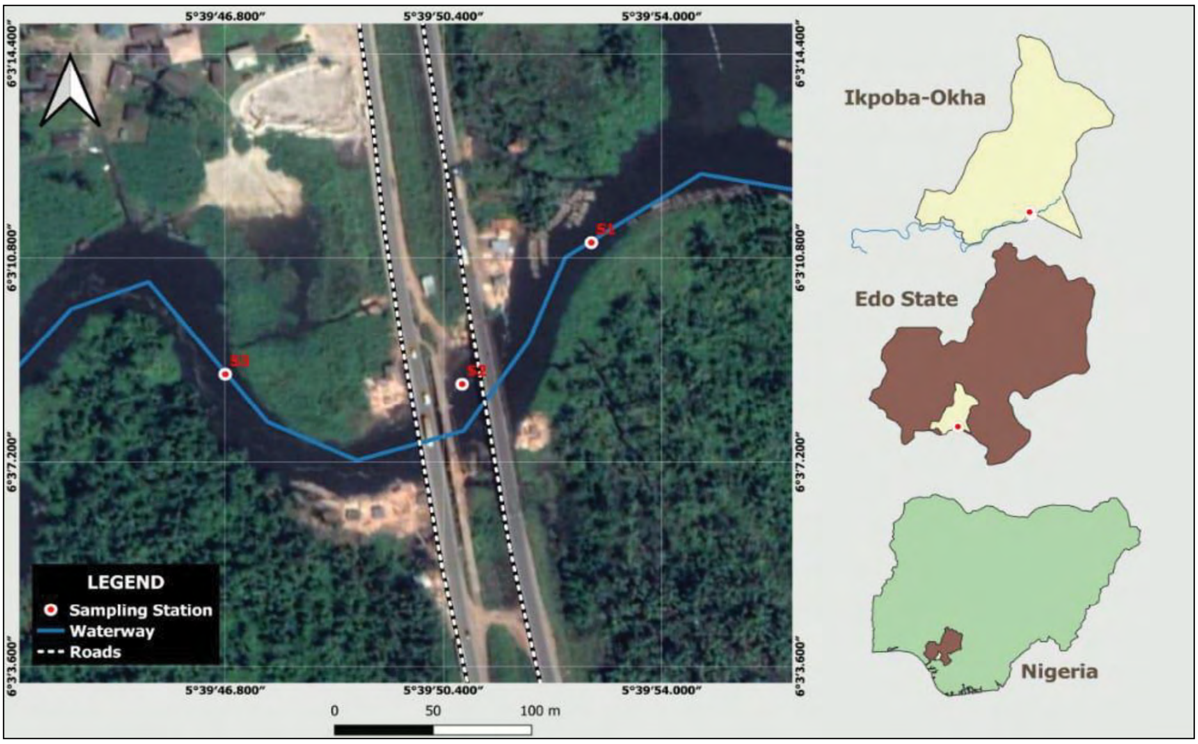

Fig. 1. Map of the Ossiomo River showing sampling stations

Fig. 2. Fish sample (*Gymnarchus niloticus*) from the Ossiomo River

the national reference laboratory – Benin Owena River Basin Authority/University of Benin Analytical Laboratory for analysis.

Bottom sediment samples were collected from three designated stations from the Ossiomo River using a 20 cm Birge-Eckman grab sampler and transferred into high density polyethylene bags. Sediment samples were collected from three designated stations on the Ossiomo River: Station 1 upstream (06° 03.197'N 005° 39.905'E), station 2 midstream (06° 03.137'N 005° 39.833'E), and station 3 downstream (6° 03.121'N 005° 39.779'E).

Laboratory analysis. The analytical methods used for the determination of sediment physicochemical parameters are summarized in Table 1.

In the laboratory, fresh samples of *G. niloticus* were thoroughly washed with distilled water. The samples were dissected, and the gills, liver, and muscles were collected. The harvested organ tissues were homogenised, and subsamples of the homogenate were taken for respective analytical tests.

Sediment and fish samples were digested by a modified procedure, and heavy metal concentration was estimated using Atomic Absorption Spectrophotometer (Bulk Scientific 210 VGP) according to the method of the Association of Analytical Chemists (AOAC, 2000). To ensure consistency and correctness of analysed samples, analytical procedures were carried out in triplicate samples.

Ecological assessment index. The extent of pollution and the contribution of each heavy metal analysed was estimated using the pollution load index (PLI), which is estimated as the concentration factor. This concentration factor ($C_f^i 1$) is the quotient obtained by dividing the concentration of each metal.

However, the PLI can be expressed as

$$\mathrm{PLI} = \sqrt[n]{C_f^i 1 \times C_f^i 2 \times C_f^i 3 \ldots\ldots\ldots C_f^i n}.$$

The formula provides a simple numerical index for determining the level of heavy metal pollution, where PLI < 1 indicates no heavy metal pollution and PLI > 1 indicates heavy metal pollution (Tomlinson et al., 1980).

Potential ecological risk index (PERI). The potential ecological risk index method of Hakanson (1980) was used to evaluate heavy metal contamination from the perspective of sedimentology reflected in equation below and was adopted to evaluate the heavy metal pollution in the sediment as well as to associate ecological and environmental effects with their toxicology and the toxic-response factor T_{ri} of Fe, Cr, Cd, Cu, Zn, Mn, and Pb, an ecological risk factor (*Er*) quantitatively expressed as the potential ecological risk of a given contaminant are given by Hakanson (1980) in the equation below:

$$Er = Tr \cdot Cf$$

where *Tr* is the toxic-response factor for a given substance and *Cf* is the contamination factor.

The following terminologies were used to describe the ecological risk factor: $Eri < 40$ – low potential ecological risk, $40 \le Eri < 80$ – moderate potential ecological risk, $80 \le Eri < 160$ – considerable potential ecological risk, $160 \le Eri < 320$ – high potential ecological risk, and $Eri \ge 320$ – very high ecological risk.

Table 1. **Analytical methods used to determine the physicochemical parameters of the sediment**

Analyte	Method reference
pH	APHA, 2005
Electrical conductivity (EC) and total hydrocarbon content (THC)	APHA, 2005
Organic carbon	Walkley and Black method
Total nitrogen	Kjeldahl wet digestion method
Exchangeable bases: potassium, sodium, calcium and magnesium	Flame photometric method
Sediment particle size distribution	Ibitoye, 2006

In the same manner as the degree of contamination, the potential ecological risk index (PERI) was defined as the sum of the risk factors:

$$\mathrm{RI} = \sum_{i=1}^{n} Eri$$

where *Eri* is the single index of ecological risk factor, and *n* is the count of the heavy metal. The following terminologies will be used for the potential ecological risk index as given by Hakanson (1980): *RI* < 150 – low ecological risk, 150 ≤ *RI* < 300 – moderate ecological risk, and *RI* > 600 – very high ecological risk (Table 2).

Bioaccumulation factor (BAF). Heavy metal accumulation in fish is quantified as BAF, which is the ratio of the concentrations of metals in fish samples to the concentration in the sediment substrate (Mountouris et al., 2002). The bioaccumulation factor higher than 1 indicates bioaccumulation (Dedeke et al., 2016). The BAF was calculated using the formula:

$$\mathrm{BAF} = C_{\mathrm{biota}}/C_{\mathrm{substrate}}$$

where C_{biota} and $C_{substrate}$ are the total concentrations of heavy metals in fish and sediment, respectively.

Data analysis. All statistical analysis was computed using Microsoft Excel, PAST 4, and Statistical Package for Social Sciences (SPSS) 21. Variations among means of heavy metal content in fish tissues were determined using analysis of variance (ANOVA).

RESULTS AND DISCUSSION

Physicochemical parameters of the sediment from the Ossiomo River

The analytical results of the physicochemical parameters of the sediment from the Ossiomo River are presented in Table 3. Sediment pH values (4.80–6.73) indicate that the sediment is acidic in nature. Similar pH values (5.58–6.34) were reported by Issa et al. (2011) for the sediment from the Orogodo River, Agbor, Delta State, which is situated within the same geological river basin as the Ossiomo River. Electrical conductivity values (54.00–373.00 uS/cm) were relatively low, and was attributed to the levels of ions within the considered water channels and dilution from rainfall during the study period.

Sediment is the key site for the disintegration of organic matter, which is principally carried out by microbes. The total organic carbon content (0.11–3.97%) in the sediment is low and an indication of the composition of the sediment. According to Daka and Moslen (2013), fine particles of bottom sediment have higher relative surface areas than coarse particles, which can absorb dissolved organic matter and colloids to form sedimentary complexes. Ezekiel et al. (2011) reported similar total organic carbon content (2.02–4.10%) values in the sediment from the Sombreiro River. Also, sediment composition for nitrogen (0.02–0.94%), sand (83.21–96.52%), silt (0.30–10.30%), clay (3.18–6.67%), calcium (12.83–132.75 mg/kg), magnesium (3.89–49.00 mg/kg), sodium (9.51–15.33 mg/kg), and potassium (6.45–30.10 mg/kg) were recorded.

Table 2. **Adjusted grading standard of potential ecological risk of heavy metals in soil**

EiR	Pollution degree	*RI*	Risk level	Risk degree
EiR < 30	Slight	*RI* < 40	A	Slight
30 ≤ *EiR* < 60	Medium	40 ≤ *Ri* < 80	B	Medium
60 ≤ *EiR* < 120	Strong	80 ≤ *Ri* < 160	C	Strong
120 ≤ *EiR* < 240	Very Strong	160 ≤ *RI* ≥ 320	D	Very strong
EiR ≥ 240	Extremely strong	*RI* ≥ 320	–	–

E^i_R is the potential ecological risk index of a single element; *RI* is a comprehensive potential ecological risk index (Jiang et al., 2014).

Table 3. **Summary of the physicochemical parameters of the sediment from the Ossiomo River (August 2021 to January 2022)**

	Station 1			Station 2			Station 3			p – value
	Mean ± SD	Min.	Max.	Mean ± SD	Min.	Max.	Mean ± SD	Min.	Max.	
pH	5.83 ± 0.93	4.87	6.73	5.09 ± 0.47	4.80	5.63	5.37 ± 0.52	4.80	5.81	$p > 0.05$
E. Conduct. (uS/cm)	142.07 ± 76.47	54	191.70	253.47 ± 103.56	190.70	373	163.30 ± 60.89	93	199.20	$p > 0.05$
Total organic carbon (%)	0.47 ± 0.39^{b}	0.11	0.87	2.35 ± 1.41^{a}	1.41	3.97	1.41 ± 0.59a^{b}	0.81	1.98	$p < 0.05$
Nitrogen (%)	0.37 ± 0.50	0.02	0.94	0.40 ± 0.35	0.06	0.75	0.09 ± 0.02	0.08	0.11	$p > 0.05$
Sand (%)	90.61 ± 5.73	85.08	96.52	88.83 ± 4.35	84.52	93.22	88.32 ± 6.42	83.21	95.52	$p > 0.05$
Silt (%)	3.13 ± 2.63	0.30	5.50	6.73 ± 3.9	2.50	10.30	5.23 ± 4.35	0.30	8.50	$p > 0.05$
Clay (%)	4.19 ± 0.97	3.18	5.12	5.27 ± 1.03	4.28	6.34	5.38 ± 1.25	4.18	6.67	$p > 0.05$
Calcium (mg/kg)	41.01 ± 26.46	12.83	65.32	77.17 ± 48.34	44.89	132.75	71.09 ± 4.89	66.5	76.24	$p > 0.05$
Magnesium (mg/kg)	10.85 ± 6.58^{c}	3.89	16.98	42.38 ± 5.88^{a}	37.78	49	26.22 ± 7.50^{b}	18.27	33.16	$p < 0.05$
Sodium (mg/kg)	12.86 ± 2.43	10.48	15.33	12.46 ± 3.28	9.51	15.99	9.89 ± 0.11	9.76	9.98	$p > 0.05$
Potassium (mg/kg)	10.50 ± 4.61	6.45	15.51	18.73 ± 10.09	10.82	30.10	13.15 ± 2.87	10.38	16.11	$p > 0.05$
Iron (mg/kg)	821.17 ± 592.56^{b}	226.70	1411.80	2005.33 ± 1460.96^{a}	555	3476.70	586.43 ± 188.54^{c}	435	797.6	$p < 0.05$
Copper (mg/kg)	5.47 ± 2.28	3.00	7.50	7.90 ± 4.37	3.30	12	7.13 ± 3.14	4.80	10.70	$p > 0.05$
Zinc (mg/kg)	18.53 ± 10.54	9.70	30.20	41.97 ± 17.57	30.60	62.20	26.33 ± 14.05	11.40	39.3	$p > 0.05$
Cadmium (mg/kg)	0.10 ± 0.06^{b}	0.10	0.10	0.21 ± 0.01^{a}	0.20	0.22	0.11 ± 0.06^{b}	0.10	0.11	$p < 0.05$
Lead (mg/kg)	3.50 ± 0.06^{b}	3.00	4.00	11.83 ± 10.13^{a}	0.50	20	2.07 ± 1.62^{b}	0.20	3.00	$p < 0.05$
Manganese (mg/kg)	8.40 ± 3.60	4.50	11.60	13.10 ± 6.90	6.30	20.10	5.57 ± 0.70	4.90	6.30	$p > 0.05$
Chromium (mg/kg)	3.44 ± 2.78	0.32	6.67	5.46 ± 2.20	3.08	7.42	3.99 ± 1.26	2.77	5.29	$p > 0.05$
THC (mg/Kg)	700.49 ± 129.42^{b}	578.43	836.19	445.96 ± 462.88^{c}	31.11	945.25	1333.94 ± 636.40^{a}	741.11	2006.41	$p < 0.05$

Note: $p < 0.05$ – significant difference; $p > 0.05$ – no significant difference. Similar superscript indicates no significant difference, different superscript indicates significant difference.

Heavy metal concentrations in bottom sediment from the Ossiomo River were in the order of Fe > Zn > Mn > Cu > Pb > Cr > Cd. The concentrations of iron across the sampling stations were above the recommended limit of 100 mg/kg in sediment by the WHO (2011). The high concentration of iron in sediment samples may be attributed to natural processes and to anthropogenic influences. The concentrations of magnesium, iron, lead and cadmium were significantly higher at station 2 among the sampling stations, which is reflective of the increased levels of anthropogenic activities at the location. The total hydrocarbon content (THC) values of 31.11–2006.41 mg/kg is indicative of the exposure of the Ossiomo River to pollution from petroleum processing facilities within the watershed.

Heavy metal concentrations in *G. niloticus*

The innate ability of fishes to accumulate heavy metals in their organs (gills, liver, and muscles) from their aquatic environment made them useful bioindicators of aquatic pollution. Heavy metal contents in the organs of *G. niloticus* from the Ossiomo River is presented in Table 4. Iron content was highest in the gills and liver; zinc was highest in the muscles, and lead concentrations was the least in all the examined organs. The sequence of heavy metals was Fe > Zn > Mn > Cu > Cr > Cd > Pb in the gills, Fe > Zn > Cu > Mn > Cu > Cd > Pb in liver, and Zn > Fe > Mn > Cu > Cr > Cd > Pb in muscles. Iron concentrations in *G. niloticus* exceeded the tolerable limit set by the WHO (0.5 mg/kg) for fish used for food and was markedly higher than other metals in the various organs of the fishes. Zinc and copper are an essential mineral element for several physiological processes in aquatic organism, but their toxicity at high concentrations in fish was reported to result in growth retardation, reproductive impairment and mortality (Akan et al., 2012). Lead, cadmium and chromium have no biological function in fishes; their uptake is dependent on their concentrations in the aquatic environment which is an indication of aquatic pollution.

Bioaccumulation of heavy metals in *G. niloticus*

Bioaccumulation is the net result of the interaction of uptake, storage, and elimination of chemical substances in biological systems. The accumulation of metals in fish tissues gives evidences of exposure to polluted aquatic environment (Qadir, Malik, 2011). The bioaccumulation of heavy metals in the organs of *G. niloticus* as depicted by their respective BAF values (Table 5) indicate that the liver has the highest BAF values for copper (7.76), iron (0.60), zinc (3.88), and chromium (1.42). The gills have the highest BAF values for cadmium (4.34), lead (0.04) and chromium (1.42), while the muscles recorded the highest BAF value for manganese (1.86). The bioaccumulation of heavy metals was in the order Cd > Zn > Mn > Cu > Cr > Fe > Pb (gills); Cu > Cd > Zn > Cr > Mn > Fe > Pb (liver), and Mn > Zn > Cu > Cr > Fe > Cd > Pb (muscle). According to Vassiliki and Konstantina (1984),

Table 4. **The contents of heavy metals in organs of *Gymnarchus niloticus* from the Ossiomo River**

Mg/kg	Gills			Liver			Muscles		
	Mean ± SD	Min.	Max.	Mean ± SD	Min.	Max.	Mean ± SD	Min.	Max.
Copper	10.61 ± 0.79	9.45	11.6	53.03 ± 2.19	49.60	55.30	3.21 ± 0.23	2.83	3.45
Iron	154.25 ± 4.97	149	162	683.25 ± 6.50	673.00	691.00	25.01 ± 1.27	23.67	27.05
Zinc	96.65 ± 2.40	93.6	100	112.23 ± 2.71	109.40	116.30	48.93 ± 1.82	46.36	51.26
Cadmium	0.61 ± 0.08	0.53	0.73	0.60 ± 0.11	0.43	0.72	0.003 ± 0.001	0.0016	0.005
Lead	0.21 ± 0.03	0.17	0.25	0.19 ± 0.03	0.16	0.23	0.0011 ± 0.001	0.00	0.002
Manganese	16.46 ± 0.50	15.74	17.04	10.69 ± 0.65	9.85	11.6	16.79 ± 0.27	16.52	17.2
Chromium	6.12 ± 0.21	5.87	6.43	6.10 ± 0.18	5.86	6.35	1.54 ± 0.05	1.48	1.62

Table 5. **Bioaccumulation factors (BAFs) of heavy metals in organs of *G. niloticus* from the Ossiomo River**

	Gills	Liver	Muscle
Copper	1.55	7.76	0.47
Iron	0.14	0.60	0.02
Zinc	3.34	3.88	1.69
Cadmium	4.34	4.29	0.02
Lead	0.04	0.03	0.0002
Manganese	1.82	1.18	1.86
Chromium	1.42	1.42	0.36

BAF values > 1 for a pollutant in an organism or tissue is an indication of the increased rate of uptake of the metal from the environment. In this study, BAF values for the metals in the gills and liver were greater than 1 (BAFs > 1) except for iron and lead, while in the muscles, BAFs < 1 except for zinc and manganese. For aquatic organisms such as *G. niloticus*, physicochemical properties of the contaminant molecules, conditions of the aquatic habitat, and the food and feeding habits of the fish affect the bioaccumulation of heavy metals in them (Egun, 2021). Several studies have reported the bioaccumulation of heavy metals and other pollutants in edible parts of various aquatic animals, thereby exposing the consumers of diverse human health risk from heavy metal contamination (Ezekiel et al., 2011; Alinnor, Alagoa, 2014; Ogbeibu et al., 2014; Adesuyi et al., 2016; Akachukwu et al., 2020; Ebong et al., 2021).

Pollution load index (PLI)

The concentration factor is used as an indicator of the pollution level in the sediment. The concentration factor and pollution load index explain the severity and variations of pollution in the sediment of the study location. In this study, the PLI values obtained across the three sampling stations was greater than 1 (PLI > 1), which indicated that there was heavy metal pollution of the sediment of the Ossiomo River (Table 6). The highest PLI value of 10.29 recorded at station 2 is reflective of the significantly higher concentrations of magnesium, iron, lead and cadmium at the station (Fig. 3). In a simi-

Table 6. **Pollution load index of bottom sediment from the Ossiomo River**

	Station 1	Station 2	Station 3
Fe	3.62	8.85	2.59
Cr	10.71	17.00	12.44
Cd	10.00	20.67	10.50
Cu	1.82	2.63	2.39
Zn	1.91	4.33	2.72
Mn	1.87	2.91	1.24
Pb	35.00	118.33	20.67
CD	64.93	174.72	52.52
PLI	5.09	10.29	4.77

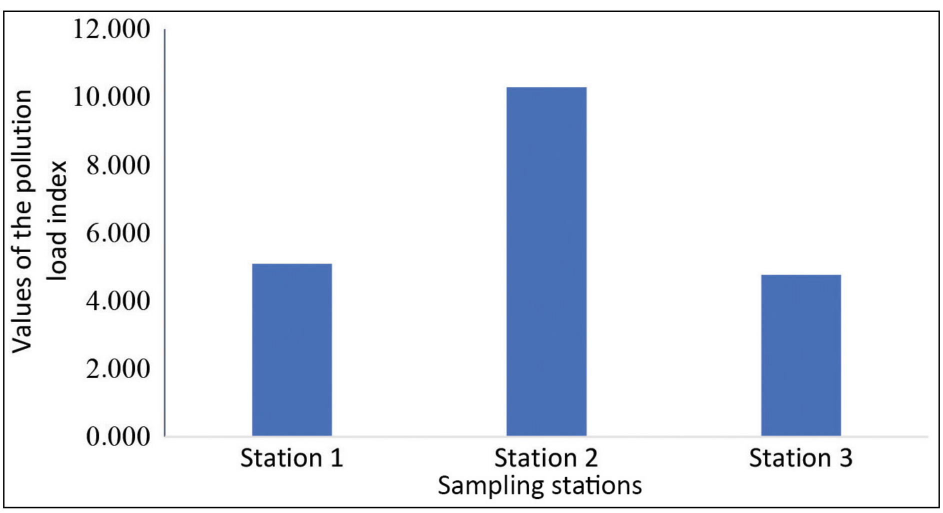

Fig. 3. Pollution load index (PLI) values in bottom sediments from the Ossiomo River

lar study, Ogbeibu et al. (2014) reported lower PLI values (0.004–0.022) for heavy metals in the sediment in the Benin river.

Potential ecological risk index (PERI)

Potential ecological risk index (PERI) of heavy metal contamination in the sediment from the Ossiomo River is shown in Table 7. In all three sampling stations, copper, zinc and manganese contributed slightly ($Ei_R < 30$) to PERI values, while cadmium showed an extremely strong pollution degree ($Ei_R \geq 240$). Chromium contributed slightly to PERI values at stations 1 and 3, and medium degree of pollution ($30 \leq Ei_R < 60$) at station 2. For lead, a strong pollution degree ($60 \leq Ei_R < 120$) at station 3, a very strong pollution degree ($120 \leq Ei_R < 240$) at station 1, and an extremely strong pollution degree ($Ei_R \geq 240$) at station 2. The PERI index values for station 1 (509.30) and station 3 (459.06) indicate a considerable ecological risk ($300 < RI \leq 600$), while station 2 (1266.07) indicates a very high ecological risk ($RI > 600$). The elevated PERI values at station 2 are reflective of the increased levels of anthropogenic activities and discharge of pollutants at the location. Cadmium and lead have been reported as eco-toxic metals with highly undesirable effects on aquatic and human health (Kabata-Pendias, Pendias, 2001). The observed contributions of cadmium to strong pollution degree and of lead to the recorded PERI values across the stations indicate a homogeneity in the constituents of pollutants in the river. This is a cause for concern in safeguarding public health as the communities which rely on the Ossiomo River for aquatic and fisheries resources are at risk of heavy metal toxicity from chronic exposure. In cognizance of the beneficial ecosystem services provided by the Ossiomo River to several communities along its water course, there is a need for monitoring of anthropogenic activities within the river watershed to identify active and potential sources of heavy metals and other persistent organic carbons. Also, periodic monitoring of the water quality and heavy metal content in sediment and aquatic organisms is recommended in order to ensure aquatic health and productivity.

Table 7. **Potential ecological risk index (PERI) values of the sediment from the Ossiomo River**

	Station 1	Station 2	Station 3
Cr	21.41	33.99	24.88
Cd	300.00	620.00	315.00
Cu	9.11	13.17	11.89
Zn	1.91	4.33	2.72
Mn	1.87	2.91	1.24
Pb	175.00	591.67	103.33
Total	509.30	1266.07	459.06

CONCLUSIONS

Increasing exposure of inland freshwater bodies to diverse forms of pollutants is a threat to sustainable development. This study determined ecological risk from heavy metal pollution of the Ossiomo River using fish (*G. niloticus*) and sediment. Results of this study show that both sediment and fish were contaminated with heavy metals. Heavy metal concentration profile of Fe > Zn > Mn > Cu > Pb > Cr > Cd was observed in the sediment. The order for bioaccumulation of heavy metals in organs of *G. niloticus* was Cd > Zn > Mn > Cu > Cr > Fe > Pb (gills); Cu > C d > Zn > Cr > Mn > Fe > Pb (liver), and Mn > Z n > Cu > Cr > Fe > Cd > Pb (muscles). The values of the pollution load index (PLI) across the three sampling stations indicate that there is heavy metal pollution of sediment ($PLI > 1$). Ecological risk assessment showed that stations 1 and 3 exhibited considerable ecological risk ($300 < RI \leq 600$), while station 2 indicated a very high ecological risk ($RI > 600$). The importance of the Ossiomo River in the provision of fresh water and fishery resources to several communities in Edo State necessitates the need for periodic water quality assessment and monitoring of human and industrial activities within the catchment area in order to forestall further deposition of more pollutants into the river and protect public health.

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BIOTINIŲ IR ABIOTINIŲ KOMPONENTŲ PANAUDOJIMAS EKOLOGINIAM OSSIOMO UPĖS VERTINIMUI (EDO VALSTIJA, NIGERIJA)

Santrauka

Žuvų (*Gymnarchus niloticus*) ir nuosėdų mėginiai buvo naudojami kaip sunkiųjų metalų užterštumo bioindikatoriai atliekant Ossiomo upės ekologinį vertinimą. Minėti mėginiai buvo renkami kas mėnesį (nuo 2021 m. rugpjūčio iki 2022 m. sausio mėn.) ir standartiniais metodais tiriamas sunkiųjų metalų kiekis. Šio tyrimo rezultatai atskleidė, kad ir nuosėdos, ir žuvys buvo užterštos sunkiaisiais metalais. Nuosėdose buvo nustatyta sunkiųjų metalų Fe > Zn > Mn > Cu > Pb > Cr > Cd koncentracijos seka. *G. niloticus* žuvų sunkiųjų metalų bioakumuliacijos koeficientas (angl. BAF) buvo > 1: žiaunose eilės tvarka Cd > Zn > Mn > Cu > Cr > Fe > Pb, kepenyse – Cu > Cd > Zn > Cr > Mn > Fe > Pb ir raumenyse – Mn > Zn > Cu > Cr > Fe > Cd > Pb. Trijų tyrimų stočių taršos apkrovos indekso (angl. PLI) reikšmės rodo, kad nuosėdos yra užterštos sunkiaisiais metalais (PLI > 1). Pagal potencialios ekologinės rizikos indeksą (angl. PERI) 1 ir 3 stotyse nustatyta didelė ekologinė rizika (300 < RI ≤ 600), o 2 stotyje – labai didelė ekologinė rizika (RI > 600). Norint užkirsti kelią tolesniam teršalų nusėdimui į upę ir apsaugoti visuomenės sveikatą, reikia periodiškai vertinti vandens kokybę ir stebėti žmonių bei pramonės veiklą Ossiomo upės baseine.

Raktažodžiai: ekologinės rizikos vertinimas, sunkieji metalai, *Gymnarchus niloticus*, taršos indeksas, Ossiomo upė