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ORIGINAL ARTICLE

Potential risk assessment and spatial distribution of elemental concentrations in sediment

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Abstract

Sediments are carrier and a sink of elements in the hydrological cycle. Monitoring of contaminated soil and sediment with metallic elements is of interest due to their influence on groundwater, surface water, plants, animals and humans. In this study, different sediment samples from five various places were taken, and the elemental concentration along with some physiochemical parameters were determined. The elemental concentrations were determined with proton-induced X-ray emission, while the physiochemical parameters were determined using a conductivity meter, pH meter and thermometer. This study showed that silicon had highest mean concentration and lead had the lowest mean concentration. Cadmium had the highest contamination values in all the locations. Okitipupa had the highest pollution load index, and the lowest pollution index was recorded in Irele. The overall risk index (RI) in all the locations in the sediment indicated very high ecological risk index. Pollution load index (PLI) also categorized ecological risk which ranged from 8.812 to 28.42. Mean PLI value (17.7) recorded in this study was far higher than the threshold (< 1), indicating the presence of heavy pollutant levels. Such high-level PLI values signified danger and measures are needed in order to reduce the sources of pollutants in the sediment. From enrichment value and Igeo-accumulation values, Sn was severely polluted. Si, Zr, Ag and Cd were extremely polluted. The physiochemical parameters correlated with the elemental concentrations both negatively and positively.

Keywords Sediment · Geo-accumulation · Enrichment factor · Risk index pollution load index · PIXE

Introduction

Sediments had been explained by many authors as the fountain of numerous chemicals and also a source of water pollution (Celo et al. 1999; Mil-Homens et al.2013; Yu et al. 2001; Sakan et al. 2015; Wepener and Vermeulen (2005); Mil-Homens et al. 2007; Shakeri and Moor (2010); Yang et al. 2009). Sediment is the loose sand, clay, silt and other soil particles that settle at the bottom of body of water (Davies and Abowei 2009). Transportation of elements from sediments had been studied by some researchers in the laboratory scale and under environmental conditions (Sun et al. 2016; Vignati et al. 2013; Milacic et al. 2017). The quantification of trace elements in the sediments can be used to evaluate the pollution level and its relation with previous human activities (Thevenon and Pote 2012). The increase in industrialization and population has birthed dangerous chemicals and elemental pollutants that are always mobilized into the soils and sediments through numerous anthropogenic activities which include: industrialization, agricultural activities, atmospheric deposition and anthropogenic activities, where harmful chemicals and metals are generated. Soil is a reservoir of heavy metal which are repeatedly leached into the environment and sediments (Peizhong et al. 2015; Uwumarongie et al. 2008; Banat et al. 2005; Rafael et al. 2016); materials beneath surface water serve as a barometer to survey the pollutant level in aquatic ecosystem (Yang et al. 2009; Safaa 2015; Pekey et al. 2004). The physicochemical properties of sediments have pivotal role to play during the distribution of elements into water body (Covelo et al.2007; Hamidpour et al. 2010). Significant correlations were reported between metal contents with fine-grained particles of sediments, the total organic carbon (TOC) and pH (Zhang et al. 2014). The relative role of sediments' physicochemical properties, metals' availability and the possible ecological risk caused by the metal release

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had been discussed (Zhao et al. 2013). Recently, in Nigeria, the investigation of wide range of elements in the sediment using more sophisticated instrumentation such as X-ray fluorescence and inductively coupled plasma mass spectrometry had been undertaken (Ediagbonya and Ayedun (2018); Ayedun et al. 2019). This study seeks to ascertain the level of metallic elements using PIXE and some selected physiochemical parameters in sediments of five different rivers and to compare the value obtained in this study to the regulatory limits and other studies. There are various mechanisms by which sediments take up heavy metals. These may include biological uptake. However, it had been widely reported that heavy metals constitute nuisance in the sediment (Mateu et al. 1996; White et al. 2005; Birch et al. 2001).

Materials and methods

Study area

The samples were collected from towns and villages across three local government areas in the Southern Senatorial District of Ondo State Nigeria. The local government areas are: Ilaje Local Government, Irele Local Government and Okitipupa Local Government.

In Ilaje Local Government, samples were collected from Igbokoda. In Irele local government samples were collected from Ode-Irele, and from Okitipupa local government samples were collected from Igodan-Lisa. Farming remains the major occupation of the inhabitants of the three local government areas.

While the inhabitants of Ilaje are predominantly into fish farming being the local government with the longest coastline in Nigeria and an oil-producing area of the state, sizeable number of Ilaje is also into, mat weaving, boat building, etc. The inhabitants of Ode-Irele and Igodan-Lisa, in Okitipupa local government, are majorly cash crop and food crop farmers. The major cash crop predominantly planted by farmers is: palm trees that produce palm kernel and red oil that serve industrial and domestic consumption purposes. The common food crops in the areas of study are: yam, plantain, maize, cassava, etc. The three local government areas have deep rivers, but Ilaje local government is the only one among the three that has access to the sea.

The major source of pollution of rivers in these areas is through crude oil spillage caused by the effect of crude oil exploration in Ilaje local government area. Oil pollution has not only become a health challenge, it has also resulted to militancy and youth restiveness in the areas of study. Pollution of rivers and canals is mostly brought about by oil pipeline vandalization or accidents from oil companies operating in the areas. Oil bunkering is also a common feature in the areas. Aside from oil spillage, open defecation on rivers, swimming and sand evacuation from rivers for construction purposes also have a significant impact in the pollution of rivers in the areas of study. The map of the various locations is shown in Fig. 1 as reported by Ediagbonya and Gbolahan (2018).

Sample collection and preparation

A total of twenty-five (25) sediment samples were randomly collected in the study areas, and five (5) samples were taken at each sampling areas. The sediment samples were also air-dried for three days. The air-dried sediment samples were kept in polythene bag and then taking to the laboratory in Obafemi Awolowo University (Ife) for elemental and some physicochemical parameters analysis. Certified reference material (IAEA Soil-7) was used for as a quality control and quality assurance. The differences between the certified and measurement results were less than 15%.

Metal analysis

Proton-induced X-ray emission (PIXE), 1.7 MeV 5SDH Pelletron Accelerator, was used to analyze the elemental

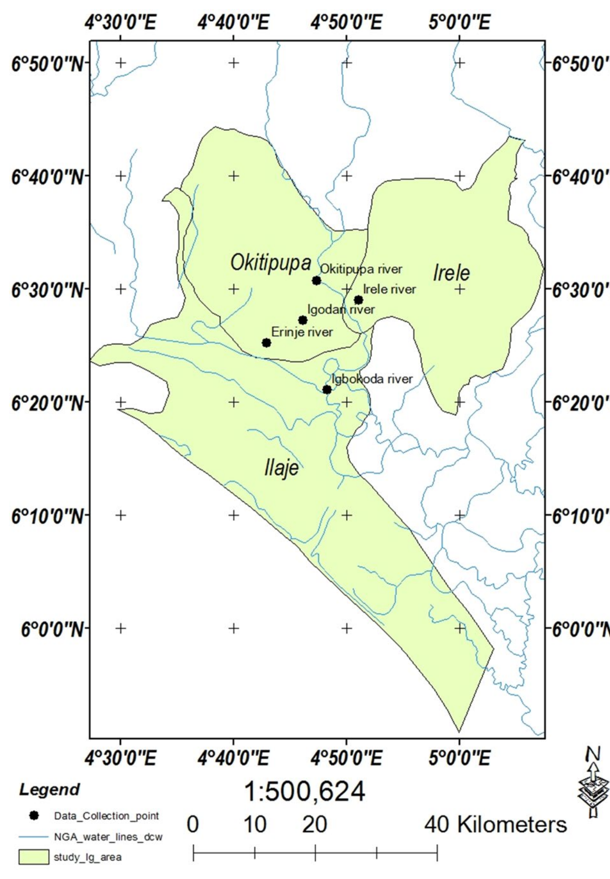

Fig. 1 A map showing the sampling areas

concentration. Detail of the analysis had reported by (Ediagbonya et al. 2020). The pH and electrical conductivity of the extracts were determined using portable pH and conductivity (Hanna 991300) meter. The nitrate and chloride were also determined as described by (Ademoroti 1996; Samira et al. 2009).

Geo-accumulation index (Igeo)

The geo-accumulation (Igeo) index is to evaluate contamination level in sediment as given by

(Müller 1969; Loska et al.1997). It had been used by (Ediagbonya and Ayedun (2018); AlKuziea 2015; Ayedun et al. 2019). C_n is the measured concentration of metal 'n' in sediments, and B_n is the background concentration of the same metal.

$$I_{geo} = \ln\left[\frac{C_n}{1.5B_n}\right]$$

Enrichment factor (EF)

Enrichment factor (EF) was used to compute the extent of pollution in the sediment. To identify abnormal metal concentration in sediment in this study Al and Fe were used as reference elements. Few authors had used these elements reference element (Schiff and Weisberg (1999); Al-Khuziea et al. 2017. Al-Kuziea 2015). According to Ergin et al. (1991), the metal EF is defined as follows:

$$\mathrm{EF} = \frac{\left(\frac{X}{\mathrm{Al}}\right)_{\mathrm{sediment}}}{\left(\frac{X}{\mathrm{Al}}\right)_{\mathrm{crust}}}$$

where X/Al is the ratio of the concentration heavy metal (X) to the Al concentration.

The reference crustal ratio of the shale value or the lithology was taken from Turekian (1961).

Pollution load index (PLI)

The pollution load index (PLI) is used to assess the level of elemental pollution in sediment. Detailed description had been reported by (Ayedun et al. 2019; Kwon and Lee 1998).

$$\mathrm{PLI} = \left(\mathrm{Cf}_1 * \mathrm{Cf}_2 * \mathrm{Cf}_3 \cdots \mathrm{Cf}_n\right)^{1/n}$$

Ecological risk

The quantitative approach developed by Hakanson (1980) was used to calculate ecological risk factor as follows:

$$\mathrm{Er} = \mathrm{Ti} * C_{\mathrm{f}}$$

$$C_{\mathrm{f}} = \mathrm{Ci}/\mathrm{Bi}$$

where Ti is the toxic response factor for a given substance (e.g., Cd = 30, Pb = 5, Cr = 2, Zn = 1 Cu = 5); C_f is the ecological risk factor; Ci represents metal content in the sediments; and Bi is the reference value.

Risk index (RI)

The overall risk index (RI) was calculated as the sum of potential ecological risk factor for heavy metals in sediments. Detailed report had been given by (Ayedun et al. 2019; Abdul-Kawi and Alhudify (2016); Mugosa et al. 2016).

Quality control

All reagents were of ultra-pure quality, and all laboratory wares used were thoroughly cleaned before utilization. All the samples were repeatedly measured (n = 5) to control the precision of analytical instruments.

Statistical data analysis

Statistical Package for Social Sciences (SPSS) version 24.0 was used for the statistical analyses in this work.

Results and discussion

Table 1 shows the descriptive statistics of physicochemical parameters in the different locations. The highest mean pH was recorded at Igodan 11.37 ± 0.38 (11.10-11.80), and the lowest recorded at Igbokoda 9.60 ± 0.10 (9.50-9.70). The highest mean (EC) was recorded at Igodan 4711.57 ± 0.31 (4711.30-4711.90) uS/cm, and lowest recorded at Erinje 2005.27 ± 0.21 (2005.10-2005.50) uS/cm. The highest

Table 1 Descriptive statistics of physicochemical parameters in the different locations

	pH	Electrical conductivity (EC) (us/cm)	°C	Cl (mg/l)	Nitrate (mg/l)
IRELE	10.23	2011.37	33.63	11.12	1.41
OKITIPUPA	10.2	2291.63	33.7	10.01	1.08
ERINJE	12.7	2005.63	31.53	14.1	0.97
IGODAN	11.37	4711.57	36.43	9.66	1.61
IGBOKODA	9.6	4499.63	37.29	13.12	2.71

mean temperature was recorded at Igbokoda 37.23 ± 0.35 (37.00-37.50), and lowest mean value reported at Erinje 31.53 ± 0.25 (31.30-31.80), highest mean chloride was recorded at Erinje 14.10 ± 0.00 (14.10-14.11) and lowest value reported at Igodan 9.6 ± 0.00 (9.66-9.66), while the highest nitrate was recorded at Igbokoda 2.71 ± 0.00 (2.71-2.71), and the lowest mean value reported at Erinje 0.97 ± 0.00 (0.97-0.97).

Table 2 shows the mean comparison of heavy metals in the different sampled location. The lowest mean Na level was recorded at Igbokoda (1415.4 ± 0.3), while the highest mean Na level was reported at Okitipupa. There was a significant spatial variation in the Na level in the different sampled locations. The different locations showed significantly spatial variations when compared with each other. The lowest mean Mg level was recorded at Igbokoda (2235.8 ± 0.2), while the highest mean Mg level was reported at Erinje (7952.3 ± 0.5). There was a significant spatial variation in the Mg level in the different sampled locations. The different locations showed significantly spatial variations when compared with each other. The lowest mean Al level was recorded at Okitipupa (2207.49 ± 1.5), while the highest mean Al level was reported at Erinje (290,934.5 ± 0.2). There was a significant spatial variation in the Al level in the different sampled locations. The different locations showed significantly spatial variations when compared with each other. The lowest mean Si level was recorded at Irele (501,037.4 ± 0.4), while the highest mean Si level was reported at Erinje (545,825.3 ± 0.4). There was a significant spatial variation in the Na level in the different sampled locations. The different locations showed significantly spatial variations when compared with each other. The lowest mean P level was recorded at Irele (269.6 ± 0.4), while the highest mean P level was reported at Erinje (7546.5 ± 0.3). There was a significant spatial variation in the different sampled locations. The different locations showed significantly spatial variations when compared with each other. The lowest mean Cl level was recorded at Igodan (188.5 ± 0.3), while the highest mean Cl level was reported at Irele (285.6 ± 0.4). There was a significant spatial variation in the different sampled locations. The different locations showed significantly spatial variations when compared with each other. The lowest mean K level was recorded at Igbokoda (2042.5 ± 0.4), while the highest mean K level was reported at Irele (8634.5 ± 0.4). There was a significant spatial variation in the different sampled locations. The different locations showed significantly spatial variations when compared with each other. The lowest mean Ca level was

Table 2 Elemental concentration (mg kg^{-1}) and some physiochemical parameters of the various location

Element	IRELE	OKITIPUPA	ERINJE	IGODAN	IGBOKODA
Na	7416.1 ± 0.7^{a}	7991.6 ± 0.0^{b}	6887.2 ± 0.4^{c}	7761.7 ± 0.2^{d}	1415.4 ± 0.3^{e}
Mg	3891.1 ± 0.8^{a}	3894.5 ± 0.4^{b}	7952.3 ± 0.5^{c}	4698.5 ± 0.4^{d}	2235.8 ± 0.2^{e}
Al	231,057.2 ± 0.8^{a}	220,749.2 ± 1.5^{b}	290,934.5 ± 0.2^{c}	282,351.9 ± 0.3^{d}	229,402.4 ± 0.4^{e}
Si	501,037.4 ± 0.4^{a}	512,119.6 ± 0.4^{b}	545,825.4 ± 0.4^{c}	509,570.4 ± 0.4^{d}	524,792.5 ± 0.4^{e}
P	269.6 ± 0.4^{a}	1056.5 ± 0.4^{b}	7546.5 ± 0.3^{c}	5746.5 ± 0.4^{d}	2839.5 ± 0.3^{e}
Cl	285.6 ± 0.4^{a}	241.5 ± 0.4^{b}	233.4 ± 0.3^{c}	188.5 ± 0.3^{d}	196.4 ± 0.4^{e}
K	8634.5 ± 0.4^{a}	8503.5 ± 0.4^{b}	4046.6 ± 0.3^{c}	3367.0 ± 2.0^{d}	2042.5 ± 0.4^{e}
Ca	5190.4 ± 0.3^{a}	2229.7 ± 0.3^{b}	35,661.4 ± 0.3^{c}	27,554.6 ± 0.4^{d}	9018.6 ± 0.3^{e}
Ti	4561.4 ± 0.4^{a}	78,811.6 ± 0.3^{b}	37,646.3 ± 2.5^{c}	28,842.4 ± 0.4^{d}	53,462.5 ± 0.3^{e}
Cr	60.6 ± 0.3^{a}	441.4 ± 0.3^{b}	565.3 ± 3.2^{c}	495.6 ± 0.3^{d}	378.3 ± 0.3^{e}
Mn	234.6 ± 0.2^{a}	1954.7 ± 3.1^{b}	1291.6 ± 0.3^{c}	1038.6 ± 0.3^{d}	2064.4 ± 0.4^{e}
Fe	20,088.4 ± 0.4^{a}	33,401.4 ± 0.2^{b}	63,973.3 ± 1.5^{c}	22,617.4 ± 0.4^{d}	40,385.3 ± 2.5^{e}
Cu	282.7 ± 0.3^{a}	2570.9 ± 0.4^{b}	373.6 ± 0.3^{c}	340.2 ± 0.7^{d}	355.4 ± 0.3^{e}
Zn	48.6 ± 0.3^{a}	91.0 ± 1.0^{b}	139.6 ± 0.2^{c}	117.0 ± 1.0^{d}	76.0 ± 3.6^{e}
Sr	67.3 ± 2.1^{a}	46.5 ± 0.3^{b}	317.5 ± 0.2^{c}	184.7 ± 0.2^{d}	166.4 ± 0.4^{e}
Rb	37.7 ± 0.6^{a}	ND	ND	ND	ND
Zr	557.5 ± 0.2^{a}	9156.7 ± 0.3^{b}	4484.5 ± 0.3^{c}	1846.6 ± 0.3^{d}	9028.4 ± 0.3^{e}
Ag	73.6 ± 0.4^{a}	33.7 ± 0.2^{b}	50.4 ± 0.4^{c}	39.2 ± 0.2^{d}	31.3 ± 1.5^{e}
Cd	27.6 ± 0.3^{a}	21.5 ± 0.4^{b}	77.5 ± 0.3^{c}	21.6 ± 0.3^{b}	42.4 ± 0.3^{d}
Sn	461.0 ± 1.0^{a}	71.2 ± 0.2^{b}	392.7 ± 2.1^{c}	437.5 ± 0.3^{d}	139.5 ± 0.1^{e}
Pb	11.5 ± 0.3^{a}	10.5 ± 0.3^{b}	12.5 ± 0.3^{c}	11.4 ± 0.4^{a}	10.3 ± 0.2^{b}
Bi	ND	ND	ND	13.4 ± 0.1	ND

Alphabets/superscripts that are used to separate the means after further post-hoc analysis. They help to identify significant differences between pairs after ANOVA

ND Not detected

recorded at Okitipupa (2229.7 ± 0.3), while the highest mean Ca level was reported at Igbokoda (9018.6 ± 0.3). There was a significant spatial variation in the different sampled locations. The different locations showed significantly spatial variations when compared with each other. The lowest mean Ti level was recorded at Igodan (28,842.4 ± 0.4), while the highest mean Ti level was reported at Okitipupa (78,811.6 ± 0.3). There was a significant spatial variation in the different sampled locations. The different locations showed significantly spatial variations when compared with each other. The lowest mean Cr level was recorded at Irele (60.6 ± 0.3), while the highest mean Cr level was reported at Erinje (565.3 ± 3.2). There was a significant spatial variation in the different sampled locations. The different locations showed significantly spatial variations when compared with each other. The lowest mean Mn level was recorded at Irele (234.6 ± 0.2), while the highest mean Mn level was reported at Igbokoda (2064.4 ± 0.4). There was a significant spatial variation in the different sampled locations. The different locations showed significantly spatial variations when compared with each other. The lowest mean Fe level was recorded at Irele (20,088.4 ± 0.4), while the highest mean Fe level was reported at Erinje (63,973.3 ± 1.5). There was a significant spatial variation in the different sampled locations. The different locations showed significantly spatial variations when compared with each other. The lowest mean Cu level was recorded at Okitipupa (257.9 ± 0.4), while the highest mean Cu level was reported at Erinje (373.6 ± 0.3). There was a significant spatial variation in the different sampled locations. The different locations showed significantly spatial variations when compared with each other. The lowest mean Zn level was recorded at Irele (48.6 ± 0.3), while the highest mean Zn level was reported at Erinje (139.6 ± 0.2). There was a significant spatial variation in the different sampled locations. The different locations showed significantly spatial variations when compared with each other. The lowest mean Sr level was recorded at Okitipupa (46.5 ± 0.3), while the highest mean Sr level was reported at Erinje (317.5 ± 0.2). There was a significant spatial variation in the different sampled locations. The different locations showed significantly spatial variations when compared with each other. Rb was only reported at Irele with a mean value of 37.7 ± 0.6. The lowest mean Zr level was recorded at Irele (557.5 ± 0.2), while the highest mean Zr level was reported at Okitipupa (9156.7 ± 0.3). There was a significant spatial variation in the different sampled locations. The different locations showed significantly spatial variations when compared with each other. The lowest mean Ag level was recorded at Igbokoda (31.3 ± 1.5), while the highest mean Ag level was reported at Irele (73.6 ± 0.4). There was a significant spatial variation in the different sampled locations. The different locations showed significantly spatial variations when compared with each other. The lowest mean Cd level was recorded at Okitipupa (21.5 ± 0.4), while the highest mean Cd level was reported at Erinje (77.5 ± 0.3). There was a significant spatial variation in the different sampled locations. The different locations showed significantly spatial variations when compared with each other, but there was no significant difference in the mean Cd levels between Okitipupa and Igodan. The lowest mean Sn level was recorded at Okitipupa (71.2 ± 0.2), while the highest mean Sn level was reported at Irele (461.0 ± 1.0). There was a significant spatial variation in the different sampled locations. The different locations showed significantly spatial variations when compared with each other. The lowest mean Pb level was recorded at Igbokoda (10.3 ± 0.2), while the highest mean Pb level was reported at Erinje (12.5 ± 0.3). There was a significant spatial variation in the different sampled locations. The different locations showed significantly spatial variations when compared with each other, but there was no significant difference in the mean Pb levels between Okitipupa and Igbokoda. Bi was only recorded at Igodan (13.4 ± 0.1).

Sediments slowly heap up elements as well as other contaminants (Bing et al., 2013), which are often transported into the water bodies when there is change in environmental condition (Akcil et al., 2014). From Table 3, the concentration of sodium and magnesium in sediments from all locations ranged from 1415.4 to 7991.6 mg kg^{-1} and from 2235.8 to 7952.3 mg kg^{-1}, respectively, with the mean values of 6294.4 and 4534.4 mg kg^{-1}, respectively. The mean values of Na and Mg obtained from the present study were higher than the values that were reported in sediments of Lagos and Ogun State, Nigeria (Ayedun et al. 2019) but lower than the value reported by Alexakis 2008. The concentration of Na and Mg is higher in this study probably because of the larger amount of limestone and dolomite present in those sampling area. Aluminum is absorbed by living things in the water bodies and transported to human by food chain (Oberholster et al. 2012) and is badly taken by this living things from water bodies. In fish most especially aluminum clogs the gill of the fish when taken (Alstad et al. 2005). The availability of element in the water bodies is due to the pH of the water. Aluminum is also notorious for causing brain lesion which is known as Alzheimer's disease (Lopez et al. 2002; Flaten 2001; Graves et al. 1990). The concentration of aluminum in sediments from all locations ranged from 220,749.2 to 290,934.5 ± 0.6 mg kg^{-1} with the mean value of 250,899.1 mg kg^{-1}. The mean value of Al obtained from the present study was higher than the value that was reported in sediments of Lagos and Ogun State, Nigeria (Ayedun et al. 2019), and in Kolkata, India (Kumar et al. 2011). The higher value of Al in this study is probably due to the higher pH of water and organic matter content; these greatly influence the toxicity of aluminum. Researches had shown that Si is important in chicks and

Table 3 Comparison between the present study and two other studies (mg kg^{-1})

Elements	Present study range ± SE (mean value)	Ayedun et al. (2019)	Abdul Kawi and Alhudify (2016)
Na	1415.4–7991.6 ± 0.3 (6294.4)	50.0–580 (188 ± 29.6)	NA
Mg	2235.8–7952.3 ± 0.7 (4534.4)	0.01-10,800 (2061 ± 819)	NA
Al	220,749.2–290,934.5 ± 0.6 (250,899.1)	2500–51,600 (23,478 ± 3944)	NA
Si	501,037.4–545,825.4 ± 0.8 (518,669.1)	NA	NA
P	269.6–7546.5 ± 0.8 (3491.7)	NA	NA
Cl	188.5–285.6 ± 0.7 (229.1)	NA	NA
K	2042.5–8634.5 ± 0.8 (5318.8)	100–12,400 (2372 ± 956)	NA
Ca	5190.4–35,661.4 ± 0.6 (15,930.9)	0.010–3900 (750.0 ± 271)	NA
Ti	4561.4–78,811.6 ± 0.7 (40,664.8)	0.010–3600 (1061 ± 265)	NA
Cr	60.6–565.3 ± 3.5 (388.2)	6.40–202 (35.6 ± 11.3)	6.65–25.58
Mn	234.6–2064.4 ± 0.6 (1316.8)	23.0–489 (163 ± 40.3)	28.95–143.16
Fe	20,088.4–63,973.3 ± 1.9 (36,093.2)	4300–70,200 (22,616 ± 2062)	814.08–2999.89
Cu	257.9–373.6 ± 0.6 (322.0)	2.04–137 (21.2 ± 7.77)	13.55- 39.95
Zn	48.6–139.6 ± 0.5 (94.0)	0.10–127 (43.4 ± 10.2)	17.4- 74.61
Sr	46.5–317.5 ± 2.3 (156.5)	0.80–47.1 (13.7 ± 3.23)	NA
Rb	37.7 ± 0.6 (37.7)	0.20–118 (28.1 ± 10.7)	NA
Zr	557.5–9156.7 ± 0.5 (5014.7)	1.10–13.3 (6.25 ± 0.886)	NA
Ag	31.3–73.6 ± 1.9 (45.6)	NA	NA
Cd	21.5–77.5 ± 0.7 (38.1)	NA	NA
Sn	71.2–461.0 ± 1.2 (300.4)	0.23–2.32 (1.05 ± 0.138)	NA
Pb	10.3–12.5 ± 0.5 (11.3)	2.21–20.2 (9.48 ± 1.47)	5.65–20.13
Bi	13.4 ± 0.1 (13.4)	NA	NA

NA Not available

rats' diet, and its deficit is associated with stunted growth, mostly with cartilage and bone formation, while in human being intake of silicon leads to exponential increase in bone mass (Refft et al. 1999; Birchall et al. 1996). The concentration of silicon in sediments from all locations ranged from 501,037.4 to 545,825.4 ± 0.8 with the mean values of 518,669.1 mg kg^{-1}. Ejection phosphorus from bottom sediments is caused by numerous factors: pH, redox potential temperature, oxygen concentration, etc (Stephen et al. 1997; Søndergaard et al. 2017, 2002). Chlorine causes environmental harm at low levels. Chlorine is especially harmful to organisms living in water. The concentration of phosphorous and chlorine in sediments from all locations ranged from 269.6–7546.5 ± 0.8 to 188.5–285.6 ± 0.7, respectively, with the mean values of 3491.7 and 229.1 mg kg^{-1}, respectively. The concentrations of these elements were not available in the other studies. The concentration of potassium, calcium and titanium in sediments from all locations ranged from 2042.5 to 8634.5 ± 0.8, 5190.4 to 35,661.4 ± 0.6 and 4561.4 to 78,811.6 ± 0.7 mg kg^{-1}, respectively, with the mean values of 5318.8, 15,930.9 and 40,664.8 mg kg^{-1}, respectively. The mean values of K, Ca and Ti obtained from the present study were higher than the values that were reported in sediments of Lagos and Ogun State, Nigeria (Ayedun et al. 2019) but lower than the values reported by Alexakis (2008). The concentration of K and Ca is higher in this study probably because the sediments in the sampling areas have more K and Ca occurring naturally in these areas. The concentration of chromium and manganese in sediments from all locations ranged from 60.6 to 565.3 ± 3.5, 234.6 to 2064.4 ± 0.6 mg kg^{-1}, respectively, with the mean values of 388.2 and 1316.8 mg kg^{-1}, respectively. The mean values of Mn obtained from the present study were lower than the values that were reported in sediments of Lagos and Ogun State, Nigeria (Ayedun et al. 2019), and higher than the values that were reported in sediments of Yemen, Korea and India (Abdul Kawi and Alhudify (2016); Kim et al. 2011; Suthar et al. 2009). Chromium is usually released by the electroplating, steel manufacturing, leather tanning and textile industries, causing surface water and well contamination which was subsequently found in sediments. Cr concentration is lower than that of Ayedun et al. (2019) because there are more steel manufacturing companies, textile industries, etc., in Lagos and Ogun state than in Ondo state, and the value is higher than that of Korea and India (Kim et al. 2011; Suthar et al.2009). The concentration of iron in the sediment from all the locations ranged from 20,088.4 to 63,973.3 ± 1.9. These concentrations of iron were relatively higher when compared to other studies both in Nigeria and in other countries (Ghrefat and Yusuf (2006); Cheggour et al. (2005); Ayedun et al. (2019); Kumar et al. 2011). The reason for this higher concentration could be due to high contamination of clay percentages, oil and gasoline spill to the water bodies in the studied area. Copper is an essential trace element for living organisms but can be harmful at high concentrations. Major causes of Cu contamination of water bodies include metal processing (Yi et al., 2011) and agriculture activities (El Azzi et al., 2013: Fontana et al., 2014).

The concentration of copper in sediments ranged from 257.9 to 373.6 ± 0.6 322.0. The mean value of Cu (322.0mgkg^{-1}) obtained from the present study was higher than the values reported in other studies (Abdul Kawi and Alhudify (2016); Alexakis,2008; Rodríguez-Barroso et al. 2009). The higher concentration in this study could be as a result of environmental contamination (Kabta Pendias 2011). Lower concentration of zinc was recorded in this study when compared to other researches (Jadal et al. 2002;Moukrim et al. 2008;Mhamdi et al. 2010). The concentration of strontium and zirconium in sediments from all locations ranged from 46.5 to 317.5 ± 2.3, 557.5 to 9156.7 ± 0.5 mg kg^{-1}, respectively, with mean values of 156.5, 37.7 and 5014.7 mg kg^{-1}, respectively. The mean values of Sr and Zr obtained from this present study were lower than the values reported in sediments in Lagos and Ogun State, Nigeria (Ayedun et al.2019), and in East Attica, Greece (Alexakis,2008). The concentration of Zr was lower in this study probably due to the fact that there is no chemical industry around the sampling areas. The mean concentration of rubidium (37.7 ± 0.6 mg kg^{-1}) which was also higher than the value reported by Alexakis (2008) but lower than the one reported by Butu and Iguisi (2013). The concentration of silver and bismuth in sediments from all locations ranged from 31.3 to 73.6 ± 1.9 and 13.4 ± 0.1, respectively, with the mean values of 45.6 and 13.4 mg kg^{-1}, respectively. The concentrations of these heavy metals were not available in the other studies. Humans may get exposed to these metal primarily by inhalation and ingestion and can suffer from acute and chronic intoxication. Cadmium distributed in the environment will remain in soils and sediments for several decades. Agricultural activities had been implicated as the major man-made source of Cd contamination in aquatic environment (Illeperuma 2000; Jauasumana et al. 2011). The value of cadmium reported in this study was higher than other studies (Bullucci et al. 2003; Tahiri et al. 2005; Zheng et al. 2008). The concentration of tin and lead in sediments from all locations ranged from 71.2 to 461.0 ± 1.2, 10.3–12.5 ± 0.5 mg kg^{-1}, respectively, with the mean values of 300.4 and 11.3 mg kg^{-1}, respectively. The mean values of Sn and Pb obtained from the present study were higher than the values that were reported in sediments of Lagos and Ogun State, Nigeria (Ayedun et al. 2019) but lower than other studies in other regions (Amri et al. 2007;Kim et al. 2011). The high concentration of Pb in this study could be probably due to contamination from sewage discharges as well as oil enrichment.

Table 4 Correlation between physicochemical parameters and elemental concentration

	pH	EC (us/cm)	Temp (°C)	Chloride	Nitrate
Na	0.448	−0.507	−0.568*	−0.560*	−0.897**
Mg	0.961**	−0.471	−0.766**	0.370	−0.724**
Al	0.907**	0.125	−0.246	0.250	−0.319
Si	0.612*	−0.118	−0.376	0.842**	−0.075
P	0.848**	0.220	−0.164	0.425	−0.160
Cl	−0.078	−0.872**	−0.659**	−0.023	−0.522*
K	−0.222	−0.744**	−0.506	−0.465	−0.607*
Ca	0.906**	0.125	−0.252	0.376	−0.262
Ti	−0.219	0.070	0.085	−0.039	0.037
Cr	0.578*	0.259	−0.057	0.193	−0.161
Mn	−0.235	0.314	0.290	0.194	0.345
Fe	0.580*	−0.274	−0.494	0..836**	−0.173
Cu	0.525*	0.419	0.127	0.691**	0.333
Zn	0.844**	0.071	−0.299	0.250	−0.389
Sr	0.791**	0.116	−0.229	0..691**	−0.052
Rb	−1.000**	−0.803	0.971	−0.756	−0.945
Zr	−0.382	0.118	0.188	0.209	0.310
Ag	0.163	−0.592*	−0.501	0.062	−0.374
Cd	0.648**	−0.299	−0.522*	0.920**	−0.144
Sn	0.546*	−0.095	−0.239	0.005	−0.290
Pb	0.865**	−0.442	−0.677**	0.348	−0.596*
Bi	−0.991	0.189	0.082	0.803	0.945

*should be placed behind correlation significance at 0.05 level (2-tailed) under the table while ** should be placed behind correlation significance at 0.01 level (2- tailed) under Table 4

Table 4 shows the correlation between physicochemical parameters and elements. Nitrate and chloride showed a negative significant relationship with Na, pH showed a positive significant relationship with Mg, and temperature and nitrate showed a negative significant relationship with Mg. pH is positively related to Al, pH, and chloride showed a positive relationship with Si. pH showed a positive relationship with P, EC, temperature, and nitrate showed a negative significant relationship with Cl. EC is significantly positively related to K, while nitrate is negatively related to K. pH showed a significant positive relationship with C. pH is positively related to Cr. pH and chloride are positively related to Fe. pH and chloride are positively related to Cu.

pH is positively related to Zn, and pH and chloride are positively related to Sr. pH has a significant negative perfect relationship with Rb, and EC has a significant negative relationship with Zr. EC shows a significant negative relationship with Ag, pH and chloride have a positive significant relationship with Cd, while temperature has a negative relationship with Cd. pH has a significant positive relationship

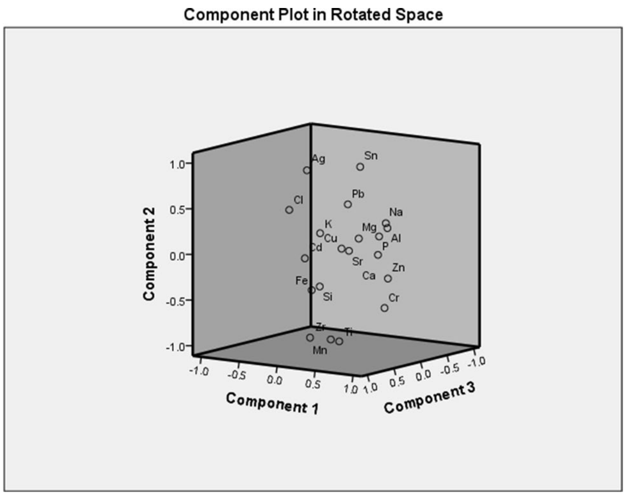

Fig. 2 Component plot in rotated space of the elemental concentration

Table 5 Rotated component matrix of the elemental concentration

	Component			
	1	2	3	4
Na	0.471	0.304	−0.262	0.786
Mg	0.703	0.280	0.579	0.301
Al	0.864	0.366	0.270	−0.215
Si	0.385	−0.236	0.860	−0.238
P	0.836	0.090	0.407	− 0.357
Cl	−0.481	0.419	0.196	0.744
K	−0.349	0.120	−0.196	0.908
Ca	0.834	0.288	0.384	−0.272
Ti	0.061	−0.991	0.030	0.118
Cr	0.801	−0.521	0.234	−0.181
Mn	0.024	− .0.958	0.136	−0.249
Fe	0.311	−0.277	0.905	−0.084
Cu	0.425	0.131	0.505	− 0.740
Zn	0.920	−0.170	0.342	−0.071
Sr	0.619	0.146	0.644	− 0.425
Zr	− 0.213	−0.954	0.187	−0.093
Ag	−0.273	0.869	0.162	0.377
Cd	0.252	0.071	0.950	−0.166
Sn	0.323	0.946	0.010	−0.027
Pb	0.504	0.624	0.500	0.215

with Sn, Pb, while temperature and nitrate have a negative significant relationship with Pb.

Figure 2 shows the component plot in rotated space. It gives a 3-dimensional plot of the principal components and the heavy metal loadings on the rotated space.

Table 5 shows the rotated component matrix. Each cell on the matrix gives the component loadings for each heavy metal. Mg, Al, P, Ca, Cr and Zn loaded highest under component 1, Ti, Mn, Zr, Ag, Sn and Pb loaded highest under component 2, Si, Fe, Cu, Sr and Cd loaded highest under component 3, while Na, Cl, K and Cu loaded highest under component 4. Metals that loaded highest under similar components are indicative of similar source.

Enrichment factor values were taken as suggested by Sutherland (2000) for the metals studied (Kabata and Pendias 1999). EF < 1 indicates no enrichment, EF < 3 is minor enrichment, EF = 3–5 is moderate enrichment, EF = 5–10 is moderate to severe enrichment, EF = 10–25 is severe enrichment, EF = 25–50 is very severe enrichment, and EF > 50 is extremely severe enrichment. In Irele, when Al was used as reference element, Na, Mg, K, Ca, Cl, P, Sr, Rb, Pb, Ti, Mn, Fe, Zn and Cr indicated no enrichment. Si, Cu and Zr were minor enriched. Cd and Sn were very severe enriched, while Ag was extremely enriched. When Fe was used as reference element, Mg, P, K, Ca, Mn, Sr, Rb, Zr indicated no enrichment. Na, Pb, Cr and Zn were minor enrichment. Cl was moderate enrichment. Al and Zr were moderate to severe enrichment. Ag, Cd and Sn were extremely enriched. When silicon was used as a reference element, Na, Mg, K, Ca, Cl, P, Sr, Rb, Pb, Ti, Mn, Fe, Al, Zn, Cu, Zn, Zr and Cr indicated no enrichment. Cd and Sn were moderate severe enrichment, while Ag was extremely enriched. In Okitipupa, when Al was used as reference element, Na, Mg, K, Ca, Cl, P, Sr, Pb, Mn, Fe and Zn indicated no enrichment. Si, Cr and Cu were minor enrichment. Ti and Sn were moderate to severe enrichment. Zr was severely enriched. Cd was severe enrichment, while Ag was extremely enriched. When Fe was Mg, K, Ca, Sr, Pb indicated no enrichment. Zn, P and Na were minor enrichment. Al and Mn were moderately enriched. Si, Cr and Cu were moderate severe enrichment. Ti and Sn were severe enrichment, while Zr, Ag and Cd were extremely severe enrichment. When Si was used in Okitipupa, Cd was severely enriched and Ag was extremely severe enrichment. In Erinje, when Al and Fe were used, Cd and Ag were extremely severe enrichment, but with Si, Ag only was extremely severe enrichment. In Igodan, when Al, Fe and Si were used as reference element, Ag, Cd and Sn were extremely severe enrichment. In Igbokoda, when Al, Fe and Si were used, Ag, Cd and Zr were extremely severe enrichment as shown in Table 6.

The original (Egrin et al. 1991) equation for the calculation of enrichment factor was substituted.

by using Al, Fe and Si as reference elements in this study. The order of sediments enrichment in Irele when Al was used as reference element was Ag > Cd > Sn > Si > Cu > Zr > Cl > Ti > Na > Cr > Pb > Zn > Fe > P > K > Mn > Rb > Mg > Ca > Sr.When Fe was used as the reference element, the order of sediment enrichment was Ag > Cd > Sn > Si >

Table 6 Enrichment values using aluminum, iron and silicon as reference elements in all the locations

Element	IRELE			OKITIPUPA			ERINJE			IGODAN			IGBOKODA		
	Al	Fe	Si	Al	Fe	Si	Al	Fe	Si	Al	Fe	Si	Al	Fe	Si
Na	0.27	1.82	0.11	0.30	1.18	0.12	0.20	0.53	0.10	0.23	1.69	0.12	0.05	0.17	0.02
Mg	0.09	0.61	0.04	0.09	0.37	0.04	0.15	0.39	0.07	0.09	0.65	0.04	0.05	0.17	0.02
Al	1.00	6.79	0.42	1.00	3.90	0.39	1.00	2.68	0.49	1.00	7.37	0.51	1.00	3.35	0.40
Si	2.38	16.13	1.00	2.54	9.91	1.00	2.06	5.52	1.00	1.98	14.57	1.00	2.51	8.40	1.00
P	0.13	0.90	0.06	0.55	2.13	0.22	2.96	7.95	1.44	2.33	17.13	1.18	1.41	4.74	0.56
Cl	0.55	3.73	0.23	0.49	1.90	0.19	0.36	0.96	0.17	0.30	2.19	0.15	0.38	1.28	0.15
K	0.11	0.76	0.05	0.12	0.45	0.05	0.04	0.11	0.02	0.04	0.26	0.02	0.03	0.09	0.01
Ca	0.08	0.55	0.03	0.04	0.14	0.01	0.44	1.19	0.22	0.35	2.60	0.18	0.14	0.48	0.06
Ti	0.34	2.33	0.14	6.21	24.21	2.44	2.25	6.04	1.09	1.78	13.08	0.90	4.05	13.58	1.62
Cr	0.23	1.58	0.10	1.78	6.93	0.70	1.73	4.63	0.84	1.56	11.49	0.79	1.47	4.91	0.58
Mn	0.10	0.65	0.04	0.83	3.25	0.33	0.42	1.12	0.20	0.35	2.55	0.18	0.85	2.84	0.34
Fe	0.15	1.00	0.06	0.26	1.00	0.10	0.37	1.00	0.18	0.14	1.00	0.07	0.30	1.00	0.12
Cu	2.18	14.76	0.92	2.08	8.10	0.82	2.28	6.13	1.11	2.14	15.78	1.08	2.75	9.23	1.10
Zn	0.18	1.20	0.07	0.35	1.35	0.14	0.40	1.08	0.20	0.35	2.57	0.18	0.28	0.93	0.11
Sr	0.08	0.53	0.03	0.06	0.22	0.02	0.29	0.78	0.14	0.17	1.28	0.09	0.19	0.65	0.08
Rb	0.09	0.63	0.04	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Zr	1.21	8.19	0.51	20.74	80.87	8.16	7.71	20.68	3.75	3.27	24.09	1.65	19.68	65.95	7.85
Ag	364.04	2470.45	153.19	174.47	680.31	68.63	197.98	531.22	96.29	158.67	1168.66	80.22	155.93	522.59	62.20
Cd	31.85	216.16	13.40	25.97	101.27	10.22	71.04	190.60	34.55	20.40	150.26	10.31	49.29	165.18	19.66
Sn	26.60	180.53	11.19	4.30	16.77	1.69	18.00	48.29	8.75	20.66	152.17	10.45	8.11	27.17	3.23
Pb	0.20	1.35	0.08	0.19	0.74	0.07	0.17	0.46	0.08	0.16	1.19	0.08	0.18	0.60	0.07

ND Not detected

Cu > Zr > Al > Cl > Ti > Na > Cr > Pb > Zn > P > K > Mn > Rb > Mg > Ca > Sr. When Si was used as the reference element, the order of sediment enrichment was Ag > Cd > Sn > Cu > Zr > Al > Cl > Ti > Na > Cr > Pb > Zn > Fe > P > K > Mn > Rb > Mg > Ca > Sr, as shown in Table 6. The three reference elements (Al, Fe and Si) used in the computation of enrichment value showed similar trend as in decreasing order, but Fe showed the highest enrichment values when compared to Al and Si as reference element. These trends of enrichment value in this study can be compared to the trends obtained in other studies (Ali et al. 2015;Ayedun et al. 2019; Ediagbonya & Ayedun (2018). In Okitipupa, the trend showed a descending order of the enrichment value when Al was used as reference element; Ag > Cd > Zr > Ti > Sn > Si > Cu > Cr > Mn > P > Cl > Zn > Na > Fe > Pb > K > Mg > Sr > Ca, while Fe and Si showed the same pattern of descending enrichment value when it was used as reference elements. In Erinje, when Al was used as reference element, the enrichment value was in the order as: Ag > Cd > Sn > Zr > P > Cu > Ti > Si > Cr > Ca > Mn > Zn > Fe > Cl > Sr > Na > Pb > Mg, while Fe and Si also showed the similar pattern of decreasing enrichment value when it was used as reference elements. In Igodan, when Al was used as reference element, the enrichment value was in the order as: Ag > Sn > Cd > Zr > P > Cu > Si > Ti > Cr > Ca > Zn > Mn > Cl > Na > Sr > Pb > Mg > K, while Fe and Si also showed the same pattern of descending enrichment value when used as reference elements as shown in Table 6.

In Igbokoda, when Al was used as reference element, the enrichment value was in the order as: Ag > Cd > Zr > Sn > Ti > Cu > Si > Ti > Cr > P > Mn > Cl > Fe > Zn > Sr > Pb > Ca > Mg > Na > K. The same was observed when Fe and Si were used as reference element in Igbokoda.

Igeo ≤ 0 was classified as unpolluted, Igeo ≤ 1 was classified as slightly polluted, Igeo ≤ 2 was classified as moderately polluted, Igeo ≤ 3 was classified as moderately severely polluted, Igeo ≤ 4 was classified as severely polluted, Igeo ≤ 5 was classified as severely extremely polluted, and Igeo ≥ 5 was classified as extremely polluted. From Table 7, in Irele, the elements whose Igeo ≤ 0 were Na, Mg, P, K, Ca, Ti, Cr, Mn, Fe, Zn, Sr, Rb and Pb and they were classified as unpolluted. While Ag, Cd, Si and Sn classified as extremely polluted and their Igeo ≥ 5, Al and, Cl were classified as slightly polluted and their Igeo ≤ 1, the element Zr and Cu were moderately polluted. In Okitipupa, Na, Mg, Cl, K, Ca, Fe, Zn and Sr were slightly polluted, Cr was moderately polluted, Sn was moderately severely polluted, Ti was severely extremely polluted, while Si, Cd, Ag, Zr and Cu were extremely polluted. In Erinje, Na, Mg, Cl, Fe, Zn, Sr and Pb were unpolluted, and Ca and Mn were slightly polluted. Al

Table 7 Geo-accumulation value, contamination factor, ecological risk, risk index and pollution load index of the various location

Element	IRELE			OKITIPUPA			ERINJE			IGODAN			IGBOKODA		
	Geo-accumulation	C_f	Er	Geo-accumulation	C_f	Er	Geo-accumulation	C_f	Er	Geo-accumulation	C_f	Er	Geo-accumulation	C_f	Er
Na	−0.957			−0.850			−1.064			−0.892			−3.347		
Mg	−2.532			−2.530			−1.500			−2.260			−3.331		
Al	0.945			0.879			1.278			1.234			0.935		
Si	5.516			5.547			5.639			5.540			5.583		
P	−1.961			0.009			2.845			2.452			1.435		
Cl	0.081			−0.161			−0.210			−0.518			−0.459		
K	−2.208			−2.230			−3.302			−3.567			−4.288		
Ca	−2.675			−3.894			0.105			−0.267			−1.878		
Ti	−0.597			3.514			2.448			2.064			2.954		
Cr	−1.156	1.73	3.46	1.709	12.60	9.80	2.066	5.65	12.56	1.876	4.96	2	1.487	3.78	8.41
Mn	−2.442			0.616			0.019			−0.296			0.695		
Fe	−1.817			−1.084			−0.146			−1.646			−0.810		
Cu	2.066	20.19	101	5.251	18.40		2.469	10.38		2.333	9.45		2.396	9.87	
Zn	−1.552	0.92	0.92	−0.647	1.72	0.96	−0.030	1.00	1.47	−0.284	0.84	1	−0.907	0.54	0.80
Sr	−2.741			−3.275			−0.503			−1.285			−1.435		
Rb	−2.478			#VALUE!			#VALUE!			#VALUE!			#VALUE!		
Zr	1.216			5.254			4.224			2.944			5.233		
Ag	9.453			8.326			8.907			8.544			8.220		
Cd	5.939	276	8280	5.578	21	6593.3	7.428	96.88	7750	5.585	27.00	30	6.558	53.00	4230
Sn	5.679			2.984			5.447			5.603			3.954		
Pb	−1.383	0.68	3.4	−1.515	0.12	2.62	−1.263	0.15	3.13	−1.396	0.13	5	−1.542	0.12	2.56
RI			8			6572.02			3			6635.46			12,873.08
PLI		5.703			8.813			14.55			10.20			10.03	

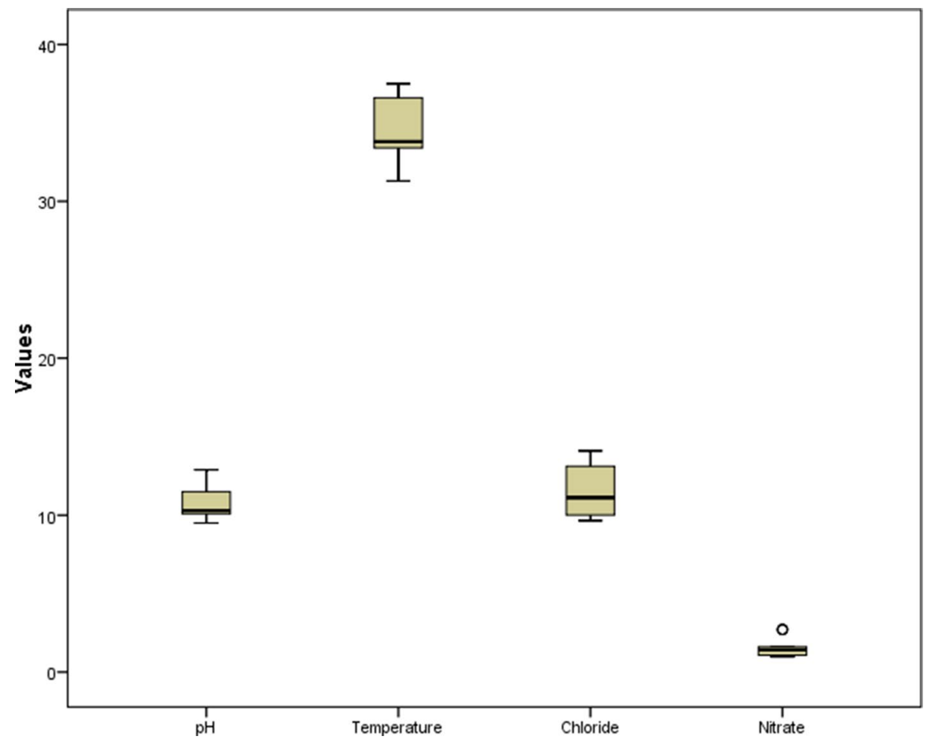

Fig. 3 Box plot

was moderately polluted; P, Ti, Cr and Cu were moderately polluted. Zr was severely extremely polluted. Si, Ag, Cd and Sn were extremely polluted. In Igodan, Na, Mg, Cl, Ca, Mn, Fe, Zn, Sr were unpolluted. Al and Cr were moderately polluted. P, Ti, Cu and Zr were moderately severely polluted. Si, Ag, Cd and Sn were extremely polluted. In Igbokoda, Na, Mg, Cl, K, Ca, Fe, Zn, Sr and Pb were unpolluted. Al and Mn were slightly polluted. P and Cr were moderately polluted. Ti and Cu were moderately severely polluted. Sn was severely polluted. Si, Zr, Ag and Cd were extremely polluted. From Table 7, the contamination values for the few elements were: in Irele, Cd > Cu > Cr > Zn > Pb; in Okitipupa, Cd > Cu > Cr > Zn > Pb. In Erinje, Cd > Cu > Cr > Zn > Pb, in Igodan, Cd > Cu > Cr > Zn > Pb, in Igbokoda, Cd > Cu > Cr > Zn > Pb. The pollution load index was highest Okitipupa, and the lowest pollution index was recorded in Irele as shown in Table 7. The ecological risk values, in Irele, Cd > Pb > Cr > Zn; in Okitipupa, Cd > Cr > Pb > Zn. In Erinje, Cd > Cr > Pb > Zn, in Igodan, Cd > Cr > Pb > ZN, in Igbokoda, Cd > Cr > Pb > Zn as shown in Table 7. The ecological risk factor (Er i) for individual metals showed that Cd ranged from (6450 to 12,720) poses greater potential ecological risk followed by Cu (92–133.5), Cr (3.46–32.4), Pb (3.05–3.7) and Zn (0.92–2.63). Cadmium has no biological significance, and it is insidious to living organism as reported by (Alloway 1990). Toxic response factor (Tr i) for Cd was high (30) as compared to Tr i of Cr, Cu, Zn and Pb. The high toxic response factor (Tr i) for Cd was due to its relatively low background value (0.12) (Wei et al. 2015; CEPA and CGSEM 1990). Potential ecological risk factor for multimetal (RI) represents the sensitivity of various biological communities to toxic heavy metals. The overall risk index (RI) in all the locations in the sediment indicated very high ecological risk index. The values obtained in this study can be compared to the values obtained in other studies (Ali et al. 2015;Ayedun et al. 2019). Pollution load index (PLI) also categorized ecological risk, and the value obtained in this study in all the locations ranged from 8.812 to 28.42. Mean PLI value (17.7) recorded in this study was far higher than the threshold (< 1), indicating the presence of heavy pollutant levels. Such high-level PLI values signified danger and measures are needed in order to reduce the sources of pollutants in the sediment. The high pollution load, contamination value and ecological risk could be as result of soil erosion and indiscriminate dumping of solid waste, sewage and human into the river as well as oil spillage.

Figure 3 shows the distribution of physiochemical parameters in the water. Median, 25th and 75th percentiles are shown in the box; whiskers indicate the maximums and minimums.

Conclusion

In this study, different sediment samples from five different locations were analyzed for the presence of some elements along with some physiochemical parameters. The elemental concentration was determined using proton-induced X-ray emission (PIXE). The result showed that silicon and aluminum have the highest mean concentration with values of 518,669.1 and 250,899.1 mg kg^{-1}, respectively, while lead and bismuth have the lowest mean concentration with values of 11.3 and 13.4 mg kg^{-1}, respectively. Cadmium had the highest contamination values in all the locations. Okitipupa had the highest pollution load index, and the lowest pollution index was recorded in Irele. The overall risk index (RI) in all the locations in the sediment indicated very high ecological risk index. The mean PLI value (17.7) recorded in this study was far higher than the threshold (< 1), indicating the presence of heavy pollutant levels. Such high-level PLI values signified danger and measures are needed in order to reduce the sources of pollutants in the sediment. From enrichment value and Igeo-accumulation values, Sn was severely polluted. Si, Zr, Ag and Cd were extremely polluted

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Compliance with ethical standards

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