A study of heavy pollution in the coastal marine sediment of Ondo State, Nigeria

Original Research Article

Abstract

: The present study was carried out to assess the pollution status of heavy metals (As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, V and Zn) in the marine sediment in Ondo coastal area. A total of 36 sediment samples were collected from the three locations (Awoye, Abereke and Ayetoro) once in a month in 2015 covering both dry and wet season. The sediment samples were subjected to digestion and Atomic Absorption Spectrophotometer (AAS) was used to measure the concentrations of As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, V and Zn. The measured concentrations data were used for evaluating the contamination level and accumulation status of heavy metals in sediment by employing several methods: contamination factor (CF), degree of contamination (C_{deg}), pollution load index (PLI), enrichment factor (EF) and index of geoaccumulation (I_{geo}). The results showed that Fe had the highest average concentration values of 248.00$\pm$ 20.00 and 324.33$\pm$ 5.80 mg/Kg at Awoye sampling site for wet and dry season, respectively while the highest mean concentration of Mn were 271.77$\pm$9.50 and 295$\pm$10.06 mg/Kg at Abereke and Ayetoro, respectively. The contamination factor (CF) values for As, Cd and Mn were $1 < \text{CF} < 3$, indicating a moderate contamination. The results of C_{deg} were ranged from 8.6 to 12.5 for both dry and wet season except in Ayetoro site that had 7.8 in the wet season. The PLI values were 0.47, 0.50 and 0.54 ($<$1) for Abereke, Awoye and Ayetoro sites, respectively, denoting unpolluted conditions. The EF values for Pb and Ni obtained from all the sites ranged from 20.8 to 38.9, showing their significantly enriched in sediment. The I_{geo} values of As, Cr, Fe, V, Zn and Cu were less than one (I_{geo} $<$1) for the three sampling locations in both seasons, implying that the sediments in the study area are practically uncontaminated by these metals. Pb had the I_{geo} values of 2.80 and 2.85 during dry and wet season at Awoye sampling site while Ni had 2.57 at Abereke only in the dry season. The heavy metals in sediment might be derived from the upstream rivers from the top soil, mechanically weathered rock materials and anthropogenic activities.

Keywords: Sediment, Heavy Metals, Contamination, Accumulation, Ondo State, Pollution

1 INTRODUCTION

Sediment is a mixture of weathered materials and mineral species from the parent rocks. It contains organic debris that are transported by detrital process from the upstream and deposited at the river bed [28]. Sediment, because of their variable physical and chemical properties acts as repository for heavy metals in the aquatic environment [13]. Naturally, sediment pollution due to heavy metals are caused by geologic weathering of the bedrock and direct atmospheric deposition. The interactions between water and crustal materials with which water is in contact is a major process by which heavy metals content in the sediment can be increased [9]. The anthropogenic activities such as sea transportation, energy generation and ultilisation, dredging, fishing, oil exploration, farming, infrastructural development and mining are crucial for several socio-economic reasons [23], however, they are probable sources of sediment pollution when their wastes are discharged into the river body by urban surface water runoff [16]. The increased concentration and accumulation of heavy metals alter sediment quality as well as the food stuff available for the aquatic organism, leading to loss of aquatic biodiversity [20].

In recent years, heavy metals pollution of the aquatic environment has become a worldwide problem due to their persistence in nature and their capacity to accumulate in living organism [31]. Ahmadipour et al. [1] reported that heavy metals have negative health implications due to their toxicity potential and tendency to accumulate in environmental media such as water, soil, sediment and other biological media. Several heavy metals persist in the sediment with varied concentrations most especially in fine grain [18]. The increased concentration of the heavy metals in the sediment has adverse health implication due to possibility of entering the food chain through aquatic organism uptake and direct consumption of aquatic organism by man [25]. Polluted sediment can act as a metal pool, thereby release metals to the overlying water column via natural or anthropogenic processes, causing potential adverse health effects to the ecosystem and degrade the sediment quality [6]. Heavy metals are not destructible and non-biodegradable, thus they may exist in an environmental medium for a long period of time [10]. Moreover, heavy metals in the sediment can undergo sorption and complexion, ion exchange, dissolution and precipitation reactions which influence their behaviour and bioavalability during transportation [4].

The capacity of sediment to accumulate heavy metals make them relevant indicators for monitoring purposes as well as the evaluation of their pollution levels and patterns of the aquatic system [29]. Based on these, several studies had been conducted on degradation of sediment quality due heavy metals using several pollution indices [8, 34, 28, 26, 17] while few studies were based on heavy metals speciation and potential bioavailability in the sediment. In the study area, quite a few studies had been undertaken on the distribution of heavy metals in the sediment [27]. In this study, the sediment samples and the concentrations of heavy metals were determined using Atomic Absorption Spectrophotometer (AAS) technique. This was with a view to assessing the pollution status due to heavy metals in the sediment. The main objective of this work was to assess the level of heavy heavy metal pollution in the sediment samples by employing the combination of pollution indices: contamination factor (CF), degree of contamination (D_{deg}), pollution load index (PLI), index of geo-accumulation (I_{geo}) and enrichment factor (EF) analysis.

2 MATERIALS AND METHODS

2.1 Description of the study area

Ondo State coast is strategically located along the gulf of guinea as the Transgressive Mud Beach (TMB) lying in the east of the West African lagoon system and on the west of the Benin Flank of the Niger Delta Basin. Most of the creeks and rivers (Omila and Edo)in the inland area are drained into the Atlantic ocean through Awoye and Abereke estuaries. Also, the sandy beach materials of the Nigeria coastal plain are replaced by mud and lacustrine deposits in Ondo state coast. Another unique features of this coast are overlying mud of about 60 m and massive incursion of the sea into the inland swamps. It is one of the longest coastlines in Nigeria (more than 10 % of the country coastline) which favour fishing activities in the riverine areas. The major anthropogenic activities around the study area are transportation services, seismic investigations, crude oil exploration, commercial and agricultural activities. The study area lies within the tropical rain forest zone and bounded by the latitude 5.56 - 6.30^{o}N and longitude 4.40 - 5.43 ^{o}E with 21.38 m above the sea level. The study area is characterized with two distinct seasons namely: dry and wet season. The dry season spans through the month of November to March while wet season occurs between April to October with the annual rainfall of about 3000 mm [14].

2.2 Sample collection and preparation

Sediment samples were collected at approximately 2.0 nautical mile from the Ondo state coastline at 10 m depth using a VanVeen grab sampler. A representative samples were taken with plastic spatula from the middle of the grab bulk sediment. Samples were collected once in a month from January to December, 2015. Three sampling locations were chosen based on their proximity to various anthropogenic activities such as oil exploration, ship breaking yard, market activities and fishing and the areas of incursion of the estuaries into the Atlantic ocean. Figure 1 shows the map of the Ondo section of the southwest coast of Nigeria with the study locations (Abereke, Ayetoro and Awoye) and other settlements along the coast. After sampling, each sample was transported to the laboratory and air dried at room temperature for two weeks, then grounded in a pre-washed agate mortar and pestle. In order to remove coarse debris, the samples were screened through a 160 μ m stainless steel sieve. The samples of the fine-grained sediment were retained for chemical analysis. All the sampling materials were washed with water and clean with acetone after each sampling to avoid possible contamination.

2.3 Elemental analysis

The samples were subjected to wet digestion in Foss Tecator digestion vessel. One (1) gram of sediment sample was added in a 15 mL mixture of nitric (HNO_3) and perchloric acid ($HClO_4$) in ratio 1:3. The whole content was placed on a heating electric plate at about 334 - 350^{0}C for 2 hours. The mixed solution was boiled until the evaporation of the acid solution and a clear solution was obtained. Upon cooling, the solution was filtered to a 100 mL volumetric flask and then diluted to 50 mL with distilled de-ionized water and kept in the sample bottle at 4^{0}C before analysis. The concentrations of As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, V and Zn were determined using Atomic Absorption Spectrophotometer (Buck Scientific VGP 210 Model) at the Central Science Laboratory (CSL), Obafemi Awolowo University, Ile-Ife, Nigeria. All reagent were of analytical grade. The detection limits of As, Cd, Cr, Cu, Fe, Mn, Ni, Pb and Ni were 0.05,0.001, 0.005, 0.001, 0.005, 0.001, 0.003, 0.003 and 0.002 mg/Kg, respectively.

2.3.1 Contamination factor and Degree of contamination ($C_{\deg}$)

The contamination factor (CF) is a single pollution index which indicates the contamination level of a particular toxic substance or elements in a given environmental medium [12]. In this study, the sediment contamination due to As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, V and Zn were assessed using the contamination factor (CF). The CF of i^{th} heavy metal was calculated as:

$$C_f^i = C_s^i / C_m^i \tag{2.1}$$

where C_s^i is the mean concentration of the element i^{th}. C_m^i is the background concentration which is the maximum level of that metal in a given, beyond which the medium is said to be contaminated [2]. In this study, Taylor and McLennan [32] continental crustal average data was used as the background concentration. The CF is classified into four main groups: CF $<$1 means low contamination; 1$\leq$ CF $<$ 3 means moderate contamination; 3$\leq$ CF $\leq$ 6 implies considerate contamination and CF $>$ 6 indicates very high contamination [25]. The degree of contamination ($C_{\deg}$) is an indicator that shows the extent to which the environmental media is polluted. The $C_{\deg}$ is estimated as the sum of the contamination factors ($C_{\deg} = CF_1 + CF_2 + CF_3 + ...CF_n$) of all the heavy metals in the sediment for a site. Four major category of the degree of contamination have been identified: $<$ 8, 8-16, 16-32 and $>$ 32 indicate low,

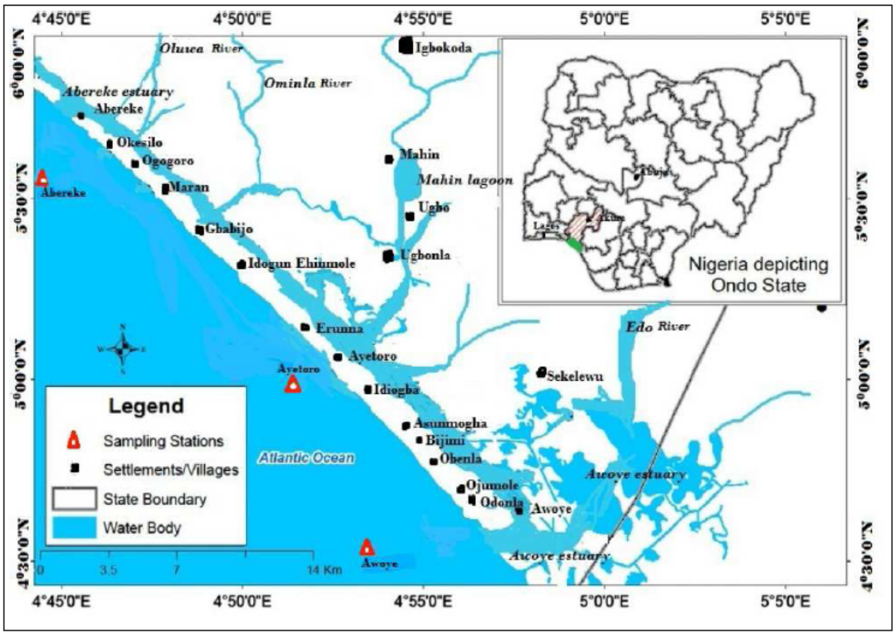

Figure 1: Map of the study area showing the sampling sites

moderate, considerable and very high degree of contamination, respectively [2].

2.3.2 Pollution load index

The pollution load index (PLI), as proposed by Tomlinson et al. [33], is a simple mathematical model use to determine the pollution status of a particular site taking into consideration the metal concentrations of that site as a single value. In this study, the PLI was evaluated as:

$$PLI = \sqrt[n]{(CF_1 * CF_2 * CF_3 * .....CF_n)} \tag{2.2}$$

CF is the contamination factor of each of the heavy metals obtained from equation 1 while n is the number of heavy metals under consideration. The PLI values could be <0, >0 and 1 implying unpolluted condition, progressive degradation in the sediment quality and the occurrence of baseline pollution level, respectively [33].

2.3.3 Enrichment factor (EF) analysis

The Enrichment Factor (EF) is used to evaluate the magnitude of the elements in air, water, soil and sediment samples. It provides information on the relative abundance of species in a given medium to the background values. It is also employed to assess the degree of pollution and to differentiate the elements of anthropogenic and natural sources [22]. Its approach is based on the standardization of the measured element against a reference element. The EF_x was estimated using the equation:

$$EF_x = \frac{\left[X_s/E_{s(ref)}\right]}{\left[X_c/E_{c(ref)}\right]} \tag{2.3}$$

where EF_x is the enrichment values for the element x. X_s and X_c are concentrations of the element of interest in the sample and in the crust while $E_{s(ref)}$ and $E_{c(ref)}$ are the concentrations of the reference element used for normalization in the sample and in the crust. A reference element is often characterized by low occurrence variability and stable chemical properties. The common reference elements for EF analysis are Sc, Mn, Ti, Al, Si and Fe. In this study, Fe was selected as the reference element due to its lithogenic origin and abundance. Taylor and McLennan [32] continental crustal average data was adopted as the background concentration. The EF values were categorized as $<$ 2, 2-5, 5-20, 20-40 and $\geq$40 and considered as deficiency to minimal, moderate, significant, very high and extremely high enrichment, respectively [21].

2.3.4 Index of geoaccumulation

The index of geoaccumulation (I_{geo}) was originally proposed by Muller [24]. It is a quantitative index which indicate the metal contamination in soil, water and sediment [28]. The (I_{geo}) compares the measured concentration C_m of the elements in a given sample with the geochemical background concentrations B_m for the element m in the sample [11]. The I_{geo} was calculated using the logrithimic function:

$$I_{geo} = \log_2({}^{C_m}/_{1.5B_m}) \tag{2.4}$$

Taylor and McLennan [32] continental crustal average data was used as the background elemental concentrations. The factor 1.5 was introduced to minimize the effect of possible variations in the background values, B_m, which may be attributed to the lithogenic variations in the sediment [28, 11, 2]. In this study, I_{geo} was estimated using the seasonal average values of the measured elemental concentrations. The categories of I_{geo} values are $<$0, 0-1, 1-2, 2-3, 2-4, 4-5 and $>$5 and their respective interpretations are practically unpolluted, unpolluted to moderately polluted,moderately polluted, moderately to strongly polluted, strongly polluted, strongly to extremely polluted and extremely polluted [24].

3 RESULTS AND DISCUSSION

3.1 Average elemental concentrations of heavy metal results

Table 1 shows the results of the seasonal average concentrations of As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, V and Zn. Fe had the highest average concentration values of 248.00$\pm$ 20.00 and 324.33$\pm$ 5.80 mg/Kg at Awoye sampling site for wet and dry season, respectively. The highest mean concentration of Mn are 271.77$\pm$9.50 and 295$\pm$10.06 mg/Kg at Abereke and Ayetoro, respectively. The high concentrations of Fe and Mn are most likely related to the local mineralogy and lithogenic origin, rather than the anthropogenic activities [30]. Fe had been reported as being an elements whose origin is fundamentally natural and one of the most common elements in the earth's crust [19]. The mean concentrations of Fe and Mn were similar to high values of 463.0 and 321.4 mg/Kg for both wet and dry season reported by Iqbal and Shah [15] in the sediment samples obtained from Khanpur Lake, Pakistan. A few differences in seasonal concentrations of Cd, Cr, Ni, V and Zn could be related to their regional deposition and the heavy metal accumulation rate in the sediment. The erosion activities, runoff by the action of water and land based sources might introduce heavy metal into the water body. Atmospheric deposition of anthropogenic metals have been reported to be the probable sources for the variation in metal concentrations in the sediment in study area [27]. Most industries such as oil exploration which are located around the sites discharged industrial waste directly into the water without treatment. This might contain heavy metals such Pb, Ni, V, Cr and Cd. The commercial ship and industrial flying boat for the transportation of the workers during oil exploration and seismic investigation could also released significant amount of Pb, Cd, V and Ni-containing contaminants into the sediment. In each site, the average values of Cd, Cu and Cd were lower than the World Health Organisation [35] sediment quality guidelines values of 6, 25 and 123 mg/Kg, respectively. These shows the unpolluted conditions of the sediment by Cu, Cr and Cd. The Ni and Cr mean concentration values in each site exceeded the [35] values of 20 and 25 mg/Kg, suggesting that a minute pollution due to Ni and Cr.

3.2 Contamination factor, degree of contamination and pollution load index results

Table 2 shows the results of contamination factor, degree of contamination and pollution load index for the wet and dry season of the three studied areas. In the dry season, Cr, Cu, Fe, Ni, Pb, V and Zn had a CF values to be $<$1, signifying the low contamination status of the sediment. The CF values for As Cd and Mn were $1 <$ CF < 3, indicating a moderate contamination. The results of C_{deg} ranged from 8.6 to 12.5 for both dry and wet season except in Ayetoro site that had 7.8. This classified the sediment from the three sites as a moderate degree of contamination. The PLI values were 0.47, 0.50 and 0.54 ($<$1) for Abereke, Awoye and Ayetoro sites, respectively, denoting unpolluted (perfection) conditions [33]. The little seasonal variations in PLI values might be associated with upstream discharged into the water and the alteration in various phases of elements in solution. In the wet season, a similar pattern of CF, C_{deg} and PLI values were observed in the three sites. This shows that the pollution of sediment is most likely less affected by the season. Although, there might be progressive accumulation of the heavy metals in the sediment which depends on the increased man-made activities such as oil exploration and waste discharge into the river from the upstream location. The wet season in 2015 was a period of heavy rainfall, leading to high fluvial inputs. The mobility

Table 1: Average elemental concentrations of the heavy metals results (mg/kg)

	Dry			Wet		
Elements	Abereke	Awoye	Ayetoro	Abereke	Awoye	Ayetoro
As	2.67±0.12	4.33±0.23	2.47±.06	5.27±0.15	6.97±0.32	3.3±0.20
Cd	0.57±0.06	1.02±0.03	0.31±0.03	0.53±0.03	0.67±0.03	0.32±0.03
Cr	0.32±0.02	0.33±0.06	0.02±0.01	0.71±0.02	1.15±0.01	0.45±0.01
Cu	2.10±0.10	1.26±0.29	1.17±0.06	2.73±0.06	1.30±0.18	2.4±0.10
Fe	185.67±5.80	324.33±5.80	126.67±5.80	153.00±10.00	248.0±20.00	108.33±11.50
Mn	271.77±9.80	265.77±14.00	215.53±10.0	273.57±9.50	288.2±9.20	295±10.60
Ni	7.09±0.02	7.42±0.03	3.07±0.06	7.63±0.04	8.44±0.13	4.39±0.12
Pb	0.71±0.02	2.05±0.01	0.05±0.01	0.63±0.02	2.08±0.08	0.10±0.02
V	3.02±0.02	4.73±0.06	2.33±0.06	4.13±0.02	5.03±0.02	3.07±0.03
Zn	11.23±0.23	28.30±0.20	1.27±0.06	17.43±0.06	22.0±0.10	3.60±0.09

of the industrial waste alongside with the soil materials into the ocean should increase the pollution of the sediment by the heavy metals in the wet season. However, in this study, the results of CF, C_{deg} and PLI showed that the sediment quality were less affected by wet season.

Table 2: Contamination Factor, Degree of Contamination and Pollution Load Index

	Dry			Wet		
Elements	Abereke	Awoye	Ayetoro	Abereke	Awoye	Ayetoro
As	1.3	2.2	1.2	2.6	3.5	1.7
Cd	3.2	5.7	1.7	2.9	3.7	1.8
Cr	0.3	0.1	0.1	0.1	0.2	0.5
Cu	0.1	0.2	0.2	0.4	0.3	0.4
Fe	0.3	0.6	0.6	0.3	0.4	0.2
Mn	2.7	2.7	2.2	2.7	2.8	2.9
Ni	0.1	0.1	0.4	0.2	0.2	0.6
Pb	0.2	0.2	0.5	0.1	0.2	0.1
V	0.8	0.4	0.4	0.2	0.3	0.2
Zn	0.3	0.3	0.5	0.2	0.3	0.4
C_{deg}	9.3	12.5	7.8	9.7	11.9	8.6
PLI	0.47	0.50	0.54	0.43	0.56	0.52

3.3 Enrichment factor and index of geoaccumulation results

The results of the enrichment factor (EF) analysis for the three locations are presented in the Table 3. The EF values of As and Cr were <2 for the three sites, signifying deficiency to minimal enrichment. Zn and V had EF between $2 <$ EF < 5 and $5 <$ EF < 10 for dry and wet season, respectively, indicating moderate and significant enrichment while Cd and Mn had the EF values of $5 <$ EF < 20 in the three sites, classifying them as significant enrichment in both seasons. The moderate and significant enrichment of Zn and V could also be related to the anthropogenic sources such as boat exhaust systems, antifouling paints and fossil fuel from mechanized boat used in fishing and transportation which were common in the studied area. The EF values for Pb and Ni were $>$ 20 in all the sampling sites at dry and wet season, indicating that the sites were highly enriched with Pb and Ni. The high enrichment of Pb and Ni might be linked to the fact that Pb and Ni are mostly anthropogenic elements associated with oil pollution which is prevalent in the study area. The enrichment of Pb might also be attributed stable isotopic nature of Pb in crustal materials and it takes a considerable period of time before an appreciable depletion can occur. The difference in the EF values of heavy metals in the coastal sediment might be related to the difference in the magnitude of input for each metal in the sediment as well as difference in the removal rate of each metal from the sediment [5, 7]. Largely, the low EF values of As and Cr indicating that they are mostly derived from soil. The high EF values of Zn, V, Pb and Ni might be attributed to contribution from anthropogenic activities such as oil exploration in the study area.

Table 3: Elemental enrichment factor (EF) analysis results

	Dry			Wet		
Elements	Abereke	Awoye	Ayetoro	Abereke	Awoye	Ayetoro
As	1.6	1.5	1.4	2.4	1.50	2.2
Cd	12.1	12.4	9.6	13.6	8.3	11.6
Cr	1.2	0.7	1.9	3.2	2.9	2.7
Cu	10.0	5.7	0.9	6.8	2.1	4.0
Mn	7.4	5.2	8.6	9.0	5.5	13.8
Ni	25.7	21.4	26.3	33.6	20.7	27.3
Pb	33.8	38.9	35.0	36.4	22.5	28.2
V	5.0	4.2	4.8	8.3	5.1	8.7
Zn	5.3	3.7	4.9	10.1	6.2	9.2

Table 4 shows the results index of geoaccumulation (I_{geo}) of As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, V and Zn. The I_{geo} values of As, Cr, Fe, V, Zn and Cu were negative for the three sampling sites in the both seasons. These indicate that the sediment in the study area are practically uncontaminated by As, Cr, Fe, V, Zn and Cu. This is in agreement with the study of Salah et al. [28] that obtained negative I_{geo} values for most metals in the sediment samples of Euphrates River in Iraq. Also, the negative I_{geo} values signify that the average heavy metal concentrations in sediment are lower than the average crustal concentration [28]. The I_{geo} values for Cd, Mn, Ni and V were $0 < I_{geo} < 1$ implying uncontaminated to moderately contaminated [11]. Pb has the I_{geo} values of 2.8 and 2.85 during dry and wet season at Awoye sampling site while Ni has 2.57 at Abereke only in the dry season. The accumulation of heavy metal in sediment might be derived from the discharge of Omila and Edo rivers into the ocean and the mechanically weathered surface materials. Generally, the results of all the pollution indices employed in this study agreed well. However, few differences exist among the pollution indices which could be attributed to their various approach of computation since the same background concentrations data were used . The CF, C_{deg} and PLI results all confirmed the uncontaminated status of most heavy metal in all the sites. The results of EF revealed that sediment were enriched by Pb, Cd and Ni but the I_{geo} values showed that the the sediments were uncontaminated to moderately

Table 4: Index of geoaccumulation (I_{geo}) results

	Dry			Wet		
Elements	Abereke	Awoye	Ayetoro	Abereke	Awoye	Ayetoro
As	-1.73	1.4	0.79	-1.05	0.50	0.50
Cd	0.75	1.33	0.17	0.67	0.14	0.14
Cr	-1.56	-1.53	-1.22	-0.76	-4.34	-4.34
Cu	0.62	0.12	-1.54	0.88	-2.26	-2.26
Fe	-1.74	-0.18	-2.28	-1.93	-2.12	-2.12
Mn	0.26	0.26	0.34	0.26	0.03	0.03
Ni	2.57	1.55	1.03	1.57	1.67	1.67
Pb	1.78	2.84	1.08	1.65	2.85	1.88
V	-0.13	0.32	-1.12	0.18	0.37	-0.39
Zn	-0.07	0.86	-1.20	0.37	0.61	-2.25

contaminated with respect to Pb and moderately contaminated with Cd. Also, the EF values of Cd and Mn were 5 $<$ EF $<$ 20, classifying the sites as significant enriched by Cd and Mn in both seasons. Meanwhile, Cd and Mn had the I_{geo} values in between 0 and 1 ($0 < I_{geo} < 1$) indicating uncontaminated to moderately contaminated. This implies that the calculations of I_{geo} had more reliability than those of EF. The differences in the results of the I_{geo} and EF in this study might be associated with the methods of their computations. The nature of the I_{geo} computation, which involved the logarithmic function and matrix correction factor of 1.5 was quite different from enrichment factor which normalised heavy metal concentration as the ratio to another constituents in the sediment. The difference in classification and interpretation of the each classes might also contribute to little differences in the results.

4 CONCLUSION

The pollution status of heavy metals in the bottom sediment of Ondo state coastal marine area, Southwestern Nigeria were assessed in this study. The concentrations of heavy metals were determined using Atomic Absorption Spectrophotometer (AAS) and pollution level was assessed by various pollution indices (contamination factor (CF), degree of contamination (D_{deg}), pollution load index (PLI), enrichment factor (EF) and index of geoaccumulation (I_{geo})). Among the heavy metals determined, Fe had the high mean concentrations in all the sampling sites. The results of heavy metal concentrations showed low contamination by heavy metals. Transportation, fishing and oil exploration activities near the location contributed insignificantly to the contamination of the sediment. Despite the pollution level, monitoring of the heavy metals is necessary because of the increasing anthropogenic activities such as boat exhaust system, petroleum mechanized boats for fishing and transportation and oil exploration. The study area is situated in a strategic locations characterize with the direct opening of the rivers to the coast upstream, which may eventually increase the heavy metal loading in the sediment.

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Competing Interests

Authors have declared that no competing interests exist.

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