Assessment of Contamination Factor (CF), Pollution Load Index (PLI) and Enrichment Factor (EF) in Otofure and Ikhueniro dumpsites, Benin-City, South-South, Nigeria

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ABSTRACT

Contamination Factor (CF), Pollution Load Index (PLI) and Enrichment Factor (EF) were examined in Otofure and Ikhueniro with a view to determining the level of heavy metal contaminations in the subsurface in the locations due to the presence of a dumpsite in each of these locations from which metals are suspected to have leached into the subsurface over the years. Two soil samples and a control soil sample were obtained from each location and heavy metals; Fe, Zn, Cu, Mn, Ni, Pb, Cr and Cd were investigated using the ASTMD and API-RP standard methods. In Otofure, the results reveal that the CF varies from 1.21 – 13.83 indicating that the level of contamination ranges from medium to very strong. PLI varies from 2.41 – 2.97 indicating an area of moderate to high metallic pollution and EF varies from 0.43 – 0.59 indicating that there is no enrichment in Otofure. In Ikhueniro, CF varies from 0.83 – 3.74 indicating a level of contamination that varies from none to moderately strong, PLI which varies from 1.19 – 2.34, indicating a moderate to a highly polluted area and the EF that varies from 0.55 – 0.75 that shows an area with no metallic enrichment. The very strong CF as revealed in Otofure may not be unconnected with Pb and Cr whose background contaminations in the control study area are in traces. The no metallic enrichment revealed in both locations shows that study areas are not sources of subsurface metallic pollution at present.

Keywords: Heavy metals; Enrichment; Contamination; pollution load index; Ikhueniro

1. INTRODUCTION

Heavy metals in sediments originate from natural sources (i.e., from physical and chemical weathering of parent rocks) and from anthropogenic sources such as dumpsites, mining activities, industrial effluents and atmospheric depositions [1-2]. These metals are discharged into the subsurface and spread between the aqueous phase and sediment. Because of adsorption, hydrolysis and co-precipitation of metal ions, an important quantity of free metal ions are deposited in the sediment while only ions remain dissolved in the water column. Therefore, compared to water, sediments or soil seem to be the major sink and main reservoir of heavy metals [3-5](Wang et al. 2012; Tavakoly-Sany et al. 2013; Alves et al. 2014). Besides, a number of studies have suggested the use of sediments as environmental indicators for the assessment of metal pollution in the environment [6-7]. In this sense, the contents of heavy metals in sediments are constantly monitored in order to provide basic information for environmental assessment in aquatic ecosystems rather than measured in water and/or in floating matter, which are not accurate because of water discharge fluctuations and low resident times.

Industrial and urban activities including waste generation have contributed during the last few decades to the increase in metal contamination in ecosystems through waste and sewage rejection and/or deposition [8-10]. A bulk of studies have been focused on the impact of heavy metals accumulation in sediments, showing an increasing ecological and global health concern, associated with contamination of different components of marine ecosystems [11-13]. Indeed, heavy metals accumulation has also had a significant impact on the other systems. It has been demonstrated that in biological systems, heavy metals could damage different parts of plant as well as their biochemical and physiological functions of their components including cell membranes, mitochondrial, nuclei and DNA [14-16]. Other studies have signaled the deterioration of various ecosystem fauna, flora and microorganisms when excessive levels of heavy metals are accumulated in sediments [17-19]. These metals have also been found to be harmful to human beings, reducing their growth and development, causing cancer, damaging some of the organs and nervous system, as shown in a number of studies, giving significant correlation between human exposure and human consumption of heavy metals (integrated in the food chain) apart from the aforementioned problems [20-22].

Heavy metal contamination of urban topsoil has been of great concern as regards their harmfulness, persistence and non-degradability in the environment [23-26]. Unfavorable effects of high concentrations of heavy metals to soil functions, soil microbial community composition and microbial growth have long been distinguished under both field and laboratory conditions [27]. Heavy metal contamination of urban topsoil is usually deduced from man-made sources such as land disposal of wastes, waste incineration, emissions from automobile exhaust, use of agricultural inputs, emissions from industrial processes and wet or dry atmospheric deposits [28].

Otofure and Ikhueniro dumpsites are active old dumpsites located in Ovia North East and Ikpoba-Okha Local Government Areas (LGA) respectively in Edo State, South-South, Nigeria. All classes of wastes are deposited on the dumpsites. Over the years, heavy metals are suspected to have been leached into the surrounding soil which by extension may as well be deposited in the groundwater

system in the vicinity, transported to the surrounding agricultural soils and eventually found their way into human system through food crops grown in the area and consume by people. In this study, CF, PLI and EF of heavy metals were investigated in Otofure and Ikhueniro to determine the level metallic contamination in the subsurface in the study areas.

2 GEOLOGY AND LOCATION OF THE STUDY AREAS

The study areas, Edo State falls within the Niger Delta Basin. The basin is an extensive continental margin basin situated in the Gulf of Guinea built out into the Central South Atlantic Ocean at the mouths of the Niger-Benue and Cross River systems during the Eocene (Figure 1). It is a wave dominated and tidally influenced delta with sand bodies whose thickness may be influenced by growth faulting [29].

Otofure dumpsite area is located within Longitudes 005° 35' 52.56" E - 005° 36' 02.29" E, Latitudes 06° 27' 40.48" N - 06° 27' 48.99" N and elevation of 97 - 106 m while Ikhueniro dumpsite is located within Longitudes 005° 44' 40.01" E - 005° 44' 66.20" E, Latitudes 06° 19' 15.45" N - 06° 19' 38.99" N and elevation of 71 - 86 m. Otofure and Ikhueniro dumpsites are located in Ovia East Local Government Area and Ikpoba-Okha LGA respectively both in Benin-City, Edo State, Nigeria. The dumpsites are presumed to have existed for over twenty (20) years and cover an area of 300 to 500 m^2 with refuse content consisting of various kinds of metallic, organic and non-biodegradable materials. The areas occupy the Southern part of Edo State which is a sedimentary terrain and is underlain by sedimentary rocks of Paleocene to recent age (Figure 2). The sedimentary rock contains about 90% of sand stone and shale intercalations [30]. Edo State is situated in South-Southern part of Nigeria. It is an important sedimentary basin in Nigeria due to her closeness to the oil fields within the Niger-Delta region.

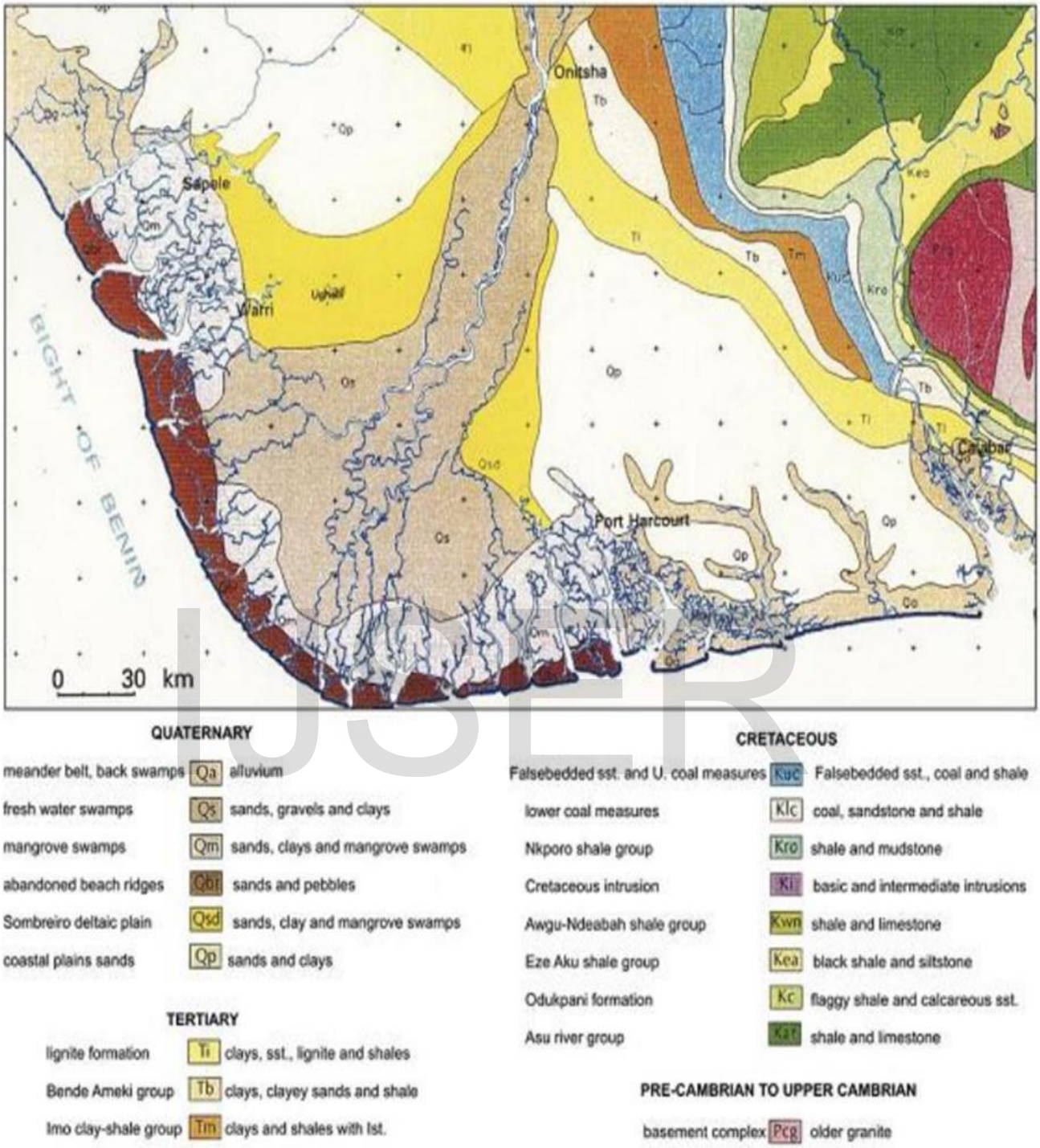

Figure 1. Geological Map of Niger Delta [31]

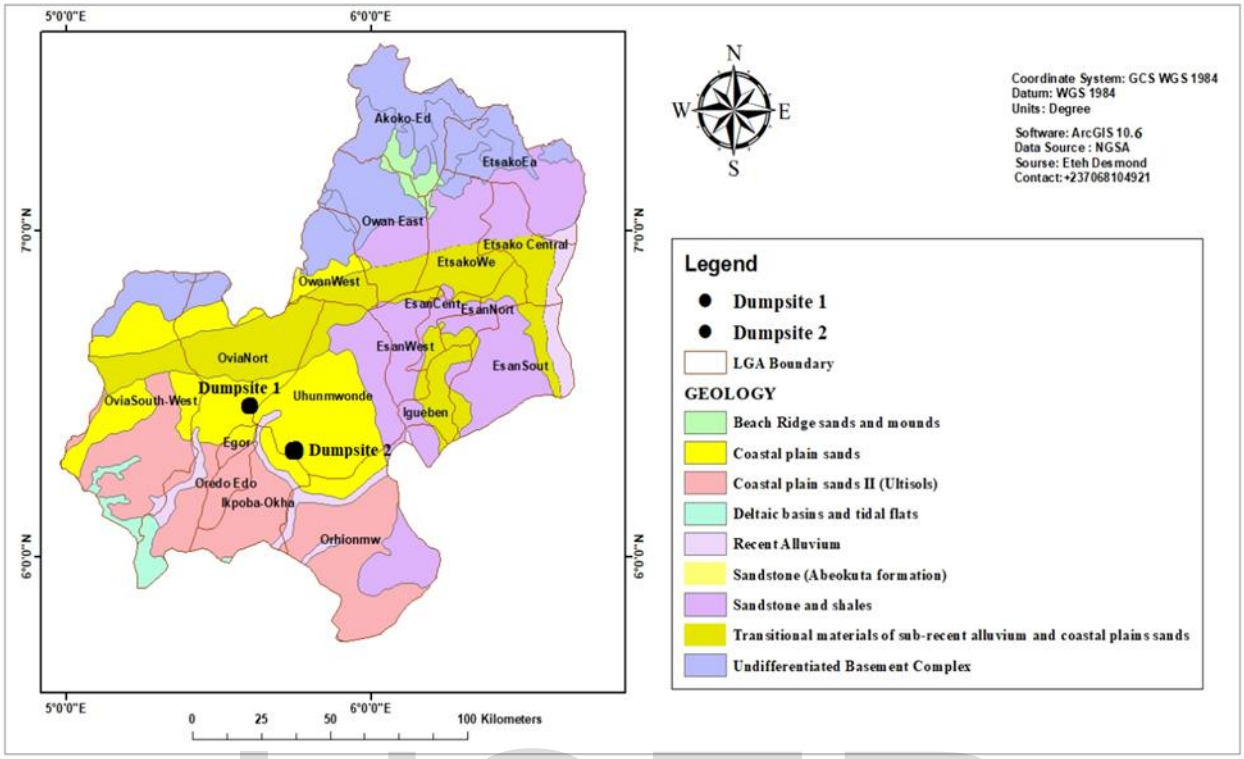

Figure 2. Geologic map of the study areas showing the Otofure and Ikhueniro dumpsites

3 MATERIALS AND METHODS

Two soil samples were collected each across Otofure and Ikhueniro dumpsites. A control sample was collected each, away from each of the study area. In both study areas, eight (8) heavy metals; Iron Fe, Zinc Zn, Copper Cu, Manganese Mn, Nickel Ni, Lead Pb, Chromium Cr and Cadmium Cd were investigated using corresponding ASTMD 1068-96, ASTMD 1691-95, ASTMD 1188-95, ASTMD 858-95, ASTMD 1886-94, ASTMD 3559-96, API-RP-45 and ASTMD 3557-95 standard methods respectively (Table 1 and 2). The CF, PLI and EF were investigated in each location.

3.1 Contamination Factor (CF)

This is the ratio obtained by dividing the concentration of each metal in the soil by the baseline or background or the control value.

$$CF = (C_{heavy\ metal} / C_{background})$$

The contamination levels may be classified based on their intensities on a scale ranging from 1-6: 0 = none, 1 = none to medium, 2 = moderate, 3 = moderately to strong, 4 = strongly polluted, 5 = strong to very strong, ≥ 6 = very strong [32].

3.2 Pollution Load Index (PLI)

The Pollution Load Index (PLI) is determined by the calculation of the product of the $CF^{1/n}$ [33]

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \cdots \times CF_n)^{1/n}$$

where n is the number of metals under investigation. In this study, n = 7 because Cadmium Cd was not detected at the control in both study areas (Table 1 and 2) The PLI provides a simple, comparative means for assessing the level of heavy metal pollution.

0 = Background Concentration, **0>PLI≤1** = unpolluted to moderately polluted, **1>PLI≤2** = moderately polluted, **2> PLI ≤ 3** = moderately to highly polluted, **3> PLI ≤ 4** = Highly Polluted, **PLI≥5** = very highly polluted [34].

3.3 Enrichment Factor

The computation of Enrichment Factor (EF) is to evaluate the impact of anthropogenic activities related to the metal abundance in sediments. EF is defined by the equation:

$$EF = \frac{\left(\frac{C_X}{C_{Fe}}\right)_{sample}}{\left(\frac{C_X}{C_{Fe}}\right)_{crust}} \quad [35]$$

Where;

i. Fe (iron) is chosen as a natural element of reference;
ii. $(C_X/C_{Fe})_{sample}$ is the ratio between concentration of the element "X" and that of Fe in the sediment sample
iii. $(C_X/C_{Fe})_{crust}$ is the ratio between concentration of the element "X" and that of Fe in unpolluted reference (control) baseline.

Calculated EF values could be interpreted after as follows [36]:

i. EF ≤ 1: no enrichment;
ii. 1 < EF < 3: minor enrichment;
iii. 3 < EF < 5: moderate enrichment;
iv. 5 < EF < 10: moderate-to-severe enrichment;
v. 10 < EF < 25: severe enrichment;
vi. 25 < EF < 50: very severe enrichment;
vii. EF > 50: extremely severe enrichment.

Table 1: Otofure Dumpsite Soil Samples

S/N	PARAMETERS	STANDARD METHOD	SAMPLE 1 (mg/kg)	SAMPLE 2 (mg/kg)	CONTROL (mg/kg)
1	IRON, Fe	ASTMD 1068-96	74.77	87.21	43.9
2	ZINC, Zn	ASTMD 1691-95	23.50	39.10	19.4
3	COPPER, Cu	ASTMD 1188-95	10.05	13.77	8.06
4	MANGANESE, Mn	ASTMD 858-95	5.08	7.21	3.25
5	NICKEL, Ni	ASTMD 1886-94	6.11	5.22	4.13
6	LEAD, Pb	ASTMD 3559-96	2.43	2.86	0.37
7	CHROMIUM, Cr	API-RP-45	0.73	0.83	0.06
8	CADMIUM, Cd	ASTMD 3557-95	0.02	0.03	ND

Table 2: Ikhueniro Dumpsite Soil Samples

S/N	PARAMETERS	STANDARD METHOD	SAMPLE 1 (mg/kg)	SAMPLE 2 (mg/kg)	CONTROL (mg/kg)
1	IRON, Fe	ASTMD 1068-96	39.07	50.68	28.4
2	ZINC, Zn	ASTMD 1691-95	11.62	38.60	12.6
3	COPPER, Cu	ASTMD 1188-95	5.16	9.36	4.5
4	MANGANESE, Mn	ASTMD 858-95	3.10	10.11	2.7
5	NICKEL, Ni	ASTMD 1886-94	1.08	3.45	1.3
6	LEAD, Pb	ASTMD 3559-96	4.29	4.40	2.16
7	CHROMIUM, Cr	API-RP-45	0.93	1.29	0.77
8	CADMIUM, Cd	ASTMD 3557-95	0.02	<0.005	ND

4 RESULTS AND DISCUSSION

4.1 OTOFURE

4.1.1 Contamination Factor (CF) and Pollution Load Index (PLI) for Otofure

Table 3: Contamination Factor (CF) and Pollution Load Index (PLI) for Otofure

Soil Sample (S)	Fe CF	Zn CF	Cu CF	Mn CF	Ni CF	Pb CF	Cr CF	(PLI)
S1	1.70	1.21	1.25	1.56	1.48	6.57	12.17	2.41
S2	1.99	2.01	1.71	2.22	1.26	7.73	13.83	2.97

Table 3 presents the Contamination Factor (CF) and Polution Load Index (PLI) across Otofure. The CF values vary from 1.21 – 13.83. These values show that in Otofure, the contamination level varies from medium to very strong. Lead Pb and Chromium Cr in Otofure have very high concentrations; 6.57 – 7.73 and 12.17 – 13.83 respectively. The Pb and Cr contaminations are responsible for the "very strong" CF extreme observed in Otofure (Table 3). Else, Otofure would naturally have been an area with medium to moderate contamination. The extreme Cr contamination around Otofure may not be unconnected with the wide anthropogenic use of Cr and therefore its consequent increased environmental contamination [37]. The PLI values vary from 2.41 – 2.97, indicating an area that is moderately to highly polluted.

4.1.2 Enrichment Factor (EF)

Table 4: Enrichment Factor (EF) for Otofure

Soil Sample (S)		Fe	Zn	Cu	Mn	Ni	Pb	Cr
S1	C_X (mg/kg)	74.77	23.50	10.05	5.08	6.11	2.43	0.73
	$\left(\frac{C_X}{C_{Fe}}\right)_s$	1	0.31	0.13	0.07	0.08	0.03	0.01
	$\left(\frac{C_X}{C_{Fe}}\right)_c$	1.70	0.54	0.23	0.12	0.14	0.06	0.02
	EF	**0.59**	**0.57**	**0.57**	**0.58**	**0.57**	**0.50**	**0.50**
S2	C_X (mg/kg)	87.21	39.10	13.77	7.21	5.22	2.86	0.83
	$\left(\frac{C_X}{C_{Fe}}\right)_s$	1	0.45	0.16	0.08	0.06	0.03	0.01
	$\left(\frac{C_X}{C_{Fe}}\right)_c$	1.99	0.89	0.31	0.16	0.12	0.07	0.02
	EF	**0.50**	**0.51**	**0.52**	**0.50**	**0.50**	**0.43**	**0.50**
Control		43.9	19.4	8.06	3.25	4.13	0.37	0.06

Table 4 presents the computed Enrichment Factor (EF) in Otofure. The EF values ranges from 0.43 – 0.59. These values show that in Otofure, there is no subsurface metallic enrichment as all the values are less than 1, indicating an important anthropogenic effect approved by non-significant metallic contamination of all studied samples.

4.2 IKHUENIRO

4.2.1 Contamination Factor (CF) and Pollution Load Index (PLI) for Ikhueniro

Table 5: Contamination Factor (CF) and Pollution Load Index (PLI) for Ikhueniro

Soil Sample (S)	Fe CF	Zn CF	Cu CF	Mn CF	Ni CF	Pb CF	Cr CF	(PLI)
S1	1.38	0.92	1.15	1.15	0.83	1.99	1.21	1.19
S2	1.78	3.06	2.08	3.74	2.65	2.04	1.68	2.34

Table 5 shows the Contamination Factor (CF) and Pollution Load Index (PLI) in Ikhueniro. The CF values vary from 0.83 – 3.74. The values show that the contamination level in Ikhueniro varies from none to moderately strong, Manganese Mn being the metal with the highest contamination (3.74) while Nickel has the lowest contamination (0.83) in the study area (Table 5). The average value of contamination in Ikhueniro is 2, indicating that the area is only moderately contaminated. The PLI values vary from 1.19 – 2.34, indicating that Ikhueniro is moderately polluted (Table 5).

4.2.2 Enrichment Factor (EF)

Table 6: Enrichment Factor (EF) for Ikhueniro

Soil Sample (S)		Fe	Zn	Cu	Mn	Ni	Pb	Cr
S1	C_X (mg/kg)	39.07	11.62	5.16	3.10	1.08	4.29	0.93
	$\left(\frac{C_X}{C_{Fe}}\right)_s$	1	0.30	0.13	0.08	0.03	0.11	0.02
	$\left(\frac{C_X}{C_{Fe}}\right)_c$	1.38	0.41	0.18	0.11	0.04	0.15	0.03
	EF	**0.72**	**0.73**	**0.72**	**0.73**	**0.75**	**0.73**	**0.67**
S2	C_X (mg/kg)	50.68	38.60	9.36	10.11	3.45	4.40	1.29
	$\left(\frac{C_X}{C_{Fe}}\right)_s$	1	0.76	0.18	0.20	0.07	0.09	0.03
	$\left(\frac{C_X}{C_{Fe}}\right)_c$	1.78	1.34	0.33	0.36	0.12	0.15	0.05

	EF	0.56	0.57	0.55	0.56	0.58	0.60	0.60
Control		28.4	12.6	4.5	2.7	1.3	2.16	0.77

Table 6 presents the computed Enrichment Factor (EF) in Ikhueniro. The EF values ranges from 0.55 – 0.75. The values show that in Ikhueniro, there is no subsurface metallic enrichment as all the values are less than 1. This is similar to Otofure, indicating a non-significant metallic contamination of all studied samples from the study area.

5 CONCLUSION

The principal objective of this study was to investigate Contamination Factor (CF), Pollution Load Index (PLI) and Enrichment Factor (EF) in the soil around Otofure and Ikhueniro dumpsites with a view to determining the level of heavy metal contamination of the subsurface in the area. Eight heavy metals; Fe, Zn, Cu, Mn, Ni, Pb, Cr and Cd were investigated. Cadmium Cd was not detected at the control samples at both location and therefore seven heavy metals were assessed. The results revealed that CF varies from 1.21 – 13.83 and 0.83 – 3.74 in Otofure and Ikhueniro respectively, indicating a level of contamination that ranges from medium to very strong in Otofure and from none to moderately strong in Ikhueniro. PLI varies from 2.41 – 2.97 and 1.19 – 2.34 in Otofure and Ikhueniro respectively indicating an area with moderate to high metallic pollution in both locations. EF varies from 0.43 – 0.59 and 0.55 – 0.60 in Otofure and Ikhueniro respectively, indicating areas with no metallic enrichment. The very strong contamination factor in Otofure is due to high concentrations of Pb and Cr in the location. These are largely local effects in the area. On a broad scale, Otofure and Ikhueniro are not polluted with heavy metals beyond the limits of tolerance at present as revealed in the subsurface metallic enrichment factor assessments in both study areas. However, continued activity of the dumpsites may push this balance beyond the limit of tolerance soonest.

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