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Heavy metal profiles and pollution indices of top soil sampled from six metallic material scrapyards located in Benin city, Mid Western Nigeria

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Abstract
Heavy metal levels and other parameters which included organic carbon content of topsoil samples collected from six metallic material scrapyards and a control sites all located in Benin city were determined using routine techniques. The locations of the visited municipal scrapyards were; Aduwawa, St Savior street, 1st and 2nd Ibiwe, Waterboard at Iyaro (Idia college), and Uwelu. The control soil samples was collected from the premises of the Botanical Garden located within the premises of the Faculty of Life Sciences, University of Benin, Benin City. Duplicate soil samples were collected from the various study locations once every month during the months of February and March, 2022. The pH and EC values of soils collected in February ranged from 6.71 – 7.47 and 606.5 – 2541µS/cm respectively. Soil borne Fe and Pb readings varied from 763.5-2034.5mg/kg and 548.5-1881.5mg/kg as well as 24.50 – 50.35 and 24.75 – 50.60 for samples obtained in February and March respectively. Findings in this study revealed that soil samples obtained from the various scrapyard dumpsites where contaminated with high levels of heavy metals such as Iron, Lead, Chromium and Cadmium. Furthermore, it was observed that the levels of heavy metals analyzed in soil samples from the various scrapyard dumpsites were generally higher in values compared to control sites. Continuous monitoring and further studies on the prevailing soil borne levels of these trace metals should be conducted at regular intervals to ascertain long-term effects on the surrounding environment.

Keywords
Benin city, contamination factor,degree of contamination, index of geoaccumulation, metallic material scrapyards, pollution load index; trace metal

Introduction

Trace metals from both natural and anthropogenic sources are known to accumulate in soil and flora, and as such can pose significant environmental contamination issues (Satpathy *et al.*, 2014). Trace metals are typically deposited in top soils; and as such, soils are regarded as an excellent medium for monitoring and assessing heavy metal pollution (Govil *et al.*, 2002). Trace metal polluted soil can have a negative impact on the entire ecosystem because toxic heavy metals are known to migrate into groundwater or are taken up by flora and fauna, posing a potential threat to ecosystems due to translocation and bioaccumulation (Bhagure and Mirgane, 2011).
Although, some heavy metals are necessary for flora nu-

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trition, plants that are capable of growing near industrial areas usually have higher concentrations of heavy metals, and as such they can serve as biomonitors of pollution loads in many cases (Mingorance *et al*., 2007). Plants grown in polluted soils are known to absorb trace metals with this acccmulated metals being present in both in edible and non-edible portions in sufficient amounts to cause clinical conditions in both fauna and humans who consume these metal-rich plants, as there is no known effective cellular mechanism for their elimination from the human body (Alam *et al*., 2003).
It has also been reported that crop flora have varying capabilities with respect to the absorption and accumulation of trace metals in their body parts, with notable differences in metal uptake as well as translocation between flora species and even cultivars of the same floral species (Liu *et al*., 2003). Plants are known to absorb heavy metals from the soil, and the surface 25cm zone of soil is the layer most affected by man made pollutants. Trace metals are likely adsorbed as well as accumulated in this soil layer principally due to the relatively elevated organic matter content of this soil layer (Satpathy *et al*., 2014). Floral parts of interest known for their important role in the direct transfer of trace metals to the human body include edible parts such as rice grains, which could as a consequence pose a threat to anthropogenic health. Although several studies on the assessment of heavy metal contamination of top soil samples collected from playgrounds located in Port Harcourt and Lagos have been respectively conducted; Okereke and Amadi (2017), and Durowoju *et al*. (2018), there is a paucity of researches targeting top soils obtained from metallic scrapyard dumpsites located in Benin city, Edo State. It is against this background that this study seeks to assess the concentration of selected trace metal in topsoil samples collected from visited metallic material scrapyards in Benin city with the aim of providing insight into the trace metal contamination profiles of the examined soil samples.

Materials and Methods

Description of Study area

Top soil samples were collected from six metallic material scrapyards and a control site located in four (4) Local Government Areas covering different parts of Benin city,the administrative head quarters of Edo State. The Local Government Areas included; Oredo, Ikpoba-Okha, Ovia North East as well as Egor Local Government Areas (LGAs). The visited scrapyards were located in; Aduwawa in Ikpoba Okha LGA, St Savior in Oredo LGA, first Ibiwe in Oredo LGA, second Ibiwe in Oredo LGA, Waterboard at Iyaro area (Oredo LGA) as well as Uwelu market spare parts in Egor LGA respectively (Fig. 1). The seventh location was a Botanical Garden sited within the premises of the University of Benin (Ovia North East LGA) which was chosen as the control site for this site. As indicated by the name, the garden was not subjected to any form of dumping of scrap or disused metallic materials at any time prior to visitation for sampling purposes.

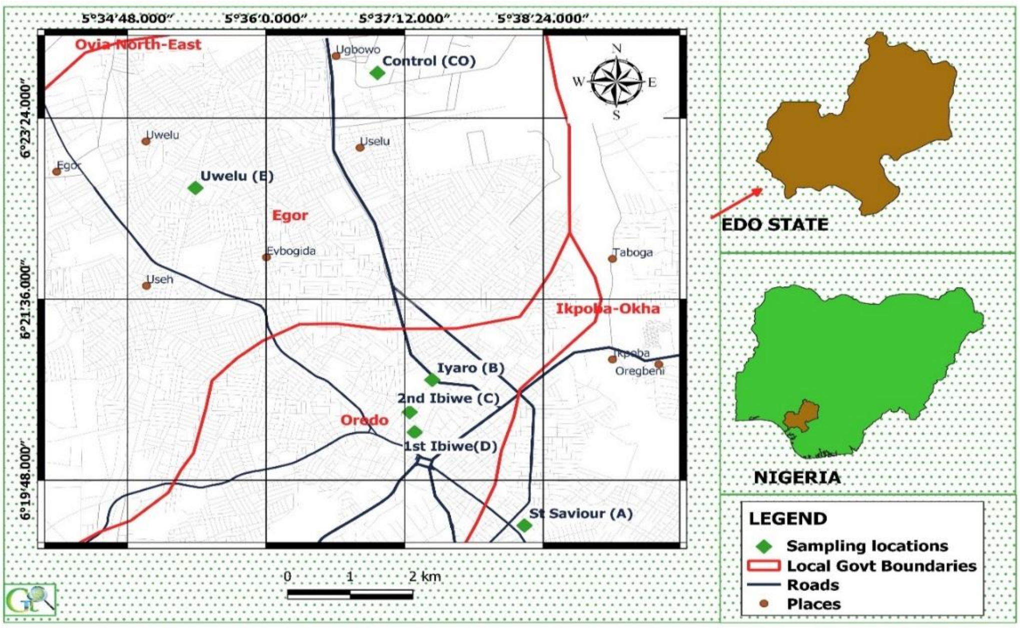

Figure 1
Location of sampling area

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Sample collection and analysis

Two soil samples were collected from the seven different locations. One of these was a control site which is a botanical garden and the other six were the experimental sites (scrapyard dumpsite). The soil samples were collected with the aid of a soil auger and about 200g was collected from each visited site for a 2 month period;February and March, 2022. The bored soil samples were dispensed onto labeled clean polyethylene bags and immediately transported to the laboratory for physico-chemical analyses. The soil samples were air-dried for several days at room temperature before being pulverized and sieved through a 0.1 mm stainless steel mesh. A digital pH meter and a digital conductivity meter were used to determine the pH and conductivity of the soil respectively. Organic carbon and effective cation exchange capacity (CEC) was determined using procedures described by Álvaro-Fuentes *et al.* (2019). Water holding capacity was ascertained determined using the weight difference technique as described by Onyeonwu (2000). For heavy metal analysis, one gram of the respective air-dried samples was dissolved into 30ml Kjeldahl digestion flasks containning 10 ml of nitric acid (HNO_3). The tubes were digested using a Digester (Gerhardt digester, UK.). An Atomic Absorbance Spectrophotometer (AAS) was used to determine the Na, K, Mg, Pb, Cd, Fe, and Cr content of the digested clear supernatants (Buck Scientific model 210 VGP USA).

Soil contamination assessment

The determined trace metal content of the respective samples were respectively utilized to ascertain the different soil associated heavy metal pollution indices. The trace metal pollution indices computed in this study were; contamination factor and degree, ecological risk index, ecological risk factor, pollution load index, geo-accumulation index as well as enrichment factor. Different contamination indices have their own unique merits as well as disadvantages but these indices are all utilized to ascertain soil quality utilizing a particular underlying principle (Duodu *et al.*, 2016).

Geo–accumulation Index (I_{geo})

A way of evaluating the contamination levels of heavy metal contents above the background level was to compute the I_{geo}. Muller (1969) introduced the I_{geo} and utilized this index to ascertain metal contamination levels in soils. The formula is provided below:

$$I_{geo} = \log 2 \frac{Cn}{1.5 \times Bn} \quad [1]$$

where Cn represents the amount of the heavy metal in the soil sample. Bn represents the background value of the heavy metal. The constant 1.5 allows for natural fluctuations in the content of a given substance in the environment. Muller (1969) stated that "the I_{geo} consists of seven classes varying from uncontaminated to very seriously contaminated. Class 0 ($I_{geo} < 0$: practically uncontaminated); class I ($0 < I_{geo} \leq 1$: uncontaminated to moderately contaminated), class II ($1 < I_{geo} \leq 2$: moderately contaminated), class III ($2 < I_{geo} \leq 3$: moderately to heavily contaminated), class IV ($3 < I_{geo} \leq 4$: heavily contaminated), class V ($4 < I_{geo} \leq 5$: heavily to extremely contaminated) and class VI ($I_{geo} \geq 5$: extremely contaminated).

Enrichment factor (EF)

EF was utilized to quantify trace metal inputs above natural levels. The EF was derived according to the formula

$$EF = \frac{Cx/Cb}{Bx/Bb} \quad [2]$$

where C_x and C_b represented the respective amount of the trace and reference metal. Bx and B_b represented the background levels of the trace and reference metals, respectively. The reference metal or element is either Al, Fe, Ti, Mn, Li, Zr, and Sc (Yongming *et al.,* 2006). EF, according to Sakan *et al.* (2009), is interpreted as follows: "EF < 1 is indicative of no enrichment; EF < 3 is indicative of minor enrichment; 3 < EF < 5 is indicative of moderate enrichment; 5 < EF < 10 is described as moderately severe enrichment; 10 < EF < 25 is described as severe enrichment; 25 < EF < 50 is described as very severe enrichment and EF>50 is described as extremely severe enrichment."

Contamination factor (Cf)

The Cf valuation as described by Hakanson (1980) was utilized to ascertain the level of the soil contamination with trace metals. Cf was computed as follows:

$$\text{Contamination factor} = \frac{\text{Cmetal}}{\text{Cbackground}} \quad [3]$$

where $C_{heavymetal}$ and $C_{background}$ represented the concentration and background concentration of the respective trace metal. Cf values are described as follows; "Cf < 1 low contamination factor which was indicative of low contamination of the soil with the examined moiety, 1 ≤ Cf < 3 moderate contamination factor, 3 ≤ Cf < 6 considerable contamination factor and lastly 6≥Cf very high contamination factor. Background values: Fe = 47,000; Pb = 20; Cd = 0.3; Cr = 90 (Iyama *et al.,* 2022).

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Pollution Load Index (PLI)

This index is principally utilized to detect multi-element contamination. . It is derived as the nth root of the product of the n^{th} measured CF of the various soil borne metals. PLI is expressed as:

$$PLI = \sqrt[n]{CF1 \times CF2 \times CF3 \times \cdots \ldots . \times CFn} \quad [4]$$

where, CF is representative of the contamination factor (CF), and n is representative of the number of metals. As stated by Chon *et al.* (1996) if PLI < 1, the soil is regarded as unpolluted; 1 ≤ PLI < 2, the soil is described as moderately polluted; if 2 ≤ PLI < 10, the soil is regarded as strongly polluted; if PLI ≥ 10, the soil is described as extremely polluted.

Contamination Degree (C_{deg})

The sum total of contamination factors for all trace metals examined is known to represent the contamination degree (C_{deg}) of the environment and is expressed as;

$$Cdeg = \sum_{i=1}^{n} cf \quad [5]$$

Four classes of contamination degree have been described; C_{deg} < 8 represent low degree of contamination, 8 ≤ C_{deg} < 16 represent moderate degree of contamination, 16 ≤ C_{deg} < 32 represent considerable degree of contamination, 32 ≤ C_{deg} represent very high degree of contamination (Hakanson, 1980).

Ecological risk index (RI) and ecological risk factor (E_R)

Hakanson (1980) utilized the RI to ascertain the likely ecological risk associated with the presence of heavy metals in the soils. The ecological risk of a specififc trace metal is computed utilizing the E_R and the element's reference value. It is derived as follows:

$$Er = Tr \times cf \quad [6]$$

Tr is representative of the toxic response factor. Cf is the contamination factor. The Tr of Fe, Pb, Cr and Cd is 1, 5, 2 and 30 respectively (Afolagboye *et al.,* 2020).
The RI is derived using this formula:

$$RI = \sum_{i=1}^{n} Er \quad [7]$$

According to Hakanson (1980), Er values are classified into five degree of ecological risks. These include; Er < 40, 40≤ Er <80, 80 ≤ Er < 160, 160 ≤ Er < 320, Er ≥ 320 which represent low, moderate, considerable, high and very high ecological risks respectively. Similarly, the RI values are classified into four degrees of ecological risk and these include RI < 150, 150 ≤ RI 300, 300 ≤ RI < 600, RI ≥ 600 which is indicative of low, moderate, considerable and very high ecological risks.

Results

Physico-chemical properties of the soil samples

The physico-chemical properties of the soil samples are shown in Table 1. For samples collected in the month of February: pH ranged from 5.68±0.16 (Control) to 7.47±0.06 (Aduwawa). Mean EC was lowest at the control site (267±23.00μS/cm) and highest at Idia College (1071±458.5μS/cm). The least organic carbon concentration was obtained at the control site (0.96±0.10%) while the highest was at Idia College (5.19±0.35%). Water holding capacity was minimum in the control sample (14.00±1.00%) and maximum in the sample from 2nd Ibiwe (22.00±2.00%). Na concentrations ranged from 0.32±0.04 meq/100g (control) to 3.16±0.37 meq/100g (1st Ibiwe). The concentrations of K ranged between 0.05±0.01 meq/100g at the control site to 0.23±0.04 in the sample from 2nd Ibiwe. The minimum concentration of Ca was 0.84±0.07 meq/100g (control) and the maximum was 8.87±1.04 meq/100g (1st Ibiwe). The least mean value for Mg was 0.20±0.04 meq/100g (contrl, while the highest was 2.18±0.26 meq/100g (1st Ibiwe). CEC value was least in the control sample (1.41±0.07) and the highest was at 2nd Ibiwe (62.90±4.65). Fe concentrations ranged from 1.61±12.00mg/kg (control) to 2060±52.00mg/kg (St. Saviour). The concentrations for Pb were in the range of 0.88±0.13mg/kg (control) - 50.35±2.05mg/kg (Idia College). Mean Cr concentrations ranged between 0.56±0.07mg/kg in the control sample and 42.90mg/kg in 2nd Ibiwe. The lowest concentration of Cd was 0.44±0.085mg/kg (control) and the highest was 30.65±5.95mg/kg (Idia College).
The results for the month of March were as follows: pH varied from 5.415±0.01 (Uwelu) to 7.82±0.48 (2nd Ibiwe). Mean EC was lowest at the control site (139±7.00μS/cm) and highest at 2nd Ibiwe (1036±393.5μS/cm). The least organic carbon concentration was obtained at the control site (1.08±0.02%) while the highest was at Idia College (6.38±0.43%). Water holding capacity was minimum in

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Table 1. *Physico-chemical values of the top soils sourced from the respective scrapyards and control site*

Sampled sites	Month	pH	EC (µS/cm)	Org.C (g)	WHC (%)	Na (meq/100g) of soil)	K (meq/100g) of soil)	Ca (meq/100g) of soil)	Mg (meq/100g) of soil)	CEC (meq/100g) of soil)	Fe (mg/kg)	Pb (mg/kg)	Cr (mg/kg)	Cd (mg/kg)
		Mean ± S.E.												
Aduwawa	Feb.	7.47±0.06	1065±205	3.50±0.82	16.00±0.00	1.78±0.40	0.17±0.04	5.00±1.12	1.23±0.28	8.17±1.76	1963.5±17.50	44.80±5.20	30.25±2.55	29.95±5.85
St. Saviour		6.72±0.11	760.5±19.5	3.91±0.06	17.50±0.50	1.32±0.23	0.16±0.02	3.70±0.63	0.91±0.16	6.08±0.99	2060±52.00	46.40±7.90	33.85±3.65	23.65±1.25
1st Ibiwe		6.86±0.46	2541±811	3.59±0.26	18.00±0.00	3.16±0.37	0.15±0.02	8.87±1.04	2.18±0.26	14.35±1.65	736.5±109.5	24.50±5.30	28.75±2.75	22.35±1.75
2nd Ibiwe		7.03±0.21	780.5±370.5	3.77±0.54	22.00±2.00	1.52±0.58	0.23±0.04	3.84±2.04	1.08±0.37	62.94.65±	1646.5±173.5	42.15±4.25	42.90±6.70	20.50±2.10
Idia College		7.03±0.02	1071.5±458.5	5.19±0.35	17.00±1.00	1.72±0.58	0.21±0.05	4.83±1.64	1.19±0.41	7.94±2.67	2034.5±6.50	50.35±2.05	33.40±1.10	30.65±5.95
Uwelu		6.71±0.21	606.5±164.5	3.12±0.34	16.50±0.50	1.01±0.29	0.10±0.03	2.83±0.81	0.69±0.20	4.63±1.32	1183.5±86.50	30.35±2.25	20.00±1.50	27.80±6.70
Control		5.68±0.16	267±23.00	0.96±0.10	14.00±1.00	0.32±0.04	0.05±0.01	0.84±s0.07	0.20±0.04	1.41±0.07	161±12.00	0.88±0.13	0.56±0.07	0.44±0.085
Aduwawa	March	7.31±0.21	1295±445	4.305±1.01	19.50±0.50	2.085±0.85	0.28±0.03	5.37±1.34	1.63±0.66	9.675±3.13	1213±263	33.40±3.90	22.50±1.90	22.35±4.35
St. Saviour		6.93±0.29	292.5±99.5	4.805±0.07	10.5±1.50	0.625±0.06	0.34±0.03	1.295±0.11	0.485±0.05	2.745±0.03	1334.5±161.5	34.60±5.90	25.20±2.70	17.65±0.95
1st Ibiwe		6.82±0.01	400.5±10.5	2.425±0.32	14.50±1.50	0.835±0.07	0.19±0.07	2.325±0.14	0.58±0.12	3.93±0.25	548.5±81.5	24.75±2.55	37.95±1.55	21.65±6.35
2nd Ibiwe		7.82±0.48	1036.5±393.5	4.63±0.66	15.00±0.00	1.505±0.58	0.36±0.05	3.69±1.40	1.175±0.45	6.73±2.47	1126.5±70.5	31.40±3.20	14.80±2.20	30.25±6.55
Idia College		7.13±0.11	940±20.0	6.38±0.43	18.50±1.50	1.37±0.03	0.49±0.03	3.35±0.07	1.02±0.03	6.23±0.10	1366±145	37.55±1.45	24.90±0.80	22.85±4.45
Uwelu		5.42±0.01	204±6.00	3.83±0.41	13.50±1.50	0.70±0.11	0.295±0.04	1.03±0.12	0.495±0.14	2.52±0.40	1881.5±64.5	50.60±3.70	34.90±1.10	23.20±2.50
Control (UNIBEN)		6.93±0.19	139±7.00	1.08±0.02	8.50±0.50	0.40±0.01	0.09±0.01	0.895±0.03	0.26±0.06	1.645±0.11	140±11.00	0.205±0.06	0.505±0.12	0.30±0.04

KEY: WHC = Water Holding Capacity:, S.E. = Standard Error

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the control sample (8.50±0.50%) and maximum in the sample from Aduwawa (19.50±0.50%). Na concentrations ranged from 0.40±0.01 meq/100g (control) to 2.085±0.85 meq/100g (Aduwawa). The concentrations of K ranged between 0.09±0.01 meq/100g at the control site to 0.49±0.03 in the sample from Idia College. The minimum concentration of Ca was 0.895±0.03 meq/100g (control) and the maximum was 5.37±1.34 meq/100g (Aduwawa). The least mean value for Mg was 0.20±0.04 meq/100g (control) while the highest was 2.18±0.26 meq/100g (1st Ibiwe). CEC value was least in the control sample (1.645±0.11) and the highest was at Aduwawa (9.675±3.13). Fe concentrations ranged from 140±11.00mg/kg (control) to 1881.5±64.5mg/kg (Uwelu). The concentrations for Pb were in the range of 0.205±0.06mg/kg (control) - 50.60±3.70mg/kg (Uwelu). Mean Cr concentrations ranged between 0.505±0.12mg/kg in the control sample and 37.95±1.55mg/kg in 1st Ibiwe. The lowest concentration of Cd was 0.30±0.04mg/kg (control) and the highest was 30.25±6.55mg/kg (2nd Ibiwe).

Geo-accumulation index of heavy metals

The I_{geo} index values derived directly from the soil borne trace metal readings are presented in Table 2. For soil samples collected in the month of February, I_{geo} index values for Fe ranged from -8.774 in the control sample to -5.097 in the sample from St. Saviour. For Pb, the values ranged from -5.091 (control) to 0.747 (Idia College). The values for Cr ranged between -7.913 (control) to -1.654 (2nd Ibiwe). The minimum I_{geo} value for Cd was -0.032 at the control site and the maximum was 6.089 at Idia College. For soil samples collected in the month of March, I_{geo} index values for Fe ranged from -8.976 in the control sample to -5.228 in the sample from Uwelu. For Pb, the values ranged from -5.893 (control) to 0.754 (Uwelu). The values for Cr ranged between -8.062 (control) to -1.831 (1st Ibiwe). The minimum I_{geo} value for Cd was -0.585 at the control site and the maximum was 6.072 at 2nd Ibiwe.

Sampled Sites	Month	Geo-accumulation Index of heavy metals			
		Fe	Pb	Cr	Cd
Aduwawa	February	-5.167	0.579	-2.158	6.056
St. Saviour		-5.097	0.629	-1.996	5.716
1st Ibiwe		-6.581	-0.292	-2.231	5.634
2ND Ibiwe		-5.420	0.491	-1.654	5.509
Idia College		-5.115	0.747	-2.015	6.089
Uwelu		-5.896	0.017	-2.755	5.949
Control (UNIBEN)		-8.774	-5.091	-7.913	-0.032
Aduwawa	March	-5.861	0.155	-2.585	5.634
St. Saviour		-5.723	0.206	-2.421	5.294
1ST Ibiwe		-7.006	-0.278	-1.831	5.588
2nd Ibiwe		-5.968	0.066	-3.219	6.071
Idia College		-5.689	0.324	-2.439	5.666
Uwelu		-5.228	0.754	-1.952	5.688
Control (UNIBEN)		-8.976	-5.893	-8.062	-0.585

Table 2
Geo-accumulation index of heavy metals in the soil samples

Contamination indices

The contamination factor (CF), contamination degree (CD) and pollution load index (PLI) values derived from the respective soil borne trace metals are presented in Table 3. For soil samples obtained in the month of February, the CF, CD and PLI values of the respective trace metals detected for the soil samples collected at the control site was the least. The CF value for the metals ranged as follows: Fe - 0.0034 to 0.0432 (Idia College), Pb - 0.044 to 2.5175 (Idia College), Cr - 0.0062 to 0.4766 (2nd Ibiwe) and Cd - 1.46 to 102.16 (Idia College). CD ranged from 1.5136 to 105.09 (Idia College), and PLI ranged from 0.0341 to 1.4149 (Idia College). For soil samples obtained in the month of March, the CF value for the metals ranged as follows: Fe - 0.0029 (control) to 0.040 (Uwelu), Pb - 0.010 to 2.53 (Uwelu), Cr - 0.0056 to 0.422 (1st Ibiwe) and Cd - 1.00 to 100.83 (2nd Ibiwe). The CD values ranged from 1.019 (control) to 102.583 (2nd Ibiwe), while the derived PLI values ranged from 0.0201 (control) to 1.3197 (Uwelu).

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Sampled sites	Month	Contamination Factor				Cont. Degree	PLI
		Fe	Pb	Cr	Cd		
Aduwawa	February	0.0417	2.2400	0.3361	99.83	102.448	1.3305
St. Saviour		0.0438	2.3200	0.3761	78.83	81.5699	1.3175
1st Ibiwe		0.0156	1.2250	0.3194	74.50	76.0600	0.8212
2nd Ibiwe		0.0350	2.1075	0.4766	68.33	70.9491	1.2449
Idia college		0.0432	2.5175	0.3711	102.16	105.092	1.4149
Uwelu		0.0251	1.5175	0.2222	92.66	94.4248	0.9410
Control (UNIBEN)		0.0034	0.044	0.0062	1.46	1.5136	0.0341
Aduwawa	March	0.0258	1.6700	0.2500	74.50	76.4458	0.9465
St. Saviour		0.0283	1.7300	0.2800	58.83	60.8683	0.9476
1st Ibiwe		0.0116	1.2375	0.4216	72.16	73.8307	0.8129
2nd Ibiwe		0.0239	1.5700	0.1608	100.83	102.585	0.8831
Idia college		0.0290	1.8775	0.2766	76.16	78.3431	1.0348
Uwelu		0.0400	2.5300	0.3877	77.33	80.2877	1.3197
Control (UNIBEN)		0.0029	0.0103	0.0056	1.00	1.01875	0.0201

Table 3 *Contamination Factor (CF), Contamination Degree (CD) and Pollution Load Index (PLI) for heavy metals in soil samples*

Enrichment factor (EF)

Table 4 revealed the derived EF values obtained for for all the assessed soil borne trace metals. For soil samples obtained in the month of February, the enrichment factor for the Fe values of all the soil samples was 1.00. The EF derived for the respective Pb readings varied from 5.27 (Aduwawa) to 78.17 (1st Ibiwe). The EF values derived for the soil borne Cr values ranged between 1.82 in the control site and 20.39 in 1st Ibiwe. The EF values derived for the soil borne The EF values derived for the soil borne Cr va-alues ranged between 1.82 in the control site and 20.39 in 1st Ibiwe. The EF values derived for the soil borne Cd readings ranged from 428.16 (control) to 4754.24 (1st Ibiwe) respectively. For soil samples obtained in the month of March, the enrichment factor for Fe was 1.00 for all samples. EF of Pb ranged from 3.44 (control) to 106.04 (1st Ibiwe). Enrichment factor for Cr ranged between 1.88 in the control site and 36.13 in 1st Ibiwe. EF for Cd was in the range of 335.71 (control) - 6183.83 (1st Ibiwe).

Sampled sites	Month	Enrichment Factor			
		Fe	Pb	Cr	Cd
Aduwawa	February	1.00	5.27	8.05	2390.30
St. Saviour		1.00	52.93	8.58	1798.62
1st Ibiwe		1.00	78.17	20.39	4754.24
2nd Ibiwe		1.00	60.18	13.61	1950.60
Idia College		1.00	58.16	8.57	2360.20
Uwelu		1.00	60.26	8.83	3680.05
Control (UNIBEN)		1.00	12.84	1.82	428.16
Aduwawa	March	1.00	64.71	9.69	2886.64
St. Saviour		1.00	60.93	9.86	2072.06
1st Ibiwe		1.00	106.04	36.13	6183.83
2nd Ibiwe		1.00	65.50	6.86	4206.98
Idia College		1.00	64.56	9.52	2620.67
Uwelu		1.00	63.20	9.69	1931.79
Control (UNIBEN)		1.00	3.44	1.88	335.71

Table 4 *Enrichment Factor (EF)*

Ecological Risk Factor (E_R) and Risk Index (RI)

The Ecological Risk Factor (E_R) and Risk Index (RI) derived values associated with the respective trace metal contents of the examined soil samples are shown in Table 5.For soil samples obtained in the month of February, the E_R of Fe ranged from 0.0034 (control) to

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0.0438 (St. Saviour) and that of Pb ranged between 0.22 (control) and 12.59 (Idia College). The minimum E_R for Cr was 0.0124 at the control site, while the maximum was 0.9532. E_R for Cd was least in the control sample (43.800) and highest in the sample from Idia College (3064.8). For soil samples obtained in the month of March, the E_R of Fe ranged from 0.0029 (control) to 0.040 (Uwelu) and that of Pb ranged between 0.0513 (control) and 12.65 (Uwelu). The minimum E_R for Cr was 0.0112 at the control site, while the maximum was 0.7754 at Uwelu. E_R for Cd was least in the control sample (30.00) and highest in the sample from Idia College (2319.9).

Table 5
Ecological Risk Factor (E_R) and Risk Index (RI)

Sampled Sites	Month	Ecological Risk Factor (E_R)				RI
		Fe	Pb	Cr	Cd	
Aduwawa	February	0.0417	11.20	0.6722	2994.9	3006.81
St. Saviour		0.0438	11.60	0.7522	2364.9	2377.29
1st Ibiwe		0.0156	6.13	0.6388	2235	2241.78
2nd Ibiwe		0.0350	10.54	0.9532	2049.9	2061.43
Idia College		0.0432	12.59	0.7422	3064.8	3078.18
Uwelu		0.0251	7.59	0.4444	2779.8	2787.86
Control (UNIBEN)		0.0034	0.22	0.0124	43.80	44.04
Aduwawa	March	0.0258	8.35	0.50	2235	2243.88
St. Saviour		0.0283	8.65	0.56	1764.9	1774.14
1st Ibiwe		0.0116	6.19	0.8432	2164.8	2171.85
2nd Ibiwe		0.0239	7.85	0.3216	3024.9	3033.09
Idia College		0.0290	9.39	0.5532	2284.8	2294.77
Uwelu		0.0400	12.65	0.7754	2319.9	2333.37
Control (UNIBEN)		0.0029	0.0513	0.0112	30.00	30.07

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Discussion

Physical properties and heavy metal concentrations of the soils

Environmental contamination attributed to trace metal accumulation and dispersion has been directly linked to anthropogenic activities which have been on the increase in recent times. Overtime, these metals are known to accumulate in soil layers which act as sink from which these metal moieties are released into groundwater and flora; which gradually build up in the food chain causing various toxicological manifestations in humans (Anyakora *et al*., 2013). pH has been described as a reliable parameter in measuring soil associated acidity and alkalinity levels (Singh *et al.,* 2015). In this study, the pH of soil samples collected in February ranged from mildly acidic to neutral while those collected in March varied from strongly acidic to neutral. Similarly, Singh *et al.* (2015) reported mildly acidic and neutral pH values for top soil samples collected from several places in Varanasi municipality, Uttar Pradesh, India and the authors also stated that most nutrients can dissolve easily when the pH of the soil solution varies from 6.0-7.5. The range of EC values reported in this study contrasted with earlier values reported by Singh *et al.* (2015) which were comparatively lower. The high EC value recorded in this study may be attributed to elevated levels of dissociated ions leached from the top soil within the dump site as previously opined by Rawat *et al.* (2009). An elevated soil EC value has also been noted as been reflective of indicative of excess nitrogen-based fertilizer application or a elevated amounts of exchangeable sodium (Raju *et al.,* 2009). Findings in this study revealed that soil samples obtained from the various scrapyard dumpsites harbored differing elevated levels of Pb, Fe, Cr and Cd. This trend is similar to a report by Anyakora *et al.* (2013) with respect to soil samples sourced from dump yards located in various industrialized areas in Lagos and the authors revealed the presence of heavy metals which included; Cd, As, Pb, Cr, Cu and Fe in all the examined soil samples. Activities conducted at these scrapyards which include; the dismantling of abandoned motor vehicles, machinery, metal cleaning, sorting and recovery especially for non-ferrous metallic materials can, pose a potential environmental health risk as these activities can lead to the release of toxic trace metals which could negatively affect human, fauna and floral health respectively. Correspondingly, the levels of hea-

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vy metals analyzed in soil samples from the various scrapyard dumpsites were generally higher in comparison to values recorded for top soil samples collected from control sites. Adedeji *et al.* (2014) reported an identical trend with respect to heavy metals levels detected for soil samples collected from the premises of scrapyards and samples obtained from the control site.

Soil contamination assessment

Fe and Cr had I_{geo} values of less than zero which indicated that the soils in the studied sites are practically uncontaminated with these metals. Pb had a I_{geo} values of less than one but greater than zero with the exception of 1st Ibiwe and control (UNIBEN) sites where Pb I_{geo} value was less than zero. This trend indicated that the soil samples are in I_{geo} class 1 which is uncontaminated to moderately contaminated. Zhao *et al.* (2022) reported that I_{geo} for heavy metals were in either class 1 or class 2. Cd had I_{geo} values greater than 5 in all the studied sites with the exception of the control site which has a I_{geo} index value of less than 0. These index values showed that these sites are highly contaminated with Cd. This trend was similar to an observation reported by Zhang *et al.* (2023) which revealed elevated levels of Cd in top soil samples collected from two chinese provinces; Panxian and Weining respectively. CF values derived for Fe and Cr readings obtained from all the soil samples indicated low contamination of the soils with these metals. This trend was in tandem with a report by Parvez *et al.* (2023) which documented low contamination with respect to these heavy metals. For all the examined sites, the degree of contamination was greater than 32 with the exception of the control site which has a contamination degree of less than 8; which revealed that the soil samples collected from the premises of the respective metallic material scrapyards had a very high degree of contamination while the control site has a low degree of contamination. Values of pollution load index in all the studied sites are less than 2 indicating that the soils were moderately polluted with trace metals. An identical trend was also reported by Zhang *et al.* (2023) wherein the authors described a range of PLI values; 0.67 - 1.47 in respect of soil samples collected from four provinces in China. The EF values associated with Fe was 1 which was indicative of minor enrichment. EF values derived for Cr were lower than the benchmark value of 10 which was indicative of a moderate severe enrichment. These trends were similar to previous observations reported by El-Anwar (2019) which indicated that all EF values in their report was below the benchmark of 10.However, in this study, EF values for Pb with the notable exception of the control site and Aduwawa site sampled in the month of February were greater than 50 which was indicative of extremely severe enrichment. The E_R values for Risk Index (RI)all the soil borne Fe, Pb and Cr readings was lower than in 40 which was indicative of a very low ecological risk. However E_R values derived for all the respective Cd readings with the exception of the control site was greater than 320 which was indicative of a very elevated ecological risk. In the same vein, cumulative RI values of the respective soil samples with the exception of the control was above the benchmark 600 value which was indicative of elevated RI for the examined soil samples.

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Conclusions and Recommendations

This study assessed the extent of trace metal contamination profiles of top soil samples collected from the premises of several disused metallic material dumpsites as well as a control site. It is recommended that the appropriate Governmental agencies should provide appropriate places that will serve as dumpsites for scrap metallic materials and other disposable items that are kept in a functional scrapyard. A number of measures can be utilized to reduce the trace metal content associated with the top soil of these scrapyards. One of these proposed measures is *via* liming to a neutral pH and maintaining optimal soil phosphorus levels which would lower trace metal availability to plants. Education and legislation on safe management of solid wastes in these scrapyards should be intensified to forestall the effects of dumped metallic material scraps related environmental issues, especially with respect to the soil and groundwater. Also, modern waste disposal facilities should be acquired by relevant public authorities and appropriate waste disposal sites be chosen to avoid the deleterious effects associated with the indiscriminate disposal of disused or scrap metallic materials. Additionally, continuous monitoring and further studies on the prevailing soil borne levels of these trace metals should be conducted at regular intervals to ascertain long-term effects on the surrounding environment.

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