Potentially Toxic Elements (PTE) Pollution in Apomu Suburban Area on southwestern Nigeria

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Pollution and Health Risk Assessment of Potentially Toxic Elements (PTE) in a Suburban Area, southwestern Nigeria

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Abstract

Potentially Toxic Elements (PTE) contaminated soils within urban areas have received global attention. However, little attention is being given to soils of suburban areas, which are also vulnerable to PTE contamination from both natural and unnatural sources. This study was conducted to determine soil quality and PTE pollution sources in soils of Apomu, Southwestern Nigeria. The concentration of PTEs was determined by subjecting soils to elemental analysis using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). Pollution indices and health risks were calculated. The results showed the following range of metal concentrations in ppm except for Al (%) in increasing order; Mo (0.58-12.29), Cu (16.65-687.47), Pb (28.64-368.75), Zn (0-9257.30), Ni (7.60-86.20), Mn (403-1756), Cr (26.40-107), Cd (0.20-11.34), and Fe (1.23-4.29). Geoaccumulation Index (Igeo) showed that Zn, Pb, Ni and Cu and moderately contaminated with Cd. The Enrichment Factor (EF) revealed minimal to very high enrichment of Cu and Zn; minimal to significant enrichment of Pb and As and a minimal to moderate enrichment of Ni and Co. The geochemical evaluation revealed that soils were heavily contaminated with PTEs which were sourced from geogenic and anthropogenic activities. Approximately 70% of sampling areas exhibited high potential ecological concerns. The hazard index (HI) values for children and adults were less than one ($HI < 1$), indicating that there was no major danger of poisoning. Carcinogenic risks for Cd, Ni, and Pb were calculated and found to be within tolerable limits, but children are more susceptible to cancer and non-cancer risks than adults.

Keywords: Apomu, Enrichment Factor, Modified pollution Index, Soils

1 Introduction

Increased concentration of Potentially Toxic Elements (PTEs) in urban and suburban soils is becoming a more serious environmental concern [1]. Soil pollution from urban areas has become a topic of worry in recent decades [2–5]. The ongoing release and discharge of harmful compounds, particularly PTEs, emanated from urbanization and industrialization, resulting in environmental degradation [6, 7]. When PTEs are found at high concentrations in soils, they are harmful to human health. They can enter the human body through inhalation, ingestion, or contact with the skin [8–10]. PTEs have been found in significant concentrations in urban settings as a result of indiscriminate trash dumping, discharge of inadequately treated effluents to the land, and particle emissions to the environment [11]. Suburban soils serve as a spatial transition zone between urban and rural areas, keeping the local environment and ecosystem in balance [12]. However, owing to increased urbanization and industrialization, PTEs concentration in suburban soils may develop more quickly than in rural soils [13]. As a result, having quick access to information on PTEs concentrations in suburban soils could help with local environmental monitoring. A full understanding of the factors that affect soil quality in suburban centers is yet to be achieved. While some important efforts have been made by several researchers [14–16] to gaining an overall assessment of the level and extent of soil pollution across Nigeria, they overlooked some peculiar and potentially important exposure sites such as the suburban areas. All over the world PTEs have been known to cause adverse effects on human health, ranging from gastrointestinal and kidney dysfunction, nervous system disorders, skin lesions, vascular damage, immune system dysfunction, birth defects, and cancer. As a contribution towards better understanding of this subject matter, this study also addresses the sources and estimation of the potential health risk of PTEs in soils from the study area.

2 Materials and methods

2.1 Study location and field sampling

The study area lies between latitudes N7^{o}14$'$00" to 7^{o}20$'$00"N and longitudes 4^{o}15$'$00" to 4^{o}20$'$00"E, it is a sub urban community along the Ibadan–Ife express road (Figure 1). Major activities is farming, other important activities in the area include auto-repairs, huge depositions of electronic wastes, petty trading and operation of abattoirs. The waste generated from these activities were often indiscriminately disposed around the area, including stream channels and poorly located dumpsites (Figure 2). The present study therefore, determines the composition of PTEs of the soils, the distribution and sourcing in the study area, using geostatistical analyses. The geological map of the study area is presented in Figure 3, the study area lies within the basement complex of Nigeria. The area is defined by a suite of rock types including migmatite gneisses and granite, schist, amphibolite, diorite, pegmatite, and quartzite

[17, 18]. Pegmatite rocks dominate the eastern part of the study area while granodiorite outcrops at the north-eastern part of the study area. The southern part of the map is dominated by the occurrence of fine to medium-grained biotite granite. Porphyritic granite is, however, located in the southwestern part of the study area. A small proportion of schist is known to be located in the southeastern part of the study area and the banded gneiss dominates the western part of the study area.

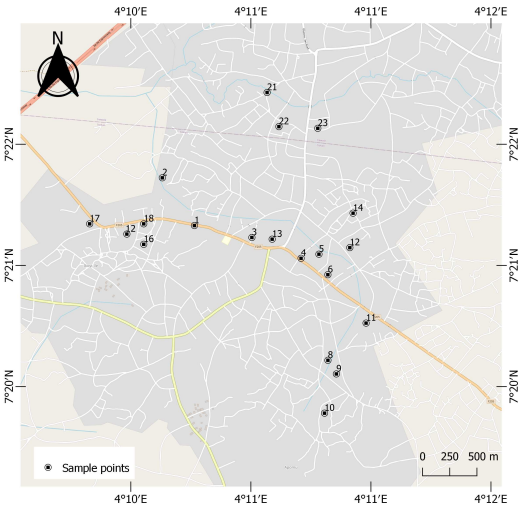


Fig. 1: Map of the study area showing the sampling points

Fig. 2: (a) A metal scrap depot (b) dumpsite in the study area

2.1.1 Soil Sampling and Analysis

Twenty-four near-surface soil samples across the different localities in the study area were purposively collected at a depth range of 0-5 cm using a hand auger.

Map showing all sample location is presented in Figure 1. Extraneous materials such as polyethene bags,grass and leaves were removed. The procedure was repeated for all sampling site. Each soil sample comprised a composite of six subsamples collected from a square of 20cm x 20cm. The samples were prepared and analysed for elemental content using inductively coupled plasma optical emission spectrophotometry (ICP-OES). Pulverized and sieved soil samples (0.5 g), were digested in a hot acid mixture to determine the elemental contents. This was accomplished by adding 10 ml of ultra-pure water (18 $M\Omega cm^{-1}$ of specific resistivity), 5 ml of nitric acid (Merck Suprapur 65%), and 2 ml of hydrochloric acid (Merck Suprapur 36%) to a Pyrex tube, which was then heated for two hours at 95°C on a heating plate. Following extraction, the solution was filtered through a Whatman N°41 (WH1441-110) filter, diluted to 50 ml with ultrapure water, and stored in previously cleaned polyethylene bottles in the refrigerator until analysis. The same procedure was used to process reagent blanks [19].

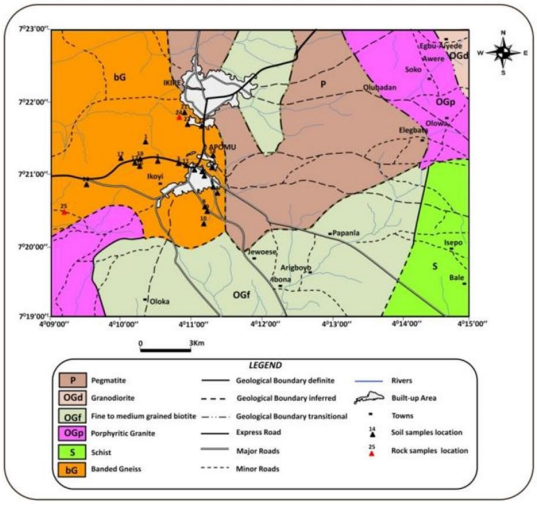


Fig. 3: Geological map of Apomu and environs

2.2 Single element pollution indices

Single element pollution indices such as Contamination Factor (CF), Enrichment Factor (CF) and Geo-accumulation Index (Igeo) are integral tools for the assessment of PTEs in sub urban soils [20]. These indices were calculated and the results obtained were used to evaluate the impact of anthropogenic activities on the quality of suburban soils. Contamination Factor (CF) is expressed in Eq 2 as the ratio between PTEs of interest $(Cx)_{sample}$ in the soil and their respective pre-industrial reference values $(Cx)_{background}$ as proposed by Hankason [21]. The calculation was further interpreted using the classification

proposed by Khalilova[22], CF values were classified into; Low contamination (CF $\leq$ 1), Middle (1 $<$ CF $\leq$ 3) and High contamination (CF $>$ 3) [23].

$$CF = \frac{(Cx)_{sample}}{(Cx)_{background}} \tag{1}$$

2.2.1 Enrichment Factor (EF)

The Enrichment Factor (EF) in metals and Geo-accumulation index (Igeo) (Eqs. 2 and 3) are good indicators which were used to assess the presence and intensity of anthropogenic contaminant deposition on soil. These indices were calculated by the normalization of the element of interest against an element that has no anthropogenic sources or it is present in high enough concentration that can negate the effect of anthropogenic sources[15]

$$EF = \frac{\left[\frac{c_x}{c_{ref}}\right]_{sample}}{\left[\frac{c_x}{c_{ref}}\right]_{background}} \tag{2}$$

Where $\left[\frac{c_x}{c_{ref}}\right]_{sample}$ is the ratio of concentration between element of interest and a reference element in the sample, whereas, $\left[\frac{c_x}{c_{ref}}\right]_{background}$ is the ratio of concentration between element of interest and a reference element in the background sample.

Table 1: EF categories [24]

Value	Soil Quality
EF $<$ 2	Deficiency to minimal enrichment
2$<$ EF $<$ 5	Moderate enrichment
5 $<$ EF $<$ 20	significant enrichment
20 $<$ EF $<$ 40	Very high enrichment
EF $>$ 40	Extremely high enrichment

2.2.2 Geo-accumulation Index (Igeo)

Geo-accumulation index (I_{geo}) proposed by Muller [25] and has gained wide acceptance and application. It is best suitably applied to soils that may have significant enrichment due to anthropogenic activities as typified by the land use pattern of the study area. Its advantage is in the qualification of sediments, Muller [25] identified six (6) classes of contamination (Table 2) in sediments that can be used to qualify the contamination of an index by any particular element.

$$I_{geo} = log_2\left[\frac{C_n}{1.5 * B_n}\right] \tag{3}$$

Where C_n is the measured concentration of the element of interest in soil and B_n is the geochemical background or reference value of the metal.

Table 2: Geo-accumulation classification after Muller [25]

Classes	Value	Quality
0	Igeo <0	Unpolluted
1	0 < Igeo <1	Unpolluted to moderately polluted
2	1 < Igeo<2	Moderately polluted
3	2 < Igeo<3	Moderately polluted to highly polluted
4	3 < Igeo<4	Highly polluted
5	4 < Igeo<5	Highly polluted to very highly polluted
6	5 < Igeo	Very highly polluted

2.3 Multi Element Pollution Indices

Single element quantification indices do not take into cognizance the enrichment of elements from rock forming processes, hence a multi-element quantification index such as Pollution Index (PI), Modified Pollution Index (MPI) and Modified Degree of Contamination (mCd) which provided a more integrated approach to the contamination of a site by Potentially Toxic Elements (PTE). Multi-element pollution indices were employed in this study to further assess soils due to the constraints of single element pollution indices [21, 26].

2.3.1 Contamination Degree (Cd)

Contamination degree (Cd) and Pollution Index (PI) developed by Hakanson and Nemerow respectively have gained wide acceptability and usage in the assessment of geo-materials in recent times. Brady et al. [26] later proposed the Modified Pollution Index (MPI) which uses enrichment factors instead of contamination factors in its calculation. This takes into account the background concentrations and the complex, nonconservative behaviour of soils. Equations 4-5 revealed how Contamination degree (Cd), Pollution Index (PI), and Modified degree of contamination (MPI) were calculated.

$$C_d = \sum_{i=1}^{n} C_f \tag{4}$$

$$PI = \frac{\sqrt{(cf_{average})^2 + (cf_{max})^2}}{2} \tag{5}$$

2.3.2 Pollution Load Index (PLI)

The Pollution Load Index (PLI) is expressed as geometric mean of the pollution indices (PI) based on Eq 6. PLI assesses the degree of PTE accumulation in soil [20]. Where n is the number of toxic element under consideration and PI is as expressed in Eq 6

$$PLI = n\sqrt{PI_1 \times PI_2 \times PI_3 \times ....PI_n} \tag{6}$$

2.3.3 Ecological risk factor (E^ir)

The ecological risk factor E^ir as proposed by Hankason [21] was used to quantify the potential ecological risk of potentially toxic elements in the study area. E^ir is expressed in Eq 7 as the product of toxic response factor T_r^i of the elements and their respective contamination factors C_f^i. According to Hakanson [21] the toxic response factor T_r^i for Cu, Co, Ni and Pb is 5; Mn and Zn is 1; As and Cr is 2 and Cd is 30. The ecological risk factor E^ir was used to assess the contamination level of the toxic metals by classifying the soil into low (E^ir <40), moderate ($40 \leq E^i$r <80), considerable ($160 \leq E^i$r < 320) and very high (E^ir ≥ 320).

The Potential ecologic risk index (RI) was expressed as summation for the risk factors Eq. 8 [27].

$$E^ir = Tr \times Cf \tag{7}$$

$$RI = \sum_{i=1}^{n} T_r^i \times C_f^i \tag{8}$$

2.4 Health Risk Assessment

Health risk assessment are important tools for quantifying the severity and risk associated with the exposure to environmental contaminants via the oral, dermal and inhalation route [28]. The health risk assessment of children and adults exposed to PTEs pollution via ingestion , inhalation and dermal assimilation were computed using Eq 9 and 10. Parameters used for the assessments are presented in Table 3 and have been used by several authors [23, 29, 30].

$$ADD_{ing} = C \times \frac{IR \times EF \times ED}{BW \times AT} \times 10^6 \tag{9}$$

$$ADD_{derm} = C \times \frac{SA \times AF \times ABS \times EF \times ED}{BW \times AT} \times 10^6 \tag{10}$$

2.4.1 Data analysis and visualization

Results from the laboratory analysis were subjected to statistical programs on Python and visualization of the data were produced with the use of Matplotlib. For this study Pearson's correlation was conducted to estimate linear

Table 3: Parameters used for health risk assessment of PTEs

Abrv.	Parameter & Unit	Value
IR	Soil ingestion rate (mg/day)	Children: 0.2 and Adult: 0.1
EF	Exposure frequency (day/y)	350
ED	Exposure duration (years)	Children: 6 and Adult: 30
BW	Body weight (kg)	Children: 15 and Adult:70
AT	Average time (day)	Children: 2190 and Adult: 10,950
AF	Skin adherence factor (mg/cm^2)	0.2
SA	Exposed surface area of skin (cm^2)	5408
ABS	Dermal absorption factor	0.001
CF	Conversion factor (kg/mg)	10^{-6}
RfD_i	Reference dose for ingestion pathway	Fe: 0.3, Cu :0.04, Mn: 0.014, Cd: 0.5, Zn: 0.3 Ni: 0.002, Pb: 0.0035, Cr: 1.5, As:0.3, Co: 0.0003
RfD_d	Reference dose for dermal pathway	Fe: 4.5e-2, Cu :12, Mn: 1.84e-03, Cd: 0.005, Zn: 60 Ni: 5.4, Pb: 0.42, Cr: 0.015, As: 0.123, Co:0.06
Tr	Toxic response factor	Cd:30, As: 10, Ni:5, Cu:5, Pb:5, Cr:2, Zn:1
$_{ref}$	Reference or background values	Mo:0.77, Cu:30.2, Pb:39.12, Zn:209.5,Ni:28.1 Cr:31.1, Mn:418, Cd:0.22, Fe:1.33

dependence between variables, Principal component analysis (PCA) was also conducted to identify latent factors. The extracted factors were used in geostatistical analysis. The data for all kinds of analysis were normalized to geochemical background values. The normalization of this kind was necessary because the natural content of elements varies a lot. Therefore, with normalization it was possible to avoid the distortion of the results by elements with a high natural content in the media sampled.

3 Results

3.1 Metal distribution

The range and mean concentration of the metals in the soils from the study area are presented in Table 1. The geometric mean concentration of each metal reveals that; Zn > Mn > Cu > Pb > Cr > Ni > Cd > Fe > Mo. The concentrations of Cu, Pb and Zn are highest at Location 7 where an active auto-repair shop is located. While the locations housing the highest concentration of other metals are widely distributed, Ni and Cd concentrations were highest at Location 11, which is very close to a dumpsite. The distribution of these metals were suspected to be in agreement with anthropogenic activities in the study area (Fig. 4). When PTEs concentrations were compared to those discovered in other cities in Nigeria and throughout the world where similar studies had been undertaken [5, 21, 31–34] , the results showed that these other sites had greater concentrations than those observed in the current study (Table 5).

Table 4: Statistical summary of PTEs in soils from the study area

Elements	Mean ± SD (ppm)	Range (ppm)	Guide value (ppm)
Mo	2.27 ± 2.40	0.58 - 12.29	2.00
Cu	157.93 ± 166.77	16.65 - 687.47	47.00
Pb	132.95 ± 89.63	28.64 - 368.75	28.00
Zn	1364.73 ± 1811.30	119.70 - 9257.30	124.00
Ni	25.97 ± 18.08	7.60 - 86.20	9.00
Cr	52.56 ± 22.30	26.40 - 107.00	44.00
Mn	1187.29 ± 420.78	403.00 - 1756.00	787.00
Cd	3.04 ± 3.45	0.20 - 11.34	3.00
Fe	2.34 ±0.81	1.23 - 4.29	3.27

Note: n=24

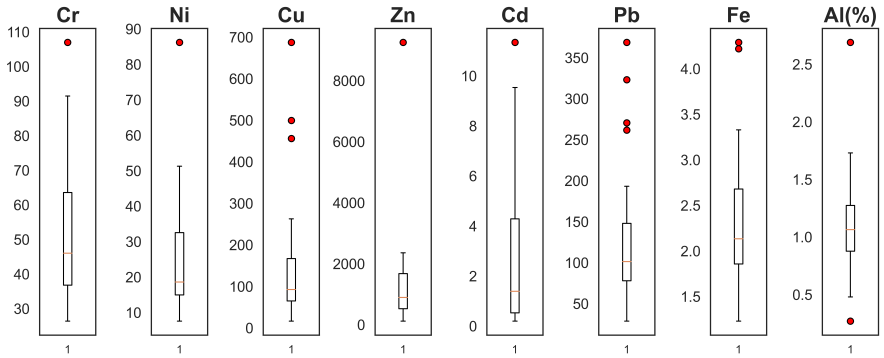


Fig. 4: Statistical summary of elements in soils from the study area

3.2 PTE Relationship and Sourcing

3.2.1 Principal component analysis (PCA)

Principal component analysis (PCA) was conducted for nine variables (Mo, Cu, Pb, Zn, Ni, Cr, Mn, Cd and Fe). Table 6 shows the component matrix rotation with two factors shown for the variables. Factor 1 captures Mo, Ni, Cr and Fe. These set of metals are indicative of soil parent material/geogenic sources [39] Factor 2 is loaded on Cu, Pb, Zn, Mn and Cd, which is attributed to anthropogenic pollution. Though, Cu and Pb pollutants in soil have been widely reported to originate from leaded gasoline, braking, engine wear and other traffic related activities[2, 22, 40] their enrichment in the study area can be attributed to [2, 40]

Table 5: Comparison of metals from soils of suburban areas across the world

City	Mo	Cu	Pb	Zn	Ni	Cr	Mn	Cd
Current study	2.27	157.93	132.95	1364.73	25.97	52.563	1187.292	3.04
Bagega, Nigeria [35]	-	-	0.00	3.90	0.00	48.7	-	1.40
Tabriz, Iran [36]	-	101.25	10.56	98.27	38.73	87.4	-	1.61
Wuhan, China [37]	-	44.1	29.7	119.1	-	97.7	-	0.36
Beijin, China54 [4]	-	26.78	22.64	78.13	21.22	58.78	-	0.2
New Zealand [38]	-	9.5	18.8	67.3	9.69	17.1	-	0.86

Note: Concentration in mg/kg

Table 6: R-mode factor analysis of metal results for soils

Metals	Factor 1	Factor 2	Communalities
Mo	0.824	-0.043	0.680
Cu	0.408	0.834	0.863
Pb	0.458	0.806	0.860
Zn	0.292	0.762	0.666
Ni	0.907	0.182	0.855
Cr	0.832	0.156	0.717
Mn	-0.229	0.629	0.448
Cd	0.032	0.884	0.783
Fe	0.883	0.241	0.837
Eigen Value	4.650	2.059	
% Variance	51.662	22.881	
Cumulative %	51.662	74.544	

Note: Loadings stronger than 0.5 are in bold font

3.2.2 Pearson Correlation

Pearson's Correlation analysis was used to distinguish groups of elements that may have been precipitated or distributed through similar geochemical processes. The correlation matrix is presented in Table 7 Cu displayed strong correlation with about 43% of all the metals sought which are; Pb (0.92), Zn (0.77) and Cd (0.69), weak correlation with about 13% which is Ni (0.51) and no correlation with 43% of the metals sought for. This is indicative of similar geochemical pathways. Pb also displayed strong correlation with Zn, Ni, Co, Cr, As, Cd and Ba. Other strong correlation between metals including Cu and Pb, are presented in Table 7. The strong correlation between similar suite of metals, suggest that the selected metals are likely from a singular geochemical pathway within the study area.

Table 7: Correlation matrix for metals from soil of study area

	Mo	Cu	Pb	Zn	Ni	Cr	Mn	Cd	Fe
Mo	1								
Cu	0.30	1							
Pb	0.29	**0.92**	1						
Zn	0.19	**0.77**	**0.68**	1					
Ni	**0.79**	**0.51**	**0.55**	0.30	1				
Cr	0.49	0.42	0.48	0.31	**0.73**	1			
Mn	-0.12	0.27	0.30	0.23	0.02	0.02	1		
Cd	0.07	**0.69**	**0.68**	**0.58**	0.22	0.14	**0.52**	1	
Fe	**0.61**	0.48	**0.58**	**0.50**	**0.78**	**0.81**	-0.03	0.22	1

Note: Correlation matrix ≥ 0.5 are in bold font

Table 8: Baseline for Soil and Sediment Quality Classification for Multi-element Indexes (Adapted from Bradly et al., [26])

Class	Qualification	Cd	PI	MPI
0	Unpolluted	Cd < 1.5	PI<0.7	MPI<1
1	Slightly polluted	1.5>Cd<2	0.7<PI<1	1<MPI<2
2	Moderately polluted	2 ≤ Cd ≤ 4	1<PI<2	2<MPI<3
3	Moderately-heavily polluted	4≤Cd≤8	-	3<MPI<5
4	Severely polluted	8≤Cd≤	2<PI<3	5<MPI<10
5	Heavily polluted	16≤Cd≤32	PI>3	MPI>10
6	Extremely polluted	Cd>32	-	-

Cd: contamination degree, PI: pollution index and MPI, modified pollution index

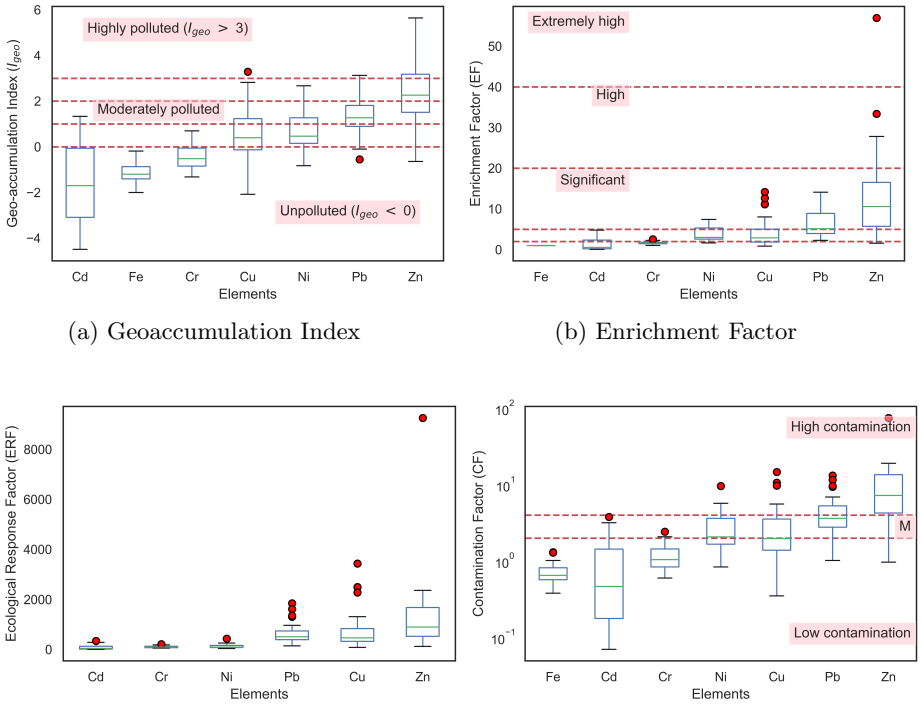
3.3 Single element pollution indices

The descriptive summary of Igeo, CF and EF are presented in Table 9. The calculated Igeo for the study area revealed that Cu, Pb and Zn were the major metals impacting soil quality in the study area Figure 6a. The contamination factor revealed that metals such as Mo, Cr, Cd, and Fe were insignificant, whereas, Cu, Pb, Zn and Mn were the prevalent contaminant heavy metals Figure 6b. The localized enrichment of these metals is a clear indication that anthropogenic activities in the study area has impacted greatly on the sub-urban soil. The estimated EF showed that there was depletion to extremely high enrichment in the sites. Mn, Cd, Fe and Cr (which were only significantly enriched in S21), have no significant enrichment in other sites. Significant to extremely high enrichment was observed in the following elements order Zn> Pb > Ni > Cu>Mo>Cr. Zn ranged from significant enrichment to extremely high enrichment in almost all the locations except S18, with highest value (46.63) in location 7, ditto for Pb in almost all the locations except S3-S4, S18 and S23 respectively.

Table 9: Summary of calculated contamination indices for Soils from the study area

	Mo	Cu	Pb	Zn	Ni	Cr	Mn	Cd	Fe
Geoaccumulation Index									
Min	-2.37	-2.08	2.27	-0.64	-0.83	-1.32	-1.55	-4.49	-2.00
Max	2.03	3.29	29.17	5.64	2.67	0.70	0.57	1.33	-0.19
Mean	-0.80	0.56	10.52	2.22	0.66	-0.44	-0.10	-1.62	-1.14
Contamination Factor									
Min	0.29	0.35	1.02	0.97	0.84	0.60	0.51	0.07	0.38
Max	6.15	14.63	13.17	74.66	9.58	2.43	2.23	3.78	1.31
Mean	1.14	3.36	4.75	11.01	2.89	1.19	1.51	1.01	0.72
Enrichment Factor									
Min	0.68	1.07	2.32	1.61	1.59	1.07	0.94	0.11	0.69
Max	21.51	18.53	18.45	46.63	33.52	7.25	3.68	5.04	4.52
Mean	2.29	4.89	7.54	15.14	5.44	2.16	2.51	1.40	1.32
Pollution Load Index (PLI)									
Min	0.42								
Max	5.06								
Mean	1.68								

Note: .



(a) Geoaccumulation Index

(b) Enrichment Factor

(c) Ecological Response Factor

(d) Contamination Factor

Fig. 5: Distribution of single element pollution indices

3.4 Multi Element Pollution Indices

The modified degree of contamination results (Figure **??** revealed that 42% of the sites have moderate degree of contamination (S2, S5, S12-S15, S21-S24), while 12.5% of the sites have high degree of contamination and 4.2% have very high to extremely high degree of contamination. The PI (Equation. 5, Figure 6) ranged between heavily to severely polluted in all the sites except S18 which is moderately polluted, while MPI observed in the study area (Figure 6), clearly distinguished between "moderately polluted' (S1), "moderately heavily polluted" (S3, S4, S6, S9, S17, S19, S20 and S24)," heavily polluted" (S5, S11, S12, S15, S21, S22 and S23) and "severely polluted" (S2, S7, S10, S13, S14 and S16).

3.5 Ecological Risk (Eir) and Potential Ecological Risk Index (RI)

The PLI values which was used to produce a total assessment of the suburban soils varied between 0.42 and 5.06 (avg. 1.68 ± 1), only samples S7 (5.06), S11

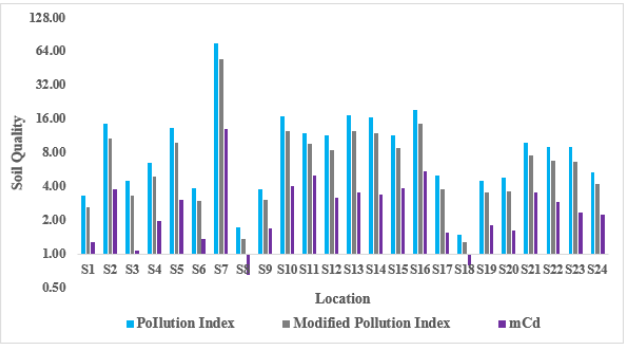


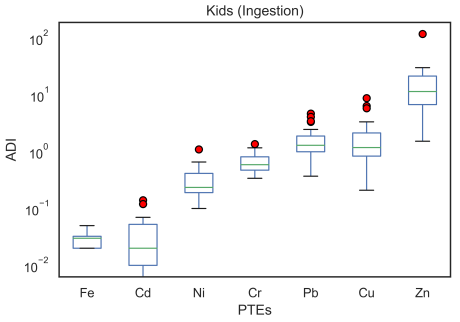
Fig. 6: Pollution index, modified pollution index and contamination degree chart from soils of the study area

(3.23) and S16 (2.66) have values greater 2.5. The result showed that pollution in the study area ranges between unpolluted an moderately polluted Samples S8, S18, S3, S1,S6 and S17 have PLI values less than 1 which showed that they are below significant pollution levels while S9, S20, S19, S4, S24 and

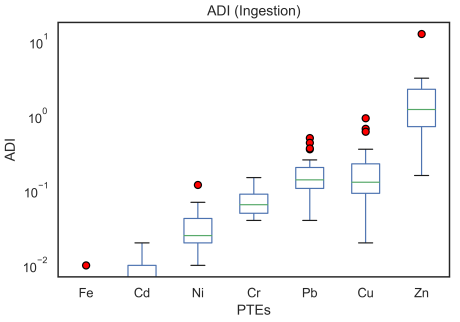
3.6 Ecological Risk (Eir) and Potential Ecological Risk Index (RI)

3.7 Health Risk Assessment

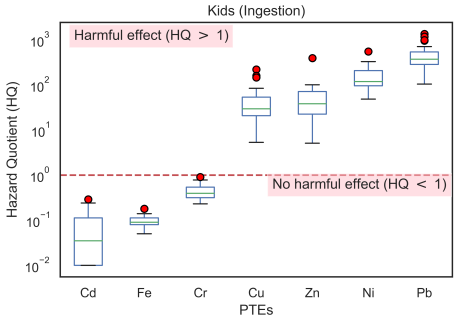
The average daily dose (ADD), Hazard Quotient (HQ) and the Hazard Index (HI) were computed to assess the non-carcinogenic health risk for adults and children contacts with PTEs in soils from the study area via ingestion and dermal pathways, the results are presented in Table 10 and the distribution shown in Figure 7. The mean of estimated average daily intake of PTEs via ingestion and dermal assimilation in both adults children are in the following descending order: Zn > Cu > Pb > Cr > Ni > Cd > Fe. However, the corresponding values are higher in children than in adults (Figure 7 a-b). The estimated HQ was used to evaluate the health risk of children and adult exposed to toxic elements. The result showed that Pb > Ni > Cu > have HQ value > 1 which suggests that they could have harmful effect via ingestion uptake (Figure 7 c-d). Also, the HQ values shows no harmful effect if introduced via dermal pathway in children The HI for ingestion in child (7.61E+02) and adult (8.15E+01) are greater than 1, indicating that ingestion of the soil samples poses a non carcinogenic threat if consumed. PTEs such as Pb, Ni, Zn and Cu (HI>1) could pose a non carcinogenic health risk if the sediment are ingested'while Cd, Fe and Cr (HI<1)would pose no harmful effect. However HI values in via dermal contact in adults (9.25E-05) and children (1.89E-03) are lesser than 1 suggesting no significant risk to the population via the dermal pathway. Results from carcinogenic risk assessment are presented in Table 11. The cancer risk are in the order of Cd >, Cr >, Ni > Pb. The calculated cancer risk of Cd, Cr, Ni and



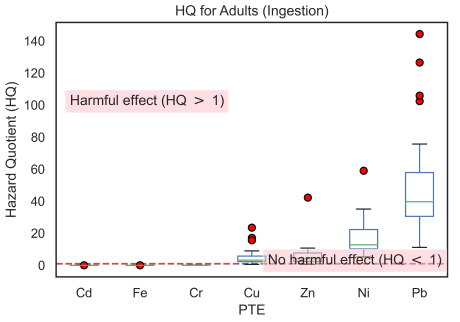
(a) ADI for kids ingestion



(b) ADI for kids ingestion



(c) HQ for kids ingestion



(d) HQ for Adult ingestion

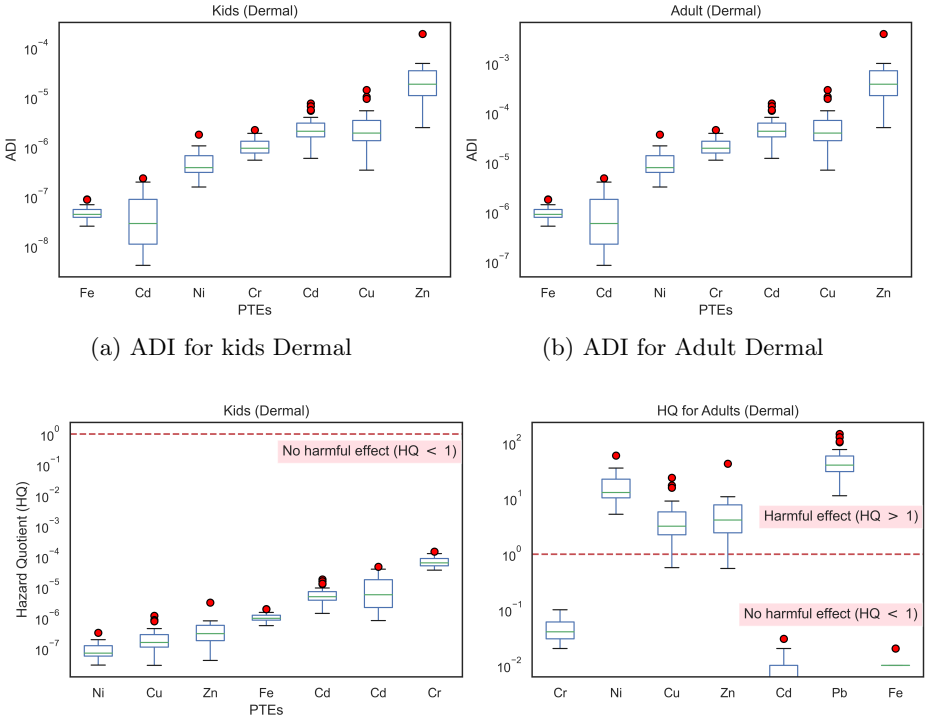
Fig. 7: Health risk assessment via ingestion

Pb via ingestion (kids and adults) and dermal(kids) pathways are greater than 1.0E-6. However, the CR values calculated for dermal assimilation in Adults are lower than 1.0E-6. According to Wu et al[4], CR values greater than 1.0E-6 represents a significant carcinogenic risk to humans.

Table 10: Statistics of health risk assessment of Potentially toxic elements in Apomu

PTE	ADD_{Ing}		ADD_{Derm}		HQ_{Ing}		HQ_{Derm}		RFD_{Ing}	RFD_{Derm}
	Child	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**		
Cr	6.73E-01	7.25E-02	1.08E-06	1.63E-05	4.49E-01	4.88E-02	7.17E-05	1.46E-03	1.5	0.015
Ni	3.32E-01	3.46E-02	5.31E-07	6.71E-06	1.66E+02	1.78E+01	9.84E-08	2.01E-06	0.002	5.4
Cu	2.02E+00	2.17E-01	3.23E-06	4.05E-05	5.05E+01	5.41E+00	2.69E-07	5.49E-06	4.0E-2	12
Zn	1.74E+01	1.87E+00	2.79E-05	3.66E-04	5.82E+01	6.23E+00	4.65E-07	9.49E-06	3.0E-1	60
Cd	3.92E-02	4.17E-03	6.21E-08	6.39E-07	7.83E-02	7.08E-03	1.24E-05	2.53E-04	5.0E-1	30
Pb	1.70E+00	1.83E-01	2.72E-06	4.01E-05	4.86E+02	5.20E+01	6.48E-06	1.32E-04	3.5E-3	0.42
Fe	3.00E-02	8.33E-04	4.80E-08	7.40E-07	1.00E-01	1.13E-02	1.07E-06	2.17E-05	3.0E-1	4.5E-2
Hazard Index (HI)					7.61E+02	8.15E+01	9.25E-05	1.89E-03		

Ing: Ingestion, Derm: Dermal



(a) ADI for kids Dermal

(b) ADI for Adult Dermal

(c) HQ for kids Dermal

(d) HQ for Adult Dermal

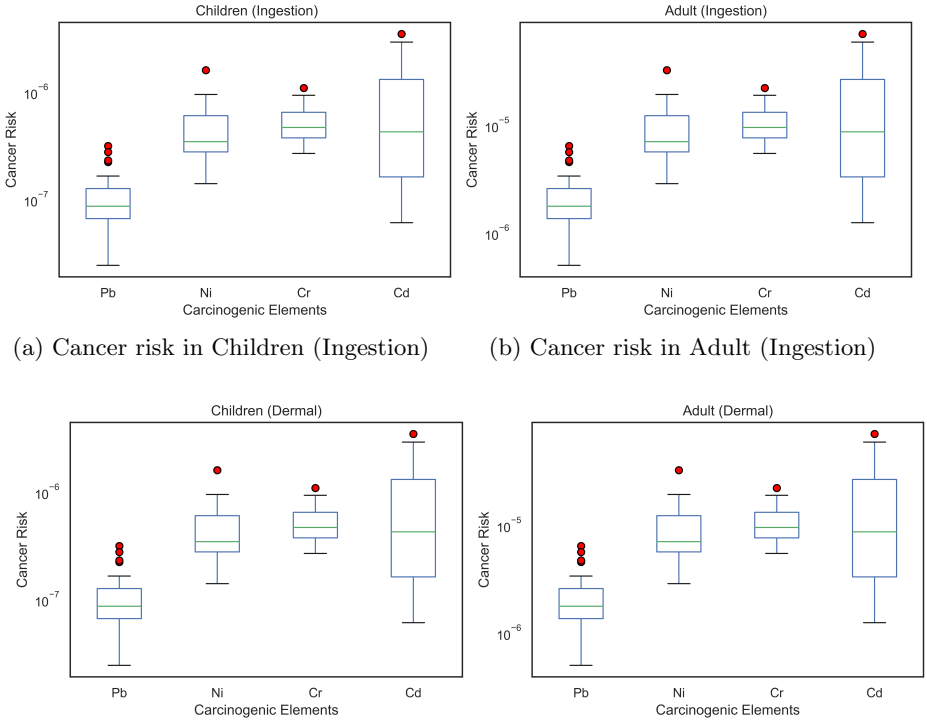
Fig. 8: Health risk assessment via dermal assimilation

Table 11: Cancer Risk (CR) of PTEs in the study area

Elements	CR (Ingestion)		CR (Dermal)	
	Kids	Adult	Kids	Adult
Cd	5.88E-01	6.25E-02	1.90E-05	9.32E-07
Ni	3.02E-01	3.15E-02	1.00E-05	4.83E-07
Pb	7.14E-02	7.67E-03	2.00E-06	1.14E-07
Cr	3.36E-01	3.63E-02	1.10E-05	5.38E-07

4 Conclusion

The present study investigated Potentially Toxic Elements (PTE) concentration in the soils of the study area, in order to determine their sources and possible status of pollution. It was observed that the mean concentration of all PTE that was investigated was frequently above the geochemical background values, with soil Zn concentration (1364.73ppm) being the most significant.



(a) Cancer risk in Children (Ingestion)

(b) Cancer risk in Adult (Ingestion)

(c) Cancer risk in Children (Dermal)

(d) HQ for Adult Dermal

Fig. 9: Cancer risk in the study area

Elemental concentrations of soils were derived from different pollution sources. Cu, Pb, Zn and Mn enrichments in soils were mainly affected by domestic and e-waste dumps, and other land use status of the study area, whereas Mo, Ni, Cr and Fe were sourced from soil parent material. Soil pollution and ecological security needs to be considered when land use status is heightened.

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