ECOLOGICAL RISK ASSESSMENT OF POTENTIALLY TOXIC METALS IN SOILS AROUND USED AUTOMOBILE PARTS AND MECHANIC WORKSHOPS IN LAGOS STATE, NIGERIA

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Abstract: Soil samples from 12 major automobile spare parts sales and car dismantling sites in Lagos and a control sample were analysed for selected potentially toxic metals (PTM): Cd, Cr, Cu, Ni, Pb and Zn. The soil samples were digested with aqua regia and analysed using a flame atomic absorption spectrophotometer. The concentrations (mg/kg) of Cd, Cu, Cr, Ni, Pb, and Zn in the soil samples ranged from 2.73- 19.2, 7.12- 113, 1.3- 77.7, 2.74- 17.7, 0.73- 68.3 and 40.4- 254, respectively. Compared with established limits set for soils in some countries, the values measured in this study were higher than these limits in several cases. Principal component analysis (PCA) was used to examine relationship between the sets of data and two major components were extracted. PC1 had a high loading of Ni, Cr and pH thus suggested to be the result of the contamination from battery charger shop close to the site where the samples were collected, while PC2 had a high loading of Zn, Cd and Cu probably also suggesting anthropogenic influence. The Hakanson ecological risk index revealed that the degree of metals pollution was greatly influenced by Cd and the other metals in the order: E_R(Cd) >E_R(Zn) >E_R(Cu) >E_R(Pb) >E_R(Cr) >E_R(Ni).

Keywords: Ecological risk assessment, mechanic workshops, potentially toxic metals

Introduction

Rapid industrialization has led to the release of a variety of pollutants into the environment especially potentially toxic metals (PTM). This worldwide problem has attracted a great deal of attention (Qingjie *et al*., 2008). One of the major sources of PTM contamination in Nigeria is auto-mechanic activities (Adewole and Uchegbu, 2010). These auto mechanic workshops are found in clusters of open plots of land in the vicinity of urban towns and cities (Nwachukwu *et al*., 2010; Nwachukwu *et al*., 2011). Within the clusters are people who specialize in electrical aspects of auto repairs, while others engage in repairs of brakes and steering wheels, automatic or standard transmission engine, and spray-painting, recharging of auto batteries, welding and soldering and many other activities. Soils are regarded as the ultimate sink for heavy metals discharged into the environment (Banat *et al*., 2005). These metals can be sensitive indicators for monitoring environmental contamination (Pekey *et al*., 2004). Metals are potentially toxic to crop production because they are easily accumulated in tissues of crops grown on these contaminated soils.

Humans and animals that consume such crops are prone to this potential toxicity (Liang *et al*., 2011). The body needs about 70 friendly trace elements to function well, but there are other elements such as Pb, Hg, Al, As, Cd, Ni amongst many others that act as poisonous interference to the enzyme systems and metabolism of the body. No matter how many good health supplements or procedures taken, PTM overload will be a detriment to the natural healing functions of the body (Lexmond, 1980). This has given impetus to the study of soil pollution by heavy metals in the last few decades (Zhang *et al*., 2007). The development of the ecological risk assessment can reveal the possibility of soil pollution (Fairbrother *et al*., 2007). Classic Potential Ecological Risk Index (PERI) method considers eight pollutants, including PCBs, Hg, Cd, As, Pb, Cu, Cr and Zn (Li *et al*., 2012). In Lagos State, the problems of contamination are increasing and control resources are scarce, therefore this indicator can be a very useful tool for soil contamination management.

In recent years, PTM pollution caused by the considerable growth of the automobile industry and the over-reliance of Nigeria on fairly-used automobile spare-parts with its effects on the environment has called for concern. Many researchers have performed related researches. Olayiwola (2011) studied the levels of Pb, Fe, Cd and Co in soils from automobile workshops in Osun State, Nigeria. The study compared the contribution of different sections of auto-repair workshops to heavy-metal pollution in soil. In another study, Udousoro *et al*. (2010), made a survey of selected soils in the South-Eastern part of Nigeria for PTM concentration. The study was carried out to determine the concentration of selected heavy metals in relation to their safety levels in arable soils in the selected sites. Michael *et al*. (2011), investigated trace metal dispersion in soil from auto-mechanic village to urban residential areas in Owerri, Nigeria. They assessed the depth and distance dispersion of selected trace metals namely: Pb, Mn, Fe, Cu, Cd, Zn and Ni within the near-surface soil profiles. Leke *et al*. (2011), investigated soils from auto-mechanic shops and refuse dumpsites in Makurdi, Nigeria. In a similar work, Adelekan and Abegunde (2011), investigated the PTM contamination of the soil and ground water of the automobile mechanic villages in Ibadan while Ogunseiju *et al.* (2015) also carried out studies on the level of metals in an active open dumpsite. However, the pollution trends of PTMs in the soil of Lagos metropolis, which is the fastest growing city in Africa and home to about 20 million people, and has high influx of fairly-used spare-parts and indiscriminate building of mechanic workshops all over has received less attention (Oyeyiola *et al*., 2014)

This work therefore reports the PTM pollution and potential ecological risk assessment of soil -metal pollution around selected major mechanic workshops and spare parts depot area in Lagos State, Nigeria. This study therefore, aims to determine level of potentially toxic metals (PTM) soils from some spare-parts sales areas, mechanic workshop and car dismantling sites in Lagos State, and to determine the relationship between metals and some soil properties using Principal Component Analysis (PCA) and Pearson correlation coefficient. It also aims to assess the ecological risk to humans and the environment.

Materials and Methods

Study area description

Lagos State is located in the South-West region of Nigeria 6°27'11"N 3°23'45"E with a total land area of about 999.6 km^2. It is Africa's biggest city and the fastest growing metropolis in the world with a population of about 20 million people (Oyeyiola *et al*., 2013). The population in the city is unevenly distributed such that auto-mechanic workshops are scattered all over the city and these serve as sources of heavy metals.

Sample collection and treatment

Samples were collected from thirteen locations chosen from the seven Local Government Areas of Lagos State. The sampling site code, the control site and features around the auto mechanic workshop clusters are shown in Table 1. Twelve (12) surface (0-5 cm) soil samples were collected randomly from various mechanic workshops, while a control sample was collected from the University of Lagos botanical garden which is free from metal pollution in October 2013. The samples were placed in polythene bags and transported to the laboratory. All soil samples were subsequently air-dried, homogenized, and passed through a 2 mm plastic sieve prior to analysis.

Table 1: Sample location and codes

Sample	Type	Site	Location
A1	C/D	Orile	6° 28' 34.21608" N, 3°20' 25.49913" E
A2	S/P	Orile	6° 28' 36.67951" N, 3°20' 29.72663" E
A3	S/P	Bode Thomas	6° 29' 15.78591" N, 3° 20' 55.22999" E
A4	S/P	Ojuelegba	6° 30' 29.42806" N, 3° 21' 47.09749" E
B1	C/D	Owode	6° 36' 24.404" N, 3° 24' 32.496" E
B2	S/P	Owode	6° 36' 40.614" N, 3° 24' 45.633" E
P1	C/D	Ladipo	6° 32'43.54219" N, 3° 20' 18.16434"E
P2	S/P	Ladipo	6° 32' 35.04269" N, 3° 20' 33.60694" E
Q1	S/P	Oyingbo	6° 28' 57.22429" N, 3° 22' 58.60972" E
R1	S/P	Wilmer	6° 26' 58.03525" N, 3° 20' 25.02884" E
S1	S/P	Ijora Oloye	6° 28' 5.86388" N, 3° 21' 56.241728" E
S2	C/D	Marine Beach	6° 27' 22.6477" N, 3° 21' 49.35919" E
C1(control)	N/A	Botanical Garden,UNILAG	6° 26' 57.70218" N, 3° 20' 25.02884" E

S/P=Spare part, C/D=Car dismantling, L.G.A=Local Government Area, N/A=Not applicable

Soil analysis

Pseudototal metal determination

The prepared soil was passed through a 2 mm sieve for heavy-metal measurement experiment. 1.0 g of the soil sample was digested with 20 mL of aqua regia and the digests was filtered into a 50 mL standard flask and made up to the mark with distilled water. The extract was analyzed for Cd, Cr, Cu, Ni, Pb, and Zn using Atomic Absorption Spectrophotometer (AAS, Perkin Elmer Analyst 200) under optimal conditions using air acetylene flame. Wavelengths (nm) of 228.80, 257.87, 232.0, 324.75, 283.81 and 213.86 were used for Cd, Cr, Cu, Ni, Pb and Zn, respectively. The final result was calculated by multiplying the result from the AAS (concentration in digest (mg/L)) by the dilution factor (50 mL) and dividing by the mass of soil weighed (1.0 g). Quality control was done with the use of a certified reference material BCR 143R.

Soil properties

The physiochemical properties of the soil samples were determined using routine methods as described by Allison (1960) and Ibitoye (2006). The following soil properties were determined: pH, organic matter (OM), soil texture, cation exchange capacity (CEC).

Statistical analysis

Principal Component Analysis (PCA) was carried out using the SPSS for windows software version 15.0. The association of parameters in soil were determined by PCA and by applying varimax with Kaiser Normalization rotation method to facilitate easier interpretation. Varimax rotation maximizes the sum over components of the variances of the squared loadings, thereby emphasizing cluster recognition. The eigenvalues were used to determine the number of PCs to be retained in order to comprehend the trends in the data. The PCA was carried out with factors that have eigenvalues greater than 1.

Risk assessment

This research employed the Potential Ecological Risk Index (PERI) proposed by Hakanson (1980) to evaluate the potential ecological risk of PTM. This method comprehensively considers the synergy, toxic level, concentration of the heavy metals and ecological sensitivity of heavy metals (Nabholz, 1991; Singh *et al*., 2010; Douay *et al*., 2013). PERI consist of three basic modules: *Degree of contamination* (C_D^i)*: toxic-response factor*(T_R^i)*and potential ecological risk factor* (E_R^i). Its main function is to indicate the contaminants and where contamination studies should prioritize. The first module of PERI corresponds to the estimate of the degree of contamination (C_D). The C_D is expressed by the sum of the contamination factor of each metal (C_f^i): C_D= SC_f^i,C_f^i being defined as the mean metal concentration (C_D^i), divided by the pre-industrial concentration of the substance (C_R^i). Regional background levels (United States) were also used. For the purpose of this study, the Screen Quick Reference Table (SQuiRTs, 2008) was used. Table 2 shows these values. The second module of PERI is a toxic-response factor (T_R^i) which is composed of the sedimentological toxic factor (S_t^i) and sensitivity factor (S) of the system:$T_R^i = \frac{S_t^i}{S} S_t^i$ is an estimate of metal toxic degrees in soil: 40> Cd = 30> Pb = 5 >Cu = 5> Cr = 2> Zn =Ni = 1.

$$C_f^i = \frac{C_D^i}{C_R^i} \quad (1)$$

$$E_R^i = T_R^i \times C_f^i \quad (2)$$

$$RI = \sum_{i-1}^{m} E_R^i \quad (3)$$

Table 2: Background value for C_R^i (mg/kg) and toxic-response factor,$T_R^i$for different metals

	Heavy Metals					
	Cd	Cr	Cu	Ni	Pb	Zn
C_R^i	0.26	37	17	13	16	48
T_R^i	30	2	5	1	5	1

SQuiRTs (2008)

Result and Discussion

Quality control

To assess the analytical performance of the laboratory during pseudototal metal digestion and analysis, certified reference material BCR CRM 143R- a sewage-sludge amendedsoil certified for aqua regia soluble potentially toxic metal was used. Found values (Table 3) were within three standard deviations of the certified values for all elements in the aqua regia digests with the exception of Cr. This is probably because of the air acetylene flame used in the AAS. This may not be hot enough to atomize all the Cr in the sample hence, the relatively low found value when compared to the target value.

Table 3: Result of the analysis of pseudototal metal concentration in reference materials- CRM BCR 143R

CRM 143R	Cd (mg/kg)	Cr (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
Certified	72 ± 1.8	426 ± 12	174 ± 5	1063±16
Found (n=3)	73.5±3.0	386 ± 8	168 ± 10	1120±20
% Recovery	102	90.6	96.6	106

Physicochemical analyses of the soil samples

The mean values of pH, organic matter (OM), soil texture, cation exchange capacity (CEC) for all the soil samples are presented in Table 4.

Soil pH is the most widely accepted parameter which exerts a controlling influence on the availability of micro-nutrients in the soil to plants (Sanders, 1982). Also, no other single characteristic is more important in determining the chemical environment of higher plants and soil microbes than the pH (Igwe *et al*., 2005). Banjoko and Sobulo (1994) reported that some Nigerian soils especially in the forest and savannah regions are within a pH range of 5.7–6.5. This was taken as the normal pH range for ordinary soils that favour plant and microorganisms. The pH the soil samples ranged from 6.4 to 9.1 indicating that the soils varied between slightly acidic to alkaline in nature. The percentage organic matter (OM) content of other soil samples ranged from 1.82 to 9.15 with the exception of sample P1 which had 22.21% (Table 4). This values obtained were mainly due to contributions from hydrocarbon from spent oil, grease, lubricant and gasoline, which were poured on the soil. A low CEC (2.4 -7.47 meq/100 g) for almost all the samples is indicative of sandy texture of the soils and is prone to drought that invariably needs more organic matter. Low CEC soils are more likely to develop cation deficiencies, hence are more susceptible to leaching losses.

Table 4: Physicochemical properties of soil sample

Site identification	pH	% OM	CEC meq/100g	% Clay	% Sand	% Silt
A1	6.9	1.82	2.47	15.5	58.1	26.39
A2	6.5	5.05	6.17	13.3	58.4	28.26
A3	7.9	8.42	7.47	20.9	51.4	27.7
A4	6.7	5.88	3.7	17.4	56.4	26.15
B1	9.1	8.15	3.7	17.6	46.4	36.00
B2	7.1	4.38	3.7	18.4	50.50	31.10
P1	6.5	22.2	4.9	25.5	42.6	31.8
P2	8.5	8.82	2.4	19.9	46.5	33.5
Q1	6.5	9.15	8.6	16.6	48.5	34.9
R1	6.4	7.31	3.71	16.7	56.9	26.4
S1	7.1	3.14	3.09	17.8	54.4	27.8
S2	8.1	6.68	6.79	18.0	46.4	35.6
Control	6.3	0.30	2.46	10.9	64.4	24.7

OM = Organic Matter, CEC = Cation Exchange Capacity

Table 5: Total metal concentration in soil samples (mg/kg)

sample	Cd	Cr	Cu	Ni	Pb	Zn
A1	10.3±0.30	16.4±0.10	10.7±1.0	9.9±0.2	7.37±0.18	141±16
A2	10.3±0.30	46.5±0.30	94±1.5	7.8±0.4	64.3±5.7	113 ± 5
A3	17.2±0.5	27.1±0.5	113±10	10.9±0.4	14.4±0.11	40.4±0.9
A4	11.7±1.5	ND	10.3±1.3	2.14±0.2	ND	157±1
B1	5.8±1.10	7.38±0.08	11.8±0.1	8.1±0.2	12.8±4.2	254±1
B2	10.4±0.01	77.8±0.30	9.84±0.1	6.7±0.2	3.86±0.00	135±14
P1	19.2±0.60	77.0±5	66.9 ±8.3	11.6±0.1	16.7±1.4	138±4.2
P2	2.7±0.09	1.3±0.1	14.9±1.7	9.18±1.3	3.3±1.7	175 ±0.2
Q1	7.52±1.8	13.7±0.07	18.3±2.1	4.5 ±0.1	2.1±0.04	220±1
R1	8.14±0.2	2.8±0.04	11.1±1.1.	4.4 ±0.1	40.1±4.1	198±13
S1	10.1±0.1	2.6±0.2	7.1±1.4	6.5 ±0.1	0.73±0.01	158±3
S2	ND	1.3±0.2	15.2±0.4	17.7±2.2	68.3±10.1	108±11
Control	ND	ND	10.7±0.5	ND	0.98±0.6	44.0±1.5
MIN.	2.73±0.1	1.3±0.1	7.2±0.1	2.14±0.02	0.73±0.1	40.4± 0.9
MAX.	19.2.0±0.3	77.7.±5	113±1.8	17.7±2.2	68.3±0.4	254±13

ND = Not Detected

Table 6: Allowable limits of heavy metal concentration in soil of some European countries (mg/kg)

Heavy metal	Netherlands	Austria	Germany	France	UK	EPA Regulations
Cd	0.5	1 - 2	1	2	4	3
Cr	30	100	60	150	400	50
Cu	40	60 – 100	40	100	135	25
Ni	15	50 – 70	50	50	75	19
Pb	40	100	70	100	3400	20
Zn	200	150	100	200	300	60

ECDGE (2010)

Lead (Pb) was present in almost all the samples (Table 5) with the exception of sample A4. Lead is a toxic heavy metal ion that affects blood transport and composition. The highest concentration of Pb was obtained in sample S2, with a concentration of 68.3±10.1 mg/kg, while the least concentration occurred in sample S1 with a value of 0.73 mg/kg. The concentration of Pb in samples A2, S2 and R1 were 64.25±5.7, 68.3±10.1, and 40.14±4.1 mg/kg, respectively may be attributed to anthropogenic factors. The high enrichment of Pb in these soils may be attributed to a substantial contribution from leaded auto mobile parts, use of paints and anti-rust agent. These values are however higher than those obtained by Luther*et al*., (2011).This may be because the soils were collected by the road side, andcarsuse gasoline that are leaded thus and contributing to the concentration of Pb in he soil (Mombeshora *et al*., 1983). Low levels of Pb were found in samples A4, B2, P2, and Q1 as well as in the control sample. In addition, Pb is generally added to the environment by aerial deposition along the highways in proportion with the density of traffic and distance from the road side (Ahmet and Ugur, 1999).

Cadmium is a very toxic heavy metal that has no beneficial function in the human body and was found in all soil samples. Samples S2, P2 had low concentration of Cd. Cadmium, unlike most heavy metals, can be taken up by several plants such as wheat, maize, rice, spinach or tobacco. It is capable of accumulating in foods and the accumulation depends on factors such as pH and high temperature (Voogt *et al*., 1980). It has been shown that the increased cadmium content is related to the specific local constituency of the soil. Cadmium (Cd) was however detected in other samples in this study and the result however was found to fall between the values obtained by Osu and Okereke (2010). The high Cd concentration at site P1 may be due to dismantling activities in the area. In addition, the presence of Cd in the samples could be attributed to the use of pigments containing cadmium such as Cd/Seas well as dumping of PVC plastics, nickel-cadmium batteries, motor oil and disposal sludge on the soil in the dismantling operation (Bohn *et al*., 1979; Jarup, 2003; Ebong *et al*., 2008). The soil samples had higher concentrations of Cd when compared to safety standards of other countries and EPA regulations (Table 6), indicates that the contaminated soil samples were grossly polluted and not safe. Although, there is no subsistence farming going on in these site, it will certainly be transported by runoff water in the form of its ion in solution into other parts and finally into plants. Voogt *et al*., (1980) showed that 'Itai-itai' disease resulted from the cultivation of rice in fields where Cd ion concentration was about 2–3 mg/kg. This situation is worse because Cd ion is relatively soluble and capable of being retained in the soil at any pH (Bohn *et al*., 1979).

The concentration of nickel in the soil samples ranged between 2.14 and 17.7 mg/kg. Nickel was observed to be present in all samples and the highest concentrations of Ni was found in sample S2 (17.7 ± 2.2 mg/kg). This concentration is higher than that permitted by Netherlands (15 mg/kg) and agrees with values obtained by Nwachukwu *et al*. (2010). Samples A3 and P1 had concentrations that were close to the background concentration of Ni. The high Ni content at sample stations S2 may be attributed to human activities such as the disposal of spent automobile batteries from the nearby auto battery charger and which may have contributed to the contamination of the different soil samples. Though Ni is a micro-nutrient in soil, excessive level of the metal in the soil may be toxic to some soil fauna such as earthworms, which are adjuncts to the microflora in organic matter decomposition (Osuji *et al*., 2002). Zinc (Zn) was detected in all the soil samples with a concentration ranging from 40.4 to 254 mg/kg(Table 5). Sample B1 (obtained from a spare part sales area amidst residential building) had the highest Zn concentration of 254±0.19 mg/kg while the lowest concentration was obtained for A3. The high concentrations of Zn at site Q1 may be due to the dumping of zinc containing solid waste materials near the sampling sites. All other samples had high concentration of zinc when compared to values obtained in the control sample. Although zinc is found useful as a metabolic antagonist of metals such as Copper, iron and Cadmium, zinc is also known to induce vomiting, dehydration, abdominal pain, nausea, lethargy and lack of muscular coordination in man when taken in excess. A high concentration of zinc was observed to kill and stunt plant growth (Okoronkwo *et al*., 2005). This metal should therefore not be introduced into the environment indiscriminately (Alloway, 1990).

Sample A3 has the highest Cu concentration of 113±1.8 mg/kg. This might be due to the fact that electrical materials which contain a lot of copper are sold around the area, with high copper content which gets into the environment. Elevated levels of copper in these auto-mechanic locations were traced to the use of copper conductors and wires, tubes, solders and myriads of other maintenance items made from copper. According to Wyszkowska (2002) and Lenntech (2009), when copper ends up in the soils, it strongly attaches to organic matter and minerals. The concentrations of Cr in sample A2, A3, B2 and P1 i.e. 46.5, 27.1, 77.8, and 77 mg/kg may be attributed to the Cr content of oil wastes dumped on the sites that leaches into the underlying soil layer as well as the panel beating of vehicular parts during dismantling activities since chromium is used in manufacturing chrome-steel alloys. Metal bit, metallic colour coats and dust are scrapped to bare ground, contaminating the soil. These values were again, higher than those obtained in other studies. As observed by Ghosh and Singh (2005), non-biodegradability of chromium is responsible for its persistence in the environment; oncemixed in soil, it undergoes transformation into various mobile forms before ending up in the environmental sink (Bartlett, 1993; Bartlett, 1988).

Although Cr toxicity in the environment is relatively rare, it still presents some risks to human health since chromium can accumulate on skin, lungs, muscles fat, and in the liver, dorsal spine, hair, nails and placenta where it is traceable.

Principal component analysis of soil samples

The distribution manners of individual associations of elements in soil were determined by principal component analysis. Table 7 gives the eigenvalues of factors. Based on the eigenvalues, the first two factors with the highest values were used. The two factors explained 50 % of the total variance. The first factor (PC1) explained about 31% of the total variance while the second factor(PC2) explained about 19% of the total variance**.** The selected soil properties are pH, organic matter (OM), sand, silt and clay. Fig. 1 showed significant negative correlations between the total metals and the percentage amount of sand, silt and clay. In Figure 1, PC1 showed significant negative correlations between all the metals determined and the % amount of sand in the soil, while the correlations between pH, Ni and Cr are positive and significant and may be as a result of the contamination from battery charger shop close to the site where the samples were collected. As indicated by PC2, none of the metals correlated significantly with sand. This is in line with the general principle that trace metal contents in sands are significantly lower than in loams and clays (Davies, 1985).

Table 7: Eigenvalues of factor for soil samples after varimax rotation

Factor	Eigenvalues		
	Total	**% of variance**	**Cumulative %**
1	3.720	31.00	31.00
2	2.388	19.89	50.81
3	1.727	14.39	65.29
4	1.407	11.72	77.01
5	1.008	8.40	85.41

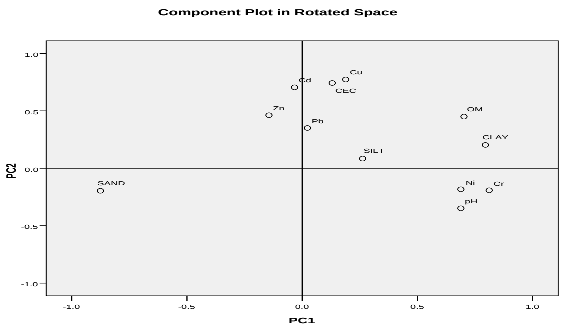

Fig 1. Plot of PC1 and PC2

As the sand content is increased, silicon content is expected to increase. Increase in silicon content (with silicon a major element in the earth crust) implies a decrease in trace and minor elements content. PC2 shows a high loading (> 0.5) for Zn, Cd, Cu, Pb and the cation exchange capacity (the sum total of the exchangeable cations that a soil can absorb) are positively correlated. According to Bloeme *et al*. (1995), an association of Cd, Pb and Zn with one another suggests an anthropogenic influence. Samples from this study are loose roadside sandy soils with low organic content (Table 5).The cation exchange capacity was also low (Table 5), thus indicating the ability of the soil to retain a high concentration of metals in the soils. PC2 established the relationship that low CEC includes the limited availability of mineral nutrient to the plant and the soil's inefficient ability to hold nutrients (supported by low organic matter of soil) is indicative of sandy texture of soil.

Ecological risk assessment

The Hakanson ecological risk method was used to assess the potential ecological risk of PTM, (E_R^i). The result and the Risk Index (RI) of the metals are listed in Table 8. According to Hakanson, the ecological risk factor(E_R^i) for a given substance and the overall Risk Index (RI) for the soil due to the presence of multiple contaminants in soil may be estimated from equations(1), (2) and(3). In the absence of background values for heavy metals concentration in soil around these sites, the values presented by the National Oceanic and Atmospheric Administration, USA (SQuiRTs) was used, together with the toxic –response factors reported by Cai *et al*. (2011). These values are given in Table 2.

Table 8:The adjusted grading standard of potential ecological risk of heavy metals in soil

E_R^i	Single pollutant ecological risk	Risk Index (R I)	Comprehensive potential ecological risk
< 40	Slight	< 90	Slight
40 – 80	Moderate	90 – 180	Moderate
80 – 160	Strong	180 -360	Strong
160 – 320	Very strong	360 – 720	Very strong
320	Highly strong	>720	Highly strong

Hakanson (1980)

Table 9: Potential ecological risk coefficient and index of metals in soil

Sample	Cd	Cr	Cu E_R^i	Ni	Pb	Zn	Risk index (RI)
A1	1191	0.4	3	0.7	2	3.1	1200
A2	1240	4.2	27	0.5	20	2	1295
A3	1994	3	33	0.7	20	0.8	2051
A4	1352	0.2	3.0	0.1	*	3.2	1359
B1	673	0.6	3	0.6	4	5.3	687
B2	1206	0.3	3	0.6	1.2	3	1214
P1	2221	2.3	20	0.5	5	3	2251
P2	315	0.5	4	0.7	1	3	325
R1	867	0.5	5	0.3	0.6	4	878
Q1	939	1.4	3	0.3	12	4	960
S1	1224	0.2	2	0.3	0.2	3	1230
S2	*	2.2	4	1.3	21	2.4	1871
Control	*	*	2.0	*	0.3	1.6	3.9

*Not calculated because result were <LOD

Table 8 shows how ecological risk factors and risk indices are related to severity of risk. Table 9 shows that Cd poses a high ecological risk in all the sites with E_R^i values ranging from 315-2221. Apart from Cu at site A3 (which is just below the threshold), all other metals pose a low potential ecological risk. As noted above, there are specific inputs of Cd in all the sites except for S2 and control due to dumping of PVC plastics, nickel-cadmium batteries, motor oil and disposal sludge on the soil in the dismantling operation. The results showed that Cd pollution was the main factor causing risk to the soil (its comprehensive RI distributed from 879 to 2251). Cd accounted for about 96.7 - 99.5 % of the total risk index with concentrations above allowable limits.

Conclusion

Elevated values of Pb, Cu, Zn and Cd were found in soil samples from the auto-spare parts sales dealership and car dismantling sites when compared to the control samples and established guidelines of some European countries. No evidence of elevated values of Ni in soils was found. Zn had the highest concentrations in the soil layers while Ni had the least. The order observed for this study was Zn > Cu > Cr > Pb > Cd > Ni. The concentrations of Pb, Cd, Cr and Zn in the soils under investigation were higher than those reported in other auto-mechanic locations and permissible level for soils, in several countries. This raises significant environmental concerns and calls for urgent attention and appropriate response. Principal component analysis (PCA) showed that PC1 suggested that anthropogenic activities were responsible for the observed association of Pb, Ni, Cr and OM in all the sites. PC2 showed that Cu, Zn Cd and CEC were observed to be from other sources such as dumping of refuse by resident, abandoned cars on the roadside and the tarred nature of the roads. Although metal loading from these sources are presently low, build-up of heavy metals associated with changes in soil properties should be considered as an environmental concern in the areas studied. This study shows that the statistical methods can be strong tools for monitoring environmental quality of soils in terms of heavy metal accumulation and for predicating future soil contaminations. The Hakanson methodology showed that the system is exposed to a high ecological risk due to cadmium pollution and should be a prime concern among these metals studied.

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