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Levels and occupational health risk assessment of trace metals in soils from automobile repair workshop village and environs in Uyo metropolis, Nigeria

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The levels of trace metals (Pb, Cu, Ni and Cd) were determined in soils from a major automobile repair workshop located in Uyo, Akwa Ibom State, Nigeria. This was carried out to evaluate the potential occupational risk to operators working in and around the site. The mean of trace metal levels were: lead (14.52 mg/kg); copper (0.50 mg/kg); nickel (0.17 mg/kg) and cadmium (0.67 mg/kg). These values were within the acceptable levels for unpolluted soils according to the Dutch standard. The trace metal levels were subjected to risk assessment model to estimate toxic risks due to occupational exposures by incidental oral ingestion of soil particles. The results obtained revealed higher risk quotients for exposed workers at the main automobile workshop area than those occupants farther away. Amongst the metals studied, lead was predicted to pose higher health risk although the hazard quotients for all trace metals were less than one. This indicates that there is little or no significant occupational health risk associated with the presence of these levels of trace metals in the soils. The physicochemical measurements gave the following mean values: pH 6.01; total organic carbon 4.05 %, while the mean particle size distributions were: sand 95.15%; clay 0.7% and silt 4.25%. The pH value of the soil under study showed slight acidity which implies that the trace metals are less likely to be solubilized. The elements are also capable of binding to the organics present in the soil; while the high sand content of the soil implies that the trace elements can be easily leached, thus being more bioavailable for uptake by plants.

Key words: Trace metals, occupational risk assessment, automobile shop, soils, physicochemical parameters.

INTRODUCTION

Measurements of trace metal levels in soils around various industries have become a routine over the years (Sanita di Toppi and Gabrielli, 1999; Xiaoli et al., 2007; Redon et al., 2013). This is due to increased concern over the negative implications of some industrial activities as well as poor waste management. The levels of these metals in the environment could serve as a reliable index to evaluate and assess environmental contamination. Trace metals have the ability to accumulate in organisms as they are difficult to metabolize (Pezzarossa et al., 2011). Hence they bind to vital cellular components such as structural proteins, enzymes and nucleic acids and

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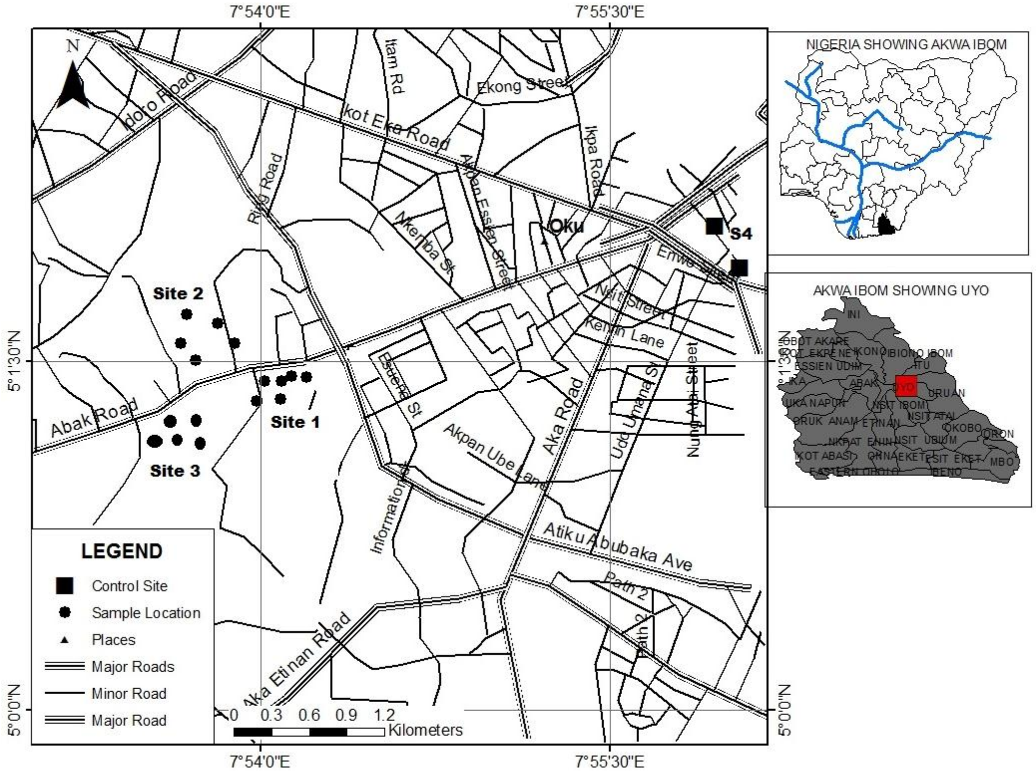

Figure 1. Study location with sample stations.

interfere with their functioning (Landis et al., 2000).

Importation of used automobiles into the country could be the reason for the high rate of automobile repair activities in the country and hence contributes significantly to the problem of soil contamination in most cities. This occur as a result of the short life span of vehicles, hence they are easily dumped by the roadsides in most cities. Metals from this source get leached into the soil in the form of rust. Other sources such as the waste oil used for cleaning machine parts during servicing, the grease used for lubrication, metal scraps as well as used batteries are indiscriminately discarded on soils by automobile engineers, due to ignorance as well as inefficient regulating mechanism to control the disposal of these kind of wastes. The metals from these sources find their way into the soil matrix and are taken up by plants in amounts that may cause detrimental effects on people or animals that consume these plants. The problem of trace metal pollution is not restricted to Nigeria alone; in some parts of the world, large amount of trace metal have been directly discharged to nearby lands (Pan et al., 2014). This activity adversely affects the quality of air, soil and ground water, in such a way that it becomes a subject of serious concern worldwide.

It is suspected that local mechanical engineers in Nigeria may be occupationally exposed to trace metals due to the complexities of problems associated with operation of automobile repair shops in the country. To the best of our knowledge, no work has been done in this area of research in Nigeria. Therefore, this study was aimed at evaluating the occupational health risk associated with exposure to trace metals in soil in an automobile repair workshop. This was achieved by determining some physicochemical parameters like soil pH, total organic carbon as well as particle size distribution in soil, which may affect the distribution of trace metals in soil, hence their uptake by plants; determining the levels of trace metals in the soil and evaluating the hazard quotients associated with exposure to these metals.

MATERIALS AND METHODS

Description of the study area

The area selected for this study is an automobile repair shop and environs, located along Abak road in the urban city of Uyo, Nigeria. The study area has a high traffic density and it is prone to different degrees of pollution due to automobile repair activities as well as other commercial activities going on in the area. The map of the study location is as shown in Figure 1.

Sample collection

Soil samples were collected from an auto-mechanic village comprising of different workshops. The samples were strategically distributed over sites 1, 2 and 3 representing different areas of the

Table 1. Exposure factors for an adult automobile engineer.

Parameter	Symbol	Unit	Value	Reference
Exposure duration	ED	Years	24	USEPA (2001); Zheng et al. (2009).
Exposure frequency	EF	Day/year	180	Ferreira-Baptista and De Miguel (2005).
Ingestion rate	IR	mg/day	100	USEPA (2001)
Body weight	W	Kg	70	USEPA (1989)
Averaging Time	AT	Days	8760	Zheng et al. (2009

auto-mechanic village where automobile repair activities were carried out (Figure 1). Sites 1 and 2 represent locations with intense activities and more workshops while site 3 had few workshops. Control samples were also taken from an area with less human activity (S4) (Figure 1). Five different soil samples were collected from each site at a depth of 0 to 5 cm and mixed into composites in four different polythene bags. The samples were immediately transported to the laboratory for further analysis.

Sample preparation and analysis

The soil samples were dried at room temperature in the laboratory. After drying, the samples were ground using a plastic pestle and mortar to break the large lumps and to homogenize the soil particles. It was then sieved using a 2 mm pore size sieve. The pH_{H2O} of the soil samples were determined using portable pH meter (Hanna Checker, China) with a resolution of 0.01.

Total organic carbon analysis was carried out using wet oxidation method according to Walkley and Black (1934). One normal solution of potassium dichromate was prepared by dissolving 24.52 g of $K_2Cr_2O_7$ in distilled water and made up to mark in 500 ml volumetric flask. One gram of each soil sample was put in an Erlenmeyer flask and 10 ml of 1 N $K_2Cr_2O_7$ solution was added to each flask, after which 20 ml of concentrated sulphuric acid was added and swirled gently to disperse the heat generated. The content was allowed to stand for 30 min to oxidize the organics present. 100 ml of distilled water was then added followed by 4 drops of ferroin indicator and then the content was titrated with 0.5 N ferrous ammonium sulphate (FAS) to a maroon end point (Walkley and Black, 1934). The percentage organic carbon was calculated using the formula given below:

$$\%\mathrm{TOC} = \frac{\mathrm{C}\ (V_1\ \times V_2)\times 0.3\ \times 1.33}{\mathrm{W}}$$

Where C is the concentration of FAS solution, V_1 is the titre value of blank, V_2 is the titre value of sample and W is the weight of the sample.

The particle size distribution of each soil sample was determined following the hydrometer method. 50 g of the air-dried soil was weighed into the stirrer cup and 20 ml of sodium hexametaphosphate (calgon) was added as dispersant. Water was added to half of the stirrer cup, the cup was fixed to the stirring machine and electrically stirred for 5 min. The cup was then removed and emptied into the measuring cylinder and rinsed with distilled water and made up to the mark. The measuring cylinder was covered and inverted several times to mix the content. The temperature of the mixture was taken and recorded, the hydrometer was inserted and readings were taken and recorded for all the samples (Piper, 1994).

The soil samples were digested using *aqua regia* which was freshly prepared by adding 150 ml of hydrochloric acid to 50 ml of nitric acid. 1 g of the soil samples were weighed into well labelled crucibles and 15 ml of *aqua regia* was added to each crucible and heated to near dryness, then 10 ml of distil water was added and heated till it boils. The digested sample was put in appropriately labelled plastic containers for trace metal analysis using atomic absorption spectrophotometer (AAS, UNICAM 969). For quality control, blank samples were also prepared.

The working standard for each of the metals with the following concentration were prepared using their sulphate salts: 1 ppm, 10ppm, 20ppm, 30ppm, 40ppm and 50ppm, following the single external standard method by Skoog et al. (1998).

Occupational risk assessment

Risk assessment in environmental science is a model that identifies estimates and quantifies the adverse health effects caused by contaminants in various environmental media (Lee et al., 2005). To achieve this task, it is necessary to first identify the potential of a source to introduce risk agents into the environment, estimate the amount of risk agents that comes in contact with the human-environment boundaries, and finally quantify the health consequence of the exposure (Khan et al., 2007). It consists of four basic steps: hazard identification, exposure assessment, dose-response assessment, as well as risk characterization (Lee et al., 2007).

The hazard identification step involves identification of the contaminant and the potential effects they can cause to human health. This was done by determining the levels of trace metals in the soil matrix in which the automobile engineers were exposed to. Exposure assessment identifies the pathways by which humans are potentially exposed to the toxicants. It could be oral, inhalation, or dermal contact with the source of contaminant. It is a function of the daily intake (I), for a specific pathway. This is given by a modified equation by Lee et al. (2007):

$$\mathrm{I} = \frac{\mathrm{C} \times \mathrm{IR} \times \mathrm{ED} \times \mathrm{EF}}{\mathrm{BW}\ \times \mathrm{AT}}$$

Where I is the daily intake; C is the concentration of the trace metal in soil (mg/kg); IR is the ingestion rate per unit time (kg/day); ED is the exposure duration (years); EF is the exposure frequency (days/year); BW represents the body weight of the receptor (kg); AT is the averaging time (years). The total intake is the sum of the oral, inhalation, and dermal intake. However, the trace metal intake through the dermal and inhalation pathways is typically less than 1% of the overall intake of heavy metals (Zhao et al., 2012). Therefore, in this study, only the oral exposure route was considered. The exposure factors are presented in Table 1.

In dose-response assessment step, the non-carcinogenic risk of trace metal due to occupational exposure was considered using the oral reference doses of the trace metals as indicated in Table 2.

The risk characterization was carried out using the hazard quotients of each of the metal under study and it is given as the ratio of the daily intake (I) to the reference dose (RfD). Thus,

Table 2. Reference dose of trace elements in soil.

Element	Reference dose (mg/kg)
Lead	3.6E-2
Cadmium	5.0E-4
Copper	3.7E-2
Nickel	2.0E-2

Source: Zheng et al. (2009).

Table 3. Physicochemical characteristics of soil samples from automobile workshop in Uyo.

Site	pH	TOC (%)	Sand (%)	Clay (%)	Silt (%)
S1	6.71	6.07	98.40	0.40	1.20
S2	5.93	3.83	92.40	0.40	7.20
S3	6.14	2.79	96.40	0.40	3.60
S4	5.25	3.51	93.40	1.60	5.00
Range	5.25-6.71	2.79-6.07	92.40-98.40	0.40-1.60	1.20-7.20
Mean ± SD	6.01 ± 0.36	4.05 ± 2.00	95.15 ± 7.58	0.70 ± 0.36	4.25 ± 6.27
CV	5.99	49.38	7.97	51.4	147

TOC,Total organic carbon; SD, standard deviation; CV, coefficient of variation.

Table 4. Levels of trace metal in soils of automobile workshop in Uyo (mg/kg).

Site	Pb	Cu	Ni	Cd
S1	16.52	0.82	4.33	0.99
S2	14.76	0.24	4.76	0.82
S3	12.40	0.43	4.38	0.53
S4	0.14	0.28	0.17	0.66
Range	0.14-16.52	0.24-0.82	0.17-4.76	0.53-0.99
Mean ± S.D.	14.56 ± 4.27	0.50 ± 0.06	4.50 ± 0.05	0.67 ± 0.02
C.V. (%)	29.32	1.29	0.01	0.03
*Dutch Standard	85.00	36.00	35.00	0.80

S.D. = standard deviation, C.V. = coefficient of variation.
*Source: Iqbal et al. (2011).

$$\text{Hazard Quotient (HQ)} = \frac{\text{I}}{\text{RfD}}$$

HQ < 1 implies no health risk, while HQ > 1 implies that the exposed population is unsafe (Khan et al., 2008).

RESULTS AND DISCUSSION

The results of the physicochemical characteristics as well as trace metal levels in the soil samples under study, and the evaluation of human health risk are discussed in the following paragraphs.

Physicochemical characteristics of the soil samples

The results of the physicochemical analysis are presented in Table 3. The physicochemical parameters that were determined include: pH, total organic carbon (TOC) as well as particle size distribution. All the soil samples showed slight acidity with a mean pH of 6.01. The control sample however had the highest acidity. Site S1 which is one of the sites of the main automobile workshop had the highest level of organic carbon which is almost twice that of site 3 as shown in Table 3. The particle size distribution showed the same clay content for site 1, 2, 3 and some degree of variation in the sand and silt contents.

Levels of trace metals

The results for the quantification of trace metal are presented in Table 4. The results revealed comparable values for lead, nickel and cadmium at the different study

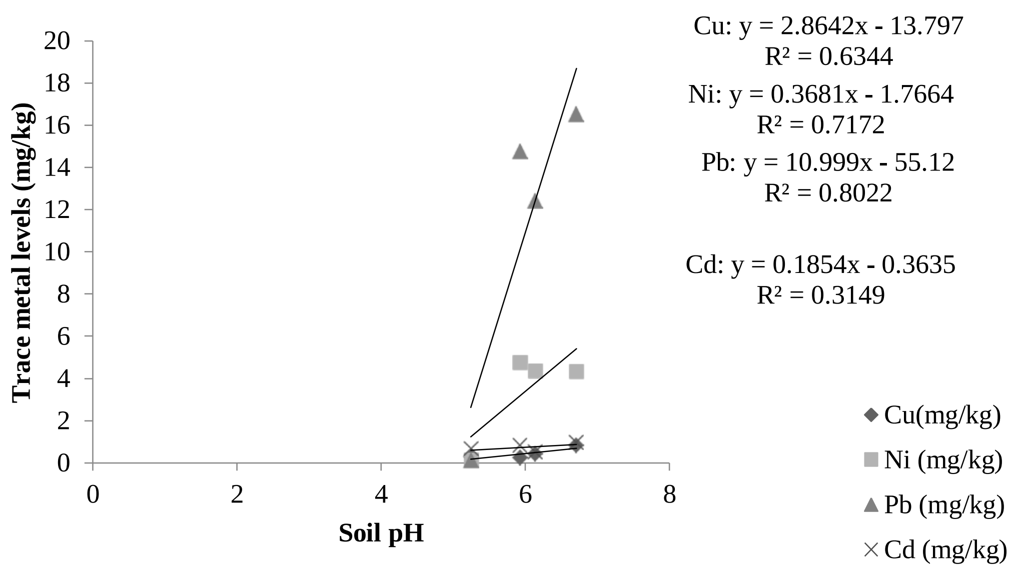

Figure 2. Correlation between trace metal levels and soil pH

Table 5. Distribution of mean trace metal levels in soils as reported in the literature (mg/kg).

Location/Type	Pb	Cu	Ni	Cd	References
China (agricultural)	66	107	-	1.2	Xu et al. (2013).
Owerri (automobile workshop)	1162	385	40	20	Nwachukwu et al. (2011).
Argentina (Salt marsh)	7.20	7.48	0.93	-	Idaszkin et al. (2014).
Portugal (Volcanic)	10.7	13.60	17.87	0.16	Parelho et al. (2014).
Malagrota (landfill)	32.0	18.00	20.00	1.00	Barbieri et al. (2014).
Beijing (Agricultural)	49.4	32.8	24.9	0.84	Khan et al. (2007).
Dabaoshan (Metal mine)	58.99	126.04	-	1.20	Zhao et al. (2012).
France (Arable)	46.8	34.9	58.5	0.55	Redon et al. (2013).
Dutch Standard (Unpolluted soil)	85	36	35	0.8	Iqbal et al. (2011)
Uyo (automobile workshop)	14.56	0.50	4.50	0.67	This study

sites, with site S1 having the highest value for Pb, Cu and Cd. However, site S2 had the highest nickel level while the control site (S4) had the lowest value as displayed in Figure 2. This indicates possible impacts from high human activities as the selected control site is generally characterised by very low human activities as at the time of the study. Cadmium level for the main automobile work area (S1) was observed to be 0.99 mg/kg which is above the permissible limit of 0.8 mg/kg as given by Dutch standard (Iqbal et al., 2011). This could probably be as a result of improper disposal of cadmium containing batteries. A comparison of the trace metal levels with literature date is presented in Table 5.

The trace metal levels from the auto-mechanic village in Uyo were not as high as those reported by Nwachuckwu et al. (2011) in Owerri. However, the levels of lead were significantly higher than those reported in salt marsh and volcanic soils in Argentina and Portugal by Idaszkin et al. (2014) and Parelho et al. (2014) respectively. All the trace metals were below the permissible limit for unpolluted soil according to the Dutch standard as reported by Iqbal et al. (2011), except cadmium for sites 1 and 2 which were slightly higher than the Dutch standard for unpolluted soil. This implies that the area under investigation is more susceptible to cadmium pollution than other trace metals under study. This could be attributed to the indiscriminate disposal of waste cadmium accumulators by the automobile engineers, which in turn leaches into the soil matrix.

Relationship between physicochemical parameters and levels of trace metals

In order to understand the relationship between the physicochemical parameters and the levels of trace

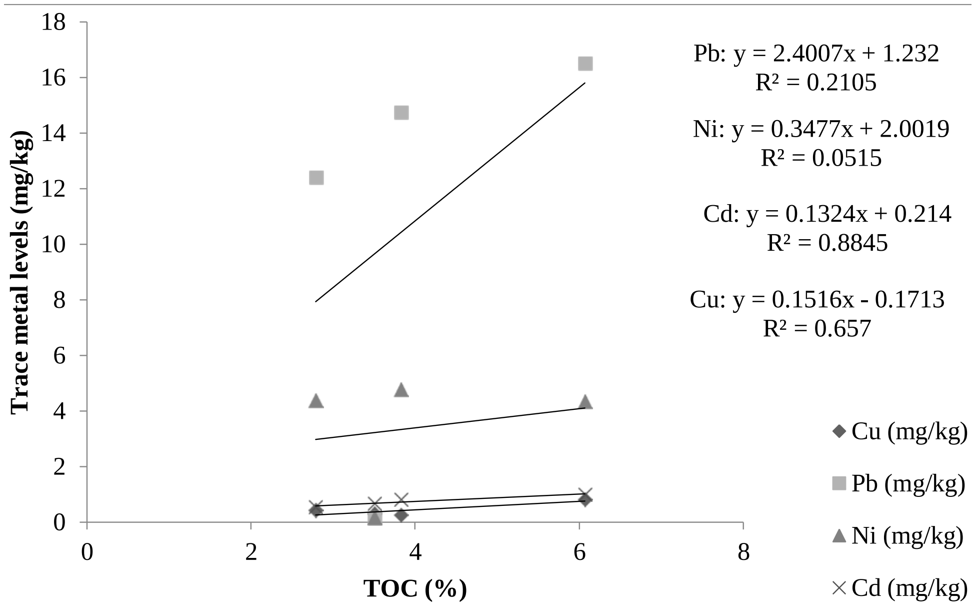

Figure 3. Correlation between total organic carbon and trace metal levels in soil.

Table 6. Estimated daily intake and hazard quotient values for trace metals in soils of automobile repair workshop in Uyo.

Site	Risk parameter	Pb	Cu	Ni	Cd
S1	I	11.64E-6	5.80E-7	3.05E-6	7.00E-7
	HQ	3.24E-2	1.57E-5	1.53E-4	1.40E-3
S2	I	10.40E-6	1.80E-7	3.35E-6	5.80E-7
	HQ	2.89E-4	5.00E-6	1.68E-4	1.20E-3
S3	I	8.74E-6	3.00E-7	3.09E-6	3.70E-7
	HQ	2.43E-4	8.00E-6	1.54E-4	7.00E-4
S4	I	1.00E-7	2.00E-6	1.20E-7	4.60E-7
	HQ	3.00E-6	5.30E-6	6.00E-6	9.30E-4

I, intake; HQ, hazard quotient.

metals in the soil samples, a linear regression analysis was carried out and the results are presented in Figures 2 and 3.

As presented in Figure 2, the concentration of lead in soil showed a linear correlation with pH levels, as shown by R^2 value of 0.802. This positive correlation implies that lead levels increases in soils with increasing pH values and vice versa. Cadmium levels however had the least linear correlation with pH, which may probably be as a result of the decreased mobility of cadmium in soils. The decreasing trend of relationship existing between trace metal levels in soil and pH is Pb>Ni>Cu>Cd.

It has been observed that trace metals accumulate in soils with increasing TOC levels (Besnard et al., 2001). This is evident in the good positive correlation of cadmium levels with total organic carbon. Nickel levels however had a poor correlation with total organic carbon as it has the least correlation value of 0.0515. The ability of cadmium to form both organic and chloride complexes unlike nickel, accounts for its high correlation with the organic content. The increasing trend is in the order Ni<Pb<Cu<Cd.

Evaluation of occupational health risk

The results of the daily intake and the corresponding hazard quotients for all the trace metals under study are presented in Table 6.

From the results presented in Table 6, it could be inferred that the area of the automobile shops represented by S1 is most likely to be of health risk to the workers than other sites. This is evident in its high intake as well as hazard quotient values for lead, copper and

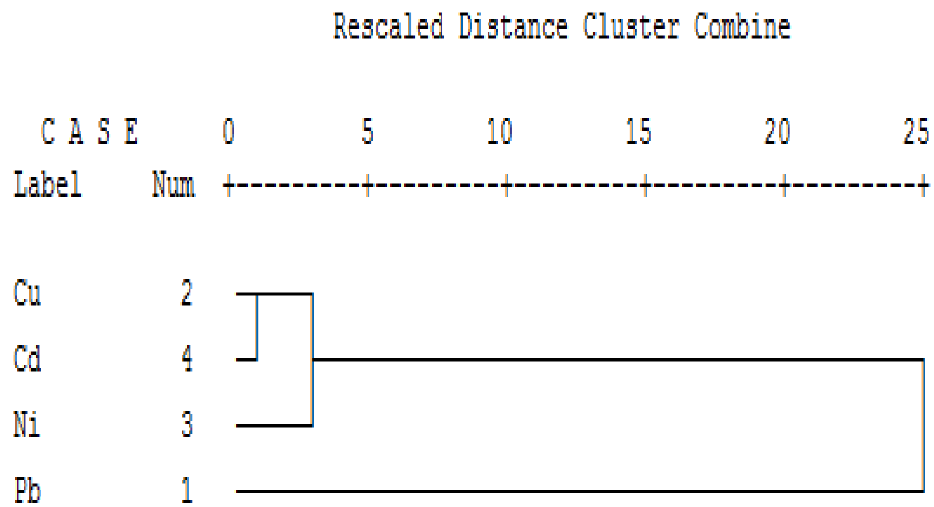

Figure 4. Dendrogram showing cluster between trace metals.

Table 7. Correlation between trace metal levels and particle size distribution.

	Pb	Cu	Ni	Cd	Sand	Clay	Silt
Pb	1						
Cu	0.522	1					
Ni	0.969*	0.342	1				
Cd	0.510	0.593	0.304	1			
Sand	0.464	0.939	0.344	0.286	1		
Clay	-0.974*	-0.409	-0.996**	-0.301	-0.424	1	
Silt	-0.265	-0.932	-0.115	-0.299	-0.969*	0.199	1

* Correlation is significant at the 0.05 level. ** Correlation is significant at the 0.01 level (2-tailed).

cadmium. This is because the workers here have direct contact with these toxicants during servicing of automobiles. The control sample station (S4) had the least I and HQ values for lead and nickel. However, all the HQ values for the study sites were less than unity which implies that that there is little or no significant health risk due to occupational exposures to trace metal levels at the workshop as at the time of this study.

Statistical analysis

To understand the pair-wise relationship between the trace metal levels, a cluster analysis was carried out as presented in Figure 4.

The results obtained from the Euclidean distance revealed that there are two major clusters, one with copper, cadmium and nickel, while lead is alone. This implies that copper, cadmium and nickel were probably from the same source while lead was likely from other sources. It is of assumption that other sources for lead such as aerial deposition from vehicle exhaust in the high traffic area may have strongly influenced this discrimination (Zheng et al., 2009).

Relationship between trace metal levels and particle size distribution

The bivariate correlation analysis was carried out to determine the relationship existing between the trace metal levels and the distribution of soil particle size. The result is presented in Table 7.

From the obtained results, nickel and lead had negative relationship with clay content in the soil. This is evident in the correlation coefficient values of -0.996 and -0.974, respectively. The correlation for nickel was significant at 0.01 confidence level while that of lead was significant at 0.05 confidence level. This implies that the bioavailability of these trace elements also depend on the clay content due to its poor aeration and slow drainage. Copper on the other hand, has a good positive correlation with sand having a correlation coefficient of 0.939. This implies that the excellent aeration and slow drainage properties of sandy soils will make this trace metal to be easily leached in soils, thereby increasing their bioavailability to plants.

Conclusion

The levels of trace metal are one of the indicators used to assess the degree of contamination of a particular environmental matrix. In this study, the physicochemical characteristics as well as the levels of trace metals in soils around automobile repair shop environs were determined and the values obtained were within the permissible limits for unpolluted soil according to Dutch standard (Iqbal et al., 2011), except for cadmium in some areas of the study site which could be attributed to improper disposal of cadmium containing batteries.

The physicochemical characteristics of the top soil including pH, total organic carbon and particle size distribution were determined. The results showed that all the soil samples were slightly acidic which implies that the metals are less likely to be solubilized. The total organic carbon content of the soils was much higher in the main automobile work area than in the agricultural soils due to the spills from organic solvents during automobile repairs. However, the trace metals here are less likely to be bioavailable due to their ability to bind to the organics in the soil.

The occupational health risk assessment due to incidental oral ingestion was carried out based on the trace metal levels of the soil. The result showed no potential health risk. However, the strong correlation existing between the working areas of the automobile shops implies that any abnormal increase in trace metal concentration at one site will affect the other sites.

Conflict of interest

The author(s) did not declare any conflict of interest.

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