Published by
NIGERIAN SOCIETY OF PHYSICAL SCIENCES
Available online @ https://journal.nsps.org.ng/index.php/jnsps

J. Nig. Soc. Phys. Sci. 4 (2022) 887

Journal of the Nigerian Society of Physical Sciences

Assessment of Heavy Metal Pollution Status in Surface Soil of a Nigerian University

M. A. Lala[a,*], S. Kawu[a], O. A. Adesina[a], J. A. Sonibare[b]

[a]*Department of Chemical and Petroleum Engineering, Afe Babalola University, Ado-Ekiti, Nigeria*
[b]*Department of Chemical Engineering Obafemi Awolowo University, Nigeria*

Abstract

The problem of urban soil contamination with heavy metals due to rapid urbanization and industrialization has been a major concern in recent years. A university can be considered as a product of industrialization and urbanization which is associated with different activities that may induce heavy metals pollution into the environment. Therefore, this research work assessed the contamination level of chromium (Cr), copper (Cu), lead (Pb), zinc (Zn) and manganese (Mn) in surface soils of Afe-Babalola university (ABUAD) using various indices. Soil samples were taken from ten (10) different functional sites in the university. These samples were taken to the laboratory and analyzed for chromium (Cr), copper (Cu), lead (Pb), zinc (Zn) and manganese (Mn) using standard method. The mean concentrations of copper (Cu), chromium (Cr) and lead (Pb) were up to 0.75, 0.66 and 0.36 mg/g respectively, while manganese (Mn) and zinc (Zn) were 1.37 and 0.49 mg/g respectively. The average concentration of manganese (Mn) was comparable to its corresponding natural background value, but the average concentration of chromium (Cr), copper (Cu), zinc (Zn) and lead (Pb) were higher. They were approximately of the ratio 1:7, 1:2, 1:3 and 1:2 respectively compared to their corresponding natural background value. The multivariate statistical analyses indicated that vehicles, power generating sets, petrol station, machine workshops, production plants and emissions from outdoor roasted food spots were the major sources of heavy metals contamination on the universitys' soil. The results from contamination indices and assessment showed that the contamination level of soils within the university can generally be classified as moderately contaminated. Therefore, periodic assessment of the sources and associated ecological risks of the heavy metals is highly recommended. This is to enable decision-makers to effectively manage the environment in the manner that will preserve public and ecosystem health.

DOI:10.46481/jnsps.2022.887

Keywords: Contamination indices, Ecological risk assessment, Multivariate techniques, Afe-Babalola University

Article History :
Received: 23 June 2022
Received in revised form: 21 July 2022
Accepted for publication: 21 July 2022
Published: 15 August 2022

Communicated by: M. Orosun

1. Introduction

Heavy metals are relatively high density (usually 3.50 to 7.00 g cm^{-3}) metallic or metalloid elements that are capable of inducing toxicity to humans and the environment at some levels of exposure [1-2]. These heavy metals include cadmium (Cd), mercury (Hg), arsenic (As), chromium (Cr), zinc (Zn), nickel (Ni), lead (Pb), copper (Cu) etc. They are widely present in the crust of the earth and are not degradable in nature [3]. Heavy metals can be considered as trace elements because of their trace quantity in the environmental. The bioavailability

*Corresponding author tel. no: +2348163280469
Email address: lalam@abuad.edu.ng (M. A. Lala)

of heavy metals is usually influenced by physical factors (i.e temperature, adsorption and phase association), biological factors (i.e biochemical adaptation, physiological adaptation and species characteristics) and chemical factors. The chemical factor affects the formation of more ions in the course of their reactions [1-6].

Sources of heavy metals pollution can generally be classified as natural and anthropogenic or manmade. The crust of the earth naturally contains heavy metals, but human or anthropogenic activities have been recognized as the major source of the pollution [1]. Considering the natural courses of heavy metal pollution, weathering and volcanic eruptions have been identified as parts of the main contributors [1, 7, 8]. Environmental pollution through anthropogenic activities includes agricultural and domestic use of compounds containing metals, mining operations and smelting operations. Industrial activities such as burning of coal in power plants and processing of metals in refineries are also major sources of manmade pollution. Moreover, petroleum combustions, textiles, plastics, microelectronics, paper processing and wood preservation also contribute immensely to heavy metals level in the environment [1].

In some years back, series of studies have been carried out on the assessment urban soils for heavy metals contamination [9-11]. This is because soil is the main geochemical reservoir for all heavy metal pollutants discharged into the environment. Heavy metals are being deposited on soil which is the most important component of the biosphere through vehicular and other combustion engines emissions. Careless waste disposals and oil spillage in auto-mechanic workshops, industrial production, energy generation, construction activities, coal and fuel combustion, as well as indiscriminate use of pesticides and fertilizers on farmlands also induce heavy metals into the environment [12-15]. In addition, study indicated that atmospheric deposition which occurs either by dry or wet deposition represents another major contributor of heavy metals into the topsoil in urbanized areas [16].

The most commonly found metals on soils of contaminated sites include zinc (Zn), arsenic (As), chromium (Cr), lead (Pb), cadmium (Cd), mercury (Hg), copper (Cu) and nickel (Ni). They do not undergo chemical or microbial degradation as applicable to organic pollutants which oxidized easily by microbial actions [1, 17]. Prolonged exposure to cadmium (Cd) and lead (Pb) even at low concentrations could cause lung damage, cancer, kidney disease, and nervous disorder. This is most common with lead (Pb). Chromium (Cr) which exists in different valence states can cause gastrointestinal, lung and nasal irritation, small intestines and stomach ulcer, decreased sperm counts and dermatitis. Nickel (Ni) also causes cancer, dermatitis and lung inflammation. Copper (Cu) is associated with cardiomyopathy and lung irritation, and the major reported side effect of copper (Cu) and zinc (Zn) on health are vomiting, abdominal pain, respiratory system irritation and nausea [18]. Other heavy metals also pose great adverse effects to humans, animals and plants.

Soils contamination in different urban sector may vary depending on the activities being carried out on them. Hence, assessment of urban soils for heavy metals contamination is highly important [19-20]. In recent years, studies have been conducted on the contamination assessment of heavy metals in soil samples from auto-mechanic workshops [21-22], dust from paved and unpaved roadside [12, 18], soil samples from developing communities [11, 13] and many more.

In the present study, assessment of heavy metals in surface soils of a Nigerian university was considered. This assessment is important because a university can be characterized by many other activities that can induce heavy metals contaminations into the environment apart from the normal academic activities. Machines workshop which comprises of welding section, automobile section, lathe machine section and other machine tools sections are prime sources of trace metals contamination in university environment. Emissions from power generating sets and the maintenance of these sets are also major contributors to heavy metal pollution in universities where electric power generating sets are installed as alternative power supply. Other contributors to heavy metals pollution in a university environment include the activities from; automobile transport pools [23], building construction sites, university petrol station, and university central works department.

Despite the significance of the discussed activities to heavy metals contamination level within a university, little or no work has been done on the assessment of heavy metals in university environment. Therefore, this research work aimed at assessing the contamination level of Mn, Pb, Cr, Cu and Zn in surface soils of ABUAD, and the specific objectives are to; (1) establish the concentrations of the selected metals in surface soil of ABUAD, (2) identify the source and contributions of the selected metals to the contamination level of ABUAD soils, and (3) evaluate the contamination and risk level of the metals using enrichment factor (EF), geo-accumulation index (Igeo), potential ecological risk index (RI), pollution index (PI) and integrated pollution load index (IPI). This is to detect areas that need special attention and to suggest appropriate control measures.

2. Materials and methods

2.1. Study area

Afe Babalola University (ABUAD) was considered for the current research work. ABAUD is located in Ado-Ekiti, Ekiti State, southwestern Nigeria (Fig. 1) The citadel of learning is located between latitude 07°35'59"and 36'50"N, and longitude 05°18'0"and 18'45"E. The geographical area is characterized by relatively low relief with dome-shaped isolated hills and inserbergs. The institution has over 8,500 students across all the colleges in the university and workforce of about 1000 staff.

The university community consist of many strategic places such as; residential apartments for staff and students, academic and administrative buildings, research centre, planetarium, petrol station, supermarkets, bakery, water production plant, restaurants, banks, ATM points, the university works department, sports pavilion, college of engineering central workshop and guest house.

Figure 1. Study area (a) Map of Nigeria (b) Map of Ekiti state showing ABAUD (c) Sampling locations within ABUAD

2.2. *Soil sampling*

Twenty four (24) soil samples taken at a depth of about 0 to15 cm of the earth surface were collected using a standard soil auger [24] from ten (10) different main functional sites in ABUAD. Two (2) control samples were also taken from an undeveloped site within ABUAD. This is between the university premises and the university farm. Samples were collected in duplicates from each site except site 9 where 4 samples were collected. Four (4) samples were collected from site 9 because the site comprises of more activities. As shown in Table 1, the sampling sites were considered based on different activities that can induce heavy metal contamination into the environment. To avoid further contamination other than the ones from the sampling site, collected soil samples were kept in clean nylon and taken directly to laboratory for analysis.

2.3. *Sample preparation and analysis*

Debris and all other foreign materials were manually removed from the soil samples, afterwards the samples were dried and reduced to about 1.18 mm soil particle size. To determine the selected metals concentration, 1 g from each dried samples were digested in standard Erlenmeyer flask using 12 mL aqua-regia solution. The solution was prepared at a ratio of 1:3 of HNO_3 to HCl [11, 21]. The beaker was covered and the contents were heated for 2 hr using medium hot plate heat [11, 21]. After heating, the mixture was left to cool down naturally and subsequently filtered using a Whatman No. 42 filter paper. The filtrate was diluted to 50 mL with de-ionized distilled water [21, 25]. These solutions were further analyzed for the selected metals concentration using AA320N atomic absorption spectrophotometer**.** To minimize error, all soil samples were analysed in triplicate. During the analysis, standards and blanks were run to ensure 95% reliability of the machine [11].

2.4. Descriptive statistics analysis

The concentration and distribution of the selected metals in ABUAD soil samples were investigated using statistical analysis. The quantified data where analysed using Microsoft Excel software to obtain mean, standard deviation, standard error, sample variation, minimum and maximum values. Also, principal component analysis (PCA) was carried out with the aid of XLSTAT software. This was used for source identification and contributions of the selected metals to the contamination level of ABUAD soils.

2.5. Contamination and risk assessment

Contamination and risk assessment levels for this study were analysed using the following indices;

1. **Enrichment factor (EF)**
The enrichment factor (EF) is a relatively straightforward and simple tool used for evaluating the extent of soils contamination and to compare the contamination of different environmental media. It involves a universal method for calculating degree of soil enrichment by dividing the ratio of a particular metal and normalizing element by the ratio of the same metals found in a baseline and normalizing element [13, 26, 27]. This can be computed using Equation 1.

$$\text{EF} = \frac{(\text{Trace metal}/\text{Fe})_{Soil\ sample}}{(\text{Trace metal}/\text{Fe})_{\text{Natural background}}} \quad (1)$$

where $(\text{Trace metal}/\text{Fe})_{\text{Soil sample}}$= ratio of heavy metal to Fe in the soil sample taken from the selected site, and $(\text{Trace metal}/\text{Fe})_{\text{Natural background}}$= ratio of heavy metal to Fe in the soil sample taken from the control site.
Similar to Ololade [22], the normalizer used for this work was Fe. This is because Nigeria soils are rich in Fe [28-29], and also due to its conservative nature during diagenesis [30]. For the background values, the average concentrations of metals detected in control site were used according to the approach given by Benhaddya and Hadjel [13]. EF values of unity or very close to unity shows that the heavy metal originated from natural sources. Values not up to 1.0 signify depletion or mobilization of trace metals, and values more than 1.0 implies that the trace metal is from an anthropogenic source [22, 31]. Values greater than 1.0 are further interpreted and classified into different categories according to Birth [32], these include; no enrichment if EF is < 1, minor enrichment if EF is < 3, moderate enrichment if EF is from 3 to 5, moderate severe enrichment if EF is from 5 to 10, severe enrichment if EF if from 10 to 25, very severe enrichment if EF if from 25 to 50, and extremely severe enrichment if EF is > 50.

2. **Geo-accumulation index (Igeo)**
Igeo index estimates contamination level by comparing present and the preindustrial concentrations level [13]. In this study, Igeo was also used to evaluate the contamination level of ABAUD soils by employing Equation 2 proposed by Muller [33].

$$\text{I}_{\text{geo}} = \log_2 \left(\frac{\text{C}_{\text{m}}}{1.5 \text{ x } \text{C}_{\text{b}}} \right) \quad (2)$$

C_{m} and C_{b} = trace metals concentration in soil samples and natural background respectively. The constant value 1.5 is a feasible alteration reference value to reduce the effect of possible variation in the background value. Levels of contamination are classified as; unpolluted for Igeo ≤ 0, unpolluted to moderately polluted for Igeo between (0–1), moderately polluted for Igeo between (1–2), moderately to strongly polluted for Igeo between (2–3), strongly polluted for Igeo between (3–4), strongly to very strongly polluted for Igeo between (4–5) and very strongly polluted for Igeo = 5.

3. **Potential ecological risk index (RI)**
This risk index (RI) was used to evaluate the ecological risk of trace metal contamination in soils by considering metals toxicity and the response to the environment. This is given by Equations 3, 4 and 5, and was originally given by Hakanson in 1980 [13, 34].

$$\text{RI} = \sum E_i \quad (3)$$

$$E_i = T_i * f_i \quad (4)$$

$$f_i = C_i/B_i \quad (5)$$

Ei is the potential ecological risk factor, *fi* is the pollution factor for metals, *Ci* is the concentration of metals in soil, *Bi* is the natural background value of metals and *Ti* is metal toxic factor. As given by Duodu et al.,[35]; the value of *Ti* for Mn and Zn = 1, Cr = 2, & Cu and Pb =5 [34, 35]. The four (4) categories of RI used in this study are; RI ≤ 50 for low contamination, 50 < RI ≤ 100 for moderated contamination, 100 < RI ≤ 200 for considerable contamination, and RI > 200 for high contamination.

4. **Pollution index (PI) and integrated pollution load index (IPI)**
These important indexes assess the contamination level of heavy metals in soils for each metal and total metals under consideration respectively. According to Chen et al, 2005 [15], PI is evaluated as the ratio of the concentration of each metal to the background value of the corresponding metal. This is given in Equation 6, where C_m is the measured concentration of each heavy metal, and C_b is the corresponding background value which is taken in this study as the mean concentrations of the corresponding heavy metal in unaffected soils (control site).

Table 1. Sampling site and the associated activities

Site	Activity
AB1	Mainly residential staff quarters
AB2	Installed and functioning university central power generating set
AB3	Installed and functioning staff quarter's power generating set
AB4	College of Social & management sciences/college of engineering transport pool
AB5	Senate building transport pool and new building construction site
AB6	College of engineering central workshop which comprises of welding section, automobile section, lathe machine section and other machine tools sections
AB7	University central works department which comprises of welding section, auto-mechanic's section, vulcanizing section, plumbing section, etc.
AB8	University filling station
AB9	Various business activities such as restaurant and cafeteria, supermarket, printing press, pure water factory, barbecue and other outdoor roasted food spots
AB10	Barbecue fish, meat, fried yam and other outdoor roasted food spots
AB11	Control site not shown on the Map

The contamination level for each metal can be categorized as; low, medium and high contamination when PI ≤ 1, 1 < PI ≤ 3, and PI > 3 respectively [13, 15].

$$PI = \frac{C_m}{C_b} \quad (6)$$

IPI as a criterion for evaluating soil pollution can be estimated as the mean PI of all estimated heavy metals. It can be categorized as; extremely high pollution level, high pollution level, moderate pollution level and low pollution level when IPI > 5, 2 < IPI ≤ 5, 1 < IPI ≤ 2 and IPI ≤ 1 respectively.

3. Results and discussion

Descriptive statistics of Cr, Cu, Zn, Pb and Mn detected in the soil of the studied university are given in Table 3. The Table also presents World Health Organization (WHO) and Standard Guidelines in Europe limits for trace metals in soils [36]. Table 2 presents the mean values for all the sampling sites. Minimum and maximum concentration of Cr, Cu, Zn, Pb and Mn were 0.2 & 1.75, 0.39 & 1.11, 0.02 & 0.70, 0.03 & 9.40, and 0.09 & 1.03 mg/g respectively, and their mean concentrations were 0.75, 0.66, 0.36, 1.37, and 0.49 respectively. The mean concentration of the considered heavy metals in the university soil follow the trend of Pb > Cr > Cu > Mn > Zn. The average concentration of Zn (0.36 mg/g) was found to be slightly higher than the permissible limit while Mn (0.49 mg/g) was below the limit. Average concentration of Cr (0.75 mg/g), Cu (0.66 mg/g), and Pb (1.37 mg/g) were found to be more than the limit. This may be attributed to the effects from different human activities or the high nature of the corresponding natural background value [11, 36]. Considering the average concentration of heavy metals and their corresponding natural background value, Mn concentrations was comparable, where Cr, Cu, Zn and Pb concentration were more than the natural background value. They were approximately of the ratio 1:7, 1:2, 1:3 and 1:2 respectively. The standard deviation and standard error for Cu, Zn, Cr and Mn were high while value of Pb was very high. This showed that the concentration of the heavy metals varied greatly across the university and this may be attributed to non-uniform dispersion in the soil [11, 37]. Cr and Pb showed high sample variation and this indicated high human influence on the concentrations [11, 38].

Furthermore, the mean concentration of metals reported in this study was generally higher than those detected in soils from some urban and industrialized areas such as Hassi Messaoud in Algeria; Bangkok in Thailand; Madrid in Spain; Hong Kong in China etc. Concentration of Cu, Pb and Zn in Hassi Messaoud (0.01317, 0.13097 and 0.061 mg/g) [11], Bangkok (0.0417, 0.0478 and 0.118 mg/g) [39], Madrid (0.072, 0.161 and 0.21 mg/g) [40] and Hong Kong (0.0233, 0.0946 and 0.125) [41] were low compared to 0.66, 1.37 and 0.36 mg/g for this study. This may be as a result of the high natural background value of metals in the soil of the present study area [11]. Also, this may be associated with the nature of the activities taken place in ABUAD. The university has automobile workshop and machines workshop which are constantly in use for training purposed. Thus, generating related heavy metals contamination.

Moreover, comparing results from the present study with the assessment of metal contamination in sediment samples collected from Lagos dockyard harbour by Basheeru et al [42], the contamination level of lagoon sediment with lead and copper is higher compared to the contamination level of ABUAD soils. In another work carried out by some researchers on estuary sediments from Olonkoro river, Oyo state, Nigeria [43], it was found that the concentration level of Zn, Cu, Zn, and Mn were also higher. This is because different industrial and domestic effluent are been discharged into the harbor and the river

Table 2. Average values of selected trace metals at each sampling site

Sampling point	Heavy metal concentrations (mg/g)				
	Cr	Cu	Zn	Pb	Mn
AB1	0.73±0.04	0.70±0.01	0.13±0.03	2.65±0.15	0.84±0.05
AB2	0.42±0.22	0.92±0.19	0.24±0.23	2.02±0.38	0.63±0.21
AB3	1.33±0.42	0.58±0.06	0.28±0.10	1.02±0.58	0.38±0.16
AB4	0.31±0.07	0.42±0.03	0.45±0.26	5.26±4.13	0.76±0.14
AB5	0.72±0.02	0.68±0.29	0.28±0.09	0.38±0.09	0.29±0.04
AB6	0.65±0.05	0.48±0.04	0.41±0.07	0.06±0.04	0.19±0.01
AB7	0.77±0.57	0.74±0.18	0.19±0.05	0.23±0.05	0.41±0.32
AB8	0.74±0.38	0.65±0.13	0.52±0.02	1.13±0.38	0.49±0.01
AB9	0.77±0.23	0.59±0.07	0.42±0.20	0.49±0.15	0.65±0.29
AB10	1.05±0.07	0.94±0.05	0.63±0.05	1.28±0.05	0.10±0.01
Control site	0.32±0.22	0.46±0.12	0.12±0.00	1.12±0.36	0.41±0.01
Limits	0.100	0.100	0.300	0.100	2.000

Table 3. Descriptive statistical analysis of selected trace metals in ABUAD soil

S/N	Data analysis	Concentrations (mg/g)				
		Cr	Cu	Zn	Pb	Mn
1	Mean	0.75	0.66	0.36	1.37	0.49
2	Minimum	0.20	0.39	0.02	0.03	0.09
3	Maximum	1.75	1.11	0.70	9.40	1.03
4	SE	0.08	0.04	0.04	0.42	0.06
5	SD	0.38	0.21	0.21	1.97	0.30
6	SV	0.15	0.04	0.04	3.88	0.09
Control value		0.32	0.46	0.12	1.12	0.41
Permissible limit		0.10	0.10	0.30	0.10	2.00

SV sample variation, *SD* standard deviation, *SE* standard error

thereby contributing to their higher heavy metal level.

3.1. Heavy metal contents in different sampling sites

As given in Table 2, the average concentrations of Cu and Zn in different functional areas were more than their corresponding natural background value except Cu detected in site AB4. This is similar to the result obtained for soils in Hassi Messaoud, Algeria [11]. The average concentrations of Cr from different sites were also higher compared to their natural background value except for site AB4 which was lower, and site AB2 which was comparable to the background value. Also, the average concentrations of Mn were comparable to the natural background value in sites AB3 and AB7, lower in sites AB5, AB6 and AB10, and higher in all other sampling sites. Pb mean concentrations were below the natural value except for the residential area (AB1), the university central power generating set area (AB2), transport pool (AB4) and site AB10.

The study area is characterized by high automobiles and power generating sets, and the trace metals such as Mn, Pb, Cu, Cr and Zn selected for consideration in the present study are reported to be present as additives in lubricants and gasoline [22, 44]. Also, Pb, Cu and Zn are reported to be present in vehicular emissions, tires, wires, alloys, brake parts, etc. [18, 45-52].

Copper (Cu) present in soils from all sampling sites were higher than the natural background value (0.46 mg/g) except site AB4 which is comparable to the background value. The average concentrations ranged from 0.42 mg/g in site AB4 to 0.94 mg/g in site AB10. These were all higher than the permissible limit (0.1 mg/g) and may be attributed to the higher natural background value. Also, it is notable that electrical and electronic parts of automobile wastes and alloys from corroding metal parts that have possibly leached into the soil of these various sites can be attributed to the high Cu present [53].

Average values of Pb in soils from sampling site AB1 (2.65 mg/g), AB2 (2.02 mg/g), AB4 (5.26 mg/g) and AB10 (1.28 mg/g) were notably higher compared to the corresponding background value (1.12 mg/g). This suggested that combustion engine emissions, spill waste oils and expired motor batteries from the high number of automobiles that cluster site AB1, AB4 and AB2 can be responsible for the high Pb concentration in these areas. This is similar to the result obtained for a study carried out by a group of researchers in Ilorin, Nigeria [54]. In the study, Pb concentration was higher compared to Cu and Cd. Higher Pb level in the study was suggested to have been influenced by traffic volume and exhaust from motor vehicles.

The mean Zn content in all soils from different sites ranged from 0.13 mg/g in site AB1 to 0.63 mg/g in site AB10. These were all greater than the natural background value (0.12 mg/g).

Also, average values from sites AB4, AB6, AB8, AB9 and AB10 were more than the given limit. This indicated that the activities from the different functional areas such as automobiles, machines workshops, petrol station and others are responsible for the high Zn content.

Cr concentrations at different sites ranged from 0.31 mg/g in site AB4 to 1.33 mg/g in site AB3. The values were all higher than the permissible limit of Cr and were also more than the natural value (0.32 mg/g) except site AB4 which is comparable to the background value. The low level of Cr in site AB4 suggested that Cr emissions were not much from the transport pool since the vehicles were always packed without any emission during the working hours and also the pool is a paved area, while high Cr concentration in other areas indicated the effects of anthropogenic activities in such areas.

Mn detected in all sampling sites was lower in concentration compared to its permissible limit. However some areas like AB1, AB2, AB4, AB8 and AB9 shows higher Mn content compared to the natural background value. This indicated that activities from automobiles, machines workshops, power generators and petrol station in these areas were responsible for the high Mn content.

3.2. *Source identification*

Principal component analysis (PCA), a multivariate receptor model analysis is applicable for contamination sources identification [55-56]. XLSTAT, a statistical software for Microsoft Excel was used in the present study for the source identification and contributions of the selected metals to the contamination level of ABUAD soils. Typical PCA score plot will have variables with the similar source located close to each other, while those with divergent sources will be far apart [57]. Figure 2 shows the PCA variable plot with a cumulative variance of 75.66% where factor 1 (F1) accounts for 45.60% and factor 2 (F2) 30.06% of the total variance. Variables that are close to each other and far from the centre as shown in Figure 2 are considered to be significantly positively correlated. Also, variables located on opposite sides are significantly negatively correlated and those located orthogonally are considered not correlated.

Also, Figure 2 shows that there is proximity between samples taken from the same site, such as samples taken within sites AB4, AB5, AB6, AB8 and AB10. This inferred that the contaminations within these sites were from the same source. There is low proximity for samples taken within sites AB3 and AB7 which implies that the contaminations on these sites may be from different sources. This is evident from the composition of the areas. Site AB7 comprises of welding workshop, auto-mechanic workshop, vulcanizing workshop and plumber workshop, and site AB3 which has functional power generating set installed on it is not too far from site AB7. Four samples were taken from site AB9 where some have proximity and some do not. This is because the site has various business activities and production plants such as restaurants and cafeterias, supermarkets, printing press, pure water factory, barbecue and other outdoor roasted food spots.

Therefore the result on the PCA variable plot implies that site with similar human activity has a single source of heavy metals while sites with various human activities have different sources of heavy metal contaminations. The PCA observation plot given in Figure 3 shows no cluster between the five selected heavy metals. This indicates that the heavy metals con-

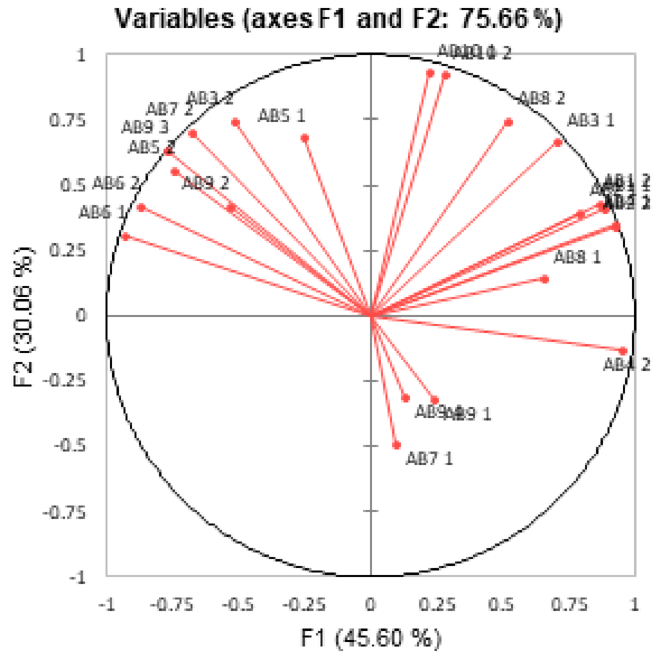

Figure 2. Variable plot for PCA

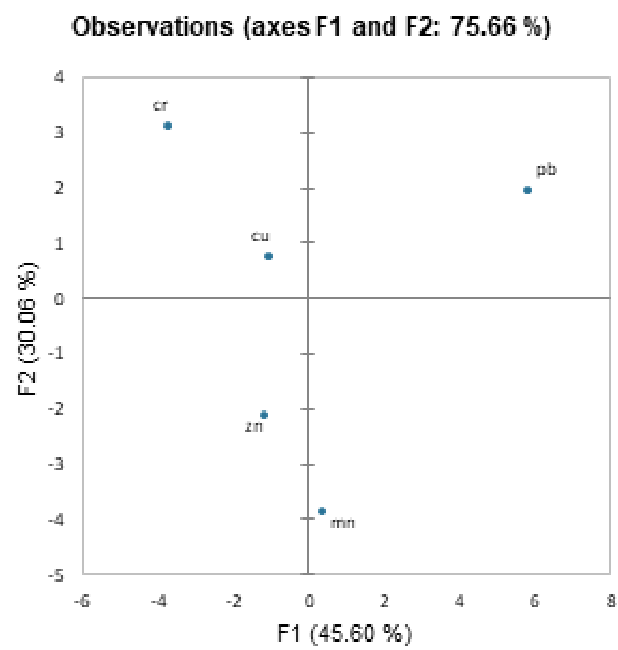

Figure 3. Observation plot of PCA indicating the positions of Cr, Cu, Pb, Zn and Mn

tamination originated from more than a single source, and these include automobiles, generators, petrol station, machine workshops, central works departments, production plants and other business activities.

3.3. Pollution assessment

1. **Enrichment factors (EF)**
   Enrichment factors (EFs) of Cu, Cr, Pb, Zn and Mn were considered to assess ABUAD soils contamination level (Fig. 4). The average EF of Cu (0.89), Pb (0.76) and Mn (0.73) were found to be less than one (1), while Cr (1.47) and Zn (1.82) were found slightly greater than one (1). This inferred no enrichment for Cu, Pb and Mn, and minor enrichment for Cr and Zn. Cr enrichment factor ranges from 0.56 to 3.12, Cu from 0.59 to 1.63, Zn from 0.67 to 4.34, Pb from 0.04 to 3.07 and Mn from 0.11 to 2.00. This result shows no enrichment or moderate enrichment for Cr, no enrichment or minor enrichment for Cu, no enrichment or moderate enrichment for Zn, no enrichment or moderate enrichment for Pb and no enrichment or minor enrichment for Mn. Site AB9 which comprises various business centres and production plants has Zn (4.34) as the metal with the highest enrichment.
2. **Geo-accumulation index (Igeo)**
   Igeo index was considered to estimate the ABUAD soils contamination level by comparing the preindustrial and present concentrations of heavy metals [13]. Figure 5 shows that the Igeo of all the selected metals in ABUAD soils does not exceed moderately polluted on an average level. Average Igeo of Cu (-0.07), Pb (-0.29) and Mn (-0.35) indicated unpolluted while Cr (0.65) and Zn (0.97) indicated moderately polluted. The highest Igeo value obtained in the present study is for Zn (1.77). This was detected on site AB10 which majorly comprises of Barbecue fish, meat, fried yam and other open roasted food spots. The findings from Igeo are in agreement with the EF values showing that the sampled environment is not highly contaminated.
3. **Potential ecological risk index (RI)**
   Ecological risk of the selected trace metal in ABUAD soils was assessed. Table 4 gives the risk index for the contamination caused by Cr, Cu, Pb, Zn and Mn in all sampled ABUAD soils as low contamination. This indicated that ABUAD soils may not be too sensitive to heavy metals contamination and the contamination level posed a low potential ecological risk. This is also in agreement with EI and Igeo assessments, showing that the sampled environment has a low level of contamination.
4. **Pollution index (PI) and integrated pollution load index (IPI)**
   Contamination level of ABUAD soils was also assessed using pollution index (PI) and integrated pollution load index (IPI). The summarized results are presented in Table 5. PI of Cr ranged from 0.99 to 4.18 and showed low contamination to high contamination. The given mean PI of 2.36 indicated medium Cr contamination of ABUAD soil. The highest PI of Cr was detected on site AB4 and this inferred possible contamination from gasoline and lubricant leakages from vehicles that dominated the area. A similar trend as noticed for Cr was also seen in Zn and Pb. The highest PI of 5.12 for Zn and 4.72 for Pb were detected on site AB10 and AB4 respectively and indicated high contamination. The high content of Zn and Pb in sites AB10 and AB4 respectively may be linked to the effect of activities in these areas. PI of Cu and Mn showed a similar trend. Their PI ranged from low contamination to medium contamination, and information on their average PI indicated medium contamination of ABUAD soils. Considering the IPI assessment, the mean value of 1.83 indicated a moderate pollution level of ABUAD soils. Signals were also given that sites AB4 and AB10 have high pollution levels. This is similar to the PI assessment of some heavy metals in these same locations.

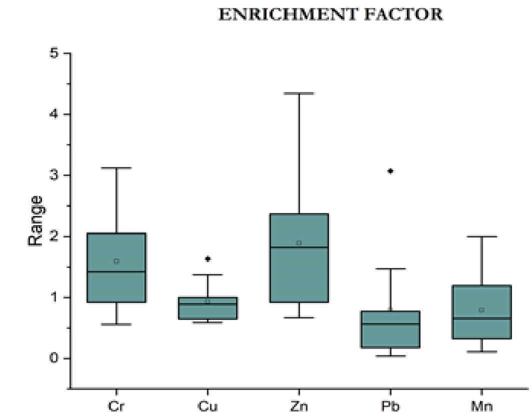

Figure 4. Enrichment factors for metals

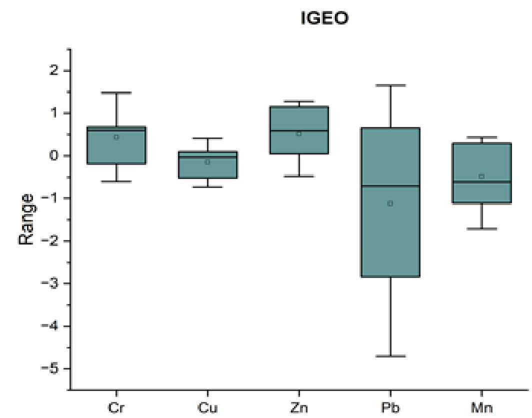

Figure 5. Geo-accumulation index (Igeo)

Table 4. Potential ecological risk indexes for heavy metals in ABUAD soils

Sampling point	E_i					***RI***	**Pollution degree**
	Cr	**Cu**	**Zn**	**Pb**	**Mn**		
AB1	4.59	7.59	1.07	11.89	2.02	27.15	Low
AB2	2.63	9.97	1.99	9.03	1.52	25.14	Low
AB3	8.36	6.24	2.26	4.58	0.91	22.36	Low
AB4	1.98	4.53	3.64	23.58	1.84	35.56	Low
AB5	4.54	7.33	2.26	1.68	0.70	16.51	Low
AB6	4.09	5.24	3.33	0.29	0.46	13.40	Low
AB7	4.81	8.02	1.55	1.05	0.98	16.41	Low
AB8	4.68	7.02	4.24	5.07	1.18	22.18	Low
AB9	4.81	6.36	3.39	2.21	1.56	18.33	Low
AB10	6.62	10.18	5.12	5.72	0.23	27.86	Low

Table 5. PI and IPI of heavy metals in ABUAD soil

Heavy metal	**PI**			**IPI**		
	Min	**Max**	**Mean**	**Min**	**Max**	**Mean**
Cr	0.99	4.18	2.36			
Cu	0.91	2.04	1.45			
Zn	1.07	5.12	2.88	1.35	2.42	1.83
Pb	0.06	4.72	1.30			
Mn	0.23	2.02	1.14			

4. Conclusion

Various assessment methods and tools were used to evaluate trace metals contamination levels of ABUAD soil. Twenty four (24) soil samples taken at a depth of about 0 to15 cm of the earth surface were collected using a standard soil auger from ten (10) different main functional sites, and were analyzed for Cu, Cr, Pb, Mn and Zn. Control samples were taken from an undeveloped area within ABUAD. These were also analyzed and served as natural background to the corresponding heavy metals collected from the different functional areas within the university. The minimum and maximum concentration of Cr, Cu, Zn, Pb and Mn were 0.2 and 1.75, 0.39 and 1.11, 0.02 and 0.70, 0.03 and 9.40, and 0.09 and 1.03 mg/g respectively, and the mean concentrations were 0.75, 0.66, 0.36, 1.37, and 0.49 mg/g respectively. Mn average concentration in ABUAD soil was comparable to natural background value; however Cr, Cu, Zn and Pb were higher than their corresponding background value and approximately of the ratio 1:7, 1:2, 1:3 and 1:2 respectively.

The multivariate statistical analyses indicated that staff and administrative vehicles, power generating sets, petrol station, machine workshops, central works department, production plants and various outdoor roasted food spots activities were the main sources of metal contamination. The results of EF, Igeo, RI, PI and IPI showed that the contamination level of ABUAD soil can be generally classified as low or moderately contaminated. Also, according to some of the indices, contamination attributed to Zn and Pb were found to be slightly high in sites AB4, AB9 and AB10. This can be linked to possible contamination from gasoline and lubricant leakages from vehicles that dominated site AB4, and various outdoor roasted food spots together with the production plants located in site AB10 and AB9 respectively.

The present study considered a university which is a community that is usually associated with a high number of people. Contamination of university soils by trace metals is of great risks and hazards to the immediate ecosystem if not properly handled. Exposure to heavy metals is usually by; dermal contact with suspended dust and soil particles and inhalation/ingestion absorption pathways. Therefore, periodic assessment of the sources and associated ecological risks of the heavy metals is highly recommended. This is to enable decision-makers to effectively manage the environment in the manner that will preserve public and ecosystem health.

Acknowledgments

We thank the referees for the positive enlightening comments and suggestions, which have greatly helped us in making improvements to this paper.

References

[1] P. B. Tchounwou, C. G. Yedjou, A. K. Patlolla & D. J. Sutton, "Heavy metals toxicity and the environment", NIH-RCMI Center for Environmental Health, College of Science, Engineering and Technology, EXS. **101** (2014) 133, https://dx.doi.org/10.1007/978-3-7643-8340-4_6.

[2] Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profile for Lead, U.S. Department of Health and Human Services, Atlanta (2007).

[3] R. K. Gautam, S. K. Sharma, S. Mahiyab & M. C. Chattopadhyaya, "Heavy metals in water: presence, removal and safety", Royal Society of Chemistry (2014), https://dx.doi.org/10.1039/9781782620174-00001.

[4] A. Kabata- Pendia, *Trace Elements in Soils and Plants (3rd edition)*, CRC Press; Boca Raton, FL (2001).

[5] J. L. Hamelink, P. F. Landrum, B. L. Harold & B. H. William, "Bioavailability: Physical, Chemical, and Biological Interactions", Boca Raton, FL: CRC Press Inc (1994)

[6] J. A. Verkleji, "The effects of heavy metals stress on higher plants and their use as biomonitors in Plant as Bioindicators: Indicators of Heavy Metals in the Terrestrial Environment", Markert, B., editor. New York: VCH (1993) 15.

[7] Z. L. He, X. E. Yang & P. J. Stoffella, "Trace elements in agro ecosystems and impacts on the environment", J Trace Elem Med Biol. **19** (2005) 125.

[8] H. Bradl, *Heavy metals in the environment: origin, interaction and remediation*, Academic Press, London (2002).

[9] S. K. Pal & R. Roy, "Evaluating heavy metals emission' pattern on road influenced by urban road layout" Transportation Research Interdisciplinary Perspectives **10** (2021) 100362.

[10] I. O. Olowofila, "Assessment of heavy metals concentrations around automobile mechanic workshops in Ilaro, Ogun State", International Journal of Women in Technical Education and Employment (IJOWITED) **2** (2021).

[11] M. Dogra, M. Sharma, A. Sharma, A. Keshavarzi, R. Minakshi, Bhardwaj, A. K. Thukral & V. Kumar, "Pollution assessment and spatial distribution of roadside agricultural soils: a case study from India", International Journal of Environmental Health Research (2019) 1369, https://doi.org/10.1080/09603123.2019.1578865.

[12] D. Y. Shinggu, "Analysis of roadside dust for heavy metal pollutants in Jimeta/Yola, Adamawa State", International Research Journal of Pure & Applied Chemistry **4** (2014) 670.

[13] M. L. Benhaddya, M. & Hadjel, "Spatial distribution and contamination assessment of heavy metals in surface soils of Hassi Messaoud", Environ Earth Sci. (2013), https://dx.doi.org/10.1007/s12665-013-2552-3.

[14] C. Li, F. Y. Lu, Y. Zhang, T. W. Liu & W. Hou, "Spatial distribution characteristics of heavy metals in street dust in Shenyang city", Ecol Environ. **17** (2008) 560.

[15] T. B. Chen, Y. M. Zheng, M. Lei, Z. C. Huang & H. T. Wu, "Assessment of heavy metal pollution in surface soils of urban parks in Beijing, China", Chemosphere **60** (2005) 542.

[16] R. A. Wuana & F. E. Okieimen, "Heavy metals in contaminated soils: a review of sources, chemistry, risks and best available strategies for remediation", International Scholarly Research Network, ISRN Ecology **2011** (2011). https://dx.doi.org/10.5402/2011/402647.

[17] T. A. Kirpichtchikova, A. Manceau, L. Spadini, F. Panfili, M. A. Marcus & T. Jacquet, "Speciation and solubility of heavy metals in contaminated soil using X-ray microfluorescence, EXAFS spectroscopy, chemical extraction, and thermodynamic modelling", Geochim Cosmochim Acta **70** (2006) 2163.

[18] V. M. Ngole-Jeme, "Heavy metals in soils along unpaved roads in south west Cameroon: contamination levels and health risks", Ambio. **45** (2015) 374, https://dx.doi.org/10.1007/s13280-015-0726-9.

[19] X. Xinghui, C. Xi, L. Ruimin & L. Hong, "Heavy metals in urban soils with various types of land use in Beijing, China", J Hazard Mater. **186** (2011) 2043.

[20] S. Rodrigues, M. E. Pereira, L. Sarabando, L. Lopes, A. Cachada & A. Duarte, "Spatial distribution of total Hg in urban soils from an Atlantic coastal city (Aveiro, Portugal)", Sci Total Environ. **368** (2006) 40.

[21] A. A. Adebayo, J. T Jayoye, F. Adejoro, I. O. Ilemobayo & L. Labunmi, "Heavy metal pollution of auto-mechanic workshop soils within Okitipupa, Ondo State, Nigeria", Academia Journal of Environmental Science **5** (2017) 215, https://dx.doi.org/10.15413/ajes.2017.0131.

[22] I. A. Ololade, "An Assessment of heavy-metal contamination in soils within auto-mechanic workshops using enrichment and contamination factors with geoaccumulation indexes", Journal of Environmental Protection **5** (2014) 970, http://dx.doi.org/10.4236/jep.2014.511098.

[23] M. A. Lala, O. A. Adesina, A. S. Yusuff, L. A. Jimoda & J. A. Sonibare, "Air quality index pattern of criteria air pollutants around a haulage truck stop", Petroleum & Coal. **60** (2018) 1072.

[24] J. O. Coker, A. A. Rafiu, N. N. Abdulsalam, A. S. Ogungbe, A. A. Olajide & A. J. Agbelemoge, "Investigation of groundwater contamination from Akanran open waste dumpsite, Ibadan, south-western Nigeria, using geoelectrical and geochemical techniques', Journal of the Nigerian Society of Physical Sciences **3** (2021) 89, https://doi.org/10.46481/jnsps.2021.166.

[25] G. M. S. Abrahim & P. J. Parker, "Assessment of heavy metal enrichment factors and the degree of contamination in marine sediment from Tamaki Estuary, Auckland, New Zealand", Environ. Monit. Assess. **136** (2008) 227.

[26] B. Rubio, M. A. Nombela & F. Vilas, "Geochemistry of major and trace elements in sediments of the Ria de Vigo (NW Spain): an Assessment of metal pollution", Marine Pollution Bulletin **40** (2000) 968, http://dx.doi.org/10.1016/S0025-326X(00)00039-4.

[27] S. R. Taylor, "Abundance of chemical elements in the continental crust: a new table", Geochim Cosmochim Acta **28** (1964)1273–1285.

[28] I. A. Ololade, L. Lajide & I. A. Amoo, "Enrichment of heavy metals in sediments as pollution indicator of the aquatic ecosystem", Pakistan Journal of Scientific and Industrial Research **50** (2007) 27.

[29] S. E. Kakulu, "Heavy Metals in the Niger Delta: Impact of Petroleum Industry on the Baseline Levels", Ph.D. Thesis University of Ibadan, Ibadan (1985).

[30] P. M. Chapman & F. Wang, "Assessing sediment contamination in Estuaries", Environmental Toxicology and Chemistry **20** (2001) 3, http://dx.doi.org/10.1002/etc.5620200102.

[31] P. Zsefer, G. P. Glasby, K. Sefer, J. Pempkowiak & R. Kaliszan, "Heavy-metal pollution in superficial sediments from the Southern Baltic sea off Poland **31** (1996) 2723.

[32] G. A. Birth, A scheme for assessing human impacts on coastal aquatic environments using sediments, Wollongong University Papers in Centre for Maritime Policy, Wollongong **14** (2003).

[33] G. Muller, "The heavy metal pollution of the sediments of Neckars and its tributary: a stock taking", Chemiker-Zeitung. **105** (1981) 157.

[34] L. Hakanson, "An ecological risk index for aquatic pollution control—a sediment ecological approach", Water Res. **14** (1980) 975.

[35] G. O. Duodu, A. Goonetilleke & G. A. Ayoko, "Comparison of pollution indices for the assessment of heavy metal in Brisbane River sediment", Environ Pollut. **219** (2016) 107, https://doi.org/10.1016/j.envpol.2016.09.008.

[36] T. M. Chiroma, R. O. Ebewele & F. K. Hymore, "Comparative assessement of heavy metal levels in soil, vegetables and urban grey waste water used for irrigation in Yola and Kano", International Refereed Journal of Engineering and Science (IRJES) **3** (2014) 01.

[37] D. Arenas-Lago, F. A. Vega, L. F. Silva & M. L. Andrade, "Copper distribution in surface and subsurface soil horizons", Environ Sci Pollut Res. **21** (2014) 10997.

[38] L. Cai, Z. Xu, P. Bao, M. He, L. Dou, L, Chen, Y. Zhou & Y. G. Zhu, "Multivariate and geostatistical analyses of the spatial distribution and source of arsenic and heavy metals in the agricultural soils in Shunde, Southeast China", J Geochem Explor. **148** (2015) 189, https://doi.org/10.1016/j.gexplo.2014.09.010.

[39] W. Wilcke, S. Muller, N. Kanchanakool & W. Zech, "Urban soil contamination in Bangkok: heavy metal and aluminium partitioning in top soils", Geoderma **86** (1998) 211.

[40] E. De Miguel, M. Jimenez de Grado, J. F. Llamas, A. Martιn-Dorado & L. F. Mazadiego, "The overlooked contribution of compost application to the trace element load in the urban soil of Madrid (Spain)", Sci Total Environ. **215** (1998) 113.

[41] X. D. Li, S. L. Lee, S. C. Wong, W. Z. Shi, & I. Thornton, "The study of metal contamination in urban soils of Hong Kong using a GIS based approach", Environ Pollut. **129** (2004) 11.

[42] K. A. Basheeru, H. K. Okoro, F. A. Adekola & N. Abdussalam, "Mobility and sequential extraction of potentially toxic elements in sediment of Lagos lagoon", Chemistry-Africa. Published by Springer International Publishing (2021), (Springer Nature Switzerland AG 2019).

[43] H. K. Okoro, J. O. Ige, O. A. Iyiola & J. C. Ngila," Fractionation profile, mobility patterns and correlations of heavy metals in estuary sediments from Olonkoro River, in tede catchment of western region, Nigeria", Environmental Nanotechnology, Monitoring & Management. Published by Elsevier Inc., Science Direct Academic Press **8** (2017) 53, https://doi.org/10.1016/j.enmm.2017.04.003.

[44] H. D. Sharma & K. R. Reddy, *Geo-environmental engineering: site remediation, waste containment and emerging waste management technologies*, John Wiley, New Jersey (2004).

[45] P. K. Hopke, R. E. Lamb & D. F. S. Natusch, "Multi-elemental characterization of urban roadway dust", Environmental Science and Technology **14** (1980) 164.

[46] Q. M. Jaradat & K. A. Momani, "Contamination of roadside soil, plants and air with Heavy metals in Jordan, a comparative study", Turkish Journal of Chemistry **23** (1999) 209.

[47] A. P. Davis, M. Shokouhian & S. Ni, "Loading estimates of lead, copper, cadmium, and zinc in urban runoff from specific sources" Chemosphere **44** (2001) 997.

[48] J. Nouri & K. D. Naghipour, "Qualitative and quantitative study of heavy metals in runoff of highways of Tehran", Iranian Journal of Public Heallth **31** (2002) 1.

[49] J. Sternbeck, A. Sjodin & K. Andreasson, "Metal emissions from road traffic and the influence of resuspension: Results from two tunnel studies", Atmospheric Environment **36** (2002) 4735.

[50] I. Oguntimehin & K. O. Ipinmoroti, "Profile of heavy metals from automobile workshops in Akure, Nigeria", J. Eviron. Sci. Technol. **1** (2008) 19.

[51] J. N. Ugwu, C. O. B. Okoye & C. N. Ibeto, "Impacts of vehicle emissions and ambient atmospheric deposition in Nigeria on the Pb, Cd, and Ni content of fermented cassava flour processed by sun-drying", Human and Ecologic Risk Assessment **17** (2011) 478.

[52] S. P. Raj & P. A. Ram, "Determination and contamination assessment of Pb, Cd, and Hg in roadside dust along Kathmandu- Bhaktapur road section of Arniko Highway, Nepal", Research Journal of the Chemical Sciences **3** (2013) 18.

[53] M. A. Nwachukwu, H. Feng & J. Alinnor, "Trace metal deposition in soil from auto-mechanic village to urban residential areas in Owerri, Nigeria", Proc. Environ. Sci. **4** (2011) 310.

[54] H. K. Okoro, O. T. Ogunsemoyin & A. A. Mohammed, "Assessment of heavy metal pollution on roadside dusts from selected locations in Ilorin, Nigeria using AAS techniques", Adamawa State University Journal of Scientific Research **04** (2016) 1.

[55] C. S. Lee, X. D. Li, W. Z. Shi, S. C. Cheung & I. Thornton, "Metal contamination in urban, suburban, and country park soils of Hong Kong: a study based on GIS and multivariate statistics", Sci Total Environ. **356** (2006) 45.

[56] Y. M. Zheng, T. B. Chen & J. Z. He, "Multivariate geostatistical analysis of heavy metals in topsoils from Beijing, China", J Soil Sediment **8** (2008) 51.

[57] W. S. Lee, G. P. Chang-Chien, L. C. Wang, W. J. Lee, P. J. Tsai, K. Y. Wu & C. Lin, "Source identification of PCDD/fs for various atmospheric environments in a highly industrialized city", Environ Sci Technol. **38** (2004) 4937.