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Assessment of anthropogenic influence on the level of selected heavy metals (Cu, Zn, Cd and Pb) in soil

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The study aimed at assessing potential influence of anthropogenic activities on the level of selected toxic heavy metals in soil in Tsumeb Township, Namibia. This was with a view of evaluating possible implications on human health and across the food chain. Soil samples were randomly collected from stratified areas and taken to the laboratory for pre-treatment and analysis. Soil metallic contents were extracted using acid digestion technique and were quantified using ICP-OES. Experimental protocol was validated using the standard metal addition techniques and was found to be applicable with quantitative metallic recoveries (n= 3) in the range of 85-90%. The overall mean concentration of analysed metals in soil samples ranged from 39.0 - 2532.8 mg/kg (Cu); 59.5- 1994.8 mg/kg (Zn); 1.7-21.3 mg/kg (Cd) and 1.2-141 mg/kg (Pb) across SCP1-SCP4. The analysed metals increased variedly at the SCPs in the order Cu: SCP1>SCP2>SCP4>SCP3; Zn: SCP1>SCP2>SCP4> SCP3; Cd: SCP1>SCP2>SCP3>SCP4; Pb: SCP1>SCP2>SCP3>SCP4. Hence, highest or most profound anthropogenic influence was observed at SCP1 for all metals while the lowest was as SCP4. Strong metallic correlation (r > 0.99) was obtained between all analysed metals and some significant above threshold metallic levels in soil were obtained for Cu and Zn but most worrisome was the high level of Cd obtained in soil. Possible uptake of these metals by plants and transfer across the food chain is highly probable.

Key words: Heavy metals, soil, human health, anthropogenic, ICP-OES, Namibia.

INTRODUCTION

The prevalence of toxic heavy metals such as Cd, As, Pb, Zn, Cu and others in the ecosystems at elevated levels continues to be of great concern in view of the health implications. The earth crust is known to contain natural level of heavy metals (Singh et al., 2011). However, as a result of rapid development and industrialization, anthropogenic activities have introduced substantial amount of these metals into the environment at an unprecedented rate (Armah et al., 2014). These activities include mining operations, metal foundries, vehicular use, petrochemicals and agricultural such use application of inorganic fertilizers, sewage sludge, pesticides and others. Heavy metals that are mostly found as a result of soil contamination by these activities include copper (Cu), zinc (Zn), lead (Pb), cadmium (Cd), manganese (Mn) chromium (Cr) mercury (Hg), arsenic

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(As) and some others (Tahar and Keltoum, 2011; Yan et al., 2012; Aslam et al., 2013).Some of these metals such as Cadmium (Cd) and Arsenic (As) have no physiological benefits; hence their transfer across the food chain and resultant health implication forms the basis of concern. The concerns are justified since Cd is a known endocrine disruptor in human (Kartenkamp, 2011) while lead (Pb) has been implicated in the disruption of gene expression (Gillis et al., 2012). Hence, the interest in monitoring the level and distribution of these metals in the ecosystems including the soil is of utmost importance.

Soil has been described as sink for heavy metals that are released into the environment due to anthropogenic activities (Cheng et al., 2013). The concern about the prevalence of these toxic metals in the environment is exacerbated by their potential for inter-ecosystem mobility. Enrichment of the aquatic bodies by heavy metals as a result of surface soil erosional process has been reported (Wantzen and Mol, 2013; Issaka and Ashraf, 2017). Soil contamination by heavy metals will continue to be of great concern as a result of the health implications on human and wildlife. The implications are reflected through the uptake of these metals by plants, the consumption of metal laden plants by ruminants and the eventual consumption of ruminant by human. Consumption of contaminated water as well as inhalation dust particles are other routes of exposure. Hence, continual monitoring and assessment of these toxic metals in soil is of great importance in view of the fact that soil continues to be viewed as a repository of heavy metals (Cai et al., 2012).

The anthropogenic generated or forms of these heavy metals in soil tend to be more mobile and readily bioavailable when compared to the pedogenic or lithogenic forms (Kaasalainen and Yli-Halla, 2003). As a result of this bioavailability, the metals can be taken up by plants with further distribution and accumulation across the food chain. The migration or transfer of heavy metals from soil to other organisms such as lower animals (Lavelle et al., 2004; Ting-li et al., 2014) and plants (Lato et al., 2012; Aktaruzzaman et al., 2013) have been reported. Soil metallic burden will eventually affect the sustenance and livelihood of lower organisms such as earthworm, insects and others.

Therefore, these lower organisms are frequently used as indicator organisms of soil heavy metals burden due to their close contact and dependence on this ecosystem. Several organisms such as earthworms, insects and plants that are in close contact with soil have been used as environmental indicators of the level of heavy trace metals level (Awofolu, 2005; Karadjova and Markova, 2009; Aleagha and Ebadi, 2011; Steindor et al., 2016). Related studies also reveal inter-ecosystem migration of trace metals from terrestrial (soil) to aquatic (Pelfrene et al., 2009; Lynch et al., 2014) and the atmospheric (Perin et al., 2012) ecosystems.

In view of the environmental and human health implications of the prevalence and mobility of these toxic heavy metals, this study aimed at assessing the influence of anthropogenic activities on the level of selected trace metals (Cu, Zn, Cd and Pb) in soil from a local municipal area of Namibia. Several commercial and industrial activities that could potential influence the metallic level and distribution are located in the area.

MATERIALS AND METHODS

Study area

The study was conducted in the local municipal area of Tsumeb in the Northern part of Namibia. The geographic description of the area is: altitude of 1, 266 m, latitude -19, 2333 (1913'59.880''S) and longitude 17, 7167 (1743'0.120''E). The study area was stratified into four stratum and samples collected randomly from each stratum named as sample collection points (SCPs). Hence the location of SCP 1:S19° 13' 58.8"; E017° 42' 35.7"; SCP 2: S 19° 14' 41.7"; E 017°43' 12.0"; SCP 3: S19° 15' 21.6"; E 017° 42' 08.5" and SCP 4: S19° 15' 38.5"; E 017° 42' 43.2".

Samples and sampling process

Soil samples to the depth of about 100 mm were collected randomly from each sample collection site (SCS) with the aid of clean stainless steel soil trowel. The trowel was washed and rinsed properly with water after each sampling.

Soil samples were collected from the four different sites represented as SCP1, SCP2, SCP3 and SCP4 between the periods of June to November 2015 using stratified random sampling within each stratum. Six different sampling periods (SPs) was undertaken between July and Nov 2015 with a view of assessing possible trend and variation in trace metal level across sampling periods and within sample collection sites. Control samples were collected from an area in Windhoek which is about 350 km distance away from the sampling site. This are is characterised by very low anthropogenic activities. These were placed in transparent plastic zipper bags, labelled and taken to the laboratory for further treatment and analysis.

Sample treatment and analysis

Soil samples were oven dried at 30°C for 12 h and then grinded gently in an acid washed mortar and pestle and then passed through a sieved with 0.63 um pore size. All metal determinations were based on the final fine powdery samples. The metallic content of soil samples were extracted using acid digestion technique as previously described by Awofolu (2005). Briefly, about 5 g of soil samples was placed in 100 mL beaker and 3 mL of 30% H_2O_2 was added. This was left to stand for about 1 h until the vigorous reaction ceased. 75 mL of 0.5 M solution of HCl was then added and the content heated gently at low heat on the hot plate for about two hours. The digest was allowed to cool and then filtered into 50 mL standard flask. Triplicate digestion of each sample together with blank was also carried out. Quality assurance of the analytical process was by standard metal addition and quantification in all cases was by Inductively-Coupled Plasma Optical Emission Spectroscopy (ICP-OES).

Statistical analysis

Possible relationship between analysed trace metals was

Table 1. Mean concentration of trace metals (mg/kg) in soil samples at SCP 1 across the six sampling periods in July 2015.

Sampling period (SPs)	Trace metals			
	Cu	**Zn**	**Cd**	**Pb**
SP 1	1999.5	1724	16.0	97.8
SP 2	3755	3135	31.7	188.9
SP 3	2695.5	2230	14.3	173.4
SP 4	1852	1312	18.5	146.1
SP 5	1785	1323	17.5	121.9
SP 6	3110	2397	29.8	117.6

CSP = Sample collection point; SP = Sampling period.

Table 2. Mean concentration of trace metals (mg/kg) in soil samples at SCP 2 across the six sampling periods in August 2015.

Sampling period (SPs)	Trace metals			
	Cu	**Zn**	**Cd**	**Pb**
SP 1	115.8	131.8	6.1	84.5
SP 2	123.6	103.5	4.3	61
SP 3	116.5	66.5	3.3	47.9
SP 4	86.7	58.0	2.2	36.5
SP 5	180.9	117.7	5.8	91.6
SP 6	185.4	120.7	3.4	50.5

CSP = Sample collection point; SP = Sampling period.

determined from the mean metal concentration across the six sampling periods for the four sample collection point (SCP1-4) using the Pearson Correlation Coefficient. The heavy metal contamination factor (CF) was calculated from the ratio of the mean concentration of each metal to that obtained from the control site (CS) in order to assess the extent of contamination at the sample collection site.

$CF = X/CS$

Where X = mean metal concentration; CS mean metal concentration at control site. CF value of < 1 is regarded as low; between 1 and 3 = moderate; from 3 to 6 = appreciable contamination while > 6 = high contamination.

The pollution load index (PLI) provides an estimate of metal contamination status and was determined as previously described by Tomlinson et al. (1980) and Likuku et al. (2013) and expressed as:

$PLI = (CF_1 \times CF_2 \times CF_3 \ldots. CF_n)^{1/n}$

PLI values that is < 1 signify pristine (no pollution) condition; when PLI = 1, it shows minimal or baseline level of pollution while PLI > 1 indicates gross contamination or deterioration in soil quality (Tomlinson et al., 1980). The Analysis of variance (ANOVA) at $P < 0.05$ was also carried out in order to evaluate whether variation in data between the heavy metals and sampling sites is significant or not significant.

RESULTS

Elevated levels of toxic trace metals in soil can be attributed to anthropogenic activities. Hence, assessment of the level of analysed metals in soil from the study area where potential impactors are located. This was with a view of examining possible anthropogenic influence on metal soil enrichment and potential implication across the food chain. The quality assurance of an experimental process is important in order to check the applicability of the method for sample analysis. Hence result of this process, represented by percentage metal recoveries were in order of 90.4% (Cu); 90.1% (Zn); 85.5% (Cd) and 89.6% (Pb).

Level of trace metals in analysed soil samples

Results of the analysed heavy metals in soil samples across the sample collection points (SCPs) are presented in Tables 1 to 4. The overall mean concentration is as presented in Table 5 while the variation trend of analysed heavy metals across these points is as shown in Figure 1. The mean concentration of trace metals at SCP 1 and across the sampling period ranged from 1785 mg/kg (SP5) – 3755 mg/kg (SP2); 1312 mg/kg (SP4) – 1335 (SP2); 14.5 mg/kg (SP3) – 31.7 mg/kg (SP2) and 97.8 mg/kg (SP1) – 188.9 mg/kg (SP2) for Cu, Zn, Cd and Pb respectively as presented in Table 1.

The mean level of analysed metals at SCP2 (Table 2) varied from 86.7 mg/kg (SP4) – 185.4 mg/kg (SP6) for

Table 3. Mean concentration of trace metals (mg/kg) in soil samples at SCP 3 across the six sampling periods in September 2015.

Sampling period (SPs)	Trace metals			
	Cu	Zn	Cd	Pb
SP 1	64.7	120	2.2	30.1
SP 2	28.5	58.6	1.7	23.5
SP 3	59.9	63.0	2.3	48.0
SP 4	17.7	23.7	1.3	4.4
SP 5	23.8	29.3	1.1	11.3
SP 6	39.1	62.4	2.5	12.7

CSP = Sample collection point; SP = Sampling period.

Table 4. Mean concentration of trace metals (mg/kg) in soil samples at SCP 4 across the six sampling periods in October 2015.

Sampling period (SPs)	Trace metals			
	Cu	Zn	Cd	Pb
SP 1	29.1	57.2	1.0	9.3
SP 2	90.3	167.2	2.2	36.0
SP 3	48.5	59.2	1.8	17.8
SP 4	25.7	32.8	1.7	11.4
SP 5	68.2	64.5	1.9	18.3
SP 6	57.7	72.9	1.6	10.7

CSP = Sample collection point; SP = Sampling period.

Table 5. Overall mean concentrations (mg/kg) of HMs across SCPs and threshold values in soil.

	Sample collection point (SCPs)	Trace metals			
		Cu	Zn	Cd	Pb
Sample collection point (SCPs)	SCP1	2532.8	1994.8	21.3	141
	SCP2	134.8	99.7	4.2	62
	SCP3	39	59.5	1.85	21.7
	SCP4	53.3	75.6	1.7	17.3
	CS	162.2	91.4	5.6	1.2
	Location				
***Threshold values**	EU	13-140	300	3.0	300
	UK	63	100-200	1.4	70
	Dutch	36	50	0.8	85

CSP = Sample collection point; CS = Control Site; *Values in unpolluted soil (Denneman and Robberse, 1990).

Cu; 58 mg/kg (SP4) – 131.8 mg/kg (SP1) for Zn; 2.2 mg/kg (SP4) – 6.1 mg/kg (SP1) for Cd and 36.5 mg/kg (SP4) – 91.6 mg/kg (SP5) for Pb at the SCP2. Table 3 shows the mean concentration of heavy metals at SCP3 which ranged from 17.7 mg/kg (SP4) – 64.7 mg/kg (SP1) for Cu; 23.7 mg/kg (SP4) – 120 mg/kg (SP1) for Zn; 1.1 mg/kg (SP5) – 2.5 mg/kg (SP6) for Cd and 4.4 mg/kg (SP4) – 48.0 mg/kg (SP2) for Pb. In Table 4, the mean level of heavy metals at SCP4 ranged from 25.7 mg/kg (SP4) – 90.3 mg/kg (SP2) for Cu; 32.8 mg/kg (SP4) – 167.2 mg/kg (SP2) for Zn; 1.0 mg/kg (SP1) – 2.2 mg/kg (SP2) and 9.3 mg/kg (SP4) – 36.0 mg/kg (SP2) for Pb. The overall mean concentration of analysed heavy metals in soil samples are as presented in Table 5. This ranged from 39.0 mg/kg (SCP3) – 2532.8 mg/kg (SCP1) for Cu; 59.5 mg/kg (SCP3) – 1994.8 mg/kg (SCP1) for

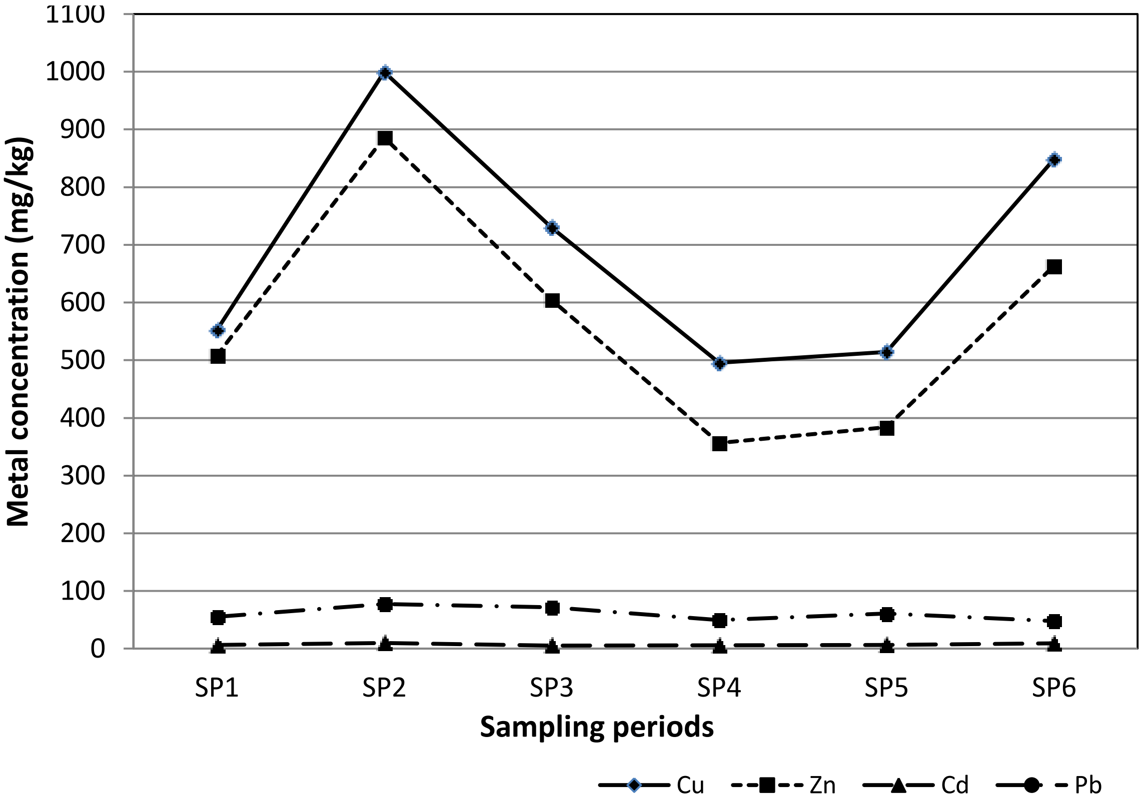

Figure 1. Variation in the mean concentrations of trace metals across sampling periods.

Table 6. Mean concentration (mg/kg) of heavy metals across sampling periods.

Sampling period (SPs)	Trace metals			
	Cu	**Zn**	**Cd**	**Pb**
SP1	552.3	508.3	6.3	55.4
SP2	999.4	886.1	10	77.4
SP3	730.1	604.7	5.4	71.8
SP4	495.5	356.6	5.9	49.6
SP5	514.5	383.6	6.6	60.8
SP6	848.1	663.1	9.3	47.9
X (Mean)	689.9	567.1	7.3	60.5
CS	162.2	91.4	5.6	1.2
CF	4.3	6.2	1.29	50.4
PLI	6.5			

CS= Control site; CF = Contamination Factor; PLI = Pollution Load Index. SP = Sampling period.

Zn; 1.70 mg/kg (SCP4) – 21.3 mg/kg (SCP1) for Cd and 17.3 mg/kg (SCP4) – 141 mg/kg (SCP1) for Pb. The mean concentration of heavy metals in soil samples from the control site (CS) varied from 162.2 mg/kg (Cu); 91.4 mg/kg (Zn); 5.6 mg/kg (Cd) and 1.2 mg/kg (Pb).

Results of the metal contamination factor (CF) and Pollution Load Index (PLI) are presented in Tables 6 and 7, respectively. Contamination factors (CFs) of analysed heavy metals in soil samples were 4.3, 6.2, 1.3 and 50.4 for Cu, Zn, Cd and Pb respectively while the PLI was 6.5.

DISCUSSION

From the quality assurance of the applied method, good recoveries (> 85 %) of the added metals standards were obtained. This indicated the applicability of the method in the analyses of selected metals in soil samples. Similar applicable range has been reported (Shirin et al., 2015).

Level of heavy metals in the analysed soil samples

Elevated level of heavy metals above the natural constituents in soil has been attributed to anthropogenic activities (Tchounwou et al., 2012). It was against the backdrop that the assessment was conducted in the study area where potential impactors are located. In this study, the selected metals were detected in all analysed soil samples from sample collection points (SCPs) across the periods of sampling. The overall mean concentration of Cu (39.0 mg/kg – 2532.8 mg/kg) obtained in soil samples from this study were higher than 36 mg/kg limit recommended by the Dutch Ministry of Environment (MHSPE, 2000). With the UK limit of 63 mg/kg of Cu in soil, only samples from SCP1 and SCP 2 exceeded the limit. However, using the EU threshold limit of 13-140 mg/kg of Cu in soil, only soil sample at SCP 1 was above the prescribed limit (Denneman and Robberse, 1990).

The highest level of Cu was obtained at SCP1 (2532.8 mg/kg) and during SP2 (3755 mg/kg) as shown in Table 5 and Table 1 respectively. The high level obtained at this SCP might be due to the nature of anthropogenic activity within this section of the study area when compared to other sampled sections. Notable activities in this area include mining, metal foundries, petrochemicals operations among others which might be responsible for the high level of contamination. The least value of 39.0 mg/kg of Cu was obtained at SCP3.

Incremental trend of Cu across the sample the SCPs were in the order of SCP1> SCP2 >SCP4 > SCP3. The mean value of 162.2 mg/kg of Cu obtained from the control site (CS) was higher than those obtained at SCP2, SCP3 and SCP4. In environmental studies, assumptions are that the level of pollution at control sites would be lower than those at the study areas or sites since control sites are generally assumed to be relatively “pristine” with much lower anthropogenic influence. This is however, not always the case. Studies where CS values were higher than those from the study areas have been reported (Ali et al., 2014).

Although, Cu is regarded as essential element due to its’ physiological roles in living organisms, high level has been reported to be toxic and dangerous to human health (Osredkar and Sustar, 2011). Copper has been implicated in the genetic disorder of hepatic copper metabolism commonly referred to as Wilson disease (Seth et al., 2004). The general implication of this considerable contamination is the potential accumulation and transfer of this metal across the food chain. Consumption of milk and meat products from ruminants that feed on road side grasses may lead to such transfer across the food chain with health implication.

Zinc (Zn) is another metal that is regarded as “essential” due to some of the role it plays as food supplement especially in sporting activities (Yang et al., 2003). High level of this metal has however, been reported to be toxic (Plum et al., 2010). The overall mean concentration of zinc metal (Zn) across the SCPs varying from (59.5 mg/kg – 1994.8 mg/kg). From this range, all mean concentrations obtained were higher than the Dutch Threshold Limit of 50 mg/kg of Zn in unpolluted soil (MHSPE, 2000). However, with the UK and EU limits of 200 and 300 mg/kg respectively, only the concentration at SCP1 as shown in Table 5 was higher than these limits. However, concentration of 91.4 mg/kg of Zn recorded at the control site (CS) was higher than those obtained at SCP 3 and SCP4.

The highest recorded value of 3135 mg/kg of Zn was obtained during SP2 with overall mean also at SCP1 as presented in Tables 5 and 1 respectively. Generally, the incremental trend of Zn in soil samples across the SCPs were SCP1>SCP2>SCP4>SCP3. This trend also revealed SCP1 as the most contaminated point within the study area. Metal ore processing activity is located within this section of the study area. Lowest overall mean value of 59.5 mg/kg was recorded at SCP3 and the lowest individual recorded concentration of 23.7 mg/kg was recorded during SP4 (Table 3). This was not surprising since anthropogenic activities within the section of the study area can be regarded as minimal with majorly residential outlook and some road side auto-repair local activities.

Cadmium (Cd) is a heavy metal that is of significant interest to environmental scientists, toxicologists and the healthcare service providers due to its’ non-essentiality and high toxicity even in small amount. The metal has been implicated in carcinogenic and endocrine disrupting activities including in humans (Pollack et al., 2011; Ali et al., 2012). Hence, monitoring of the level and anthropogenic contributions to the environment especially in soil is of utmost importance. The overall mean concentration of Cadmium (Cd) obtained in this study across the SCPs ranged from (1.7 mg/kg – 21.3 mg/kg).

All the mean concentrations of Cd were higher than the Threshold limit of 1.4 mg/kg prescribed by UK as well the 0.8 mg/kg by the Dutch’s guideline (MHSPE, 2000). Only the overall mean values obtained from SCP3 and SCP4 were below the recommended threshold limit of 3 mg/kg of Cd in unpolluted soil by the EU while all values were below that of the control site (CS) with the exception of 21.4 mg/kg as the highest overall mean value of Cd obtained at SCP1. The lowest individual concentration of Cd obtained was 1.0 mg/kg during SP1 (Table 4). Hence, the incremental trend of Cd across the SCPs was from SCP1>SCP2>SCP3>SCP4.

Lead (Pb) is another toxic heavy metal with no physiological importance in human. It has been implicated in a number of health problems in human including brain damage and neurological disorder in children (Monnot et al., 2015). The overall mean concentration of Pb across the SCPs varying from (17.3

mg/kg – 141.0 mg/kg). From this range, all overall mean concentrations were below the UK and Dutch threshold limits of 70 mg/kg and 85 mg/kg respectively of Pb in unpolluted soil with the exception of the highest value of 141 mg/kg of this metal obtained at SCP1. In addition, all individual mean concentration of Pb obtained during SP1-SP6 at SCP1 were higher than these limits. However, both the overall mean values across SCPs and the individual mean concentration of Pb across SPs were below the 300 mg/kg threshold values recommended by the EU (Table 1) as well as the 1.2 mg/kg of Pb obtained at the control site. In a similar manner with Cd, the incremental pattern of Pb across the SCPs were in the order of SCP1>SCP2>SCP3>SCP4.

Contamination Factor (CF), Pollution Load Index (PLI), Inter-elemental Correlation (r), ANOVA ($p < 0.05$) and metal variation pattern

The extent of contamination of the soil was deduced from the contamination factor (CF) as described earlier. The CF for Cu was in the category of “appreciable”, that is, considerable contamination with a value of 4.3. Zinc recorded a CF of 6.2 which was within the “highly contaminated” category. Anthropogenic input is most likely to be the contributing factor to this high level of contamination in soil. Some studies have reported similar level of anthropogenic contributions on the level of toxic metals in soil (Rahman et al., 2012; Jiao et al., 2015). Potential uptake of these heavy metals by plants and subsequent accumulation across the food chain cannot be ruled out. Contamination factor of 1.3 was recorded for Cd which indicated moderate level of pollution. By this, anthropogenic contribution could be regarded as minimal. Nonetheless, possible impact across environmental strata is possible in view of the non-essentiality of this metal to living organisms. Potential contributing sources of Cd include atmospheric deposition from mining activities, wastes from Cd-based batteries and runoff from agricultural soils where phosphate fertilizers are used. Cadmium is a common impurity in phosphate fertilizers (Benson et al., 2014).

Contamination Factor (CF) value of 50.4 was obtained for Pb which indicated gross/high contamination of the metal in soil samples. Anthropogenic influence could be responsible for the high CF of this metal in soil. High level of Cd in the environment particularly in soil is quite worrisome. Apart from possible uptake of the metal by plants and consumption of these plants by ruminants, the lower organisms that inhabit the soil such as earthworms and insects could be affected with possible loss of biodiversity. Possible sources of Pb in the environment include atmospheric particulate deposition, lead-based wastes such as painted materials, used dry-cell batteries and mine tailings. The inter-elemental correlation analysis as presented in Table 7 revealed that correlation, $r > 0.9$ was obtained for all analysed metals. For Cu/Zn ($r = 0.999$); Cu/Cd ($r = 0.996$) and Cu/Pb ($r = 0.95$). For Zn/Cd ($r = 0.994$); Zn/Pb ($r = 0.94$) and Cd/Pb ($r = 0.97$). These strong correlations reflected an association between the analysed metals and the sampled sites. In addition, the analysis of variance revealed no significant difference between the analysed metals and the SCPs with $p > 0.05$. Furthermore, the post-hoc analysis revealed that the factor level SP1 is significantly different from all the other levels, but SP2, SP3 and SP4 are not significantly different from each other.

A distinctive variation pattern for the analysed metals can be observed with respect to the sampling periods as shown in Figure 1. An increase in metallic level was observed from SP1 – SP2 which then decreased across SP3 and SP4. There was a marginal increase in metallic level from SP4 to SP5 which was followed by a sharp increase during SP6. The increases during SP2 and SP6 might be due to corresponding increase in anthropogenic activities during these periods. However, the influence of climatic factors such as rainfall on the metallic pattern may not be ruled out. The influence of erosion on metallic mobility and variation in some studies has been reported (Wijngaard et al., 2017).

Pollution Load Index (PLI) value of 6.5 was obtained in this study (Table 6). This value is > 1, which according to the index scale represents a highly polluted condition. The high level of analysed metals obtained across the SPs at SCP1 when compared to others would most likely have significant influence on the high PLI value obtained in this study. This might be due to the nature of anthropogenic activities taking place in this area which include mining, metal foundry involving use of Pb solder and automobile garages. The high level of heavy metals obtained in this section of the study area could be remedied through the use of hyper-accumulating plants. However, the long-term remedial action is to identify the source of these metals and prevent them from entering the ecosystems.

The high PLI and various levels of soil contamination at the SCPs as revealed by the CF values will have negative impact on living organisms including human being. Soil as a form of physical environment can act as a reservoir through which metallic contaminants can find their way into the atmosphere and aquatic ecosystems. Human health has been reported to be compromised through environmental physical exposures such as air pollution (Ghorani-Azam et al., 2016). Hence, people living within the study area may be exposed to these metals through atmospheric particulate matter (PM) distribution. Exposure and continual inhalation of metal-bound PMs especially those with particle sizes of < $PM_{2.5}$ fractions could result in serious health problem. Exposure to PMs has been found to result in cardiovascular and respiratory mortality and morbidity (Laumbach and Kipen, 2012; Huang and Mao, 2012). Children are noted for ingesting small amount of dust especially during recreational activities. Lead (Pb) laden soil has been

Table 7. Inter-elemental correlation of analysed metals in soil.

Correlation	Cu	Zn	Cd	Pb
Cu	1			
Zn	0.999832	1		
Cd	0.996107	0.994326	1	
Pb	0.947569	0.94156	0.972046	1

known to affect cognitive development in children (Bellinger, 2008). Lead is probably carcinogenic to human and its' compound can damage human organs in the event of prolong exposure (Towle et al., 2017).

Children are noted for ingesting small amount of dust especially during recreational activities. Lead (Pb) laden soil has been known to affect cognitive development in children (Bellinger, 2008). Lead is probably carcinogenic to human and its' compound can damage human organs in the event of prolong exposure (Towle et al., 2017).

The removal of top soil into aquatic bodies through erosional processes may increase the metallic burden of the aquatic ecosystem. Consumption of contaminated water resources and aquatic organisms such as fishes from such contaminated water bodies may result is serious health problems. Hence, it is important for the level of these toxic metals to be monitored and for countries to pass stringent legislation for the control, management, use and disposal of wastes containing these toxic metals.

Conclusion

The outcome of the study showed the influence of anthropogenic activities on the level of heavy metals in soil samples. This influence was revealed by the high level of analysed metals when compared to international threshold limits of the analysed metals in soil. This was further corroborated through statistical pollution indicators such as CF and PLI which indicated the high level of pollution based on the data obtained. Of particular concern was the high level of metallic contamination recorded at SCP1 when compared to other sites. This section of the study area is noted for higher concentration of anthropogenic activities which was reflected in the level of heavy metals in soil obtained. As a consequence, metallic mobility across the ecosystems may occur as a result of the high level of contamination of the soil. The study generally revealed the influence of anthropogenic activities on the level of analysed heavy metals in soil samples. This could have serious implications on human health based on potential metal transfer across the food chain.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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