

Topsoil Contamination by Heavy Metals from a Local Brass Industrial Area of Nigeria

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Abstract Contents of Cu, Zn and Pb in top soils of the vicinity of a local brass industrial site within a residential area in Bida, Niger State, Nigeria were determined. The obtained results from the soils of the vicinity of the local brass industrial site showed some extent of contamination with significant elevated mean values of $467 \pm 455 \mu\text{gCu g}^{-1}$, $181 \pm 44 \mu\text{gZn g}^{-1}$ and $181 \pm 201 \mu\text{gPb g}^{-1}$, when compared to $5.4 \pm 1.2 \mu\text{gCu g}^{-1}$, $12 \pm 3.2 \mu\text{gZn g}^{-1}$ and not detectable value for Pb from the control soils. Hence, this study has helped to create the public awareness with regard to the risk of the adverse health effects that could possibly arise from the environmental pollution by heavy metals, particularly with regard to Pb in soils and the consequent need for immediate remediation of the studied area.

Keywords Local Industrial Site, Heavy Metals, Contamination

1. Introduction

Heavy metals play a significant role in the modern environmental problems that are associated with pollution and they occur naturally in earth's crust in varying concentrations, while Cr, Cu, Ni, Pb, Sb and Zn are mostly used and discharged industrially [1]. In alloys and steels, heavy metal pollution occurs through production stage, corrosion in use, disposal to landfills and by recycling of the alloys in the scrap metal[2]. However, Cu pollution may arise from brass manufacture[1], and other major sources such as copper mining and smelting. Major uses of Zn have also been associated with the production of non – corrosive alloy; brass and in galvanized steel and iron products, and Zn may also contain small amounts of more toxic metals, such as Pb as impurities[3].

Kabata- Pendias and Pendias[4] observed that soil acts as a geochemical sink for contaminants, and as a natural buffer controlling the environmental cycling of the chemical elements to the atmosphere, hydrosphere and biota. Moreover, the concern for heavy metals in soils is directly related to their interactions within all the systems through the food chain; soil heavy metals composition may influence uptake by plants, which consequently determines that of animals and humans[5-7]. Previous researchers have reported heavy metal pollution in soils from the vicinity of industrial areas with peculiar feature of decrease in concentration with

increase in distance from industrial sites[8-10].

Local brass industry in Bida, Niger state, Nigeria may be traced back to the settlement of Egyptian emigrants in 1834, and their products are mainly bangles, cups, rings and swords[11]. The local brass industrial site is located within the residential areas and the public concern over the possible potential adverse health effects has been undermined. Furthermore, there has been no major research study reported in literature about the heavy metal contents in soils from the vicinity of this local brass industrial area. Hence, this study examined the total metal concentrations of Cu, Zn and Pb in the topsoil within the vicinity of the local brass industrial area with the aim of investigating the possible impacts the enrichment of these heavy metals may have on the environment, particularly on humans.

2. Experimental Section

2.1. Sampling Sites and Sample Collection

Soil samples of topsoil were collected from thirteen (13) locations within the vicinity of a local brass industry in Bida, Niger State, Nigeria. Four (4) control soil samples were collected from locations within the city that were far from any major pollution sources. The sampling approach was random and systematic; at each sampling location or point a stainless steel auger was used to collect five sub-samples from the top layer at a depth of 0-20cm. The collected sub-samples were then pooled together to form a composite of each individual sample.

2.2. Preparation of Samples

The soil samples were air-dried for one week, ground,

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passed through 2.0mm sieve, further pulverized to a fine powder and passed through 0.5mm sieve for the total metal content determination.

2.3. Chemical Analysis of Samples

Soil samples were digested with HNO_3 - H_2O_2 - HCl using USEPA SW-846, method 3050[12]. The USEPA SW-846, method 3050 developed for total sorbed heavy metals in soils, gives a reliable measure of the amount of the metals added to soils as nonsilicates[13] that is potentially available for natural leaching and biological processes. The concentrations of Pb, Cu and Zn in the digestion solution were determined with a Unicam 969 Atomic Absorption Spectrophotometer - solar in the flame mode.

2.4. Quality Assurance and Quality Control (QA/QC)

At least one reagent blank and one duplicate sample were run for every batch of four (4) samples for background correction and to verify the precision of the method. Accuracy was however, assessed by analyzing three (3) replicates of certified reference materials, soil sample S0-1, obtained from Canada Centre for Mineral and Energy Technology (CANMET). Recoveries were satisfactory; average values being in excess of 90% for Pb, Cu and Zn analysed.

3. Results and Discussion

Table 1. Total metal content ($\mu\text{g g}^{-1}$) in topsoil of local brass industrial area

Sample point			
Number	Cu	Zn	Pb
01	1069	228	741
02	258	175	75
03	214	174	78
04	91	155	109
05	835	229	185
06	1286	236	295
07	1151	232	419
08	27	114	20
09	395	196	109
10	382	190	133
11	248	176	64
12	81	128	75
13	29	116	48

3.1. Copper

Cu has the highest concentration range for all the heavy metals examined in the soil samples from the vicinity of the local industrial area; varying considerably from $27\mu\text{g g}^{-1}$ to $1286\mu\text{g g}^{-1}$ (Table 1). In about 69% of the samples studied, Cu levels exceeded the Soil Quality Criteria values for many countries; $50\mu\text{g g}^{-1}$ for Switzerland[14], $100\mu\text{g g}^{-1}$ for Norway[15], and maximum allowable limit set by Kloke[16]

was also exceeded. Up to 85% of the analysed soils from this local industrial area also had total Cu contents that exceeded the residential acceptable limit of $63\mu\text{g g}^{-1}$ recommended in Canadian Soil Quality Guidelines for the Protection of Environment and Human Health[17]. Furthermore, the Cu values obtained from soils in this study were significantly higher than the Cu ranged content of $11\mu\text{g g}^{-1}$ to $116\mu\text{g g}^{-1}$ reported by Ekosse et al.,[18] in their study of nickel – copper mine and smelter plant area of Botswana. The $2.4\mu\text{g g}^{-1}$ to $6.5\mu\text{g g}^{-1}$ Cu concentrations documented by Iyaka and Kakulu[19] in their study of urban agricultural soils of Bida, Niger state, Nigeria were also remarkably lower than obtained ranged value from this study. Nevertheless, the soil total Cu contents of the vicinity of this local brass industrial area were distinctly lower than those reported by Freeman and Hutchinson[20] in their study of the vicinity of a nickel-copper smelter at Sudbury, Ontario, Canada.

3.2. Zinc

The Zn contents obtained from the vicinity of the local brass industrial site (Table 1) were generally higher than the normal concentration range of $17 - 125\mu\text{g Zn g}^{-1}$ for top surface soils suggested by Ward[5]. The Zn levels in soil samples of this study also exceeded the $36 - 113\mu\text{g Zn g}^{-1}$ range documented by Sharma et al.,[21] in their determination of total micronutrients in relation to pedogenesis in some soil samples in India. A lower ranged value of $10 - 85\mu\text{g Zn g}^{-1}$ than obtained in this study (Table 2) has also been reported by Iyaka and Kakulu[22] in their study of roadside topsoil of the Bida city. However, the Zn values of the soils in the vicinity of this local brass industrial site are within a soil level range of $0 - 250\mu\text{g Zn g}^{-1}$ classified as being typical of uncontamination by the UK Department of the Environment for the recreational and Agricultural uses[23].

Table 2. Concentration Range and Mean of Heavy metals ($\mu\text{g g}^{-1}$) in studied soils

Location	Number of samples	Heavy Metals	Range	Mean \pm SD ^a
Local brass industry	13	Cu	27 – 1286	467 \pm 455
		Zn	114 – 236	181 \pm 44
		Pb	20 – 741	181 \pm 201
Control	4	Cu	4.2 – 7.0	5.4 \pm 1.2
		Zn	8.4 – 16	12 \pm 3.2
		Pb	Nd ^b	Nd

^aStandard deviation

^bNot detected

3.3. Lead

The Pb contents in the examined soil samples from the vicinity of this local brass industrial site varied widely between $20\mu\text{g g}^{-1}$ and $741\mu\text{g g}^{-1}$ (Table 1). The very high Pb concentrations in some locations may be attributed to the contribution or effect of Pb – based paint whose contamination may occur when paint chips from old buildings mix with the soil. EPA[24] asserted that soil adjacent to houses with exterior Pb – based paints may have Pb levels of as high as

greater than 10, 000 $\mu\text{g g}^{-1}$. In three of the soil samples studied, Pb contents exceeded the 250 $\mu\text{g g}^{-1}$ permissible level of Pb in soils proposed by Madhavan et al.,[25] ; this value applies to a worst – case scenario in which children below five years of age repeatedly use an area without grass cover (as experienced in this study) and mouthed objects frequently. ATSDR[26] stated that a soil Pb concentration of 250 $\mu\text{g g}^{-1}$ would add at most an estimated 2 $\mu\text{g Pb l}^{-1}$ to the blood Pb level of children.

Furthermore, seven of the thirteen sample locations had Pb levels above the 100 $\mu\text{g g}^{-1}$ recommended by Shellshear et al.,[27] as permissible level for protecting pica children or established as a bare soil standard by the Minnesota State Legislature[28] The dietary exposure that results in blood levels of concern has been estimated to be 6 $\mu\text{g Pb day}^{-1}$ for children of six years or younger, with a further argument by ATSDR[26], that there may be no level of blood Pb that is not toxic, particularly in the developing central nervous system. Thus, given a soil Pb content of 100 $\mu\text{g g}^{-1}$; consumption of approximately two teaspoons of this soil per week (as it may occur in some environments) would be sufficient to produce the same amount of Pb found in a diet that can cause elevated blood levels of concern, depending on many factors that include the age of the child, diet and health. This calculation is however, based on the assumption that half of the Pb in the soil eaten by children is absorbed[28]. Juberg et al[29] observed that children absorb about 30 - 40% of ingested Pb , while adults absorb only 5 – 15% and retain less than 5% of what is absorbed.

3.4. Correlation Analysis

Interelement association shows significant correlation between Cu, Zn and Pb in soils from the local brass industrial area (Table 3). The interelemental correlation between these elements in this study may possibly be ascribed to the control of the elemental association by factors such as soil genesis and properties as well as anthropogenic impact on the environment.

Table 3. Elemental correlation coefficients of local brass industrial area

	Zn	Pb
Cu	0.989 ^c	0.857 ^c
Zn		0.835 ^c

^ccorrelation is significant at the 0.01 level

3.5. Percentage Enrichment Factor (%EF)

Table 4 shows the evaluation of the soil contamination using the percentage enrichment factor adapted from Loska and Weichula[30], and Ali and Malik[31]. Generally, the obtained results showed that %EF of the studied heavy metals depicted contamination of the topsoil; however, Zn had the highest %EF probably because the minimum concentration of Zn from the soil samples of the local brass industrial area was about ten times the obtained mean value from the control soils.

$$\%EF = (C - C_{\min}) / (C_{\max} - C_{\min}) \times 100$$

where, C is the mean total content, C_{\min} is the minimum content determined and C_{\max} is the maximum content determined.

Table 4. Percentage Enrichment Factor (%EF) for the studied heavy metals in soils of the local brass industrial area

Heavy metals	Cu	Zn	Pb
%EF	34.94	54.91	22.33

Table 5. Comparison of mean total content ($\mu\text{g g}^{-1}$) in this study with the soil quality criteria for other countries

Cu	Zn	Pb	Country/source	Reference
466	181	181		This study
63	200	140	Canada (residential)	CCME[17]
50	200	50	Switzerland (guide values)	FOEFL[14]
150	200	100	Taiwan	Chen et al.[32]
100	185	55	S. Africa	Chen et al.[32]
1500	2800	300		USEPA[33]

4. Conclusions

Average heavy metal contents in the topsoil of the local brass industrial area of this study were substantially higher than in the control soils (Table 2) ; the Pb concentration in the background level was however, too low to be detectable. Since Nigeria does not have quality criteria for soil metal levels, the mean heavy metal contents from this study were compared with criteria from other countries and USEPA upper limit values (Table 5). The mean contents for Cu and Pb in this study are higher than criteria for the various countries shown in Table 5, but lower than the USEPA upper limit of allowable heavy metals in soils. However, the Zn average value was generally lower in comparison to the cited concentrations. Hence, the findings of this study indicate that there is a significant accumulation of Cu, Zn and Pb above the background level in the studied soils of the local brass industrial site located in residential area, thereby increasing the public awareness with regard to the risk of the adverse health effects that could possibly arise from the environmental pollution by heavy metals and the consequent need for immediate remediation.

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