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Research Article

Application of Pollution Load Indices, Enrichment Factors, Contamination Factor and Health Risk Assessment of Heavy Metals Pollution of Soils of Welding Workshops at Old Panteka Market, Kaduna-Nigeria

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Abstract

The concentration of five soil heavy metals ions (Cr^{6+}, Cu^{2+}, Cd^{2+}, Pb^{2+}, and Ni^{2+}) was measured in eleven sampling sites along Old Panteka market Kaduna from two different depths. These chemical elements in the samples were determined using atomic absorption spectrometer. The assessment of heavy metal pollution was derived using the Enrichment Factors (EF) and geoaccumulation index (Igeo). This study revealed that the soil is predominantly polluted by $Pb^{2+}>Cu^{2+}>Cd^{2+}>Ni^{2+}>Cr^{6+}$ and $Cu^{2+}>Pb^{2+}>Cd^{2+}>Ni^{2+}>Cr^{6+}$ metal ions at 0-5 cm and 5-10 cm depths respectively. As recorded the highest EF value of 29.63 and 20.54 for Pb and Cu at 0-5 cm and 5-10 cm depths respectively followed by Cu (17.13), Cd (10.07), Ni (0.99) and Cr (0.53) at 0-5 cm and Pb (19.68), Cd (12.47), Ni (1.19) and Cr (0.55) at 5-10 cm depths respectively, and the mean Igeo provided the same trend of pollution levels as in the case of the EF, which indicates that the highest level goes to Pb (1.61) and Cu (1.58) at 0-5 cm; Cu (1.71) and Pb (1.50) at 5-10 cm depths respectively, which exhibits unpolluted to moderately polluted. Meanwhile, Ni recorded (0.15) and (0.22) at 0-5 cm and 5-10 cm depths respectively, while Cr recorded (-0.07) and (0.08) also at 0-5 cm and 5-10 cm depths respectively, which illustrates that both of these metals vary from unpolluted to moderately polluted. The concentrations of Cr, Cu, and Ni levels are below 0 at the control sites, which demonstrates background concentrations. Risk assessment results show high health risk to human adults and children due to metals' exposure through contaminated soil ingestion.

Abbreviations

AAS: Atomic Absorption Spectrometer; LADD: Lifetime Average Daily Dose; HQ: Hazard Quotient; HI: Hazard Index

Introduction

Pollution of the environment may occur through the industrial and commercial activities of man. This happens when substances resulting from human activities enter the environment. The environment is said to be polluted when the concentration of these substances attain levels that may cause discomfort and/or harm to man, fauna, and flora of his environment. The pollution of the environment has been found to result from man's determination to match desire with

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production through the establishment of various industries with the potentials to pollute the environment. Industry, big or small, is a source of pollution of water, soil, and air [1]. The sizes of workshops vary but the typical medium-sized workshop occupies about 5 ha of land area [2]. Activities conducted in these shops are typical of metal fabrication workshops and invariably involve working with solders, metal filings, and other materials that contain heavy metals unto bare soil. Lead (Pb^{2+}), for example, is known to come from the use of leaded gasoline whereas Cu^{2+} and Cd^{2+} from tyre abrasion, lubricants, industrial and incinerator emissions [3,4]. The source of Ni^{2+} and Cr^{6+} in welding workshop is believed to be due to corrosion of vehicular parts [5], Akhter & Madany [5] and Fergusson & Kim [6] and chrome plating of some motor vehicle parts [7]. The phenomenon contributes significantly to the pollution of the urban environment. This makes the study of welding workshops soil important for determining the origin, distribution, and level of heavy metal in urban workshop surface environments. However, the quantitative data on heavy metal concentrations, their contamination levels, and their pollution sources have not been systematically gathered and intercompared. Therefore, this study focuses on heavy metal ions contamination in urban welding workshop soils. The sources, concentrations, pollution levels, sample collection and analytical tools of heavy metals are elucidated in this study; moreso, it is very mportant to assess and monitor the concentrations of potentially toxic heavy metals ions in different environmental soils as regards what constitute occupational hazard to man.

Materials and methods

Study area

The study area, situated in the northern part of Kaduna state between 10°23' -10°43'N and i7°17'-7°37'E (Figure 1). The climate of the study area; wet season is characterized by torrential rainfall from May to October, while the dry season is November to April [8]. The natural vegetation cover is tropical grassland of the Northern guinea savannah type with short scattered trees interspersed with tall grasses. Urbanization has

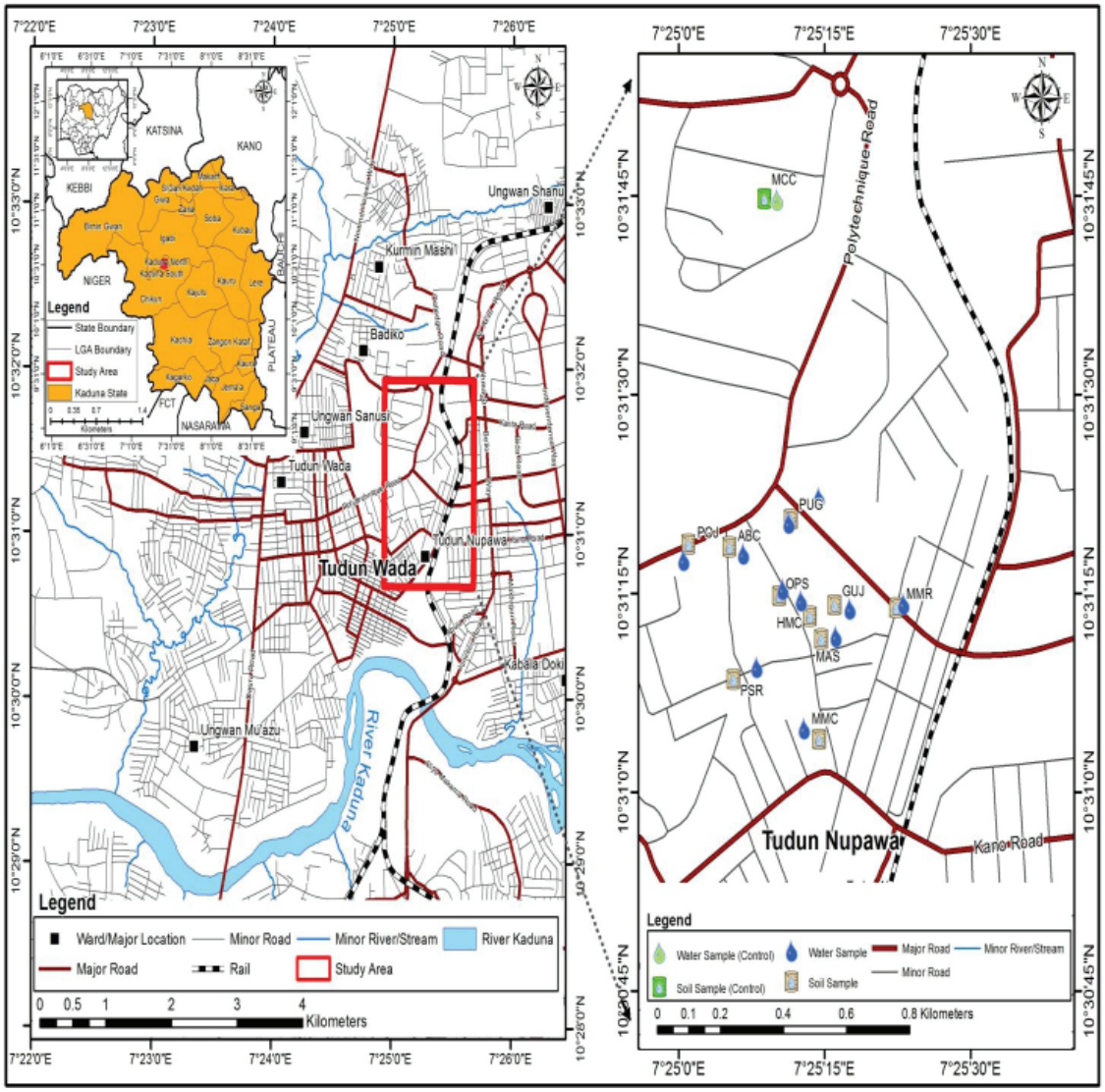

Figure 1: Map of Kaduna Metropolis showing Soil & Water Sampling Points.
Source: Geography department A.B.U Zaria

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taken over the original vegetation of Kaduna. The soil is mainly sandy clay, which reduces infiltration and accelerates overland flow and erosion, particularly where the soil surface has little or no vegetation cover.

Soil sampling

Twenty-two soil samples were collected during May 2016 from different depths with an interval of 0-5 cm and 5-10 cm. The 1 kg of each soil sample was collected using a stainless steel spade and a plastic scoop; all samples collected were stored in sealed polythene bags and transported to the laboratory for pre-treatment and analyses Figure 2.

Chemical analysis

The soil samples were dried, mechanically in the laboratory, the soil samples after air drying at room temperature, were sieved with nylon mesh (2 mm). The <2 mm fraction was ground in agate and pestle and passed through a 63-micron sieve. Soil samples were analyzed for heavy metals. Furthermore, soil samples were digested by taken 2 g each, weighed into a beaker using an analytical balance (Mettler AE160), 50 cm^3 of concentrated Nitric acid (HNO_3), and 1 cm^3 Perchloric acid ($HClO_4$) were measured and added to the already weighed soil sample. The mixture was digested by boiling gently on a hot plate. After digestion, the sample was evaporated to dryness and the residue mixed with 0.1M HNO_3 and filtered into a 100 cm^3 flask using Whatman No.1 filter paper [9]. The blank determination was also carried out. Metals in the final solutions were determined using (variant model AA650FS), Atomic Absorption Spectrometer (AAS). Standard stock solutions for all the elements were prepared in the laboratory following the procedures as described in Omoniyi, et al. [10]. The glassware used was made fromi borosilicate, which was washed several times with liquid soap, rinsed with distilled water and then soaked in 10 % HNO_3 solution for 24 hours [11]. Thereafter, they were washed with distilled water and dried in Memmert drying oven at 80 ^oC for 5 hours [11].

Contamination assessment methods

The assessment of soil enrichment can be carried out in many ways. The most common ones are the index of geoaccumulation and enrichment factors [12]. In this work, the index of geoaccumulation (Igeo) and Enrichment Factor (EF) have been applied to assess heavy metals ions (Cr^{6+}, Cu^{2+}, Cd^{2+}, Pb^{2+} and Ni^{2+}) distribution and contamination in the welding workshop samples within Old Panteka market, Kaduna Figure 3.

A quantitative measure of the extent of metal pollution in the studied soil was calculated using the geoaccumulation index proposed by Muller [13], as shown in Table 1. This index (Igeo) of heavy metal concentration pollution is calculated by computing the base 2 logarithms of the measured total concentration of the metal over its background concentration using the following mathematical relation [14]:

$$lgeo = log_2(Cn/1.5Bn) \quad 1.0$$

Figure 2: Poly Junction (POJ) welding workshop soil sampling point.

Table 1: Geo-accumulation Indices of the Selected Heavy Metals in the Study Area at 0 - 5 cm and 5 - 10 cm Depths.

Source	Site	Cr^{6+}	Cu^{2+}	Cd^{2+}	Pb^{2+}	Ni^{2+}	
Soil (0 – 5 cm)	GUJ	-0.12	1.58	1.08	1.58	0.15	
	MMC	-0.94	0.22	0.57	0.83	-0.61	
	OPS	-0.81	0.35	0.50	0.91	-0.45	
	MMR	-0.67	0.84	0.48	0.59	-0.34	
	ABC	-0.59	0.68	0.47	0.77	-0.34	
	PSR	-0.25	1.07	0.86	1.59	0.00	
	HMC	-0.21	1.55	0.91	1.50	0.04	
	PUG	-0.07	0.71	1.15	1.48	-0.01	
	POJ	-1.07	1.13	0.56	0.80	-0.35	
	MAS	-0.49	0.81	1.11	1.61	-0.12	
	CONTROL	BDL	-0.63	0.51	0.86	-1.04	
Soil (5 - 10 cm)	GUJ	-0.17	1.60	1.21	1.50	0.22	
	MMC	-1.20	0.43	0.45	0.67	-0.41	
	OPS	-1.19	0.45	0.48	0.86	-0.31	
	MMR	-0.69	1.36	0.45	0.63	-0.25	
	ABC	-0.69	0.38	0.79	0.59	-0.37	
	PSR	0.08	0.88	0.69	1.05	0.07	
	HMC	-0.28	1.71	1.00	1.45	0.19	
	PUG	-0.21	0.72	1.40	1.35	0.03	
	POJ	-0.72	0.39	0.67	0.86	-0.27	
	MAS	-0.59	1.12	1.09	1.29	-0.13	
	CONTROL	-3.13	-0.63	0.54	0.50	-0.86	

where Cn is the measured total concentration of the element n in the soil fraction, Bn is the average (crustal) concentration of element n in shale (background) and 1.5 is the factor compensating the background data (correction factor) due to lithogenic effects [15]. gave the following interpretation for the geoaccumulation index:

Igeo<0 = practically unpolluted,

0<Igeo<1 = unpolluted to moderately polluted,

1<Igeo<2 = moderately

2<Igeo<3 = moderately to strongly polluted,

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3<Igeo<4 = strongly polluted,

4< Igeo<5= strongly to extremely polluted and

Igeo >5 = extremely polluted.

Contamination Factor (CF): CF is a quantification of the degree of contamination relative to either average crustal composition of a respective metal or to the measured background values from geologically similar and uncontaminated area as shown in Table 2 [16]. It is expressed as:

$$CF = Cm/Bm \quad (2.0)$$

Where; Cm is the mean concentration, while Bm is the background concentration of metal either from literature (average crustal abundance) or directly determined from a geologically similar area. CF in this study was considered as:

CF < 1 - Low contamination factor

1 < CF < 3 - Moderate contamination factor

3 < CF < 6 - Considerable contamination factor

6 > CF - Very high contamination factor [17].

Pollution load index: This was determined using the equation below as described by Tomlinson, et al. [18], was evaluated with the expression:

$$\mathbf{PLI} = \left[\delta^{n} i\left(C_{f}\right)\right]^{1/n} \quad (3.0)$$

Where; C_f is the contamination factor of each metal obtained by the ratio of the concentration of each metal in soil to that of the metal in background soil or groundwater; π is the geometrical mean operator; n is the number of metals investigated in each sample as shown in Table 3.

Enrichment Factor: Enrichment Factor (EF) has been employed for the assessment of contamination in various environmental media by several researchers as shown in Table 4. Its version adapted to assess the contamination of various environmental media is as follows:

Figure 3: Hamzy metal construction (HMC) welding workshop soil sampling point.

Table 2: Contamination Factor of the Selected Heavy Metals of the Study Area at 0 - 5 cm and 5 - 10 cm Depth Respectively.

Source	Site	Cr^{6+}	Cu^{2+}	Cd^{2+}	Pb^{2+}	Ni^{2+}
Soil (0 – 5 cm)	GUJ	1.13	56.68	17.83	56.69	2.13
	MMC	0.17	2.47	5.60	10.17	0.37
	OPS	0.23	3.37	4.77	12.16	0.53
	MMR	0.32	10.32	4.50	5.82	0.68
	ABC	0.39	7.13	4.43	8.81	0.69
	PSR	0.83	17.66	10.83	57.94	1.51
	HMC	0.91	52.87	12.33	47.87	1.64
	PUG	1.27	7.76	21.00	45.1	1.48
	POJ	0.13	20.15	5.50	9.40	0.67
	MAS	0.49	9.66	19.27	61.02	1.14
	CONTROL	0.00	0.35	4.83	10.97	0.14
Soil (5 – 10 cm)	GUJ	1.01	59.84	24.33	47.92	2.51
	MMC	0.10	4.08	4.27	7.04	0.59
	OPS	0.10	4.23	4.50	10.99	0.74
	MMR	0.31	34.37	4.27	6.34	0.85
	ABC	0.31	3.56	9.17	5.82	0.64
	PSR	1.80	11.43	7.33	16.85	1.77
	HMC	0.79	76.59	15.00	42.68	2.30
	PUG	0.92	7.79	37.43	33.72	1.60
	POJ	0.29	3.72	7.00	10.83	0.81
	MAS	0.39	19.94	18.5	29.49	1.10
	CONTROL	0.00	0.36	5.17	4.79	0.21

Table 3: Pollution Load Indices (PLI) of Soil Samples from the Study Areas at 0 - 5 cm and 5 - 10 cm Depth.

Site	0 - 5 cm	5 - 10 cm
GUJ	10.66	11.20
MMC	1.55	1.47
OPS	1.89	1.72
MMR	2.26	3.00
ABC	2.37	2.06
PSR	6.75	5.38
HMC	8.59	9.77
PUG	6.73	6.80
POJ	2.46	2.31
MAS	5.75	5.42
CONTROL	0.00	0.29

Table 4: The Degrees of Pollution of Soils by the Selected Heavy Metals in the Study Area.

Metals	Average shale value	Soil mean conc. (mg/kg)		Enrichment factor (EF)		Degree of contamination
		0 – 5 cm	5 – 10 cm	0 – 5 cm	5 – 10 cm	
Cr^{6+}	90	48	49.1	0.53	0.55	Uncontaminated
Cu^{2+}	45	770.79	924.14	17.13	20.54	Extremely contaminated
Cd^{2+}	0.3	3.02	3.74	10.07	12.47	Extremely contaminated
Pb^{2+}	20	592.63	393.61	29.63	19.68	Extremely contaminated
Ni^{2+}	68	67.91	81.17	0.99	1.19	slightly contaminated

$$EF = \frac{(Cx/Cref)sample}{(Bx/Bref)background} \quad (4.0)$$

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Where;

Cx = Content of the examined element in the examined environment

Cref = Content of the examined element in the reference environment

Bx = Content of the reference element in the examined environment

Bref = Content of the reference element in the reference environment

An element is regarded as a reference element if it is of low occurrence variability and is present in the element in trace amounts. It is also possible to apply an element of geochemical nature whose substantial amounts occur in the environment but has no characteristic effects i.e. synergism or antagonism towards an examined element. The contamination categories are recognized on the basis of the enrichment factor:

EF<2 states deficiency to minimal enrichment,

EF = 2-5 moderate enrichment,

EF = 5-20 severe enrichment,

EF = 20-40 very high enrichment and

EF>40 extremely high enrichment [19].

The enrichment factor, due to its universal formula is relatively simple and easy tool for assessing enrichment degree and comparing the contamination of the different environment.

Human health risk assessment

Health risk estimation includes the identification of exposure pathways, which is the course a chemical takes from a source to an organism [20] and an exposure route, the way a chemical comes in contact with a receptor (i.e., by ingestion, inhalation, dermal contact, etc.). In this study, ingestion of soils contaminated with metals was considered as the main pathways for risk assessment. The health hazard to human adults and children from metals was derived after hazard quotient (HQ) estimation. HQ is the measure of the magnitude of exposure potential or a quantifiable potential for developing health effects after an averaged exposure period. The potential for non-cancer effects was evaluated by comparing the estimated average daily dose (mg kg^{-1} d^{-1}) of the metal with the reference dose (RfD) (mg kg^{-1} d^{-1}). The total health hazard was derived simply by summing the HQ values of all the metals. This total HQ is referred to as the Hazard Index (HI). Recommended equations used for estimating ADD, HQ, and HI were from EPA [20]:

$$ADD\ (mg\ kg^{-1}\ day^{-1}) = (Cs \times IR \times F \times EF \times ED)/(BW \times AT) \quad 5.0$$

$$Hazard\ Quotient\ (HQ) = LADD/RfD \quad 6.0$$

$$Hazard\ Index\ (HI) = HQ_{CD} + HQ_{CR} + HQ_{CU} + HQ_{Ni} + HQ_{PB} \quad 7.0$$

where Cs is the metal's concentration in soil (mg kg^{-1}), IR is the soil ingestion rate (adult, 100 mg day^{-1}; children, 200 mg day^{-1}), F is the unit conversion factor, EF is exposure frequency (365 days/year), ED is the lifetime exposure duration (children, 12 years; adults, 70 years), BW is the bodyweight (children, 27 kg; adults,70 kg), and AT is the averaging time (EF × ED days). RfD is the reference dose for individual metal (mg kg^{-1} day^{-1}) [21].

Results and Discussion

Heavy metal concentrations

Table 5 summarizes the minimum, maximum, mean and standard deviation of a number of metals ions (Cr^{6+}, Cu^{2+}, Cd^{2+}, Pb^{2+}, and Ni^{2+}) in twenty-two soil samples collected at old Panteka market welding workshops soil of Kaduna State. A close look at Table 5 shows that the variability in the range of all the metal distributions as compared with their means respectively is an indication of pollution of the sample with those metals ions. The decreasing trend of averages of metal levels was as follows: Cu^{2+}>Pb^{2+}>Ni^{2+}>Cr^{6+}>Cd^{2+} mg/kg concentrations at both depths respectively.

Distribution and enrichment of metals

The Enrichment Factor (EF) of Cu^{2+}, Cd^{2+}, Pb^{2+} and Ni^{2+} concentration in the soil as shown in Table 4 are 17.13, 10.07, 29.63, 0.99 and 20.54, 12.47, 19.68, 1.19 at 0 – 5 cm and 5 – 10 cm depths respectively. Meanwhile, enrichment factor (EF) of Cr^{6+} at both depths recorded 0.53 and 0.55 at 0 – 5 cm and 5 – 10 cm depths respectively, which indicates that the soil is uncontaminated (deficiency to minimal enrichment) by Cr^{6+} metal. Since the soil samples have been taken from welding workshops with considerable high volume of metal works, heavy traffic rates, and motor vehicles burning leaded gasoline and spent engine oil from welding generator sets could be considered as the main sources of the lead in the soils of the study area. The behaviour of Cu^{2+} shows that the enrichment factors (EF) are 17.13 and 20.54 at both depths, whereas, the values of the geochemical index range from -0.63 to 1.58 at 0 – 5 cm and -0.63 to 1.71 at 5 – 10 cm respectively, indicating uncontaminated to slightly contaminated soil. Relatively higher values of Cu^{2+} concentrations in the analyzed soil samples reflect anthropogenic effects which might be as aire sultiofiburningifossilifuel,iweariand teariofityresiand other metal filing emanating from welding activities taken place in the workshops [22]. The Enrichment Factor (EF) values between 0.5 and 1.5 indicates that the metals are entirely from the coastal materials whereas EF values greater than 1.5 indicates that the sources are most likely to be anthropogenic activities [23].

In order to have an idea about the levels of contamination of the soils of the various welding workshops clusters, data obtained were compared with the background values. The background value of an element is the maximum level of the element in an environment beyond which the environment is said to be polluted with the element [24].

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Table 5: Basic Statistical Parameters for the Distribution of Heavy Metals in the Investigated Soil Sample (mg/kg).

	Soil (0 - 5 cm)					Soil (5 - 10 cm)				
Sites	Cr^{6+}	Cu^{2+}	Cd^{2+}	Pb^{2+}	Ni^{2+}	Cr^{6+}	Cu^{2+}	Cd^{2+}	Pb^{2+}	Ni^{2+}
GUJ	101.55	2550.53	5.35	1133.73	145.05	90.68	2692.73	7.3	958.4	170.78
MMC	15.45	111.2	1.68	203.45	25.1	8.58	183.6	1.28	140.8	40
OPS	21.03	151.5	1.43	243.28	36.23	8.8	190.53	1.35	219.75	50.35
MMR	28.65	464.35	1.35	116.3	46.23	27.63	1546.78	1.28	126.88	57.9
ABC	34.9	320.8	1.33	176.23	47.08	27.73	160.15	2.75	116.43	43.5
PSR	75.1	794.68	3.25	1158.88	102.7	161.73	514.15	2.2	337	120.43
HMC	82.33	2379.2	3.7	957.3	111.63	71.1	3446.43	4.5	853.68	156.53
PUG	113.95	349.33	6.3	902.08	100.5	82.8	350.48	11.23	674.48	108.93
POJ	11.48	906.85	1.65	187.95	45.83	26	167.43	2.1	216.68	55.33
MCC	0.001	15.68	1.45	219.3	9.35	0.1	16	1.55	95.85	14.18
MAS	43.93	434.6	5.78	1220.45	77.33	34.98	897.23	5.55	589.75	74.95
Sum	528.37	8478.72	33.27	6518.95	747.03	540.13	10165.5	41.09	4329.7	892.88
Mean	48.03	770.79	3.02	592.63	67.91	49.1	924.14	3.74	393.61	81.17
StDev.	137.87	2283.84	8.58	1698.84	192.27	143.15	2773.03	10.76	1129.69	229.86
Min	0.001	15.68	1.33	116.3	9.35	0.1	16	1.28	95.85	14.18
Max	113.95	2550.53	6.3	1220.45	145.05	161.73	3446.43	11.23	958.4	170.78

Source: Experimentation

Key: GUJ: Gulubi Junction; MMC:Mallam Madori Close; OPS: Opposite Police Station; MMR: Mallam madori Road before bridge; ABC: Adjacent Baptist Church; PSR: Police Station Road; HMC: Hamzy Metal Construction; PUG: Pick-Up Garage; POJ: Poly Junction; MAS: Masallaci Street; MCC: Madori Close Control

The highest CF was observed in Pb and the least in Cr^{6+} at 0 – 5 cm depth (Table 2). A similar trend was observed in Cu^{2+} and the least also in Cr^{6+} at 5 - 10 cm depth. In general, the decreasing order of CFs of heavy metals was $Pb^{2+} > Cu^{2+} > Cd^{2+} > Ni^{2+} > Cr^{6+}$ at 0 – 5 cm depth and at $Cu^{2+} > Pb^{2+} > Cd^{2+} > Ni^{2+} > Cr^{6+}$ 5 - 10 cm depths respectively.

On variation with depths, the CFs values generally increased down the soil profile. The very high values of Cu^{2+} and Pb^{2+} at both depths could be due to the influence of welding activities taking place at the workshops such as indiscriminate disposal of substances containing metals such as vehicles spare parts, smelting and so on. The PLI which represents the number of times by which the metal content in the soil exceeds the average natural background concentration, and gives a summative indication of the overall level of heavy metal toxicity in a particular sample was also presented in Table 3. The result showed that the highest PLI at both depths were recorded at Gulubi Junction (GUJ) study sites and the lowest PLI at the control site. All study sites had their PLI > 1 and the control site recorded PLI = 1. Based on the PLI grade standard by [25], results showed pollution for the study sites and no pollution for the control site as shown in Table 3.

Human health risk estimates

Health risk assessment was based on the assumption that humans exposed to metals through soils may suffer harmful effects. We assume that human adults and children are exposed to metals through ingested soils all the days in a year during the life span. Risk was assessed by estimating the incremental lifetime average daily dose (LADD), hazard quotient (HQ), and hazard index (HI) for the selected metals.

LADD is the amount of pollutant intake per kg of bodyweight per day that is sufficient to cause adverse health effects when absorbed into the body over a long period of time. If the HQ for a chemical is equal to or less than 1, it is assumed that there is no appreciable risk that health effects will occur. A hazard index (HQs) <1 suggests that risks are not expected from any chemical, alone or in combination with others. The average daily dose (ADD) and hazard index (HI) for adults and children from selected exposure to metals through soil contact are presented in Tables 6,7.

The LADD of Cr^{6+}, Cu^{2+}, Cd^{2+}, Pb^{2+}, and Ni^{2+} through soil ingestion for human adults at 0 – 5 cm depth ranged between 1.43E-06 –i0.163 mg kg^{-1} d^{-1} (mean, 8.14E-02 mg kg^{-1} d^{-1}), 0.0224 – 3.664 mg kg^{-1} d^{-1} (mean, 1.84E+00 mg kg^{-1} d^{-1}), 0.0019 – 0.009 mg kg^{-1} d^{-1} (mean, 6.4E-03 mg kg^{-1} d^{-1}), 0.166 – 1.7435 mg kg^{-1} d^{-1} (mean, 1.04E+00 mg kg^{-1} d^{-1}), and 0.0134 – 0.2072 mg kg^{-1} d^{-1} (mean, 1.17E-01 mg kg^{-1} d^{-1}) respectively. However, average LADD for children at this depth was 4.22E-01 mg kg^{-1} d^{-1} (range, 7.41E-06 – 0.844 mg kg^{-1} d^{-1}), 9.563 mg kg^{-1} d^{-1} (range, 0.1161 – 18.893 mg kg^{-1} d^{-1}), 0.033 mg kg^{-1} d^{-1} (range, 0.0098 – 0.04667 mg kg^{-1} d^{-1}), 5.381 mg kg^{-1} d^{-1} (range, 0.8615 – 9.0403 mg kg^{-1} d^{-1}), and 0.6065 mg kg^{-1} d^{-1} (range, 0.0693 – 1.0744 mg kg^{-1} d^{-1}) respectively for Cr^{6+}, Cu^{2+}, Cd^{2+}, Pb^{2+} and Ni^{2+} from soil ingestion. The LADDs of total metals for adults and children ranged from 2.04E-01 to 5.77E+00 mg kg^{-1} d^{-1} with mean value of 3.09E+00 mg kg^{-1} d^{-1}, and from 3.09 to 2.99E+01 mg kg^{-1} d^{-1} withimean value of 1.60E+01 mg kg^{-1} d^{-1}, respectively for children at this depth.

These average daily intakes (ADIs) were mostly above the recommended reference dose (RfD) values for Cr^{6+} (Cr^{6+} salt, 1.5 mg kg^{-1} d^{-1}), Cu^{2+} (0.04 mg kg^{-1} d^{-1}), Cd^{2+} (0.001mg kg^{-1} d^{-1}), Pb^{2+}

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Table 6: Lifetime Average Daily Dose (LADD) (mg $kg^{-1}d^{-1}$) of Metals and Health Hazard through Soils Ingestion for Adults and Children at 0-5 cm Depth.

Human adults				Children		
Metals	Minimum	Maximum	Average	Minimum	Maximum	Average
Cr^{6+}						
ADD	1.43E-06	0.162786	8.14E-02	7.41E-06	0.844074	4.22E-01
HQ	9.52E-07	0.108524	5.43E-02	4.94E-06	0.562716	2.81E-01
Cu^{2+}						
ADD	0.0224	3.643614	1.84E+00	0.116148	18.89281	9.562553
HQ	0.560	91.09036	4.61E+01	2.903704	472.3204	239.0639
Cd^{2+}						
ADD	0.0019	0.009	6.40E-03	0.009852	0.046667	0.033186
HQ	1.900	9.000	6.40E+00	9.851852	46.66667	33.18519
Pb^{2+}						
ADD	0.166143	1.7435	1.04E+00	0.861481	9.04037	5.381666
HQ	1186.735	12453.57	7.41E+03	6153.439	64574.07	38440.47
Ni^{2+}						
ADD	0.013357	0.207214	1.17E-01	0.069259	1.074444	0.606481
HQ	0.667857	10.36071	5.85E+00	3.462963	53.72222	30.32407
Total metals						
ADD	2.04E-01	5.77E+00	3.09E+00	3.09E+00	2.99E+01	1.60E+01
HI	1.19E+03	1.26E+04	7.47E+03	6.17E+03	6.51E+04	3.87E+04

Table 7: Lifetime Average Daily Dose (LADD) (mg $kg^{-1}d^{-1}$) of Metals and Health Hazard through Soils Ingestion for Adults and Children at 5 - 10 cm Depth.

Human adults				Children		
Metals	Minimum	Maximum	Average	Minimum	Maximum	Average
Cr^{6+}						
ADD	0.000143	0.231043	0.115664	0.000741	1.198	0.599741
HQ	9.52E-05	0.154029	0.07711	0.000494	0.798667	0.399827
Cu^{2+}						
ADD	0.022857	4.923471	2.484593	0.118519	25.52911	12.88307
HQ	0.571429	123.0868	62.11483	2.962963	638.2278	322.0769
Cd^{2+}						
ADD	0.001829	0.016043	0.009851	0.009481	0.083185	0.051074
HQ	1.828571	16.04286	9.850001	9.481481	83.18519	51.07408
Pb^{2+}						
ADD	0.136929	1.369143	0.821501	0.71	7.099259	4.25963
HQ	978.0612	9779.592	5867.857	5071.429	50708.99	30425.92
Ni^{2+}						
ADD	0.020257	0.243971	0.142243	0.105037	1.265037	0.737556
HQ	1.012857	12.19857	7.112142	5.251852	63.25185	36.87778
Total metals						
ADD	0.182015	6.783671	3.57385	0.943778	35.17459	18.53107
HI	9.81E+02	9.93E+03	5.95E+03	5.09E+03	5.15E+04	3.08E+04

(0.00014 mg kg^{-1} d^{-1}) and Ni^{2+} (0.02 mg kg^{-1} d^{-1}) except for Cr^{6+} which was below the RfD [21].

The total health hazard index (HI) for adults and children ranged between 1.91E+03 to 1.26E+04 with mean value of 7.47E+03 and between 6.17E+03 to 6.51E+04 with mean value of 3.87E+04, respectively. These estimated higher values of HI were all above the acceptable safe risk level (HI ≥ 1), indicating high risk to human adults and children from the studied metals through soil ingestion (Table 6).

Similarly, the LADD of Cr^{6+}, Cu^{2+}, Cd^{2+}, Pb^{2+} and Ni^{2+} through soil ingestion for human adults at this 5 – 10 cm ranged between 0.000143– 0.231043mg kg^{-1} d^{-1} (mean, 0.115664mg

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$kg^{-1} d^{-1}$), 0.022857 – 4.923471 mg $kg^{-1} d^{-1}$ (mean, 2.484593 mg $kg^{-1} d^{-1}$), 0.001829 – 0.016043 mg $kg^{-1} d^{-1}$ (mean, 0.009851 mg $kg^{-1} d^{-1}$), 0.136929 – 1.369143 mg $kg^{-1} d^{-1}$ (mean, 0.821501 mg $kg^{-1} d^{-1}$), and 0.020257 – 0.243971 mg $kg^{-1} d^{-1}$ (mean, 0.142243 mg $kg^{-1} d^{-1}$) respectively. However, average LADD for children at this depth was 0.599741mg $kg^{-1} d^{-1}$ (range, 0.000741 – 1.198 mg $kg^{-1} d^{-1}$), 12.88307 mg $kg^{-1} d^{-1}$ (range, 0.118519 – 25.52911 mg $kg^{-1} d^{-1}$), 0.051074 mg $kg^{-1} d^{-1}$ (range, 0.009481 – 0.083185 mg $kg^{-1} d^{-1}$), 4.25963 mg $kg^{-1} d^{-1}$ (range, 0.71– 7.099259 mg $kg^{-1} d^{-1}$), and 0.737556 mg $kg^{-1} d^{-1}$ (range, 0.105037 – 1.265037mg $kg^{-1} d^{-1}$) respectively for Cr^{6+}, Cu^{2+}, Cd^{2+}, Pb^{2+} and Ni^{2+} from soil ingestion. The LADDs of total metals for adults and children ranged from 0.182015 to 6.783671 mg $kg^{-1} d^{-1}$ with mean value of 3.57385 mg $kg^{-1} d^{-1}$, and from 0.943778 to 35.17459 mg $kg^{-1} d^{-1}$ with mean value of 18.53107 mg $kg^{-1} d^{-1}$, respectively for children at this depth.

These average daily intakes (ADIs) were mostly above the recommended reference dose (RfD) values for Cr^{6+} (Cr^{6+} salt, 1.5 mg $kg^{-1} d^{-1}$), Cu^{2+} (0.04 mg $kg^{-1} d^{-1}$), Cd^{2+} (0.001mg $kg^{-1} d^{-1}$), Pb^{2+}i(0.00014 mg $kg^{-1} d^{-1}$) and Ni^{2+} (0.02 mg $kg^{-1} d^{-1}$) [21].

The total health hazard index (HI) for adults and children ranged between 9.81E+02 to 9.93E+03 with mean value of 5.95E+03, and between 5.09E+03 to 5.15E+04 with mean value of 3.08E+04, respectively. These estimated higher values of HI were mostly above the acceptable safe risk level (HI ≥ 1), indicating high risk to human adults and children from the studied metals through soil ingestion (Table 7).

Based on the analysis of variance (ANOVA) test at $p<0.05$ level of confidence, there was significant difference in the concentration of metal ons in the soils of the study areas as compared to that of control site. This may reflect the level of pollution within the sampling locations (Table 8).

Conclusion

Overall, the results of the analyses revealed that soil samples within the vicinity of the welding workshops were heavily polluted by Cr^{6+}, Cu^{2+}, Cd^{2+}, Pb^{2+} and Ni^{2+}. This was due to the activities within these areas that generated a lot of wastes, ranging from scrap metals to used solders and electrodes which contaminated the soils with heavy metals.

Table 8: ANOVA Metal Locations.

	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
	metals	7920417.957	1.268	6244900.683	15.980	0.000
Test of within-subject Effects	metals * location	10258321.799	12.683	808823.488	2.070	0.053
	Error(metals)	10904130.517	27.903	390792.119		
Test of Between-Subjects Effects	Intercept	6423279.073	1	6423279.073	24.166	0.000
	location	4824071.844	10	482407.184	1.815	0.117
	Error	5847627.506	22	265801.250		

*There are significant differences (P<0.05) within the levels of metal pollution in each site.

Similarly, the contamination indices indicated a significant degree of contamination which suggests anthropogenic origins and confirmed the effects of welding activities within these areas. These showed heavy metal ons concentrations in the soil samples from welding workshops as a source of pollution.

These results imply that pollution of the environment by welding workshops has human health and ecological risks. The soil samples were high in Cr^{6+} (113.95 mg/kg;PUG & 161.73 mg/kg; PSR respectively at both depths) Cu^{2+}(2550.53 mg/kg;GUJ & 3446.43 mg/kg; HMC respectively at both depths), Cd^{2+} (6.30 mg/kg;PUG & 11.23 mg/kg; PUG respectively at both depths), Pb^{2+} (1158.88 mg/kg;PSR & 853.68 mg/kg; HMC respectively at both depths), and Ni^{2+} (145.05 mg/kg;GUJ & 170.78 mg/kg; GUJ respectively at both depths) concentrations which were far above WHO maximum contaminant limit. The Enrichment and Contamination Factors, Pollution Load and the Geo-accumulation Indices values also showed that the soils in the study area were polluted with these heavy metals. A comprehensive study of the pollution/contamination indices of hazardous heavy metals ons shows that steps should be taken to minimize the impact of these elements on human health and the environment especially as.

To this end, intense torrential rainfall in this study areas get some of these ions leached into the soil and by extension into underground water; whereas some few impermeable once get wash-away into new by wells located within the vicinity of the workshops.

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Authors' Contributions

The design and experiments of this research from the measurement, sample collection, preservation, and analysis of heavy metals were performed by Jimoh Abdullateef; Edith.B. Agbaji, Victor.O. Ajibola and Mustapha.A. Funtua supervised and guided the work while MUSRL staff provided access to the laboratory where digestion and heavy metal analyses were carried out using AAS technique. All authors read and approved the final manuscript.

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Availability of data and materials

General data repository and workflow management/ versioning connect to other services; free Open Science Framework.

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