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ORIGINAL RESEARCH PAPER

Assessment of some Heavy Metals in Soil Samples Around Identified Metal Workshops in Otun-Ekiti, Nigeria

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A B S T R A C T

This study was undertaken to determine the levels of ten heavy metals (Cd, Cu, Cr, Co, Fe, Mn, Ni, Pb, Zn and As) in twelve soil samples from selected goldsmith workshops in Otun-Ekiti, Nigeria using Flame Atomic Absorption Spectrometry (FAAS). Identical samples were also collected (outside the workshops as control) and analyzed using the same analytical technique. The results showed that the levels (mg/kg) of these metals ranged from (0.009 to 0.056), (6.418 to 34.598), (0.876 to 4.978), (0.024 to 0.229), (766.744 to 1062.958), (16.089 to 27.539), (0.666 to 1.435), (2.075 to 2.987), (24.474 - 36.310) and (0.012 to 0.117) for Cd, Cu, Cr, Co, Fe, Mn, Ni, Pb, Zn and As respectively. The levels in samples from the sites were found to be relatively higher than the control ($t < 0.05$). Results from this study revealed that Cr (1.04 E-01) and Zn (6.09 E-06) recorded the highest and lowest hazard quotient and the trend of total hazard quotient of all the heavy metals analyzed. The hazard Quotients (HQ) and Hazard Index (HI) deduced from the workshops fall below the acceptable level indicating unlikelihood of non-carcinogenic health risks. However, site 2, site 3 and site 4 workshops were estimated to pose medium cancer risks with Incremental Lifetime Cancer Risk (ILCR) values of 9.788 x 10-5, 7.568 x 10-5 and 8.369 x 10-5 respectively. The levels of these heavy metals were slightly enriched in Fe, Mn, Ni, Pb and Zn (EF = 1.000 – 9.398) in the sites except Zn in site 1. The results revealed the soil samples were slightly contaminated with these heavy metals and soil in these areas might not be good for farming.

Introduction

One of the oldest industrial processes in the world, jewelry creation has always required certain risky procedures. Workers in the goldsmith industry are frequently exposed to acid, wax, and coal dust vapors. As exposure rose, the likelihood of respiratory conditions like lung cancer and cardiovascular disease also increased (Choudhari *et al.,* 2014). The craftsmen' chest and lungs are harmed by constant mouth breathing and they are more likely to develop asthma and tuberculosis. Workers are severely impacted by occupational exposures and soil contamination in these unorganized industries because there is little monitoring, all terrestrial creatures rely on dirt for their physical support (Singhal *et al.,* 2018). It is a composite mixture of organic and inorganic stuff, and its physical, chemical, and biological characteristics are determined by diverse constituents. It serves as a crucial sink for toxins and minerals (Luo *et al.,* 2007; Masindi *et al.,* 2018). The development of industries with the potential to affect the natural environment as a result of human determination to equate demand with production has been established to be the cause of environmental contamination; however, the impacts of anthropogenic activities have higher effects on the properties of soil than climatic change. (Masindi *et al.,* 2018; Jimoh *et al.,* 2020). Environmental pollution brought on by human activity has become a widespread problem in Nigeria and all other developing nations, primarily as a result of non-compliance or the lack of stringent regulations to control the activities, which creates a number of health concerns (Ogunkan 2022). Heavy metals are poisonous to living things and polluted levels of heavy metals can hinder vital biochemical processes, endangering the health of people, plants, and animals (Ikenaka *et al.,* 2010; Briffa et al., 2020). Due to the fact that these heavy metals cannot biodegrade, the environment needs to be cleaned up (Yan A *et a.,* 2020; Adamu 2023). The accumulation of excess heavy metals in soil through skin contact, ingestion, and inhalation poses a major hazard to the safety of human life (Lim *et al.,* 2008; Mitra *et al.,* 2022). According to the kind and amount of the metal, heavy metals present in high quantities in the environment generally provide a variety of health risks with varying symptoms (Momodu and Anyakora, 2010). With respect to their locations and the nature of the work they perform, industrial activities like workshops are now a significant source of environmental pollution (Manisalidis *et al.,* 2020). In Ekiti State's otun town, there are many metal workshops, which is a sign of increased human activities that produce a lot of environmental toxins, especially heavy metals, which have a negative impact on the health of the exposed population. Potential environmental hazards, such as the toxins emitted by these workshops, require immediate care. The proximity of individuals to the health dangers connected with such soil increases as it becomes more heavily metal-contaminated. According to a study by (Adekeye et al., 2011) there are large concentrations of heavy metals in the soil near metal welding shops, which could be dangerous if they get into the food chain and end up endangering both plants and animals in the ecosystem. A highly widespread practice of displaying and selling meals and food items by the roadside vendors among others exposes consumers to health risks. This is because many workshops in Otun town are located by the roadsides inside residential areas where their customers might readily have access to them. It is impossible to overstate the importance of assessing the soils' heavy metal pollution near these workshops.

Methodology

Study Area

The research area is Otun-Ekiti in Ekiti State. It is situated between latitudes 70°151′ and 80°51′ north of the equator and longitudes 40°51′ and 50°451′ east of the Greenwich meridian. With a total land area of 5887.890 sq km. It is bordered by Ondo State in the east and south, Kwara and Kogi States to the south and Osun States to the east.

Figure 1. Location map of the study area

Population of the Study

For this research work, the population of this study specifies the aggregate of workshops where the data for the study was collected. The study area was Otun-Ekiti, Ekiti State, Nigeria.

Sampling Method

Purposive sampling was the method of sampling employed in this investigation. Four (4) goldsmith's workshops in Otun-Ekiti were considered in this study.

Sample collection

Sixteen samples were collected in all. Four samples were collected at different locations in each workshop while three (3) samples were collected in a far place (as control) where no anthropogenic activities took place. Each sample was collected using different nylon glove and labelled accordingly.

Sample pre-treatment

Each collected soil samples were air dries, grounded in a ceramic mortar and pestle, sieved and also labelled according. The same procedure was used for the control.

Air drying

The samples were air dried in a clean environment at chemistry laboratory to avoid contamination, Federal University Oye-Ekiti. Air-drying refers to the exposure of moist soil samples from the field to ambient air and drying of the sample at room temperature (20°C – 25°C). This method of drying was employed to avoid loss of volatile elements.

Figure 2: Process of air drying

Sample digestion and procedure for analysis

One gram of pulverized and air dried (25^0c) soil sample was weighed into a 100ml conical flask and moistened with distilled water, 10ml aqua regia HNO_3: HCl (3:1) was added and then boiled with steady heat to almost dryness. It was cooled and filtered; the filtrate was made up to 100ml with distilled water and was subjected to metal analysis. The analytical method used for the analysis of metal concentration was spectrometry and the equipment used was Atomic Absorption Spectrophotometer (AAS) Buck Scientific model 211 VGP using the calibration plot method. Three processes were involved; standard preparation, equipment calibration and sample analysis. For each element, the instrument was auto-zeroed using the blank (distilled water) after which the standard was aspirated into the flame from the lowest to the highest concentration. The corresponding absorbance was obtained by the instrument and the graphs of absorbance against concentration were plotted (R = 0.997 – 0.998). The samples were analyzed with the concentration of the metals present being displayed in milligram per kilogram (mg/kg) after extrapolation from the calibration curves.

Human Health Risk Assessment
The effects of exposure to dangerous heavy metals on human health are estimated using the risk assessment approach. For this, the contaminant level, exposure assessment, toxicity/dose-response assessment and risk characterization of the pollutants are examined.

Assessment of Exposure
The assessment of human exposure to the heavy metals is usually carried out by calculating the Average Daily Intake, ADI (mg/kg/day) using equations 1 - 3 (USEPA, 2001; (Orosun *et al.,* 2020; Abdullahi & Musa 2023)

Ingestion Pathway $ADI_{ing} = \frac{Cs \times IngR \times EF \times ED \times CFd}{BW \times AT}$ (1)

Inhalation Pathway $ADIinh = \frac{Cs \times InhR \times EF \times ED}{PEF \times BW \times AT}$ (2)

Dermal Pathway $ADI_{derm} = \frac{Cs \times SA \times AF \times ABS \times EF \times ED \times CF}{BW \times AT}$ (3)

ADI stands for average daily intake of heavy metals (kg/day) from ingestion, inhalation, and skin exposure. (Dermal), heavy metal concentrations are expressed as Cs, body weight of the exposed person is expressed as BW, lifetime exposure duration is expressed as ED, ingestion rate is expressed as IngR (mg/day), exposure frequency is expressed as EF (day/year), and average exposure time is expressed as AT (day).

Table 1: Exposure parameters

S/N	Parameters	Values
1.	Ingestion Rate (IngR)	100 mg/day
2.	Exposure Frequency (EF)	365 day/year
3.	Exposure Duration (ED)	55 years
4.	Conversion Factor (CF)	$1 x 10^{-6}$ kg/mg
5.	Body Weight (BW)	70 kg
6.	Time Period of Exposure (AT)	ED x 365 days
7.	Inhalation Rate (InhR)	20 m^3/day
8.	Particle Emission Factor (PEF)	1.36×10^9
9.	Exposed Skin Surface Area (SA)	5700 cm^2
10.	Adherence Factor (AF)	0.07 $mgcm^{-2}day^{-1}$
11.	Dermal Absorption Factor (ABS)	0.001

(Ihedioha, 2017; Isinkaye, 2018; Orosun et al., 2020

The Non-Carcinogenic Risk Assessment
Hazard Quotient (HQ) which is the ratio of the protracted average daily intake (ADI) to the Reference Dose, RfD (daily absorption rate that is projected to have no significant risk of adverse health effects, over about 70-years lifetime) of a particular heavy metal was determined using equation 4 (USEPA, 2017; Abdullahi & Musa 2023)

$$HQ = \frac{ADI}{RfD} \quad (4)$$

Table 2: Reference Dose of Heavy Metals

Heavy Metals	Ingestion RfD (mg/kg/day)	Inhalation RfD (mg/kg/day)	Dermal RfD(mg/kg/day)
Cd	1.00 x 10^{-3}	5.70 x 10^{-5}	5.00 x 10^{-4}
Co	2.0 x 10^{2}	5.71 x 10^{-6}	1.60 x 10^{-2}
Mn	4.60 x 10^{-2}	1.43 x 10^{-5}	1.84 x 10^{-3}
Ni	2.00 x 10^{-2}	2.06 x 10^{-2}	5.40 x 10^{-3}
Pb	3.50 x 10^{-3}	3.25 x 10^{-3}	5.25 x 10^{-4}
Zn	3.00 x 10^{-1}	3.00 x 10^{-1}	6.00 x 10^{-2}
Cr	3.00 x 10^{-3}	2.86 x 10^{-5}	6.00 x 10^{-5}
Cu	4.00 x 10^{-2}	4.02 x 10^{-2}	1.20 x 10^{-2}
Fe	7.00 x 10^{-1}	8.00 x 10^{-1}	7.00 x 10^{-1}

(kamunda et al., 2017; Lu et al., 2014; Chen et al., 2015; Abdullahi & Musa 2023; Orosun et al., 2020) Non-carcinogenic risks were estimated using Hazard Index (HI) which is an overall non carcinogenic risk posed by more than one heavy metal. It is a total summation of Hazard Quotient (HQ) of the individual heavy metal as illustrated in equation 5 (USEPA, 2001; Orosun et al., 2020)

$$HI = \sum HQ \quad (5)$$

If HQ/HI > 1, then there is likelihood of adverse health effect to the exposed population.

HQ/HI < 1 then there is no likelihood of adverse health effects.

Enrichment Factors

The Enrichment Factors of the selected elements Fe, Mn, Ni, Pb and Zn (with Fe as a reference) were calculated using:

$$E.F = \frac{X/(CONC\ of\ Fe\ (sample)}{Y/CONC\ of\ Fe\ (reference)} \quad (6)$$

Where X is the concentration of an element in the sample

Y is the concentration of an element in the reference

The Reference used in this research is the non-contaminating site (i.e., the control).

The above equation assisted in computing the levels of enrichment of the observed heavy metals (Oyedele *et al.,* 2023)

The Carcinogenic Risk Assessment

The Incremental Lifetime Cancer Risk (ILCR), which is the estimated likelihood that a person exposed to carcinogenic heavy metals will develop cancer over time, was used in the carcinogenic risk assessment (estimation and determination of the possibility of a population developing cancer of any kind after exposure to a carcinogen) (Kamunda *et al.,* 2016; Aliyu *et al.,* 2020). The ILCR were estimated using equation (7).

$$ILCR = ADI \times SF \quad (7)$$

Table 3. Carcinogenic Slope Factor (SF) of Heavy Metals

Heavy Metals	Ingestion SF (mg/kg/day)-1	Inhalation SF (mg/kg/day)-1
Cd	3.80 x 10^{-1}	6.30
Cr	5.00 x 10^{-1}	4.20 x 10^{-1}
Ni	4.40 x 10^{0}	8.40 x 10^{-1}
Pb	8.50 x 10^{-3}	-
As	1.50 x 10^{0}	1.50 x 10^{1}
Cr	5.00 x 10^{-1}	4.20 x 10^{-1}

(Orosun *et al.,* 2020; Aliyu *et al.,* 2020)

Cancer risk greater than 1 × 10^{-4} are considered high, values while below 1 × 10^{-6} are considered not to pose any risk; the acceptable range is between 1 × 10^{-4} and 1 × 10^{-6}.

Results and Discussion

Assessment of Human Exposure

In Tables 1 through 8, the results for the analysis of the control samples for determining the Average Daily Intake (ADI) of the heavy metals found by ingestion, inhalation, and dermal contact pathways are shown. In general, all of the workshops' average daily intake of heavy metals was primarily obtained from eating (ingestion), followed by skin contact (dermal) and then breathing (inhalation) as shown in figure 3 This suggests that people living or working close to these workshops may be exposed to heavy metals through their food and mouths. The findings also showed that, of all the heavy metals examined, Fe had the greatest average daily intakes, with portions of 1.40 x 10^{-3}, 1. 56 x 10^{-3}, 1.04 x 10^{-3}, 1.16 x 10^{-3}, and 3. 48 x 10^{-4} mg/kg/day in soil samples from the Goldsmith Workshops, respectively while As contributed the least to the average daily intakes of heavy metals in soil samples from all the workshops, recording the lowest ADI values (2.63 10^{-7}, 8.32 10^{-8}, 6.01 10^{-8}, and 6.09 10^{-8} mg/kg/day), and for Table 8, Cd is the least in the control group (1.19 x 10^{-9} mg/kg/day). The average daily intakes of all the heavy metals across all three pathways in the workshops, were obtained to be lower than their respective chronic reference doses (RfD), a rate of daily absorption that is anticipated to have no appreciable risk of negative health effects over a lifespan of approximately 70 years, according to USEPA (2001).

Table 4. Average Daily Intakes of the Heavy Metals in Goldsmith Workshop (site 1) (mg/kg/day)

Heavy Metals	ADIing	ADIinh	ADIderm	Total ADI
Cd	1.42 E-6	2.09 E-10	5.67 E-8	1.46 E-6
Cu	4.56 E-5	6.72 E-9	1.82 E-6	4.74 E-5
Cr	4.83 E-6	8.40 E-10	1.71 E-7	5.00 E-6
Co	1.13 E-6	1.63 E-10	4.4 E-8	1.17 E-6
Fe	1.35 E-3	1.99 E-7	5.40 E-5	1.40 E-3
Mn	2.29 E-5	3.36 E-9	9.12 E-7	2.30 E-5
Ni	9.51 E-7	1.38 E-10	3.76 E-8	9.80 E-7
Pb	3.41 E-6	5.00 E-10	1.35 E-7	3.50 E-6
Zn	3.49 E-5	5.15 E-9	1.36 E-6	3.60 E-5
AS	2.57 E-7	3.74 E-11	1.05 E-8	2.63 E-7
Total	1.47 E-3	7.26 E-7	5.85E-5	

Table 5. Average Daily Intakes of the Heavy Metals in Goldsmith Workshop (site 2) (mg/kg/day)

Heavy Metals	ADIing	ADIinh	ADIderm	Total ADI
Cd	9.28 E-7	1.36 E-11	3.70 E-9	9.32 E-6
Cu	6.27 E-5	9.24 E-9	2.50 E-6	6.52 E-5
Cr	1.15 E-5	1.68 E-9	4.60 E-7	1.19 E-5
Co	2.57 E-7	3.78 E-11	1.03 E-8	2.67 E-7
Fe	1.5 E-3	2.23 E-7	6.05 E-5	1.56 E-3
Mn	2.50 E-5	3.78 E-9	1.03 E-6	2.6 E-5
Ni	1.43 E-6	2.28 E-10	5.7 E-8	1.48 E-6
Pb	2.85 E-6	4.34 E-10	1.14 E-7	3.01 E-6
Zn	4.00 E-5	5.80 E-9	1.59 E-6	4.16 e-5
As	8.00 E-8	1.17 E-11	3.19 E-9	8.32 E-8
Total	1.65E-3	2.44E-7	6.64E-5	

Table 6. Average Daily Intakes of the Heavy Metals in Goldsmith Workshop (site 3)(mg/kg/day)

Heavy Metals	ADIing	ADIinh	ADIderm	Total ADI
Cd	5.86 E-8	8.61 E-12	2.34 E-9	6.09 E-8
Cu	5.00 E-5	7.35 E-9	1.99 E-6	5.20 E-5
Cr	7.14 E-6	1.05 E-9	2.85 E-7	7.30 E-6
Co	2.77 E-7	3.99 E-11	1.08 E-8	3.10 E-7
Fe	1.9 E-3	1.61 E-7	4.36 E-5	1.04 E-3
Mn	3.40 E-5	5.04 E-9	1.36 E-6	4.10 E-5
Ni	2.04 E-6	2.10 E-10	8.18 E-8	2.00 E-6
Pb	4.26 E-6	6.30 E-10	1.60 E-7	4.20 E-6
Zn	4.71 E-5	6.93 E-9	1.85 E-6	5.20 E-5
As	5.78 E-8	8.35 E-12	2.31 E-9	6.01 E-8
Total	2.04 E-3	1.82E-7	4.93E-5	

Table 7. Average Daily Intakes of the Heavy Metals in Goldsmith Workshop (site 4) (mg/kg/day)

Heavy Metals	ADIing	ADIinh	ADIderm	Total ADI
Cd	8.00 E-8	1.17 E-11	3.19 E-9	8.32 E-8
Cu	3.40 E-5	4.83 E-9	1.31 E-6	3.53 E-5
Cr	7.11 E-6	1.85 E-9	2.80 E-7	7.39 E-6
Co	3.27 E-7	4.8 E-11	1.31 E-8	3.40 E-7
Fe	1.12 E-3	1.64 E-7	4.47 E-5	1.16 E-3
Mn	4.00 E-5	5.88 E-9	1.54 E-6	4.15 E-5
Ni	1.20 E-6	1.82 E-10	4.56 E-8	1.25 E-6
Pb	4.28 E-6	6.19 E-10	1.65 E-7	4.45 E-6
Zn	5.14 E-5	7.56 E-9	2.05 E-6	5.34 E-5
As	5.86 E-8	8.61 E-12	2.34 E-9	6.09 E-8
Total	1.26E-3	1.84E-7	5.01E-5	

Table 8. Average Daily Intakes of the Heavy Metals in Goldsmith Workshop CONTROL (mg/kg/day)

Heavy Metals	ADIing	ADIinh	ADIderm	Total ADI
Cd	1.14 E-8	1.68 E-12	4.56 E-10	1.19 E-9
Cu	1.00 E-5	1.52 E-9	3.99 E-7	4.11 E-7
Cr	1.2 E-6	1.94 E-10	5.13 E-8	1.25 E-6
Co	5.70 E-8	9.87 E-10	2.28 E-9	6.03 E-8
Fe	3.35 E-4	4.93 E-8	1.34 E-5	3.48 E-4
Mn	4.00 E-6	5.88 E-10	1.59 E-7	4.21 E-6
Ni	2.88 E-8	5.88 E-12	1.60 E-9	3.04 E-8
Pb	2.80 E-8	4.78 E-11	1.30 E-8	4.11 E-8
Zn	7.50 E-6	1.09 E-9	2.85 E-7	7.78 E-6
As	2.88 E-8	5.88 E-12	1.60 E-9	3.04 E-8
Total	3.45E-4	5.37E-8	5.01E-5	

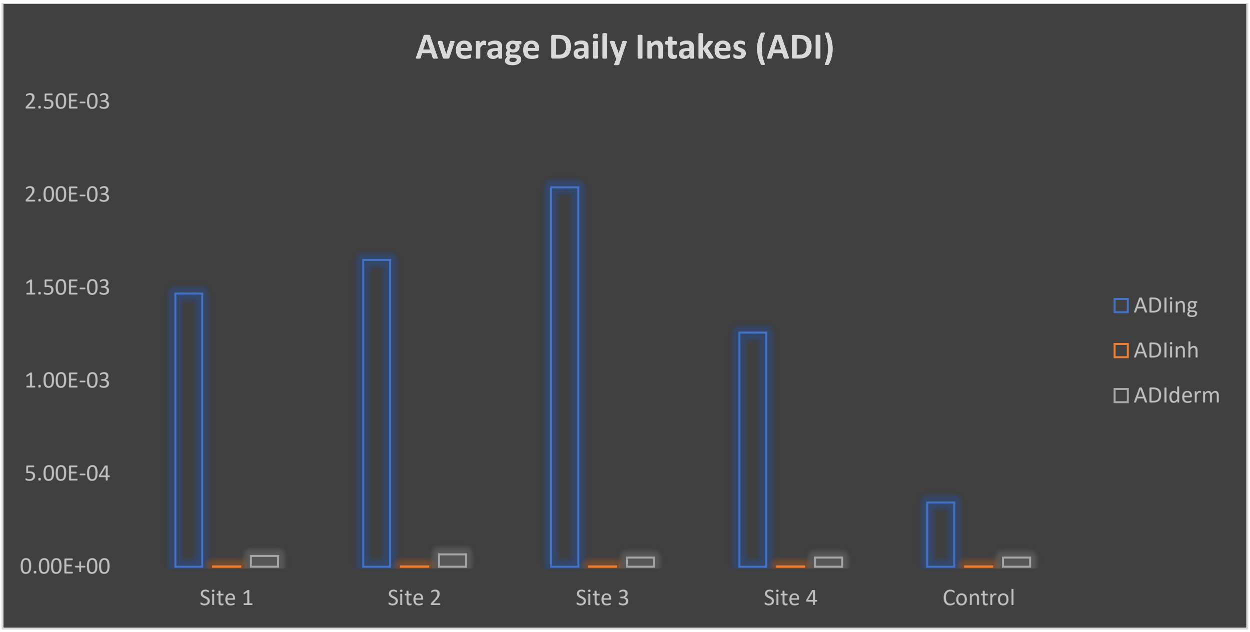

Figure 3. Comparison of Average Daily Intakes of all the sites and control

Table 9. Comparison of the levels of heavy metals (mg/kg) in soil samples with FEPA/WHO limits.

Heavy metals	Site 1	Control (mg/kg)	Site2	Control (mg/kg)	Site3	Control (mg/kg)	Site 4	Control (mg/kg)	WHO/FEPA limits (mg/kg) (2013) Soil for agriculture
Cd	0.037	0.011	0.065	0.008	0.041	0.009	0.056	0.010	3-30
Cu	31.972	5.135	43.927	7.252	34.598	5.920	25.080	6.418	1.500
Cr	3.382	0.876	8.083	0.931	4.845	1.039	4.978	1.519	0.050
Co	0.110	0.024	0.047	0.048	0.194	0.040	0.229	0.064	0.010
Fe	947.46	219.52	1062.96	254.74	766.74	296.451	784.90	314.28	220 - 1200
Mn	16.089	3.191	17.563	2.821	23.827	3.981	27.539	5.191	200
Ni	0.666	0.012	1.098	0.028	1.435	0.065	0.874	0.076	68
Pb	2.388	0.197	2.075	0.288	2.987	0.257	2.955	0.315	85
Zn	24.474	7.298	28.078	5.294	32.546	5.982	36.310	8.172	50
As	0.095	0.018	0.084	0.012	0.117	0.016	0.115	0.019	0.050

Non-carcinogenic Risk Assessment

The estimation of the workshops' non-carcinogenic health risk assessment results was shown in Table 10. The findings showed that Cd provided the greatest individual target Hazard Quotient (HQ) calculated in site 2 soil samples (9.31×10^{-3}), while Ni contributed the least (1.34×10^{-5}) in the same soil samples. For the control the highest heavy metal was found at Pb (1.17×10^{-3}) and the least was Ni (1.52×10^{-6}). Similarly, Cr was found to records the highest total hazard quotient of heavy metal across the workshops while Zn records the lowest. The trend of total hazard quotient of all the heavy metals analyzed proceed in decreasing order of Cr > Cd > Fe > Cu > Pb > Mn >Ni > Co > Zn. however, the hazard quotients of all the heavy metals measured were less than one (<1), the related standard limit by USEPA. The estimated Hazard Index (HI) in soil samples of all the workshops ranges between 6.57 $\times10^{-3}$ to 1.88 $\times10^{-2}$, site 2 workshop soil samples were estimated to have highest hazard index whereas site 3 workshop soil samples recorded the lowest in order. Site 2 > Site 1 > Site 4 > Site 3 was the overall order of decreasing danger index for the workshops. However, every workshop's projected hazard index is below the accepted safe level of one (1) established by the USEPA. According to this, there is no chance that any non-carcinogenic health consequences will materialize (USEPA, 2001). In a related investigation, all of the soil samples had an estimated Hazard Index of less than one (1), according to Orosun *et al.* (2020), Abdullahi and Musa (2023), and others. In contrast, research of a similar nature by Liang *et al.* (2017) and Jimoh *et al.* (2020), both revealed raised hazard index estimates over the tolerable safe level and suggested potential health risks to the surrounding inhabitants in each case.

Table 10. Non-Carcinogenic Health Risk Assessment of the Workshops

Heavy Metals	Site 1	Site 2	Site 3	Site 4	Total HQ	Control
Cd	1.45 E-3	9.31 E-3	6.08 E-5	8.32 E-5	1.08 E-2	1.19 E-5
Cu	1.19 E-3	1.63 E-3	1.30 E-3	8.83 E-4	5.00 E-3	1.03 E-5
Cr	1.67 E-3	3.96 E-3	2.43 E-3	2.46 E-3	1.04 E-1	4.17 E-4
Co	5.85 E-5	1.34 E-5	1.55 E-5	1.70 E-5	1.04 E-4	3.02 E-6
Fe	2.00 E-3	2.23 E-3	1.48 E-3	1.65 E-3	7.41 E-3	4.97 E-4
Mn	5.00 E-4	5.65 E-4	8.91 E-4	9.02 E-4	2.87 E-3	8.95 E-5
Ni	4.94 E-5	7.40 E-5	1.00 E-4	6.25 E-5	2.86 E-4	1.52 E-6
Pb	1.00 E-3	8.60 E-4	1.20 E-4	1.27 E-3	3.25 E-3	1.17 E-3
Zn	1.20 E-4	1.38 E-4	1.73 E-4	1.78 E-4	6.09 E-6	2.59 E-5
Hazard Index (HI)	8.04 E-3	1.88 E-2	6.57 E-3	7.51 E-3		2.22 E-3

Carcinogenic Risk Assessment

Table 11 displays the findings for the workshops' assessment of Incremental Lifetime Cancer Risk (ILCR). The ILCR estimates determined in workshop soil samples ranged from 9.788 x 10^{-5} to 4.385 x10^{-5}. The workshops at sites 2 and 1, respectively, recorded the greatest and lowest ILCR values. The workshops' ILCR estimations are listed in decreasing order as follows: site 2 > site 4 > site 3 > site 1. According to the contributions of each heavy metal to the ILCR estimates, As and Pb had the highest and lowest amounts in each workshop. The workshops at sites 2, 3, and 4 were determined to have a medium cancer risk based on the ILCR values, but site 1 was in the risk category for low cancer risk.

Table 11. Estimated Incremental Lifetime Cancer Risk (ILCR) Assessment of the Workshop

Workshop	Cd	Cr	Ni	Pb	As	ILCR	Risk Status
Site 1	5.555E-07	2.500E-06	4.312E-06	2.975E-08	4.148E-05	4.385E-05	Low Risk
Site 2	3.542E-06	5.950E-06	6.512E-06	2.556E-08	8.195E-05	9.788E-05	Medium Risk
Site 3	2.314E-08	3.650E-06	8.800E-06	3.570E-08	6.313E-05	7.568E-05	Medium Risk
Site 4	3.162E-08	3.695E-06	5.500E-06	3.782E-08	7.443E-05	8.369E-05	Medium Risk
Control	4.522E-10	6.250E-07	1.340E-07	3.494E-10	7.443E-06	8.230E-06	Low Risk

The findings suggest that while site 1 workshop is regarded as safe, the medium risk classification of sites 2, 3, and 4 raises significant alarm. Due to the potential impact the risk may have had on human health, monitoring the situation is crucial. A study by Orosun et al. (2020) that used the ILCR to estimate the carcinogenic risk in soil samples likewise reports results above the USEPA-recommended safe zone.

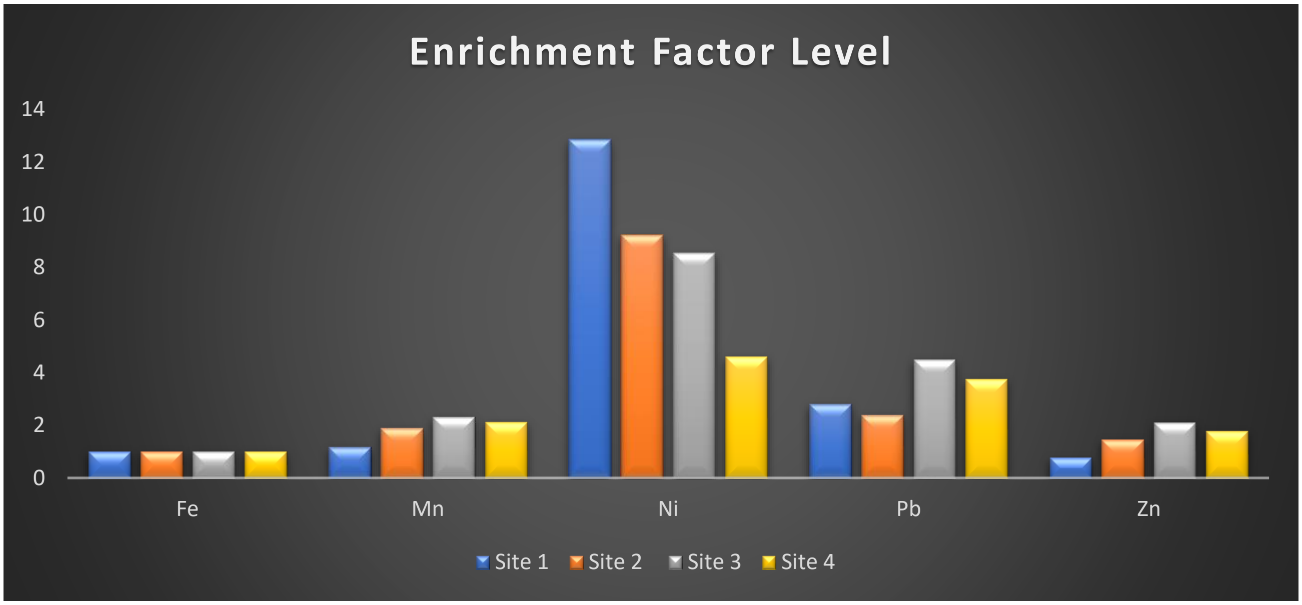

Figure 4. The enrichment factors (E.F) of heavy metals in the soil samples

Figure 4 depicts the enriched factors (E.F) of the heavy metals found in the soil and vegetable samples, respectively. Indicators include E.F 1 (not enriched), E.F = 1–10 (somewhat enriched), and E.F 10 and above (enriched).

Conclusion

According to the study, individuals are exposed to heavy metals through ingestion, inhalation, and cutaneous pathways, with ingestion being the main one. In the workshop soils, Fe and As made up the largest proportions of the heavy metals' average daily intakes. The results gave the baseline levels of the metals in the soil samples of the sites considered. The soil samples were slightly enriched in Fe with their enrichment factors ranging from (1.000 to 9.398) Sites 1, 2, 3 and 4 soil samples were slightly enriched in all the heavy metals assessed while soil samples in site 2 were slightly enriched in Fe, Mn and Pb but not enriched in Ni and Zn. The mean concentration of Fe, Mn, Pb, Ni and Zn (mg/kg) in all the four goldsmith workshops were below the permissible limits set by WHO/FEPA (Table 9). The total hazard quotient for all the heavy metals analyzed was found to be Cr > Cd > Fe > Cu > Pb > Mn >Ni > Co > Zn, with Ni and Pb recording the highest and lowest hazard quotients respectively. However, the workshops' Hazard Quotients (HQ) and Hazard Index (HI) are below the acceptable level. Thus, it was determined that the workshops were unlikely to have any non-carcinogenic health risks. Based on the Incremental Lifetime Cancer Risk (ILCR) values, site 2, site 3, and site 4 workshops were found to have a medium cancer risk, while site 1 workshop pose a low cancer risk to humans.

Recommendations

i. Environmental impact assessment (EIA) must be carried out periodically to monitor the levels of heavy metals.
ii. Considering the time and financial constraints XRF techniques should be employed to analyze soil samples in the study areas for comparison with AAS results obtained in this study.
iii. The sample size can be increased as far as this study is concerned.

Conflict of interest

The author declares that there was no conflict of interest.

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