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HEALTH RISK ASSESSMENT OF SOME HEAVY METALS IN SOIL SAMPLES AROUND IDENTIFIED METAL WORKSHOPS

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ABSTRACT

Soil properties may change due to climate change, but in recent times, the changes occur as a result of anthropogenic activities such as metal workshop operations. This study was conducted to assess the impact of metal contamination on human health due operating activities of metal workshops. In this research work which was carried out to estimated human health risk due to heavy metal contamination around metal workshops, five different workshops, Garejin Oga Abdul (GOA), Nakowa Welding Construction (NWC), Garejin Da'awa (GDH), Garejin Adamu Salisu (GAS) and Garejin Iliya Maina (GIM) all in Potiskum town, Yobe State were sampled for the study and analyzed for eight heavy metals (Pb, Zn, Cr, Cd, Co, Mn, Ni and Cu) levels using Atomic Absorption Spectrophotometer (AAS). Results from this study revealed that Cr (2.37E-01) and Co (5.77E-04) recorded the highest and lowest hazard quotient and the trend of total hazard quotient of all the heavy metals analyzed is Cr > Pb > Mn > Cu > Cd > Ni > Zn > Co. 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, GDH, GIM and GOA workshops were estimated to pose medium cancer risks with Incremental Lifetime Cancer Risk (ILCR) values of 8.195×10^{-5}, 6.313×10^{-5} and 7.443×10^{-5} respectively.

Keywords: Hazard Index, Hazard Quotient, Health Risk, Heavy Metals, Workshop

INTRODUCTION

Soil provides the means of physical support for all terrestrial organisms (Garba and Abubakar, 2018). It is a composite mixture of organic and inorganic matter, with distinct constituents that determine its physical, chemical and biological properties. It is an essential sink for nutrients and pollutants (Luo *et al.,* 2007). However, the properties of soil may change due to climate change, but mostly due to impact of activities of anthropogenic origin.

The pollution of the environment has been found to result from human's determination to match desire with production through the establishment of industries with the potentials to pollute the environment (Jimoh *et al.*, 2020). Pollution of the environment by anthropogenic activities have become a rampant phenomenon in Nigeria and all other developing countries mostly due to non-compliance or absence of strict measures to regulate the activities, leading to various health risks.

Heavy metals are toxic to the living organism and contaminated levels of heavy metals can impair important biochemical process posing a threat to human health, plant growth and animal life (Ikenaka *et al.*, 2010). These heavy metals are non-biodegradable and therefore need to be removed from the environment (Adamu, 2023). Soil containing excess heavy metals pose a serious threat to the safety of the human life by accumulating in human body via direct inhalation, ingestion and dermal contact (Lim *et al.*, 2008). In general, the presence of heavy metals in high concentrations in the environment results to various health hazards with varied symptoms depending on the nature and quantity of the metal (Momodu and Anyakora, 2010).

Environmental pollution from industrial activities such as workshops has become a serious issue in the recent past especially due to their locations and types of activities carried out (Abah *et al.,* 2014). Large number of metal workshops in Potiskum town of Yobe State is an indication of increased anthropogenic activities that generate a lot of environmental contaminants including heavy metals which in turn exert negative health impact to the exposed residents. The contaminants released by these workshops are potential environmental pollutants that need to be given a serious attention. The more such soil become contaminated with heavy metals, the more the proximity of people to the health risks associated with it.

A study by Adekeye *et al.* (2011) revealed that the soil at the surroundings of metal welding workshops contain high level of heavy metals that could serve as potential danger if enters the food chain which passes toxic and hazardous threats to both plant and animals in the environment. As many workshops in Potiskum town are located by the roadsides within residential areas where their customers could easily have access to them, a very common trend of displaying and selling of foods and food items by the roadside hawkers among others exposes consumers to health hazards. Therefore, heavy metal contamination assessment of soils around these workshops cannot be overestimated and this is the basis for this study.

METHODOLOGY

Study Area

Potiskum town lies within the wet and dry Sudano-Sahelian Savanna belt of Nigeria, West Africa. It is the headquarter of Potiskum local Government Area of Yobe State. The town is situated at 11ºº43'N and 11º04'E with a total population of 244,050 people (NPC, 2006). The Local Government covers a land area of 559 km^2 (Daura et al., 2006) and shares boundary with Nangere LGA to the north, Fune LGA to the east and south and Fika LGA to the west. The average annual rainfall range of the town is 600-800 mm which falls between May/June to September/October (NIMET, 2014). Potiskum have heterogeneous ethnical composition including both indigenous and settlers. The ethnic groups considered to be indigenous include the Ngizim, Kare-Kare and Bolewa, whereas the settlers' ethnic groups include the Hausa, Fulani, Babur, Kanuri, Igbos, Yoruba and Shuwa-Arabs.

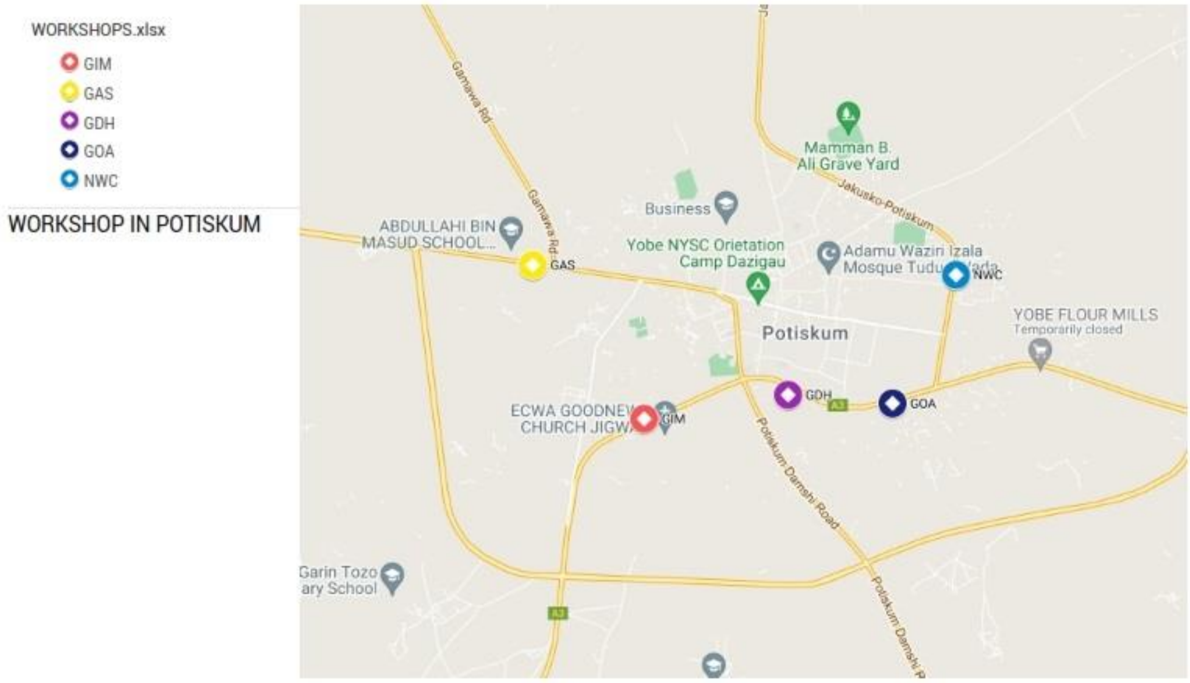

Figure 1: Map of Potiskum Showing the Workshops Sampling Site

Sample Collection
Soil samples were composited at a depth of 6 – 7 inches into polythene bags from five different workshops namely Garejin Oga Abdul (GOA), Nakowa Welding Construction (NWC), Garejin Da'awa (GDH), Garejin Adamu Salisu (GAS) and Garejin Alhaji Iliya Maina (GIM) in Potiskum town.

Sample Preparation and Analysis
The soil samples were ground, sieved with 0.25 mm mesh and dried for 72 hours in drying cabinet. Tecator digestion system was used to digest 5 g of each of the soil samples in a mixture of 10 cm^3 nitric acid (HNO_3) and 5 cm^3 of hydrochloric acid at 250^oC for 40 minutes. Distilled water was added unto the digested samples after cooling, and filtered using Whatman no. 1 filter paper into sample bottles and filled to 100 cm^3 marks with the distilled water. Blank solution was also prepared following the same procedure undergone by the sample solutions. Each sample was analyzed for ten (10) heavy metals concentration viz; Lead (Pb), Zinc (Zn), Chromium (Cr), Cadmium (Cd), Cobalt (Co), Manganese (Mn), Nickel (Ni), Iron (Fe), Selenium (Se), and Copper (Cu) using Atomic Absorption Spectrophotometer (AAS).

Human Health Risk Assessment
Human health risk assessment method is employed to estimate the health-related effects from exposure to hazardous heavy metals. This is done by examining the contaminant level, assessment of exposure, toxicity/dose-response assessment and risk characterization of the contaminants.

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; Liang *et al.*, 2017; Orosun *et al.*, 2020):

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

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

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

Where $ADI_{ing,\ inh,\ derm}$ are average daily intake of heavy metals (kg/day) through ingestion, inhalation and dermal, Cs is the concentration of heavy metals, BW is the body weight of the exposed individual, ED is the lifetime exposure duration (year), IngR is the ingestion rate (mg/day), EF is the exposure frequency (day/year) and AT is the time period over which the dose is averaged (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)	$1x10^{-6}$ 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 is determined using equation 4 (USEPA, 2017; Oguh and Obiwulu, 2020)

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

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	1.00×10^{-3}	5.70×10^{-5}	5.00×10^{-4}
Co	-	5.71×10^{-6}	1.60×10^{-2}
Cr	3.00×10^{-3}	2.86×10^{-5}	6.00×10^{-5}
Cu	4.00×10^{-2}	4.02×10^{-2}	1.20×10^{-2}
Mn	4.60×10^{-2}	1.43×10^{-5}	1.84×10^{-3}
Ni	2.00×10^{-2}	2.06×10^{-2}	5.40×10^{-3}
Pb	3.50×10^{-3}	3.25×10^{-3}	5.25×10^{-4}
Zn	3.00×10^{-1}	3.00×10^{-1}	6.00×10^{-2}

(Ferreira-Baptista and De Miguel, 2005; Lu *et al.,* 2014; Chen *et al.,* 2015; Liang *et al.,* 2017; 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.

The Carcinogenic Risk Assessment

The carcinogenic risk assessment (estimation and determination of the possibility of a population acquiring cancer of any kind after exposure to carcinogen) was done by the use of Incremental Lifetime Cancer Risk (ILCR**)** which is the estimated probability of an individual exposed to carcinogenic heavy metals to develop cancer over a period of time (Kamunda *et al.*, 2016; Isinkaye, 2018). The ILCR were estimated using equation (6).

$$ILCR = ADI \times SF \quad (6)$$

Where ILCR is the Incremental Lifetime Cancer Risk, ADI (mg/kg/day) is the average daily intake and SF (mg/kg/day) is the carcinogenic slope factor.

For this assessment, only the known human carcinogens (Cd, Cr, Ni and Pb) among the heavy metals analyzed were considered.

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

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

(Orosun *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

The results for assessment of human exposure to the heavy metals through calculating the Average Daily Intake (ADI) of the heavy metals identified through ingestion, inhalation and dermal contact pathways are presented in Tables 4 – 8. In general, ingestion pathway constitutes the highest portion of average daily intake of the heavy metals in all the workshops followed by dermal contact pathway and lastly inhalation pathway. This implies that human beings residing/working around these workshops may be highly exposed to the heavy metals via oral and dietary route.

The results also revealed that among all the heavy metals investigated, Mn contributed the highest portion of 9.26×10^{-5}, 1.87×10^{-4} and 8.37×10^{-5} mg/kg/day to the average daily intakes of heavy metals in soil samples from GAS, GIM and NWC workshops respectively, while Cr contributed the greatest portion to the average daily intakes of heavy metals in GDH (1.63×10^{-4} mg/kg/day) and GOA (1.49×10^{-4} mg/kg/day) workshops. Similarly, Cd contributed the lowest portion to the average daily intakes of heavy metals in soil samples of all the workshops recording the least ADI values of 4.88×10^{-7}, 7.17×10^{-7}, 1.81×10^{-7}, 6.31×10^{-7} and 4.30×10^{-7} mg/kg/day in GAS, GDH, GIM, GOA and NWC workshops respectively.

However, average daily intake of all the heavy metals across all the three pathways in the workshops were found to be lower than their respective chronic reference dose (RfD), a daily absorption rate that is projected to have no significant risk of adverse health effects over about 70-years lifetime USEPA (2001).

Table 4: Average Daily Intakes of the Heavy Metals in GAS Workshop (mg/kg/day)

Heavy Metals	ADIing	ADIinh	ADIderm	Total ADI
Cd	4.857E-07	7.143E-11	1.938E-09	4.88E-07
Co	3.571E-06	5.252E-10	1.425E-08	3.59E-06
Cr	8.234E-05	1.211E-08	3.285E-07	8.27E-05
Cu	1.023E-05	1.504E-09	4.081E-08	1.03E-05
Mn	9.226E-05	1.357E-08	3.681E-07	9.26E-05
Ni	7.543E-06	1.109E-09	3.010E-08	7.57E-06
Pb	1.391E-05	2.046E-09	5.552E-08	1.40E-05
Zn	3.334E-05	4.903E-09	1.330E-07	3.35E-05
Total	1.53E-03	2.25E-07	6.11E-06	

Table 5: Average Daily Intakes of the Heavy Metals in GDH Workshop (mg/kg/day)

Heavy Metals	ADIing	ADIinh	ADIderm	Total ADI
Cd	7.143E-07	1.050E-10	2.850E-09	7.17E-07
Co	5.971E-06	8.782E-10	2.383E-08	6.00E-06
Cr	1.625E-04	2.390E-08	6.484E-07	1.63E-04
Cu	2.309E-05	3.395E-09	9.211E-08	2.32E-05
Mn	7.926E-05	1.166E-08	3.162E-07	7.96E-05
Ni	1.686E-05	2.479E-09	6.726E-08	1.69E-05
Pb	4.834E-05	7.109E-09	1.929E-07	4.85E-05
Zn	4.494E-05	6.609E-09	1.793E-07	4.51E-05
Total	2.15E-03	3.17E-07	8.59E-06	

Table 6: Average Daily Intakes of the Heavy Metals in GIM Workshop (mg/kg/day)

Heavy Metals	ADIing	ADIinh	ADIderm	Total ADI
Cd	1.800E-06	2.647E-10	7.182E-09	1.81E-06
Co	4.800E-06	7.059E-10	1.915E-08	4.82E-06
Cr	1.241E-04	1.826E-08	4.953E-07	1.25E-04
Cu	7.500E-05	1.103E-08	2.993E-07	7.53E-05
Mn	1.860E-04	2.736E-08	7.423E-07	1.87E-04
Ni	1.514E-05	2.227E-09	6.042E-08	1.52E-05
Pb	4.306E-05	6.332E-09	1.718E-07	4.32E-05
Zn	8.074E-05	1.187E-08	3.222E-07	8.11E-05
Total	1.86E-03	2.73E-07	7.40E-06	

Table 7: Average Daily Intakes of the Heavy Metals in GOA Workshop (mg/kg/day)

Heavy Metals	ADIing	ADIinh	ADIderm	Total ADI
Cd	6.286E-07	9.244E-11	2.508E-09	6.31E-07
Co	4.371E-06	6.429E-10	1.744E-08	4.39E-06
Cr	1.481E-04	2.177E-08	5.907E-07	1.49E-04
Cu	2.797E-05	4.113E-09	1.116E-07	2.81E-05
Mn	6.963E-05	1.024E-08	2.778E-07	6.99E-05
Ni	1.169E-05	1.718E-09	4.663E-08	1.17E-05
Pb	1.740E-05	2.559E-09	6.943E-08	1.75E-05
Zn	4.586E-05	6.744E-09	1.830E-07	4.60E-05
Total	1.90E-03	2.79E-07	7.58E-06	

Table 8: Average Daily Intakes of the Heavy Metals in NWC Workshop (mg/kg/day)

Heavy Metals	ADIing	ADIinh	ADIderm	Total ADI
Cd	4.286E-07	6.303E-11	1.710E-09	4.30E-07
Co	3.514E-06	5.168E-10	1.402E-08	3.53E-06
Cr	8.071E-05	1.187E-08	3.221E-07	8.10E-05
Cu	3.769E-05	5.542E-09	1.504E-07	3.78E-05
Mn	8.331E-05	1.225E-08	3.324E-07	8.37E-05
Ni	7.114E-06	1.046E-09	2.839E-08	7.14E-06
Pb	1.914E-05	2.815E-09	7.638E-08	1.92E-05
Zn	2.931E-05	4.311E-09	1.170E-07	2.94E-05
Total	1.42E-03	2.09E-07	5.68E-06	

Non-carcinogenic Risk Assessment

Table 9 shows the results for estimation of non-carcinogenic health risk assessment of the workshops. The results revealed that the highest individual target Hazard Quotient (HQ) of the workshops was estimated in GDH workshop soil samples and was contributed by Cr (6.581×10^{-2}) while the least was contributed by Co (9.139×10^{-5}) in soil samples of NWC workshops. Similarly, the Cr was found to records the highest total hazard quotient of heavy metal across the workshops while Co records the lowest. The trend of total hazard quotient of all the heavy metals analyzed proceed in decreasing order of Cr > Pb > Mn > Cu > Cd > Ni > Zn > Co. 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 3.612×10^{-2} to 8.518×10^{-2}, GDH workshop soil samples were estimated to have highest hazard index whereas GAS workshop soil samples record the lowest. In general, the order of decreasing hazard index for the workshops is GDH > GIM > GOA > NWC > GAS. However, all the estimated hazard index of the workshops falls below the acceptable safe level of one (<1) set by USEPA. This indicated that there is no likelihood of non-carcinogenic health risks effects (USEPA, 2001). A similar study by Orosun *et al.* (2020) also reported an estimated Hazard Index of less than one (< 1) in all the soil samples. In contrast to this, a similar study by Liang *et al.* (2017) and Jimoh *et al.* (2020) reported an elevated hazard index estimate above the acceptable safe level and suggested potential health risk to the local residents in each case.

Table 9: Non-Carcinogenic Health Risk Assessment of the Workshops

Heavy Metals	Target Hazard Quotient (HQ) of the Workshops					Total HQ
	GAS	GDH	GIM	GOA	NWC	
Cd	4.870E-04	7.218E-04	1.819E-03	6.352E-04	4.331E-04	4.10E-03
Co	9.198E-05	1.553E-04	1.248E-04	1.137E-04	9.139E-05	5.77E-04
Cr	2.787E-02	6.581E-02	5.027E-02	5.996E-02	3.269E-02	2.37E-01
Cu	2.558E-04	5.849E-04	1.900E-03	7.087E-04	9.548E-04	4.40E-03
Mn	2.954E-03	2.710E-03	6.361E-03	2.381E-03	2.849E-03	1.73E-02
Ni	3.772E-04	8.554E-04	7.684E-04	5.930E-04	3.610E-04	2.96E-03
Pb	3.976E-03	1.418E-02	1.263E-02	5.104E-03	5.616E-03	4.15E-02
Zn	1.112E-04	1.528E-04	2.746E-04	1.559E-04	9.968E-05	7.94E-04
Hazard Index (HI)	3.612E-02	8.518E-02	7.415E-02	6.965E-02	4.309E-02	
Risk Status	No risk	No Risk	No Risk	No Risk	No Risk	

Carcinogenic Risk Assessment

The results for Incremental Lifetime Cancer Risk (ILCR) estimation of the workshops are presented in Table 10. The ILCR estimates measured in soil samples of the workshops ranged within 8.195×10^{-5} to 4.069×10^{-5}. The highest and lowest ILCR estimates were recorded by GDH and NWC workshops respectively. The decreasing order of ILCR estimates of the workshops is GDH > GOA > GIM > GAS > NWC. The individual heavy metals contribution to the ILCR estimates reveals that Cr and Ni contributed the highest and lowest portions to the ILCR estimates in all the workshops. Based on the ILCR values, GDH, GIM and GOA workshops were estimated to have a medium cancer risk, while the remaining workshops, GAS and NWC were estimated to fall within risk category that pose low cancer risk.

Table 10: Estimated Incremental Lifetime Cancer Risk (ILCR) Assessment of the Workshops

Workshop	Cd	Cr	Ni	Pb	ILCR	Risk Status
GAS	1.850E-07	4.118E-05	9.318E-10	1.183E-07	4.148E-05	Low Risk
GDH	2.721E-07	8.127E-05	2.082E-09	4.109E-07	8.195E-05	Medium Risk
GIM	6.857E-07	6.208E-05	1.871E-09	3.660E-07	6.313E-05	Medium Risk
GOA	2.394E-07	7.404E-05	1.444E-09	1.479E-07	7.443E-05	Medium Risk
NWC	1.633E-07	4.036E-05	8.788E-10	1.627E-07	4.069E-05	Low Risk

The results implies that while GAS and NWC workshops are considered safe, the medium risk status of GDH, GIM, GOA calls for much concern. Monitoring of the situation is of great necessity owing to the potential effect the risk may have caused on human health. A study by Orosun *et al.* (2020) employed ILCR for carcinogenic risk assessment in soil samples also reports values above the safe region recommended by USEPA.

CONCLUSION

The study revealed that ingestion, inhalation and dermal pathways are routes through which humans are exposed to the heavy metals with ingestion pathway being the major one. Mn and Cr contributed the highest portions of average daily intakes of the heavy metals in the workshop soils. It was also revealed that Cr and Co recorded the highest and lowest hazard quotient and total hazard quotient of all the heavy metals analyzed proceed in decreasing order of Cr > Pb > Mn > Cu > Cd > Ni > Zn > Co. however, the Hazard Quotients (HQ) and Hazard Index (HI) in the workshops falls below the acceptable level. Thus, it was concluded that the workshops have no likelihood of non-carcinogenic health risks effects and based on the Incremental Lifetime Cancer Risk (ILCR) values, GDH, GIM and GOA workshops were estimated to pose medium cancer risks, while GAS and NWC workshops pose low cancer risk to human beings.

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