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ORIGINAL RESEARCH ARTICLE

Assessment of Heavy Metal Exposure and Cancer Risks for Communities Proximal to Gubi Dam Agricultural Area, Bauchi State, Nigeria

Mohammed A. Shettima[1], Haruna B. Wayar[2], Zakari Mohammed[3], Mohammed A[4], Ayuba M. Jatau[5] and Joseph C. Akan[5]
[1,2,3,4,5&,6]Department of Pure and Applied Chemistry, Faculty of Physical Sciences, University of Maiduguri, Maiduguri, Borno State, Nigeria

ABSTRACT
This study assessed the levels of some heavy metals (Cr, Mn, Fe, Cu, Ni, Cd, Hg, As, Pb) that were detected using Atomic Absorption Spectroscopy (AAS). Soil samples were collected at different depths (0-5, 5-10, 10-15cm) using a spiral Auger from five different agricultural locations (S1 – S5) around Gubi Dam, Bauchi State. The Concentration of those selected heavy metals in the soil samples was below the maximum recommended limits. Also, the carcinogenic health risk of heavy metals (Cr, Ni, As, Pb) and noncarcinogenic health risk of (Cr, Mn, Cu, Ni, Cd, Hg, As, Pb) in fifteen (15) soil samples collected at different depth of 0 – 5cm, 5 – 10cm and 10 – 15cm from Gubi Dam agricultural locations. The assessment was carried out using three different pathways: ingestion, dermal contact, and inhalation for children and adults with respect to average ages of 15 years and 70 years, respectively. In comparison, the result revealed that cancer risk (CR) levels of Cr Ni and Pb were found to be within the safer limit of 1.00E-06 – 1.00E-04, except As (1.14E-04mg/kgd^{-1}, 1.52E-04mg/kgd^{-1}, 1.03E-04mg/kgd^{-1}) in adult through oral ingestion at sampling locations S1, S2, and S4 respectively, which exceeded the threshold limit; hence the population around the study area are possibly at a verge of CRs induced by As. Similarly, the study further revealed the CR levels in adults are greater than those for children, while the levels of the contact risk factors revealed in the order of ingestion > Dermal > Inhalation. Also, the noncarcinogenic health risk assessment with respect to Hazard Quotient (HQ) and Hazard Index (HI) revealed that the HQ values of all the heavy metals were found to be lower than the threshold limit of 1mg/kgd^{-1} with the exception of Cd (3.62E+00mg/kgd^{-1}) in children through injection at S1 sampling location recorded a higher value above the standard limit. Likewise, the HI results were also within the accepted limit, except Cd (6.39E+00mg/kg) in soil at sampling point S1 recorded a higher value of above the safe limit. Therefore, findings from HQ and HI show that the populace around the study area might result in potential health risks concerning Cd.

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INTRODUCTION
All over the world, soils from more than 10 million sites were being reported as being polluted, and more than 50% of these sites are found to be contaminated with heavy metals (EPMC, 2015; Santanu *et al.*, 2018). Heavy metals naturally occur in the soil through pedogenetic processes of weathering at concentrations that are regarded as trace (<1000 mg kg^{-1}) and rarely toxic (Kabata-Pendias and Pendias, 2001; Raymond and Felix, 2011). Due to numerous factors related to human activity and the slow nature of geochemical cycles of heavy metals, virtually soils in urban and rural environments may pile up higher Concentrations of one or more heavy metals above already established permissible limits, such results in greater risks to human health and the entire ecosystems (D'Amore *et al.*, 2005). Therefore, higher concentrations of heavy metals could be connected with various factors such as poor management practices, excessive use of fertilizers (synthetic or organic), industrialization, and or urbanization (Wen *et al.*, 2018). Atmospheric deposition of heavy metals due to high anthropogenic activities also contributes to higher Concentrations of heavy metals (Akan *et al.*, 2014). Hence, understanding the problems concerning the biogeochemistry of heavy metals in soils is paramount because only the minute soluble form of heavy metal is biologically significant, rather than the total Concentration in soils (Bradl *et al.*, 2005).

The heavy metals are regarded as serious contaminants in the soil environments due to various reasons related to (i)

Correspondence: Mohammed Abba Shettima. Department of Pure and Applied Chemistry, Faculty of Physical Sciences, University of Maiduguri. PMB 1069, Maiduguri, Borno State, Nigeria. ✉ mashettima23@unimaid.edu.ng.
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their high pace of accumulation via man-made cycles than natural ones, (ii) their high tendency of mobility from their source to a place most likely with greater potentials of direct exposure will occurs, (iii) the chemical species through which heavy metals are making their way into the environmental system allows higher bioavailable (D'Amore *et al*., 2005).

The mobility of Heavy metals from anthropogenic sources was found to be very rapid, which resulted in their higher prevalence in soil or bioavailability than those from pedogenic or lithogenic (Kaaasalainen and Yli-Halla, 2003; Raymond and Felix, 2011). Contamination of soil by heavy from a wide variety of anthropogenic sources can originate from different forms such as improper disposal of waste containing high levels of metals, gasoline from heavy duties machinery, atmospheric deposition, applications of synthetic fertilizer and pesticides, plants, animal remains or waste (manure) and as well as biosolids (sewage sludge) (Zhang *et al*., 2010).

Basic knowledge of environmental chemistry and related health effects of heavy metals is important in their bioavailability and possible options for remedy. The increasing activities and mobility of heavy metals in soil significantly reckons on factors such as chemical form and their speciation. The redistribution of heavy metals into various chemical forms and different speciations with diverging mobility, toxicity, and bioavailability results from rapid initial adsorption during the geochemical process (Buekers, 2007; Wuana and Okieimen, 2011).

Therefore, it is of paramount to understand that health risk associated with heavy metals varies on their bioavailability, which depends on the type of soil and activities related to chemical behavior in soil; their precipitation and other environmental factors should be taken into account in other to estimate and evaluate their precise risk for different age group (Gao *et al*., 2021).

Gubi dam is one of such numerous reservoirs in the country, which holds runoff during periods of high runoff and releases it during periods of low runoff; the specific functions of the reservoir are to supply the state capital and its environs with potable water, irrigation and serve as a water body for fish production. The dam's water source mainly comes from three tributaries: Gubi River, Tagwaye River, and Shadawanka and Ran River (Abdullahi *et al*., 2014). The most common sources of heavy metal around the agricultural areas of the dam could emanate from excessive usage of agrochemicals by the farmers, city waste and runoff, mining and other industrial activities.

MATERIALS AND METHODS

Sample collections

A total of fifteen (15) soil samples were collected from five agricultural locations around Gubi Dam in September 2024. In each location, five soil samples were collected diagonally at three different depths (0-5cm, 5-10cm, and 10-15cm), using a spiral auger of 2.5cm diameter. The soil samples were then randomly selected and bulked together to form a composite sample before being placed in clean, well-labeled plastic bags and transported to the Department of Pure and Applied Chemistry Laboratory, University of Maiduguri.

Sample Digestion

In an effort to achieve quality and accurate results, laboratory precautions were strictly observed to avoid contamination of samples, and all the equipment and glassware to be used were rinsed and cleaned using distilled water. Accurately, 2g of each soil sample were weighed into 250cm^3 conical flasks, and 10 ml of mixture of Nitric acid and Hydrochloric acid in a ratio of 1:3 were added to each sample. The solution was then heated on a hot plate inside the fume cupboard until white dense fume was observed. The solutions were then removed and allowed to cool to avoid overflow before 3cm^3 of 30% H2O2 was added. The solutions were then heated again until the volume was reduced to 2 ml. Then, the digests were allowed to cool and then filtered into 100 ml volumetric flask. The content was diluted to the 100 ml mark with distilled water. Determination of Cr, Mn, Fe, Cu, Ni, Hg, Cd, As, and Pb were made directly on each final solution using Perkin-Elmer Analyst 300 Atomic Absorption Spectroscopy (AAS).

Exposure Risk Assessment

The assessments of daily environmental exposure to heavy metals in soil were done as carcinogenic and noncarcinogenic health risk assessments. The assessment was carried out for both adults and children based on exposure pathways of (i) oral ingestion, which results from intake of heavy metal through consumption of edible fruit without proper washing, and (ii) dermal contact, which as a result of prolonged sticking of soil on human skin (iii) Inhalation. The calculations for all the pathways both in adults and children were carried out based on the standard procedures by (USEPA, 1996; Isa *et al*., 2015). This process involves using science and statistics tools to measure and determine hazards and exposure pathways and eventually use the calculated or estimated numerical values to ascertain potential risk (Lushenko, 2010). The noncarcinogenic health risk assessments comprise the Hazard Quotient and Hazard Index, which are regarded as categorizations of ascertaining probabilities of advance health-related risk concerning the metals (USEPA, 2012). Heavy metals' Hazard Quotient (HQ) value was estimated based on the quotient between the Concentration of metal, environmental exposure values, and unique reference dose (RfD) established for each metal. Hence, Hazard Quotient (HQ) was regarded as an evaluation of health risk levels due to exposure to heavy metals with respect to average daily intake.

$$HQ_{ing} = \frac{C \times IngR \times EF \times ED}{BW \times AT} \times \frac{CF}{RfD} \quad (1)$$

$$HQ_{der} = \frac{C \times SA \times EF \times ABS \times AF \times ED}{BW \times AT} \times \frac{CF}{RfD} \quad (2)$$

$$HQ_{inh} = \frac{C \times InhR \times EF \times ED}{BW \times AT \times PEF} \times \frac{CF}{RfD} \quad (3)$$

Similarly Hazard Index (HI) values, expressed as a total health risk value, comprise all the estimated exposure pathways (USEPA, 1989). Hence, the (HI) values were calculated using the summation of each heavy metal through all the exposure pathways (Ingestion, Dermal, and Inhalation).

$HI = \sum HQing + HQder + HQinh$ (4) (USEPA, 2011).

The Carcinogenic Health Risk Assessment

The carcinogenic health risk assessment is a way of assessing carcinogenic risk, thereby estimating the probability of an individual developing cancer due to exposure to a potential carcinogenic heavy metal over a lifetime. The cancer risk (CR) values of each metal were calculated using the estimated average daily dose converted by a unique cancer slope factor (CSF) established for each potential carcinogenic heavy metals, which indicate a chance for average direct exposure of an individual to develop cancer over a lifetime (UAEPA, 1989).

$$CRs = \sum ADD \times CSF \quad (5)$$

Table 1: Heavy Metal Exposure Factors used in Equ. 1-3.

Factors	Definition	Value		Unit
		Adult	Child	
C	Soil Metal Conc.	-	-	mg/kg
ingR	Soil Ingestion Rate	100	200	mg/d
SA	Skin Surface area available for Exposure	6032	2373	cm2/d
AF	Soil - Skin Adherence factor	0.07	0.2	mg/d2
inhR	Soil Inhalation Rate	0.83	0.53	m3/h
ED	Exposure Duration	20	6	Yrs
BW	Body Weight	70	15	kg
AT	Average Time	365 x ED		Days
PEF	Soil - Air Particulate Emission Factor	1.36E+09		m3/kg
CF	Conversion Rate	1.00E-06		kg/mg
ET	Exposure Rate	24		hrs/d
EF	Exposure Frequency	350		Days/Year
ABS	Absorption Factor	0.03 For As, 0.01 for other metals		

Shahir *et al.* (2021)

RESULT AND DISCUSSIONS

Mean Concentration of the heavy metals

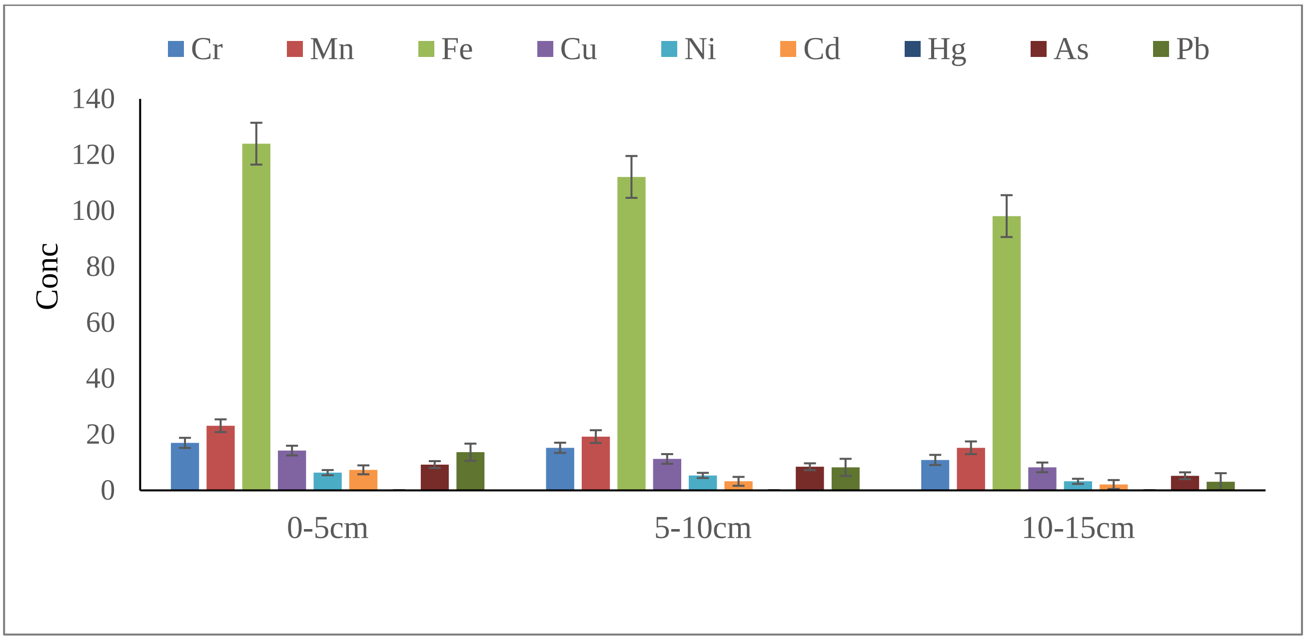

Figure 1: Mean Concentration of Selected Heavy Metals in Soil Samples from S_1 Depth Agricultural Location around Gubi Dam.

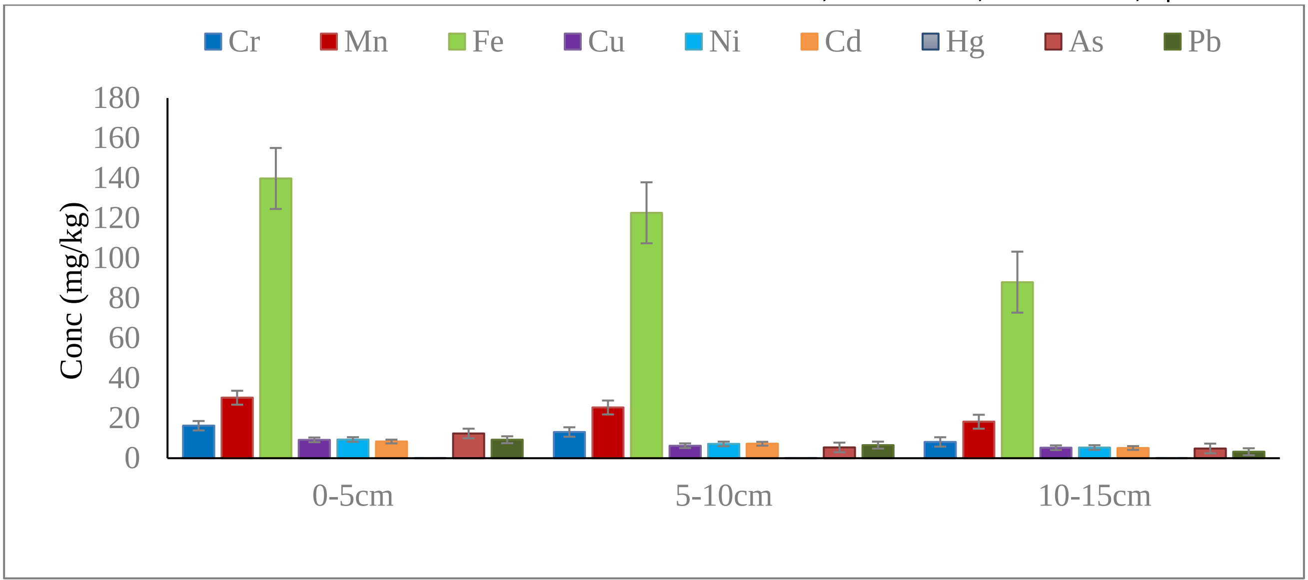

Figure 2: Mean Concentration of Selected Heavy Metals in Soil Samples from S_2 Depth Agricultural Location around Gubi Dam

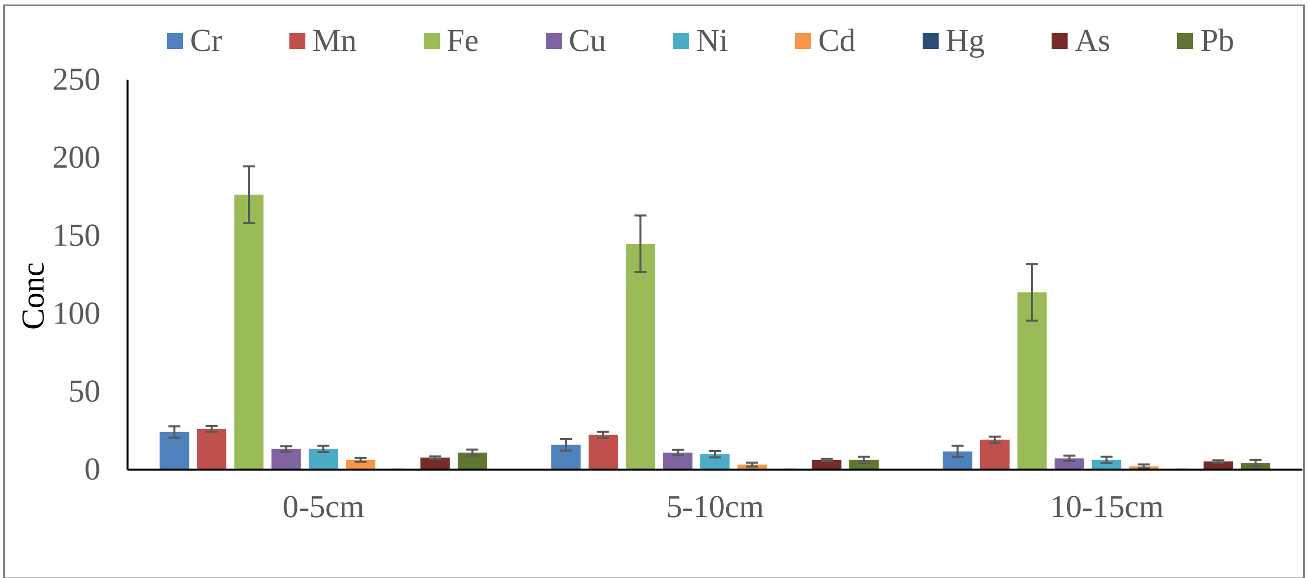

Figure 3: Mean Concentration of Selected Heavy Metals in Soil Samples from S_3 Depth Agricultural Location around Gubi Dam

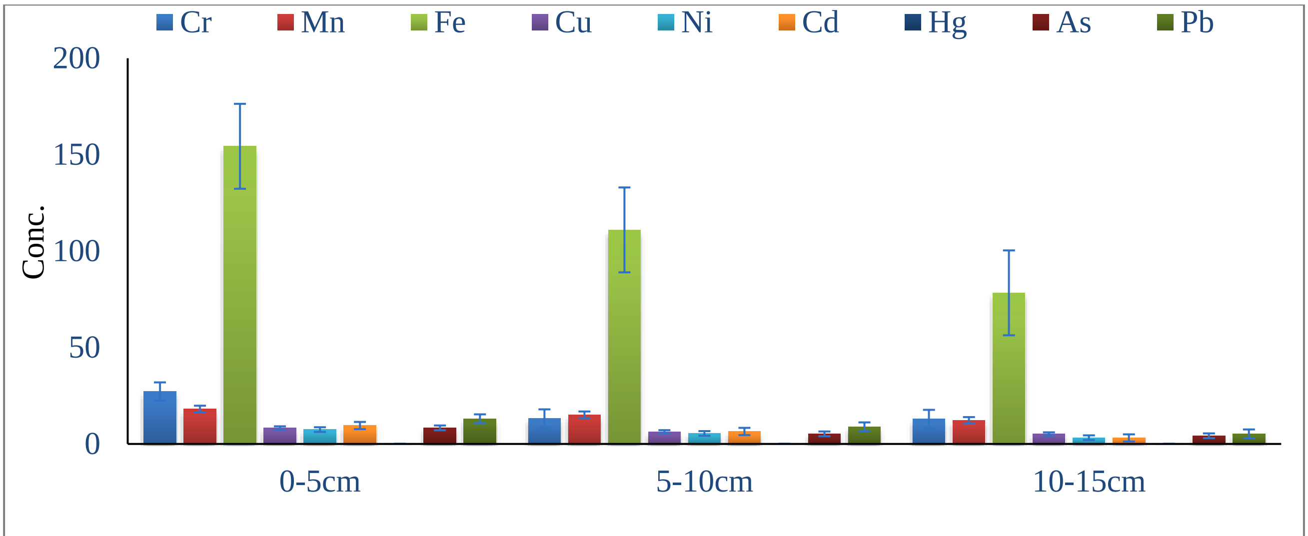

Figure 4: Mean Concentration of Selected Heavy Metals in Soil Samples from S_4 Depth Agricultural Location around Gubi Dam

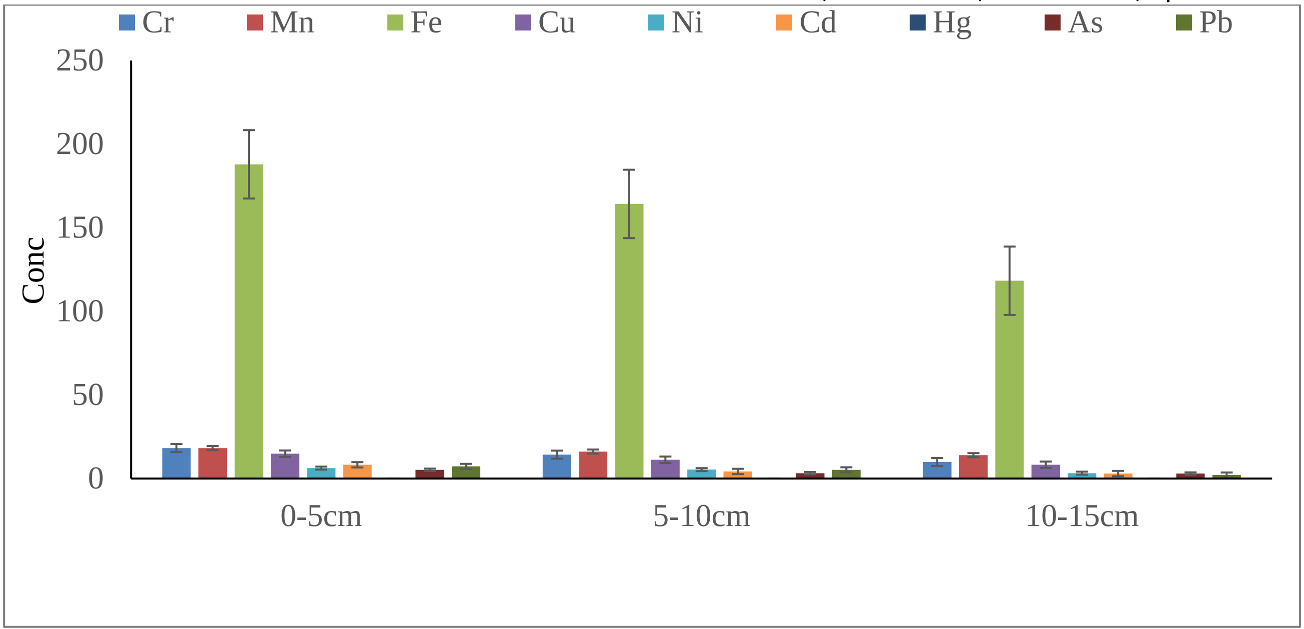

Figure 5: Mean Concentration of Selected Heavy Metals in Soil Samples from S_5 Depth Agricultural Location around Gubi Dam

Chromium is one of the heavy metals in the environment whose Concentration is steadily increasing due to industrial growth, particularly in the development of metals, chemicals and tanning industries (Adeleken and Abegunde, 2011). From the results of this study, the mean Concentration of Cr in soil samples shows a significant value ($p > 0.05$) of 27.2 mg/kg in soil obtained from location S_4 at a depth of 0-5 cm, while the least Concentration of 8.12 mg/kg was recorded in soil sample obtained from location S2 at a depth of 10-15 cm. The Concentration range of Cr reported in this study was found to be higher than the reported range values of 0.23 – 0.37 mg/kg by Shittu *et al.* (2024). Several studies have revealed that chromium is a toxic element that negatively affects human and plant metabolic activities, such as hampered crop growth and reduced vegetable and grain yield and quality. Thus, there is a need for frequent monitoring in soil and crop production systems. However, the level of Cr in the soil samples was further observed to be lower than the permissible limit of 100 mg/kg assigned by FAO/WHO (2013).

Higher exposure to manganese could lead to a neuro impairment known as manganism, which is similar to Parkinson's disease (Obeng *et al.*, 2024). The mean Concentration of (Mn) in this study shows that the soil sample collected at point S2 recorded the highest value of 30.8 mg/kg at a depth of 0-5 cm, while S4 recorded the lowest value of 12.2 mg/kg at a depth of 10-15 cm. These concentrations were found to be lower than the concentration range of 298.3 to 218.9 mg/kg reported by Hura *et al.* (2013) and (1341.41±33.98 and 1248.68±34.51 mg/kg soil) by Ashraf *et al.* (2021). The Mn level in soil samples was also below the permissible limit of 2000 mg/kg as specified by FAO/WHO (2013).

The Concentration of Iron (Fe) reported in this study was observed to be dominant, with a value of 188 mg/kg in soil sample collected from point S5 at a depth of 0-5 cm, while the least value of 78.3 mg/kg was recorded in soil sample collected from point S4 at a depth of 10-15 cm. Similarly, Most *et al.* (2019) reported higher concentration values of 38,353.65 to 18,469.09 mg/kg in Soil than the present study. Also, the concentrations of Fe in the soil reported in this study were much lower than the standard limit of 50,000 mg/kg by FAO/WHO (2013).

Cu recorded a higher concentration of 1.49E + 01 mg/kg in the soil sample collected from point S_5 location at a depth of 0.5cm, while point S_4 recorded the lowest concentration of 5.12E + 00 mg/kg at a depth of 10-15cm. However, Oladeji *et al.* (2016) and Chen *et al.* (2024) reported a higher value of 2.49E + 02 and 1.40E + 02mg/kg and 37.2 - 4.74 mg/kg respectively. The concentrations of Cu in the soil samples reported in this study were below the maximum limit of 100 mg/kg as reported by FAO/WHO (2013).

The concentrations of Ni in the present study show that the soil sample collected from point S_3 revealed the highest value of 1.32E + 01 mg/kg at a depth of 0.5 cm, while the soil sample collected from point S_5 revealed the lowest concentration of 3.22E + 00 mg/kg at a depth of 10-15 cm. Previous studies by Akan *et al.* (2013) reported higher concentrations of Ni in soil ranging from 25.65 to 2.33 mg/kg and also 193 mg/kg by Zhao *et al.* (2024). Similarly, the levels of Ni in the soil samples were found to be lower than the maximum permissible limit of 50 mg/kg recommended by FAO/WHO (2013).

The Concentration of Cd was significantly higher, with a value of 9.55E + 00 mg/kg in the soil sample collected from point S_4 at a depth of 0-5 cm, while the soil sample collected from S_3 at a depth of 10-15 cm recorded the lowest concentration value of 2.08E + 00 mg/kg. However, the Cd concentration range in this study was higher than the reported range of 0.03 to 0.05 mg/kg by Shittu *et al.* (2024). A previous study by Arise *et al.* (2015) reported lower Concentrations of Cd ranging from 0.0007 to 0.004 mg/kg in soil samples collected at various distances around Odo-Efo River, Kwara State, Nigeria. However, the concentrations of Cd in the soil samples exceeded the permissible limit with the exception of soil samples collected from S_1, S_3, and S_5 at a depth of 10-15cm, which were lower than the standard permissible limit of 3mg/kg as recommended by FAO/WHO (1995).

This study revealed the highest concentration of Hg was (3.00E – 03 mg/kg) in a soil sample collected from S_1 at a depth of (10-15cm), while the soil collected from S_2, S_3, S_4, S_5, as well as S1 at a depth of 0-5cm, recorded the lowest Concentration of Hg as 1.00E-03 mg/kg. This result is similar to the report of Arise *et al.* (2015), who also reported Hg range of 0.001 to 0.03 mg/kg in soil samples. Lawal *et al.* (2017) reported concentrations of Hg in the soil samples with values ranging from 2.12 to 1.85 mg/kg, these values were higher than the values detected in the present study. The concentrations of Hg in the soil samples were lower than the value of 0.3 mg/kg specified by FAO/WHO (1995).

In this present study, the Concentration of As in the soil sample collected from point S_2 at a depth of 0-5 cm was highest with a value of 1.23E+01 mg/kg, while point S_5 at a depth of 10-15 cm recorded the least Concentration with a value of 2.98E+00 mg/kg. Uwah *et al.* (2011) reported some concentrations of As in soil at a range of 3.42 to 4.84 mg/kg. The concentrations of As in this study were compared with FAO/WHO (1995) permissible limits of 20mg/kg. The levels of As in the soil samples were below the FAO/WHO (1995) standard limits,

Pb in this study shows that the soil sample collected from S_1 at a depth of 0-5cm recorded the highest Concentration with a value of 1.37E+01 mg/kg, while point S_3 at a depth of 10-15cm recorded the lowest Concentration of 2.11E+00 mg/kg. These values were lower than the values of 43.54 to 7.34 mg/kg reported by Akan *et al.* (2013) and 227.4mg/kg reported by Kacholi and Sahu (2018) but higher than the report of Arise *et al.* (2015). The Concentration of Pb in the soil analysed was compared with the permissible level of 100mg/kg specified by FAO/WHO (2013).

Furthermore, this study's result also revealed that heavy metals' concentration decreases with increased depth (0-5cm>5-10cm>10-15cm). This concentration trend does not agree with the order reported by Bala et al. (2016) but is similar to the trend reported by Oladeji *et al.* (2016).

Statistical Analysis

Values obtained were subjected to a one-way analysis of variance (ANOVA), which was used to assess whether the parameters varied significantly across the three depths. A probability less than 0.05 ($p<0.05$) was considered statistically significant. All statistical calculations were performed using SPSS 9.0 for Windows. Statistically significant differences were found for Cr, Fe, Cu, Ni, Cd, As, and Pb across different depths in all sampling locations. While non-significant metals ($p > 0.05$) include Mn and Hg, these imply that their concentrations do not vary significantly across depth.

Non-Cancer Risk Assessment

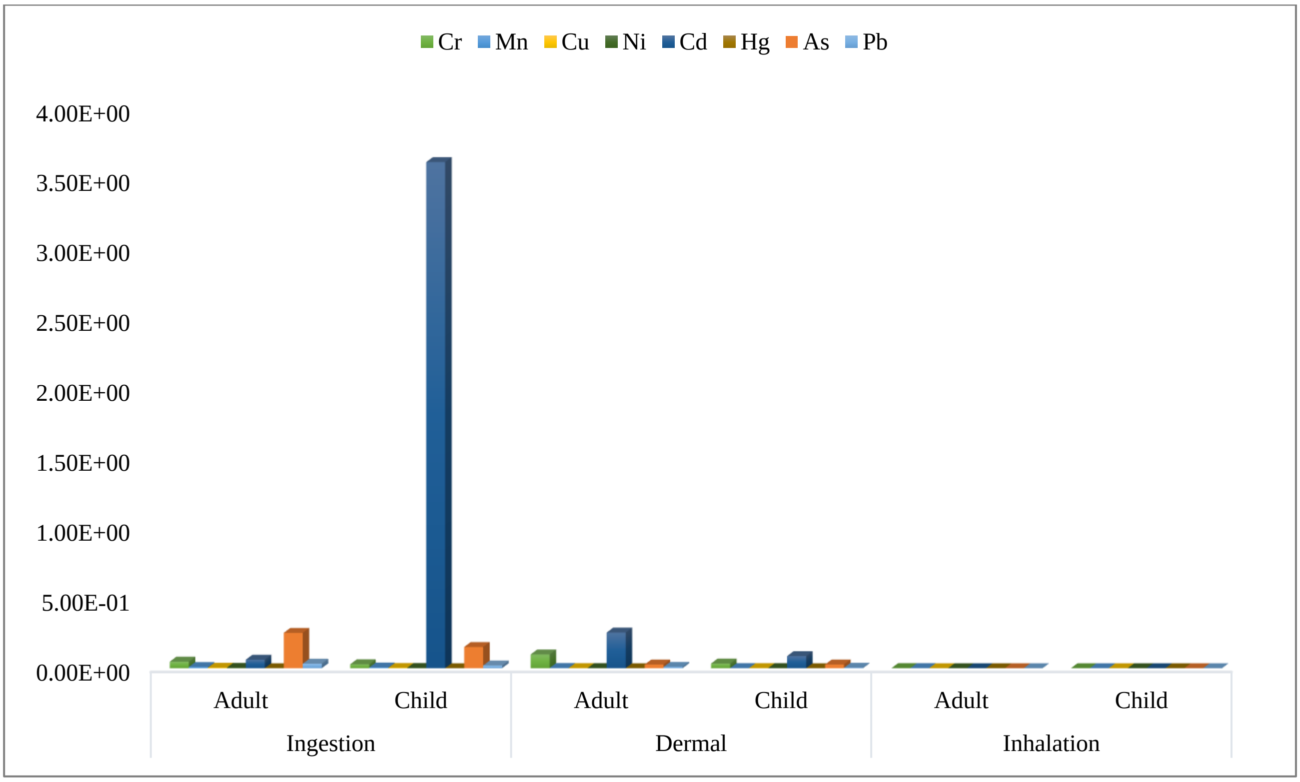

Figure 6: Hazard Quotient (HQ) value of Heavy metals from location S1

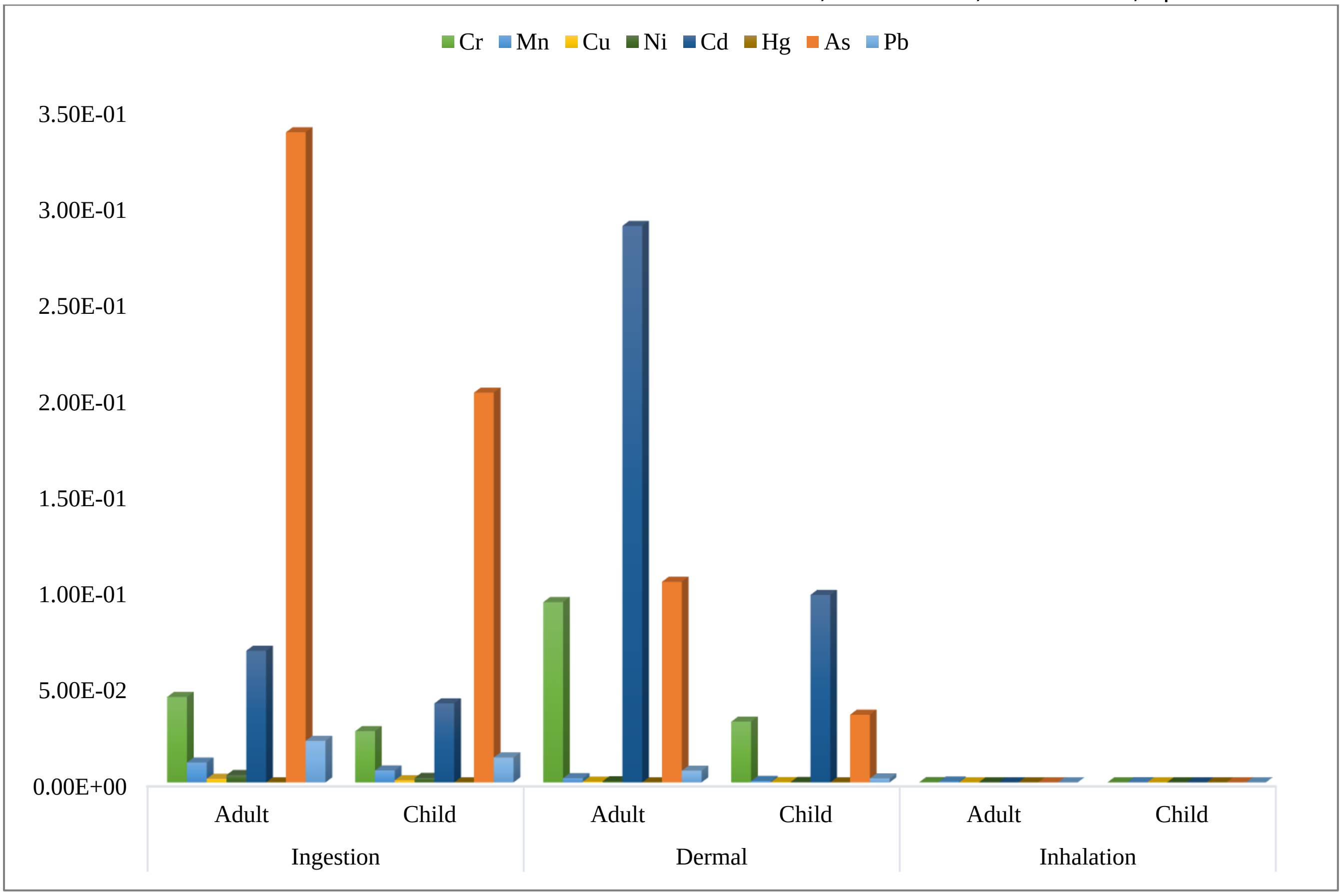

Figure 7: Hazard Quotient (HQ) value of Heavy metals from location S2

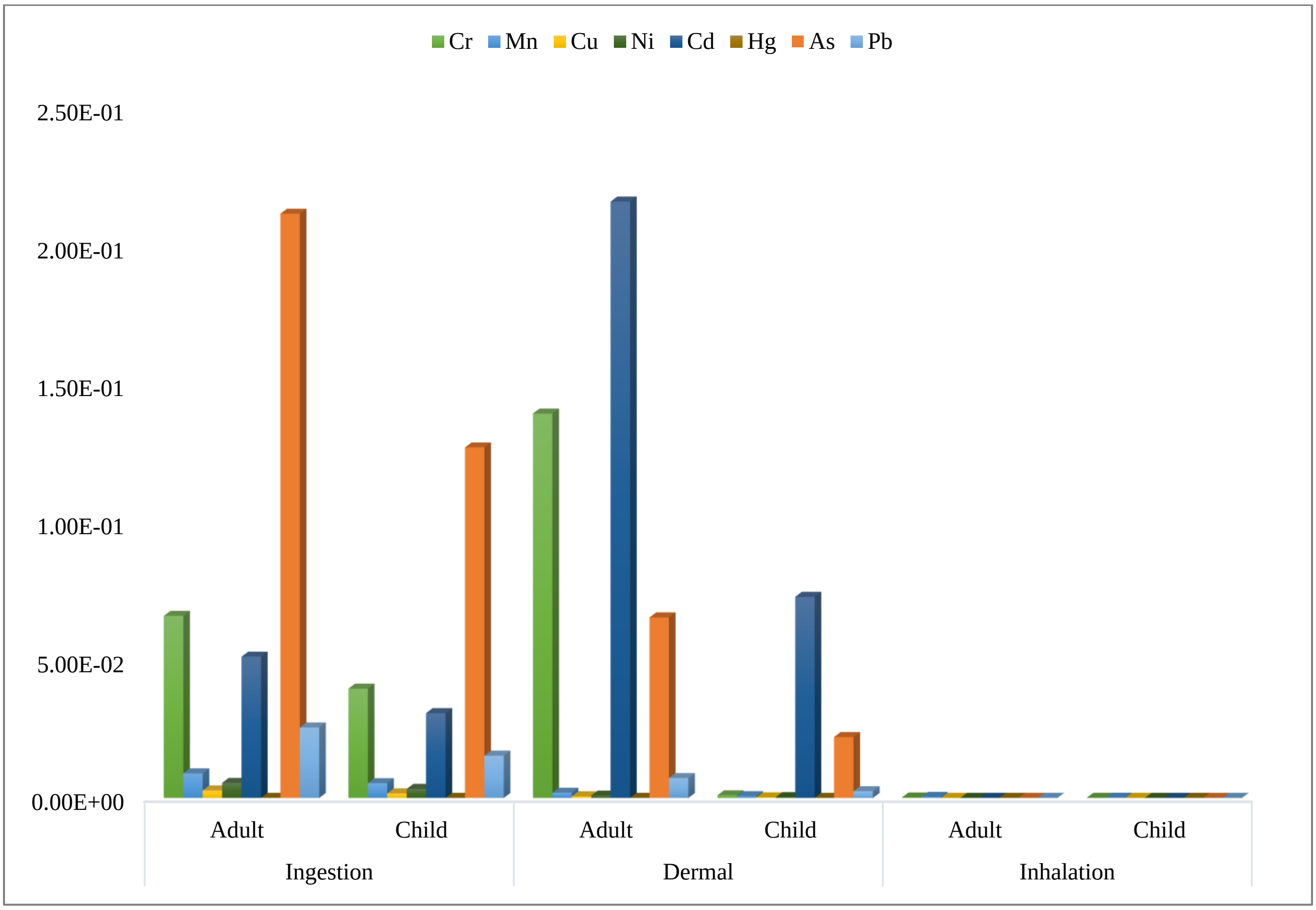

Figure 8: Hazard Quotient (HQ) value of Heavy metals from location S3.

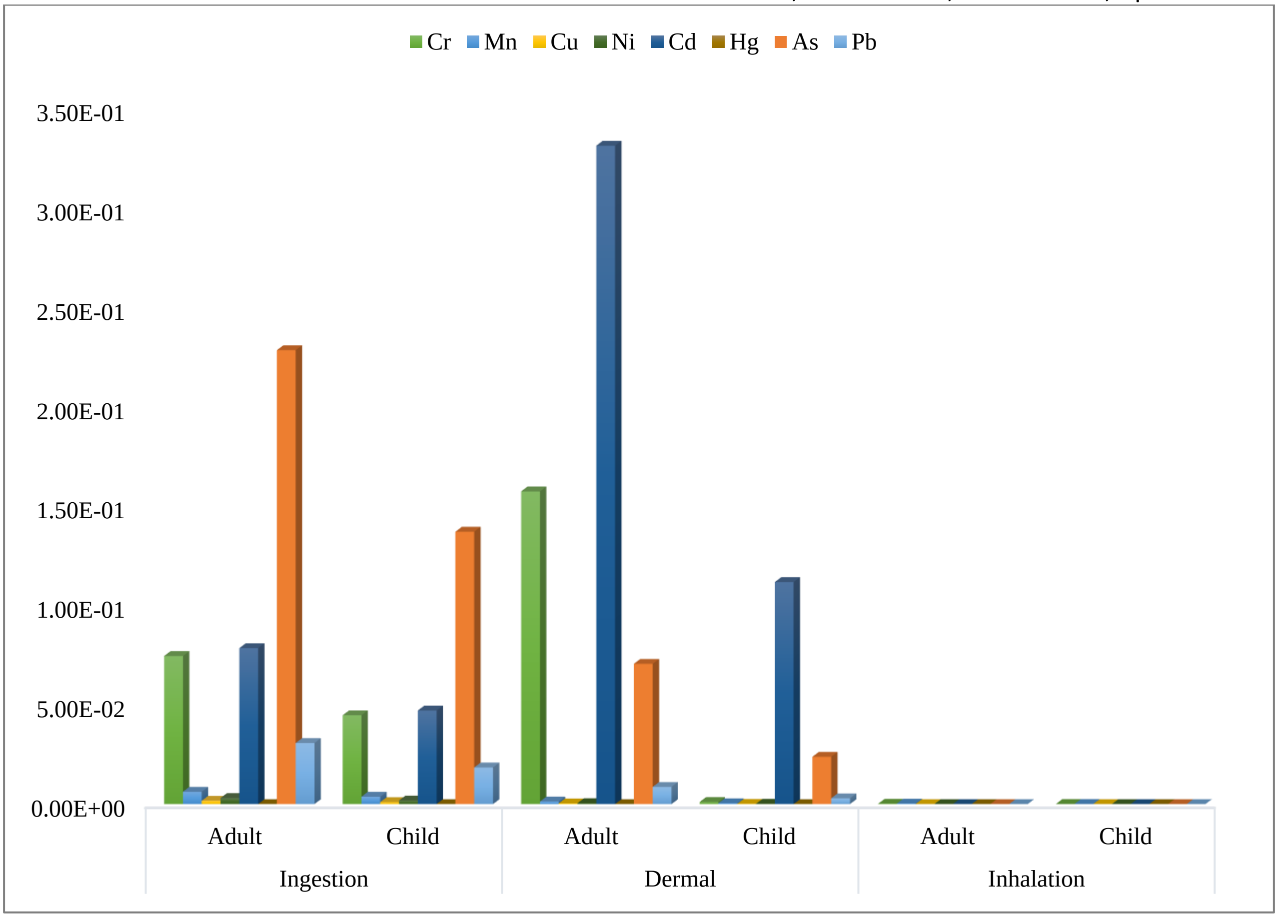

Figure 9: Hazard Quotient (HQ) value of Heavy metals from location S4

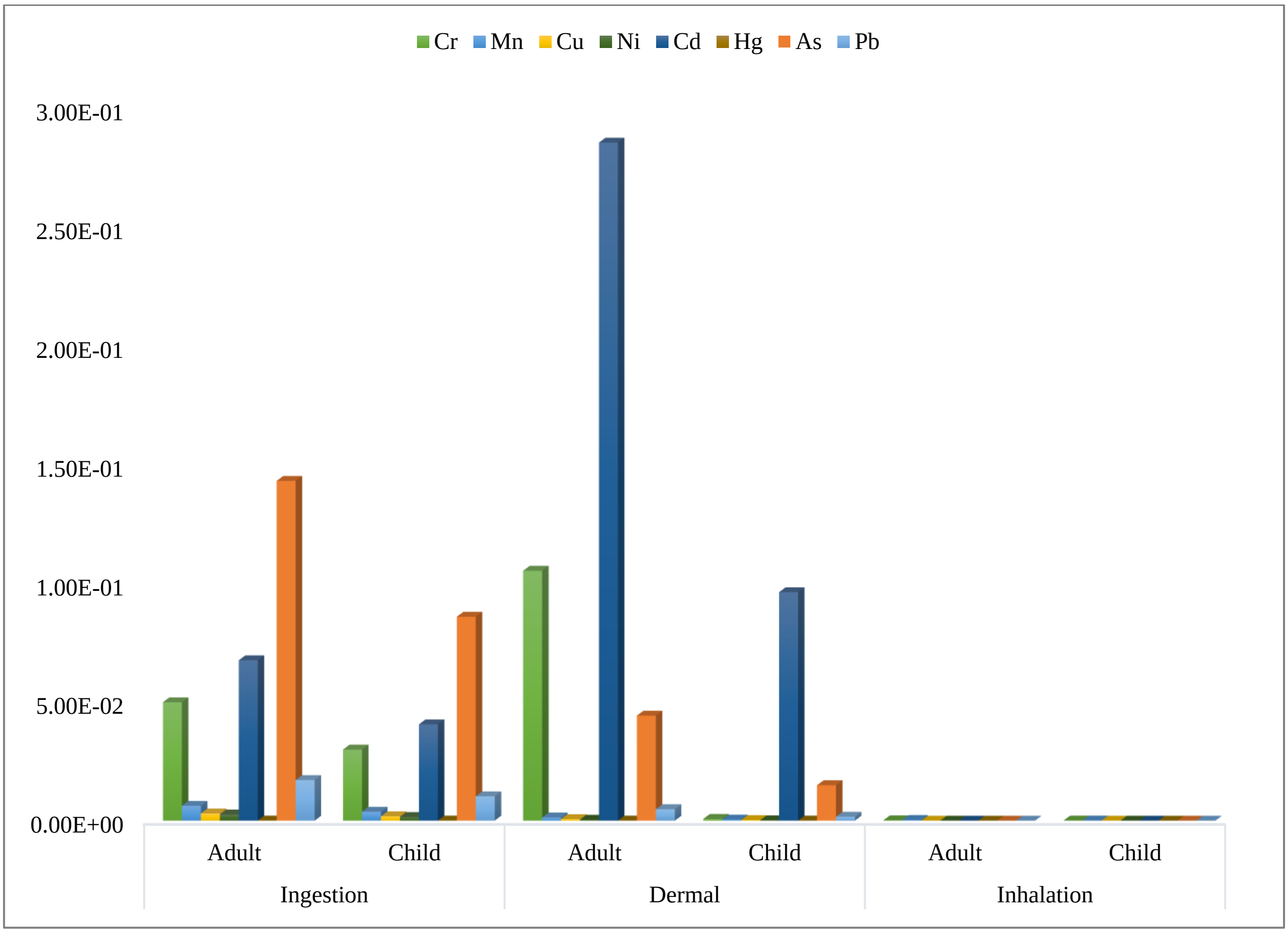

Figure 10: Hazard Quotient (HQ) value of Heavy metals in soil from location S5

Table 2: Hazard Index (HI) values of Heavy Metals soil from location S1 – S5.

Location		Cr	Mn	Cu	Ni	Cd	Hg	As	Pb
S1	**Adult**	1.45E-01	9.92E-03	3.54E-03	3.01E-03	3.15E-01	4.39E-05	2.79E-01	4.11E-02
	Child	6.11E-02	5.38E-03	1.96E-03	1.70E-03	3.71E+00	2.20E-05	1.78E-01	2.23E-02
S2	**Adult**	1.38E-01	1.30E-02	2.28E-03	4.44E-03	3.58E-01	4.39E-05	4.43E-01	2.77E-02
	Child	5.84E-02	7.03E-03	1.26E-03	2.51E-03	1.39E-01	2.20E-05	2.38E-01	1.50E-02
S3	**Adult**	2.06E-01	1.11E-02	3.29E-03	6.29E-03	2.67E-01	4.39E-05	2.77E-01	3.27E-02
	Child	4.06E-02	6.04E-03	1.82E-03	3.55E-03	1.04E-01	2.20E-05	1.49E-01	1.77E-02
S4	**Adult**	2.32E-01	7.78E-03	2.05E-03	3.54E-03	4.10E-01	4.39E-05	2.99E-01	3.94E-02
	Child	4.58E-02	4.21E-03	1.14E-03	2.00E-03	1.59E-01	2.20E-05	1.61E-01	2.14E-02
S5	**Adult**	1.55E-01	7.82E-03	3.70E-03	2.96E-03	3.53E-01	4.39E-05	1.88E-01	2.19E-02
	Child	3.07E-02	4.24E-03	2.05E-03	1.67E-03	1.37E-01	2.20E-05	1.01E-01	1.19E-02

The Hazard Quotient values of heavy metals (Cr, Mn, Cu, Ni, Cd, Hg, As, Pb) in soil samples collected from point S1 at the Gubi Dam Agriculture location are presented in Figure 6. The result shows that Cd in Children through Ingestion revealed a highest value of 3.62E+00mg/kg while Hg also in children through inhalation recorded a lowest value of 4.48E-10mg/kg. Also, Figure 7 shows a Hazard Quotient value of heavy metals in soil samples collected from point S2 agricultural location. The highest value of HQ in this location is recorded by As in Adults through ingestion with a value of 3.38E-01mg/kg, while Hg in children through inhalation recorded a lowest of 4.48E-10mg/kg. Similarly, Figure 8-10 shows a HQ value of heavy metals in soil samples collected at S3 – S5 agricultural locations. From all three locations Cd in Adults through Dermal recorded the highest value of (2.16E-01mg/kg, 3.31E-01mg/kg, 2.86E-01mg/kg) respectively, while Hg also in children through inhalation recorded the lowest value of (4.48E-10mg/kg, 4.48E-10mg/kg, 4.48E-10mg/kg) respectively. In comparison, the HQ result presented in this study is lower than the reported result by Caspah *et al.* (2016), and Waqar *et al.* (2021) but also higher than the result reported in a similar study by Enyinna and Nte (2013) and Sonomdagva *et al.* (2019). Equally, the result of the Hazard Index of heavy metals in soil samples collected from point S1 – S5 agricultural location is also presented in Table 2. From the result, Cd in soil from Point S1 in children recorded the highest value of 3.71E+00mg/kg, while Hg in children from all five sampling points recorded the lowest value of 2.20E-05mg/kg. Azam *et al.* (2020) reported a HI values from heavy metals through three exposure routes for adults and children 9.13E−01 and 1.10E+00. Also, Xiao *et al.* (2015) and Gao *et al.* (2021), in a separate study, reported lower HI values of heavy metals than presented in this study.

The Hazard quotient and Hazard index values were calculated to evaluate noncarcinogenic health issues with respect to effects of heavy metals in soil which enter the human system through different pathways, namely oral ingestion, dermal contact, and inhalation. The noncarcinogenic levels of each heavy metal were estimated based on the unique RFD value of the individual metal. If the HQ/HI>1 value indicates a probable risk of exposure of the populace within the study area to noncarcinogenic health effects. The Hazard Quotient (HQ) and Hazard Index (HI) values of the selected heavy metal assessed in this study were based on exposure for children and adults. However, the result of the heavy metals (Cr, Mn, Cu, Ni, Cd, Hg, As, Pb) in this study revealed the Hazard Quotient value of both adults and children estimated under three different pathways (Oral Ingestion, Dermal Contact and Inhalation) in all the sampling locations were found to be lower than the threshold limit of 1mg/kgd^{-1} with the exception of Cd which revealed a higher value of 3.62E+00mg/kgd^{-1} for children through ingestion at S1 sampling location. In separate studies, Libo et al. (2017) and Narsimha (2019) reported a HQ values lower than the threshold limit. The value of Cd in this study is three times higher than the maximum accepted limit. Similarly, the HI result of all the heavy metals was also within the accepted limit, but Cd in the soil at sampling point S1 recorded a higher value of 6.39E+00mg/kg above the safe limit, Suporn *et al.* (2020) also reported Cd as a dominant heavy metal with a HQ and HI value above the maximum standard limit. Based on the result, a tendency of exposure of children to potential noncarcinogenic health-related issues with respect to Cd via oral ingestion pathway within the sampling location. A similar observation was reported by Azam *et al.* (2020), indicating noncarcinogenic risk for children through three different pathways. Poor disposal of industrial waste, disposition of atmospheric contaminants from burning fossil fuel, and as well excessive usage of agricultural inputs such as fertilizers, pesticides, and biosolids (sewage sludge) elevate the Concentration of Cd in soil (Wuana and Okieimen, 2011). Cd is regarded as part of an impurity in fertilizer; hence, its higher value could be attributed to the excessive applications of fertilizer and herbicide into the soil within the study area for better yield. However, (GWRTAC, 1997; Wuana and Okieimen, 2011) reported that the higher concentration of specific heavy metals in a given soil is directly associated with the activities in the area. Thus, the chemical form and Concentration of a contaminant depend on the operations and disposal system of waste products containing contaminants, local transport pathways, and chemistry of underground water and soil are also considered factors that increase the Concentration and distribution of metals in soil. Similarly, the result revealed a trend in which the HQ values in the adult are all greater than those of children in all three pathways (Ingestion, Dermal, and Inhalation) across the locations; so also, the trend across the pathway shows that ingestion revealed a higher value in all the heavy metals except Ni and Cd hence the trend is Ingestion > Dermal

> Inhalation respectively. A similar trend was observed in a study carried out by Huang *et al.* (2017) on risk assessment of heavy metals in the soil of a lead-zinc mining area in Hunan Province (china) also reported a lower value of HQ and HI for children and adults.

Cancer Risk Assessment

Table 3: Cancer Risk (CRs) values of Heavy Metals in soil from location S1 – S5

LOCATION	Pathways		Cr	Ni	As	Pb
S1	Ingestion	Adult	5.86E-05	4.74E-05	1.14E-04	9.54E-07
		Child	3.52E-05	2.85E-05	6.83E-05	5.73E-07
	Dermal	Adult	1.24E-05	1.00E-05	4.84E-06	2.01E-06
		Child	4.17E-06	3.38E-06	4.89E-06	6.79E-07
	Inhalation	Adult	1.43E-07	1.16E-09	6.78E-09	1.15E-10
		Child	2.74E-08	2.21E-10	1.30E-09	2.20E-11
S2	Ingestion	Adult	5.60E-05	6.99E-05	1.52E-04	6.44E-07
		Child	3.36E-05	4.19E-05	9.13E-05	3.86E-07
	Dermal	Adult	1.18E-05	1.47E-05	1.94E-05	1.36E-06
		Child	3.99E-06	4.97E-06	6.54E-06	4.59E-07
	Inhalation	Adult	1.37E-07	1.71E-09	9.06E-09	7.77E-11
		Child	2.61E-08	3.26E-10	1.73E-09	1.49E-11
S3	Ingestion	Adult	8.32E-05	9.90E-05	9.53E-05	7.59E-07
		Child	4.99E-05	5.94E-05	5.72E-05	4.56E-07
	Dermal	Adult	1.76E-05	2.09E-05	1.22E-05	1.60E-06
		Child	5.92E-06	7.04E-06	4.10E-06	5.41E-07
	Inhalation	Adult	2.03E-07	2.42E-09	5.68E-09	9.16E-11
		Child	3.88E-08	4.62E-10	1.09E-09	1.75E-11
S4	Ingestion	Adult	9.39E-05	5.57E-05	1.03E-04	9.15E-07
		Child	5.64E-05	3.34E-05	6.17E-05	5.49E-07
	Dermal	Adult	1.98E-05	1.18E-05	1.31E-05	1.93E-06
		Child	6.69E-06	3.97E-06	4.42E-06	6.51E-07
	Inhalation	Adult	2.29E-07	1.36E-09	6.12E-09	1.10E-10
		Child	4.38E-08	2.60E-10	1.17E-09	2.11E-11
S5	Ingestion	Adult	6.29E-05	4.66E-05	6.45E-05	5.09E-07
		Child	3.77E-05	2.80E-05	3.87E-05	3.05E-07
	Dermal	Adult	1.33E-05	9.84E-06	8.22E-06	1.07E-06
		Child	4.48E-06	3.32E-06	2.77E-06	3.62E-07
	Inhalation	Adult	1.54E-07	1.14E-09	3.84E-09	6.13E-11
		Child	2.94E-08	2.17E-10	4.53E-10	1.17E-11

The CRs value of heavy metals (Cr, Ni, As, Pb) in soil sample collected from point S1-S5 at Gubi Dam Agriculture location are presented in Table 3. From the result it revealed that As in adult through ingestion at location, S2 recorded the highest value 1.52E-04mg/kg, while Pb in soil sample collected at S5 recorded the lowest value of 1.17E-11mg/kgd^{-1}. A similar result was reported by Abad *et al.* (2021).

The human health risk index with respect to cancer risk assessment of the soil was also calculated for both children and adults under three exposure pathways (Oral Ingestion, Dermal Contact, and Inhalation) using the unique Cancer Slope Factor (CSF) established for each heavy metal, the target cancer risk (CRs) derived from the intake of (Cr, Ni, As, Pb) were calculated as these metals may promote carcinogenic effects depending on the exposure dose. The total CRs above this range of 1.00E-06 – 1.00E-04 are unacceptable, and risks less than 1.00E-06 are not regarded to cause significant health effects (USEPA, 2015). The carcinogenic risk of all the metals are within the safe limit except As with (1.14E-04mg/kgd^{-1}, 1.52E-04mg/kgd^{-1}, 1.03E-04mg/kgd^{-1}) under oral ingestion for adults at the sampling location S1, S2, and S4 exceeded the threshold limit of 1.00E-04. This indicates that the sampling locations S1, S2, and S4 pose a significant health risk of cancer-related ailment concerning As. Ava *et al.* (2021) and Gao *et al.* (2021), in a similar study, reported a CRs values of Cr, Ni, As, Pb in which only As recorded a higher value than the threshold limit, also Aluko *et al.* (2018) reported higher values of Cd, Cr, and Pd than the threshold limit, hence suggested that As was the most important risk factor causing cancer for the human being in the study. However, the study further revealed a trend where the value in Adults is higher than that of children across all the locations also, based on the pathways, Ingestion was observed to be higher than Dermal, followed by inhalation; hence, the trend is as Ingestion > Dermal > Inhalation in all the sampling locations.

CONCLUSION

The HQ and HI values show a potential risk of noncarcinogenic health issues related to Cd in children through dermal contact at location S1 sampling location; similarly, the CRs values in this study also indicate a possibility of developing cancer and other related illnesses with respect to As over a lifetime. Hence, soil samples from locations S1, S2, and S3 are of great risk of exposing the population to noncarcinogenic and carcinogenic issues at the time of sample collection. Therefore, it is recommended that given the high concentrations of heavy metals in the soil samples as at the time of sample collection, it is of paramount importance for certain measures to be taken in order to monitor the excessive usage of fertilizer and other agrochemicals by farmers within the study area. Also, further research should be carried out in order to ascertain the level of agro-chemicals in soil samples within the study area. Action such as phytoremediation, thermal desorption and other techniques should be carried out to remove excess Concentration of the metals in soil.

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