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## RESEARCH ARTICLE

# HUMAN HEALTH RISK ASSESSMENT OF SELECTED HEAVY METALS IN SOILS AROUND MINING AREAS OF IKPESHI DISTRICT, EDO NORTH, EDO STATE, NIGERIA

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## ARTICLE DETAILS

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## ABSTRACT

This study assessed evaluated the human health risks associated with heavy metals contamination in soils around quarrying sites in Ikpeshi district, Edo State, Nigeria. Twenty-nine (29) samples were using Atomic Absorption Spectrophotometer (AAS) to determine the concentration of Fe, Zn, Cu, Pb, Cd, Mn, Ni, Co and Cr. Human exposure risks for adults and children were assessed via ingestion, dermal, and inhalation pathways using Chronic Daily Intake (CDI), Hazard Quotient (HQ), Hazard Index (HI) and Total Cancer Risk (TCR). Results showed children were more vulnerable to non-carcinogenic risks, with the highest HI values associated with Cobalt (Co), cadmium (Cd), and copper (Cu). Overall, the non-carcinogenic risk were in the following order: Co>Cd>Cu>Pb>Ni>Fe>Mn>Zn>Cr. For carcinogenic risks, Nickel (Ni) posed the greatest concern, with TCR values of  $2.13 \times 10^{-4}$  for children and  $3.06 \times 10^{-5}$  for adults, exceeding or approaching the acceptable risk threshold. Chromium (Cr) presented the acceptable cancer threats, while Lead (Pb) showed minimum carcinogenic impact. The findings highlight that ingestion is the predominant exposure pathway for children, whereas dermal contact and inhalation pathways contribute more significantly to adult exposure. Although the estimated HQ values for most metals were below the acceptable threshold ( $HQ < 1$ ), the relatively high contributions of Cd and Co highlight potential health concerns under prolonged exposure conditions, thereby necessitating continuous environmental monitoring and appropriate mitigation measures.

## KEYWORDS

Environment, Hazard quotient, Human health, Quarrying and Cancer risk

## 1. INTRODUCTION

Mining and including rock quarrying activities have been recognized as a main source of anthropogenic input of heavy metals contamination, particularly in developing countries where adherence to environmental regulations and monitoring are often inadequate. In Nigeria, full scale mining began in 1939 under private ownership arrangement, marking the beginning of sustained environmental pressure associated with mining industries (Al Naggat et al., 2018; Nwogha et al., 2017). Since that time, rock quarrying, smelting and mining operations have contributed significantly to environmental degradation including formation of gullies, production of acid mine drainage and release of toxic metals into environmental components.

The introduction of heavy metals into the environment through mining and quarrying activities pollute soils, hydrological processes (surface water and groundwater) and disruption of the food chain, thereby posing serious ecological and public health risks. Human exposures to these toxic metals occurs mainly through ingestion of contaminated food and water, inhalation of atmospheric dusts and particulate matter and via dermal contact with contaminated soils. Such exposures have been linked to contribute to adverse health conditions including cellular dysfunction, DNA mutation, organ failure, congenital abnormalities and carcinogenic conditions (Witkowska et al., 2021). Although heavy metals occur geogenically in the environment, elevated concentrations due to

anthropogenic inputs renders them an environmental threat (Shakya and Agarwal, 2020).

Heavy metals unlike some organic pollutants are persistent and non-biodegradable and may become available for uptake through the process of bioaccumulation and biomagnification within ecosystems. Soils are major sinks for heavy metals via atmospheric deposition, particularly in mining environments where dust emissions, surface runoff, and waste disposal are prevalent (Lameed and Ayodele, 2010; Wu et al., 2016). Previous studies have reported increased concentration of cadmium (Cd), lead (Pb), Chromium (Cr), cobalt (Co) nickel (Ni) and zinc (Zn) in soils surrounding mine sites raising serious concern about long term soil quality, ecological sustainability and food security (Adeyanju and Okeke, 2019; Anand, 1999).

The environmental hazards associated with rock quarrying is further exacerbated by rapid industrialization, urbanization and mechanized agricultural practices, these activities contributes one way to another to heavy metal loads in the environments (Gabarron et al., 2017; Zorpas et al., 2021) Quarrying operations contributes also to land degradation, habitat destruction, air pollution, water pollution, and loss of biodiversity. Excessive noise is generated due to blasting operations and the use of heavy machinery may lead to loss of hearing among quarry operators and residents (Soofastaei et al., 2018). These impacts more often than not exceeds the natural assimilative capacity of the environment, thereby disrupting ecological balance and aiding the transfer of heavy metals into

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the food chain (Egorova and Amanikov, 2017)

Heavy metals contributes to toxicity due to their ability to form reactive cations that binds to proteins, enzymes, and nucleic acids, impairing critical biological functions. The presence of heavy metals enhances toxicity through synergistic effects; for example, combined prolonged exposure to lead and mercury has been associated with severe renal and neurological complications (Morais et al., 2012). Even at low concentrations, metals such as lead (Pb) and zinc (Zn) can affect multiple organs in the human body, while chronic exposure to nickel has been linked to DNA damage, altered gene expressions and elevated cancer risk (Itam et al., 2024). Heavy metals are persistent in the environment and are readily taken up by plants in soils, ultimately posing risks to humans and animals through dietary intake.

Ikpeshe and environs have witnessed appreciable socio-economic development in recent years due to the proliferation of rock quarrying industries within surrounding communities. While these industrial activities contribute to economic growth, they also simultaneously increase environmental degradation and human exposure to potentially toxic materials like the heavy metals. Consequently, evaluating the associated health risks is essential for determining the vulnerability of residents particularly adults and children in the area. Previous studies in the area have largely focused on geochemical source characterization. (Ojeaga and Ehinlaye 2025) investigated the geochemical sources of physico-chemical parameters in groundwater from the area. However, to the best of our knowledge, no published studies have assessed human health risks associated with heavy metals contamination of soils in the study area. This represents a critical knowledge gap given the central role of soil as a pathway for human exposure.

## 2. MATERIALS AND METHODS

### 2.1 Study Area Description

Ikpeshe and its environs are characterized by intensive rock quarrying activities that have supported significant socio-economic development in

surrounding communities. The area hosts several active quarry sites where blasting, crushing, and hauling operations are routinely conducted. These activities generate large volumes of dust and waste materials that may act as sources of heavy metal contamination in surrounding soils. The local population includes both adults and children who may be exposed to contaminants through daily residential, agricultural, and recreational activities.

### 2.2 Geology of the Study Area

The study area lies beneath the Precambrian Basement Complex rocks that belongs to the southwest basement complex of Nigeria and Cretaceous sediments. The Basement Complex rocks consist of migmatite gneisses, metasedimentary rocks (calc silicate gneisses, quartzite schists, marbles, amphiboles), metaconglomerates and porphyritic granites while the Cretaceous sediments are represented by the Lokoja- Basange formation (Imeokparia and Emofurieta, 1991; Ocan et al., 2003). The metasedimentary rocks found in the area shows evidence of polyphase deformation that has been changed by the processes of thermo tectonic orogenesis (migmatitic and granitic processes) leading to creation of faults, mineral lineation and foliations, strike-slip, joints. There are some schists foliated in the N-S direction others in the NW-SE orientation within the area of study. Additionally present in the granite body are quartz veins, joints and fractures. There are also presence of quartz veins, joints and fractures in the granite body. The Igarra granites intruded the most easterly schist belts in Southwestern Nigeria (Turner et al., 1983).

The study area, is located within the southwestern part of the Nigerian Basement Complex. The study area is positioned approximately between latitudes 7°07'59"N and longitudes 6°12'25"E and is part of Igarra schist belt of southwestern Nigeria. The region is characterized by basement rocks, including the Migmatite Complex, Gneiss, and Schist. Overlying the crystalline basement rocks in some parts of Ikpeshe are sedimentary units, primarily limestone and marble which make up part of the mineral resources, alongside Quartz, Feldspar and clay minerals (Sanni et al., 2023).

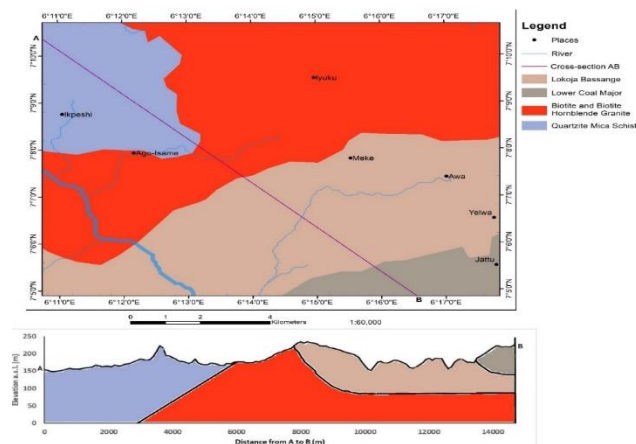


Figure 1: Geological map of the study area

Modified by (Ojeaga and Ehinlaye, 2025)

### 2.3 Soil Sampling and Analysis

Twenty nine (29) soil samples were collected randomly from locations surrounding active quarry sites at a depth of 0-15cm using a stainless-steel

auger to minimize contamination. Samples were air-dried at room temperature, homogenized, and sieved through a 2 mm mesh prior to analysis. Representative subsamples were digested using 9 mL of 65% HNO<sub>3</sub> and 3ml of perchloric acid, followed by ashing at 450°C, after which the residues were dissolved in 5 mL of 1.5% HNO<sub>3</sub> and made up to 25 ml with deionized water.

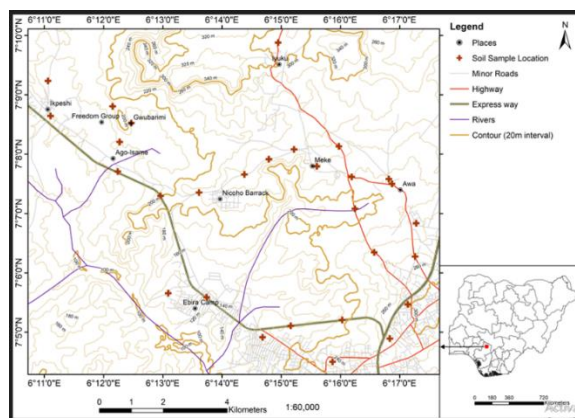


Figure 2: Map of sampling location within the area of study area

### 2.3.1 Determination of metals

Iron (Fe), cadmium (Cd), lead (Pb), zinc (Zn), manganese (Mn), nickel (Ni), chromium (Cr), cobalt (Co) in soil samples were evaluated using Atomic Absorption Spectrometer (AAS). The details of AAS analysis were previously reported (Bahrami et al., 2019; Effiong et al., 2023). The instrument was recalibrated after every 10 runs for validity of data, spike recovery method (SRM) using known concentration of metals added to samples was used. The percentages of recovery varied between 96.5% and 100% and precision (as relative standard deviation, RSD%) between replicated analyses was less 3%.

### 2.3.2 Quality control

Standard Reference Materials (SRMs) for Cadmium, Chromium, Zinc and Lead were used (CRM 1570 AND BCR 277). Spike Recovery Method and spike recovery data are essential in validating the accuracy and reliability of metal concentration measurements in environmental samples, especially water and soil samples. The spike recovery process involves adding a known quantity of target metals to the sample matrix and measuring how much of it is recovered after analysis. This ensures that the analytical methods used are effective and there is minimal loss or interference affecting the results. For this study the spike recovery method was conducted by spiking metal standards into blank samples and actual environmental matrices (soil), followed by analysis using the same procedures applied to field samples. The spike recovery percentages were calculated to confirm that the analytical method maintained precision and accuracy. Ideally, recoveries within 80-120% are considered acceptable, indicating that the method effectively extracts and quantifies the metals presents without significant losses or interferences.

The spike recovery results showed that the recovered metal concentrations were within acceptable range and comparable to the target matrix. This confirmed that the analytical procedures used for detecting metals in soil were reliable and reproducible. Additionally, the results demonstrate that the method applied is suitable for determining contamination levels in soils around rock quarrying in Ikpeshi and environs without significant biases or errors. This study therefore ensured

transparency and scientific rigor. The findings validate the accuracy of metal concentrations, supporting the reliability of comparisons made with other international safety standards.

### 2.4 Exposure Assessment

The Exposure parameters includes Body weights (BW) of 20kg and 70kg, Exposure frequency (EF) 365 Days/year; Exposure duration (ED) 10 and 70 years; Ingestion rate (IR) 200 and 200 mg/day, Inhalation rate 10 and 20 m<sup>3</sup>/day, Skin surface area (SA) 2800 and 3300 cm<sup>2</sup>; Soil adherence factor (SAF) of 0.2 mg/cm<sup>2</sup>, Dermal absorption factor (DAF) 0.001, Average time (AT) given as ED × 365 and Particle emission factor (PEF) of 1.36×10<sup>9</sup> m<sup>3</sup>/kg for children and adults respectively. Average Daily Dosage (ADD) estimates the average daily exposure to a contaminant over a certain period (Nyambura et al., 2020). ADD via ingestion, dermal and inhalation routes were determined using equation 1, 2 and 3 and values presented in Table 1.

Average daily dose (ADD):

$$ADD(ingestion) = \frac{C \cdot IR \cdot EF \cdot ED}{BW \cdot AT} \quad (1)$$

$$ADD(dermal) = \frac{C \cdot SA \cdot KP \cdot ET \cdot EF \cdot ED \cdot CF}{BW \cdot AT} \quad (2)$$

$$ADD(inhalation) = \frac{C \cdot inhR \cdot EF \cdot ED}{PEF \cdot BW \cdot AT} \quad (3)$$

#### 2.4.1 Carcinogenic risk

This is typically estimated using the Incremental Lifetime Cancer Risk (ILCR), which represents the likelihood of an individual developing any form of cancer over their lifetime due to daily exposure to a specific amount of a carcinogenic element (Sultana et al., 2017). The cancer slope factor used in the cancer risk formula to estimate the probability of developing cancer as a result of that exposure.

$$\text{Cancer Risk (CR)}: CR = CDI * CSF \quad (4)$$

CSF = Cancer Slope Factor

**Table 1:** Reference dose of selected heavy metals via ingestion, dermal, inhalation pathways and cancer slope factor (CSF) (Orisakwe et al., 2012; USEPA, 2002)

Heavy metals	Pb	Fe	Cu	Ni	Zn	Mn	Cd	Cr	Co
Reference dose(ingestion)	0.0035	0.7	0.04	0.02	0.3	0.024	2x10 <sup>-5</sup>	1.5	0.0000057
Reference dose(dermal)	0.000525	0.14	0.012	0.0054	0.06	0.00096	0.00002	0.003	0.02
Reference dose(inhalation)	0.034	0.045	0.8	0.35	0.025	0.001	0.0014	0.00003	0.0000057
Cancer slope factor (CSF)	0.0085	-	-	0.91	-	-	0.38	0.0085	

#### 2.4.2 Non Carcinogenic risk:

Evaluated using the Hazard Quotient

$$HQ = \frac{CDI}{RFD} \quad (5)$$

(Das et al., 2020).

2. Cumulative Hazard Index (HI): For multiple contaminants, the cumulative hazard index is calculated by summing the individual hazard quotients (HQs). The total of all the hazard quotients represents the overall potential health risk, or hazard index (Wongsasuluk et al., 2014)

$$HI = \sum HQ \quad (6)$$

(Wongsasuluk et al., 2014)

An HI value of less than 1 is considered safe, while an HI value greater than 1 indicates potential non-carcinogenic risk

## 3. RESULTS AND DISCUSSION

### 3.1 Human health risk assessment

#### 3.1.1 Average daily Dose

The average daily dose of analyzed heavy metals analyzed in soil samples from the study area in three different exposure pathways (ingestion, dermal and inhalation) for both children and adults are summarized in Table 2. The average daily dosage (ADD) in children through the ingestion ranged from 1.04×10<sup>-5</sup> to 4.14×10<sup>-3</sup> and decreased in the following order Fe>Zn>Cu>Ni>Cr>Mn>Co>Pb>Cd. Similarly, the ADD in children via the dermal exposure ranged from 1.15×10<sup>-5</sup> to 2.91×10<sup>-8</sup> and decreased in the same order; Fe>Zn>Cu>Ni>Cr>Mn>Co>Pb>Cd. The same decreasing pattern of metals was also observed for inhalation pathway; Fe>Zn>Cu>Ni>Cr>Mn>Co>Pb>Cd whose values ranged from 1.56×10<sup>-7</sup> to 3.83×10<sup>-10</sup>. Iron (Fe) had the highest ADD for children ingestion exposure pathway. These pattern of metal decrease was contrary to (Itam et al., 2024) who reported that Ni had the highest ADD value in children via the three exposure pathways.

**Table 2:** The average daily dose (mg/kg/day) of heavy metals through ingestion, dermal and inhalation exposure for Children and Adults

Metal	ADDing	ADDderm	ADDinh
<b>Children</b>			
Fe	$4.14 \times 10^{-3}$	$1.15 \times 10^{-5}$	$1.56 \times 10^{-7}$
Zn	$4.10 \times 10^{-4}$	$1.14 \times 10^{-6}$	$1.49 \times 10^{-8}$
Cu	$2.83 \times 10^{-4}$	$7.93 \times 10^{-7}$	$1.04 \times 10^{-8}$
Pb	$2.16 \times 10^{-5}$	$6.06 \times 10^{-8}$	$7.95 \times 10^{-10}$
Cd	$1.04 \times 10^{-5}$	$2.91 \times 10^{-8}$	$3.83 \times 10^{-10}$
Mn	$7.5 \times 10^{-5}$	$2.11 \times 10^{-7}$	$2.77 \times 10^{-9}$
Ni	$1.25 \times 10^{-4}$	$3.51 \times 10^{-7}$	$4.62 \times 10^{-9}$
Cr	$9.16 \times 10^{-5}$	$2.56 \times 10^{-7}$	$3.37 \times 10^{-9}$
Co	$7.18 \times 10^{-5}$	$2.01 \times 10^{-7}$	$2.64 \times 10^{-9}$
<b>Adults</b>			
Fe	$5.89 \times 10^{-4}$	$3.89 \times 10^{-6}$	$8.67 \times 10^{-8}$
Zn	$5.80 \times 10^{-5}$	$3.83 \times 10^{-7}$	$8.54 \times 10^{-9}$
Cu	$4.04 \times 10^{-5}$	$2.67 \times 10^{-7}$	$5.95 \times 10^{-9}$
Pb	$3.09 \times 10^{-6}$	$2.03 \times 10^{-8}$	$4.54 \times 10^{-10}$
Cd	$1.48 \times 10^{-6}$	$9.81 \times 10^{-9}$	$2.19 \times 10^{-10}$
Mn	$1.07 \times 10^{-5}$	$7.11 \times 10^{-8}$	$1.58 \times 10^{-9}$
Ni	$1.79 \times 10^{-5}$	$1.183 \times 10^{-7}$	$2.64 \times 10^{-9}$
Cr	$1.31 \times 10^{-5}$	$8.64 \times 10^{-8}$	$1.93 \times 10^{-9}$
Co	$1.02 \times 10^{-5}$	$6.77 \times 10^{-8}$	$1.51 \times 10^{-9}$

The ADD for adult via ingestion pathway ranged from  $1.48 \times 10^{-6}$  to  $5.89 \times 10^{-4}$  (Fe>Zn>Cu>Ni>Cr>Mn>Co>Pb>Cd). However, ADD for adult through dermal exposure ranged from  $6.77 \times 10^{-8}$  to  $3.89 \times 10^{-6}$  (Fe>Zn>Cu>Pb>Cd>Mn>Ni>Cr>Co) in similar sequence to dermal exposure, ADD for adult through inhalation pathway ranged from  $1.51 \times 10^{-9}$  to  $8.67 \times 10^{-8}$  (Fe>Zn>Cu>Pb>Cd>Mn>Ni>Cr>Co). Also the highest ADD for adult was Fe and was observed through ingestion. It is clear from the results that Fe contributes more to the ADD values. The result also indicates that ingestion is the primary/main route of exposure of Fe and other metals in both children and adults. The ADD values for both children and adults via the three pathways with the exception of (Fe) were below the reference dose recommended by (USEPA). Hence do not represent any safety concerns or health risk to humans via ingestion, dermal, and inhalation exposure to soils containing the metals. These results are in disagreement with (Ugwu et al., 2022; Ekere et al., 2014; Ayantobo et al., 2014) that revealed a higher ADD values than the USEPA recommended reference dosage.

### 3.2 Non-Carcinogenic Risk.

The hazard quotient (HQ) values for non-carcinogenic heavy metal exposure in soils through ingestion, dermal contact, and inhalation pathways for children and adults are presented in Table 3. For children, HQ values via ingestion followed the decreasing order: Cd > Cu > Ni > Pb > Fe > Co > Mn > Zn > Cr. Dermal exposure followed the sequence Cd > Mn > Pb > Cr > Cu > Ni > Fe > Zn, while inhalation exposure followed the order Co > Cr > Mn > Cd > Cu > Pb > Fe > Ni > Zn. For adults, HQ values via ingestion decreased in the order Cd > Cu > Ni > Pb > Fe > Mn > Co > Zn > Cr. Dermal exposure followed the pattern Co > Cd > Mn > Pb > Cr > Cu > Ni > Fe > Zn, and inhalation exposure followed the order Co > Cr > Cd > Mn > Cu > Pb > Fe > Ni > Zn. The cumulative hazard quotient ( $\sum$ HQ) values for children were 0.137, 0.0648, and 0.0598 for ingestion, dermal contact, and inhalation pathways, respectively. Corresponding  $\sum$ HQ values for adults were 0.00626, 0.0132, and 0.000329.

**Table 3:** The Hazard quotient and hazard index of non-carcinogenic metals through ingestion, dermal and inhalation exposure for Children and Adults

Metal	HQing	HQ(derm)	HQinh	HI
<b>Children</b>				
Fe	$5.86 \times 10^{-3}$	$1.65 \times 10^{-5}$	$1.89 \times 10^{-7}$	$5.87 \times 10^{-3}$
Zn	$1.36 \times 10^{-3}$	$3.79 \times 10^{-6}$	$4.26 \times 10^{-8}$	$1.36 \times 10^{-3}$
Cu	$7.07 \times 10^{-3}$	$1.98 \times 10^{-5}$	$2.31 \times 10^{-7}$	$7.09 \times 10^{-3}$
Pb	$6.18 \times 10^{-3}$	$1.15 \times 10^{-4}$	$2.27 \times 10^{-7}$	$6.29 \times 10^{-3}$
Cd	$1.04 \times 10^{-2}$	$2.91 \times 10^{-3}$	$3.83 \times 10^{-7}$	$1.33 \times 10^{-2}$
Mn	$3.12 \times 10^{-3}$	$2.20 \times 10^{-4}$	$1.98 \times 10^{-6}$	$3.34 \times 10^{-3}$

**Table 3 (cont):** The Hazard quotient and hazard index of non-carcinogenic metals through ingestion, dermal and inhalation exposure for Children and Adults

Metal	HQing	HQ(derm)	HQinh	HI
Adults				
Ni	$6.27 \times 10^{-3}$	$1.75 \times 10^{-5}$	$1.85 \times 10^{-7}$	$6.28 \times 10^{-3}$
Cr	$6.10 \times 10^{-5}$	$8.53 \times 10^{-5}$	$1.124 \times 10^{-4}$	$2.58 \times 10^{-4}$
Co	$3.59 \times 10^{-3}$	0.03528	$4.63 \times 10^{-4}$	0.03933
	$\Sigma HQ = 0.137$	$\Sigma HQ = 0.0648$	$\Sigma HQ = 0.0598$	THI=0.262
Children				
Fe	$5.56 \times 10^{-6}$	$5.56 \times 10^{-6}$	$1.08 \times 10^{-7}$	$8.46 \times 10^{-4}$
Zn	$1.27 \times 10^{-6}$	$1.27 \times 10^{-6}$	$2.44 \times 10^{-8}$	$1.94 \times 10^{-4}$
Cu	$6.68 \times 10^{-6}$	$6.68 \times 10^{-6}$	$1.32 \times 10^{-7}$	$1.01 \times 10^{-3}$
Pb	$3.88 \times 10^{-5}$	$3.88 \times 10^{-5}$	$1.29 \times 10^{-7}$	$9.21 \times 10^{-4}$
Cd	$9.81 \times 10^{-4}$	$9.81 \times 10^{-4}$	$2.19 \times 10^{-6}$	$2.46 \times 10^{-3}$
Mn	$7.40 \times 10^{-5}$	$7.40 \times 10^{-5}$	$1.13 \times 10^{-6}$	$5.23 \times 10^{-4}$
Ni	$5.91 \times 10^{-6}$	$5.91 \times 10^{-6}$	$1.05 \times 10^{-7}$	$9.01 \times 10^{-4}$
Cr	$2.88 \times 10^{-5}$	$2.88 \times 10^{-5}$	$6.42 \times 10^{-5}$	$1.01 \times 10^{-4}$
Co	0.01188	0.01188	$2.64 \times 10^{-4}$	0.0126
	$\Sigma HQ = 0.00626$	$\Sigma HQ = 0.01302$	$\Sigma HQ = 0.000329$	THI=0.0196

In this study it was observed that Cadmium (Cd) had the highest contribution to the hazard quotient (HQ) through the ingestion pathway, accounting for 23.69% in adults and 10.20% in children. Conversely, cobalt (Co) contributed more to the non-carcinogenic risk, accounting for 91.38% and 54.40% in adults and children HQs, respectively, mainly via dermal contact, while inhalation accounted for 79.86% in adults and 0.77% in children. It was also observed that the sum of hazard quotient ( $\Sigma HQ$ ) was in the order of ingestion>dermal>inhalation in children. This align with the finding of (Itam et al., 2024) who reported a higher HQ value for children via ingestion. These results indicate that ingestion as the dominant exposure pathway for children, with cadmium contributing the highest non-carcinogenic risk across pathways. For adults the sum of hazard quotient ( $\Sigma HQ$ ) was in order of dermal>ingestion>inhalation, indicating that dermal exposure is the main route of toxic metals. Compared to children, adults exhibited lower HQ values across all exposure routes, reflecting reduced vulnerability due to higher body weight and lower exposure frequency. In all cases, the  $\Sigma HQ$  values were below the acceptable threshold of unity ( $HQ < 1$ ), indicating no significant non-carcinogenic health risk. The result of hazard index (HI) were in the following order Co>Cd>Cu in both children and adults, suggested Co as the main contributor to non-carcinogenic risks in the area of study, particularly in children, with an HI of 0.0392. Given the naturally low concentration of Co in the Earth's crusts, its presence concentration in soils is largely due to attributed to anthropogenic activities such as burning of coal or oil, and production of Co alloys (Garba et al., 2024). High concentrations of Co in soil cause an adverse impact on plant growth (Garba et al., 2024). The cumulative hazard index (HI) of all analyzed metals was below 1, below the (USEPA, 2010) permissible limit of 1, indicating no significant non-carcinogenic health risk for both children and adults in the study area. Nonetheless, risks were generally higher in children than adults. This heightened vulnerability in children is pointing

to the fact that children are more sensitive to heavy metals than adult due to their behavior such as frequent hand- to- mouth actions, crawling and other outdoor activities (Itam et al., 2024; Alhazimi, 2022). This findings align with those of (Enuneku et al., 2022 Kurt-Karakus, 2012; Wang et al., 2021) who reported a total hazard quotient ( $\Sigma HQ$ ) less than one and hazard index below threshold ( $<1$ ) indicating that exposure to heavy metals in quarrying site pose no health hazards to children and adults.

### 3.3 Carcinogenic risks

The carcinogenic risk (CR) is the incremental risk or the probability of an individual developing cancer over a lifetime (Gebeyehu and Bayissa, 2020). The United States Environmental Protection Agency (USEPA) proposed an acceptable cancer range of  $1E-6$  to  $1E-4$  (USEPA, 2016). The cancer risk (CR) posed by carcinogenic metals via ingestion exposure in children ranged from  $1.83 \times 10^{-7}$  to  $2.13 \times 10^{-4}$  and decreased in the following order of Ni>Cr>Cd>Pb. For dermal, it ranged from  $5.14 \times 10^{-10}$  to  $5.96 \times 10^{-7}$ , and for inhalation, it ranged from  $6.75 \times 10^{-12}$  to  $7.85 \times 10^{-9}$  as presented in Table 4. For adults, the ranged of carcinogenic metals via ingestion pathway was from  $2.62 \times 10^{-8}$  to  $3.04 \times 10^{-5}$ ,  $1.73 \times 10^{-10}$  to  $2.01 \times 10^{-7}$  via dermal and  $3.86 \times 10^{-12}$  to  $4.48 \times 10^{-9}$  as presented in Table 4. In this study the sequence of risk exposure was in the order of ingestion > dermal > inhalation. The variation in cancer risk in the different exposure pathways could be associated with metal accumulation, feeding habit Consumption of contaminated food, and drinks are major exposure pathway through which metals enters the body (Ossai et al., 2025). These results implies that the average (CRs) of Cd, Cr, and Pb were below the standard permissible limit ( $1E-4$ ) in both children and adults and pose no threat to human health, the CR of Nickel ( $2.13 \times 10^{-4}$ ) in children via ingestion pathway exceeded the limit  $1E-4$ , indicating that Ni in the soil had a negative impact on human health. It also suggests that Ni contributes to a higher cancer risk both in children and adults than other metals.

**Table 4:** Carcinogenic Risk through ingestion, dermal and inhalation exposure, and the total Carcinogenic risk through all pathways (TCR) for Children and Adults in the study area.

Pathways	Cr	Pb	Cd	Ni	TCR
Children					
Ingestion	$4.58 \times 10^{-5}$	$1.83 \times 10^{-7}$	$3.95 \times 10^{-6}$	$2.13 \times 10^{-4}$	$2.62 \times 10^{-4}$
Dermal	$1.28 \times 10^{-7}$	$5.14 \times 10^{-10}$	$1.10 \times 10^{-8}$	$5.96 \times 10^{-7}$	$7.35 \times 10^{-7}$

**Table 4 (cont):** Carcinogenic Risk through ingestion, dermal and inhalation exposure, and the total Carcinogenic risk through all pathways (TCR) for Children and Adults in the study area.

Inhalation	$1.68 \times 10^{-9}$	$6.75 \times 10^{-12}$	$1.45 \times 10^{-10}$	$7.85 \times 10^{-9}$	$1.83 \times 10^{-9}$
Pathways	Cr	Pb	Cd	Ni	TCR
Adults					
Ingestion	$6.54 \times 10^{-6}$	$2.62 \times 10^{-8}$	$5.65 \times 10^{-7}$	$3.04 \times 10^{-5}$	$3.75 \times 10^{-5}$
Dermal	$4.32 \times 10^{-8}$	$1.73 \times 10^{-10}$	$3.72 \times 10^{-9}$	$2.01 \times 10^{-7}$	$2.48 \times 10^{-7}$
Inhalation	$9.63 \times 10^{-10}$	$3.86 \times 10^{-12}$	$8.30 \times 10^{-11}$	$4.48 \times 10^{-9}$	$5.52 \times 10^{-9}$

The total cancer risk (TCR) of carcinogenic metals in children ranged from  $1.83 \times 10^{-9}$  to  $2.62 \times 10^{-4}$  in order of ingestion>dermal>inhalation, while for adult, it followed similar trend ingestion>dermal>inhalation and ranged from  $5.52 \times 10^{-9}$  to  $3.75 \times 10^{-5}$ . From this study, total cancer risks reported for children via ingestion pathway was higher than the (USEPA, 2002) permissible limit ( $1E-4$ ). The result is in agreement with (Itam et al., 2024). These suggests a significant health risks for children through ingestion exposures in the area of study. This also confirms ingestion as the main contributor of cancer risks. However the TCR values in children was higher than those in adults. Also reported higher cancer risks in children than adults (Ugwu et al., 2022). The higher risk in children could be attributed to children behavior (hand-to mouth) and sensitivity to indoor dusts. The high cancer risk (CR) and total cancer risk (TCR) values associated with nickel also suggest that this metal is a major contaminant of concern in the study area. The observed pattern reflects potential anthropogenic inputs, likely originating from industrial activities, vehicular emissions, and waste disposal practices.

#### 4. CONCLUSION

The evaluated the human health risks associated with toxic metals in soils around quarrying communities Ikpeshi and environs. The study of non-carcinogenic risk assessment show that values of HQs and HI via ingestion, dermal and inhalation pathways were below 1 and do not pose immediate significant non-carcinogenic health threat for both children and adults in the study area. However, the relatively higher contribution of cadmium and cobalt suggests potential health concerns under prolonged exposure, thereby underscoring the need for continuous environmental monitoring and appropriate mitigation measures. The cancer risk values of nickel (Ni) in children via the ingestion pathway exceeded the permissible limit. Thus, designating (Ni) as the primary contributor to a higher cancer risks for both children and adults. The TCR values in children exceeding permissible threshold, confirms ingestion as the most prolific and significant exposure pathways. The elevated cancer risk from Ni, coupled with Cd enrichment, indicates potential long-term health concerns for residents. Therefore, continuous monitoring, strict environmental management at quarry sites, and soil remediation measures are strongly recommended to minimize future exposure. Public health awareness and regulatory enforcement are essential to safeguard vulnerable populations, particularly children, living near quarrying operations.

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