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Contamination Levels and Human Health Risk Assessment of Heavy Metals in Soil from the Royal Salt Mining Site, Ikwo, Ebonyi State, Southeastern Nigeria

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ABSTRACT

Background and Objective: Heavy metal contamination in residential soils near mining sites poses significant health risks. The Royal Salt mining site in Ikwo, Ebonyi State, may contribute to elevated levels of Pb, Cr, and Cd in surrounding soils. This study aims to evaluate the chronic daily intake of Lead (Pb) and Chromium (Cr) for both adults and children through ingestion and dermal exposure. Additionally, it seeks to assess the potential non-carcinogenic and carcinogenic health risks associated with heavy metal exposure in residential soils. **Materials and Methods:** A total of 100 soil samples were collected from the study area at a depth of 0-10 cm using a soil auger and core sampler at a horizontal spacing of 100 m between each location (A, B, C, D, and E) points in 2024. The soils were analyzed for Pb, Cr, and Cd using an atomic absorption spectrophotometer. **Results:** The mean concentrations of Pb and Cr in soil samples were 70.6 and 83.6 mg/kg, respectively, while Cd was not detected. The hazard quotient (HQ) for Pb via ingestion was above one for both adults (22.8) and children (11.43), indicating potential health risks, whereas the HQ for Cr and all dermal exposures were below one. Cancer risk values for Pb and Cr via ingestion and dermal exposure ranged between 10^{-6} and 10^{-4}, indicating an acceptable cancer risk level. **Conclusion:** The findings indicate that residents near the Royal Salt mining site are at risk of non-carcinogenic health effects due to Pb exposure via ingestion. However, the carcinogenic risk for both Pb and Cr remains within acceptable limits, suggesting no significant cancer risk for residents.

KEYWORDS

Carcinogenic and non-carcinogenic risks, dermal routes, heavy metal, mining, soil, toxicity

INTRODUCTION

Throughout human history, heavy metals have been present in our surroundings and have exposed people to them. But because of human activities like mining, the environment now contains higher concentrations of these pollutants[1]. By definition, a heavy metal is any hazardous metal, regardless of its density or atomic mass. Certain metalloids, basic metals, transition metals, lanthanides, actinides, and metals from periodic table groups III through V are all included in this categorization. Lead (Pb), Mercury (Hg), Cadmium (Cd),

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Chromium (Cr), Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), and Aluminum (Al) are a few examples. Certain metals are necessary for life and serve as invaluable sources of vitamins and minerals that are necessary for the proper operation of bodily organs. While the levels of metals required by all living things vary, larger concentrations of certain elements can be harmful. There is no beneficial function for other metals in human physiology. Examples of these elements that will be taken into account in the study are lead, mercury, and chromium[1]. Even at low exposure levels, heavy metals have the potential to be hazardous. After entering the body, they can remain in key organs such as the kidneys, liver, brain, and bones for years or decades, eventually leading to detrimental health effects[1].

According to the US Agency for Toxic Substances and Disease Registry's priority list of heavy metal contaminants, mercury, lead, and chromium pose the greatest risks. For example, very minimal amounts of exposure to inhaled chromium VI are considered carcinogenic to humans[2]. Lung cancer risk rises as a consequence. Studies on animals have demonstrated that inhaling chromium (VI) can result in lung tumors. Chronic exposure to chromium compounds is linked to peripheral nerve damage that results in diabetes, whereas acute exposure can induce nausea, vomiting, abdominal pain, cramping in the muscles, and diarrhoea. The Pb, however, is thought to be a possible carcinogen and mutagen for humans. Along with causing renal tumours, it also interferes with the kidneys, joints, reproductive systems, and nerve systems' regular operation[3].

Acute intake of inorganic mercury may result in bleeding, diarrhoea, and gastrointestinal problems. Prolonged and frequent exposure can have a major negative impact on the skin, liver, and kidneys. Even at low concentrations, cadmium is known to be poisonous and is thought to be a likely carcinogen. Prolonged and intense exposure to mercury can cause lung diseases such as bronchiolitis, emphysema, and alveolitis. In addition, cadmium can cause kidney failure, hypertension, bone fractures, and even cancer. Among its peculiar long-term symptoms are arthritis, diabetes, anemia, cardiovascular disease, cirrhosis, decreased fertility, headaches, and strokes[4]. While chromium (VI) compounds are known to be carcinogenic and mutagenic, chromium (III) is an important element. Breathing excessive amounts of chromium (VI) can aggravate asthma and induce dyspnoea. Long-term exposure can harm the kidneys and liver. On the other hand, Ni has been linked to intestinal and mouth cancer. In addition, it leads to issues with depression, heart attacks, and hemorrhages. Despite being vital to human life, excessive consumption of zinc and copper may have non-carcinogenic impacts on health. While zinc deficiency may hinder growth and reproduction, excess copper has been linked to liver damage[5].

Because of nature and human activity, heavy metals, including Lead (Pb), Cadmium (Cd), Iron (Fe), and Manganese (Mn), are always present in life. Since metals are typically found naturally in the earth's crust, they make up a significant portion of the soil. In normal soil, there are potentially at least 200 g of chromium, 80 g of nickel, 16 g of lead, 0.5 g of mercury, and 0.2 g of cadmium for every 103 kg[5]. Therefore, without first determining the metal's background level, it might be difficult to pinpoint the exact reason for a rise in the amount of metal in a soil sample. The mining and movement of mineral materials from their natural reserves have coincided with global industrialization[6]. Such operations typically leave behind by-products and tailings that settle or seep into the soil. Different types of metals can be found in their ores, and the pH of the soil can affect how abundant a particular metal is in a certain area. The amount of metal in the environment is increased by inputs from mining, quarrying, and agriculture operations, as well as emissions from air fallouts, weathering of parent rocks, and the transit of accumulated contaminants into soil and water. Burning fossil fuels, industrialization, waste disposal, and metalliferous mining and smelting activities all significantly impact the number of heavy metals present in soil[7]. Heavy metal contamination is poisonous to plants, reduces soil bioproductivity, and poses a serious hazard to human health, especially at high levels. Some heavy metals, such as lead, mercury, and arsenic, are known carcinogens that have long-term effects on the central nervous system. They are non-biodegradable and can collect and biomagnify from one trophic level to the next[8]. Plants grown in polluted environments are more likely to accumulate hazardous metals than those grown elsewhere. According to studies, vegetables cultivated in metal-contaminated soils accumulate more heavy metals than those grown in uncontaminated soils[9].

The goal of detecting hazards is to examine the evidence for harmful consequences in humans by analyzing the toxicity and mechanism of action of all available data. It is intended to mainly address two questions: (i) If an agent could be harmful to human health, and (ii) In what situations could an identified hazard manifest? The process of identifying hazards involves analyzing a wide range of data, which can include human observations and structure-activity relationship assessments[9]. A scientific determination of whether the chemical under evaluation can harm human health under the specified exposure conditions is the outcome of the hazard identification exercise. Toxicity is often seen in a variety of target organs. Many endpoints are frequently seen after being exposed to a particular chemical. It is decided what the critical effect is, which is typically the first notable side effect that happens with an increasing dose[9].

Dose-response assessment involves defining the relationship between the amount of a substance administered or encountered and the occurrence of negative health effects[7]. In the case of most toxic effects-such as those affecting specific organs, neurological or behavioral functions, the immune system, non-genotoxic cancer development, as well as reproductive or developmental issues-it is widely accepted that there exists a certain dose or concentration below which adverse effects do not manifest (referred to as a threshold)[7]. Conversely, for other types of toxic effects, it is believed that there is a risk of harm at any level of exposure, indicating that no threshold is present[7]. Currently, this latter assumption is predominantly applied to mutagenesis and genotoxic carcinogenesis[7]. The study aims to evaluate the contamination levels and human risk occasioned by heavy metals in soil samples from the Royal Salt Mining Site, Ikwo, Ebonyi State, Southeastern Nigeria, with specific objectives as: evaluating the chronic daily intake of Pb for both adults and children through ingestion and dermal routes, and evaluating the chronic intake of Cr for both adults and children through ingestion and dermal routes.

MATERIALS AND METHODS

Study area and duration: The study was carried out at the Royal Salt mining site, Enyigba, in Ikwo Local Government Area, Ebonyi State, Nigeria, in the 2024 study year (Fig. 1). In Southeastern Nigeria, Enyigba is located 14 km Southeast of Abakaliki. The research area is located in the derived savannah vegetation zone between Latitudes 6°07"N and 6°12"N and Longitudes 8°05"E and 8°10"E. With a brief dry spell in August that is typically referred to as "August break", the region receives a bimodal pattern of rainfall from April to July and from September to November. Between 1700 and 2000 mm of rainfall on average each year. When it first starts to rain, it is severe and torrential and can linger for up to an hour. The relative humidity ranges from 60 to 80%, and the temperature ranges from 27 to 31°C, respectively[10]. During the dry season, the dry harmattan wind from the Sahara Desert is predominant. The marine breeze from the Atlantic Ocean is the main wind during the rainy season. This area's soil is a component of the Ultisol soil order[11]. Although there are isolated hillocks that climb up to 200 m above sea level, the relief of the area is undulating[11]. Parkland is the dominant type of vegetation in the area, deriving from savannah in terms of its predominant grasses and shrubs[12]. Surface drainage is highly uneven and undulating in the area, with many ephemeral ponds, streams, and rivers that invariably dry up as soon as the rainy season arrives. Those who live in this area work primarily as farmers.

Soil sample collections: A total of 100 soil samples were collected from the study area at a depth of 0-10 cm using a soil auger and core sampler at a horizontal spacing of 100 m between each location (A, B, C, D, and E) points (Fig. 2).

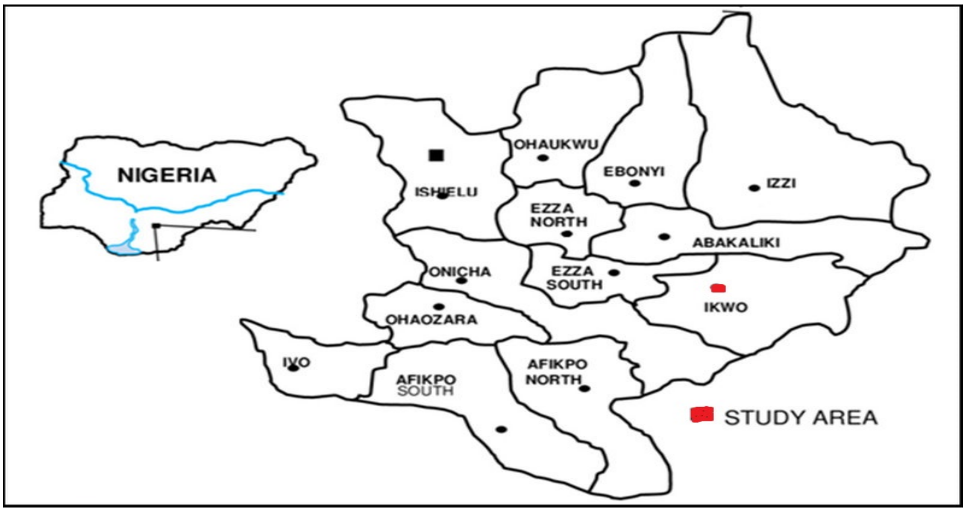

Fig. 1: A map of Ebonyi State showing the study location
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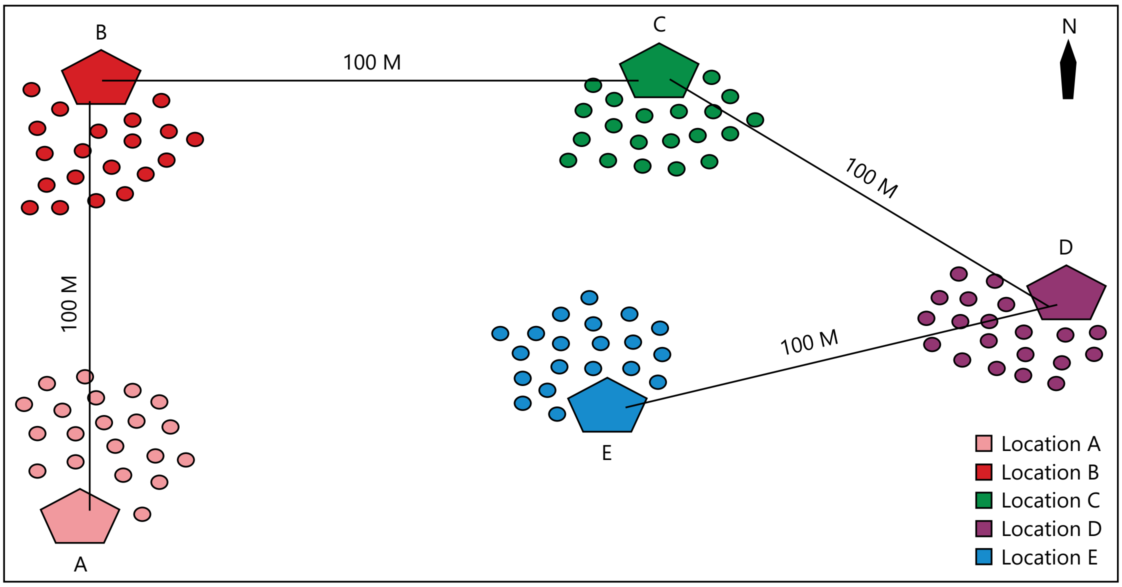

Fig. 2: Sample points locations
Researcher's Intern, 2024

Sample preparations and treatments: Collected soil samples were air-dried, sieved with a 2 mm laboratory sieve, and thereafter stored in black polythene bags to conserve their properties and nutrients at room temperature without being lost to the atmosphere before they were all subjected to proper laboratory analysis.

Determination of soil samples: Following air drying, the collected soil samples were transported to the Research Laboratory of the Project Development Institute, Enugu State, Nigeria, for soil analysis. Two grams of the soil sample was added to the Teflon crucible, which could withstand any amount of heat. Hydrofluoric acid was added to the Teflon crucible containing the soil sample, and then it was heated. The hydrofluoric acid was added to break down the soil particles into liquid. After 30 min, the color of the soil sample turned darker, indicating that the soil had been digested. Hydrofluoric acid can be continuously added until the desired color is obtained.

After digestion, the solution was poured into a 50 mL beaker and diluted slightly with distilled water before filtering. It was then filtered into a 100 mL conical flask, and distilled water was used to fill it up to the 100 mL mark. Afterward, the liquid solution was poured into a small container and taken to the machine for analysis. The atomic absorption procedure of the spectrophotometer DR3900 Ammonium Acetate was used to analyze heavy metals (Pb, Cr, and Cd).

Calculation of chronic daily intake of Pb in soil for both children and adults via the ingestion and dermal routes: The human health risk assessment method used in this study was for non-carcinogenic[12]. The chronic daily intake (CDI) of heavy metals in the Royal Salt mining site was evaluated[13]. The chronic daily intake (CDI) for the determination of human health risk through the two pathways was used and calculated using the following equations[12]:

$$\text{CDI ingestion} = \text{BW}\times\text{ATC}\times\text{IR}\times\text{EF}\times\text{ED}/\text{BW}\times\text{AT} \quad (1)$$

Where:

C = Contaminant concentration (mg/kg)
IR = Ingestion rate (kg/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (days)

$$\text{CDI dermal} = \text{C}\times\text{SA}\times\text{AF}\times\text{ABS}\times\text{EF}\times\text{ED}\times\text{CF}/\text{BW}\times\text{AT} \quad (2)$$

Where:

C = Contaminant concentration (mg/kg)
SA = Skin surface area exposed (cm^2)
AF = Soil-to-skin adherence factor ($mg/cm^2/day$)
ABS = Dermal absorption fraction (unitless, chemical-specific)
CF = Unit conversion factor (10^{-6} kg/mg for soil)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (days)

Calculation of hazard quotient: The hazard quotient (HQ) was used to estimate the potential non-carcinogenic health risks associated with exposure to lead and chromium in the contaminated soil via ingestion and dermal routes using this equation[13]:

$$\text{HQ ingestion/dermal} = \text{CDI ingestion/RfD oral} \quad (3)$$

Where, RFD is the Reference Dose for Pb and Cr.

Where, RFD is the Reference Dose for Pb and Cr shown in Table 1.

The hazard quotient (HQ) is a numeric estimate of the toxicity potential posed by an element through a single route of exposure.

Note: An HQ under 1 is assumed to be safe, but HQ values above 1 may be a major potential health concern in association with overexposure of humans to the contaminants.

Calculation of carcinogenic risk: The carcinogenic risk, which is the probability of an individual developing cancer throughout exposure to a potential environmental carcinogen, is assessed using the equation[6]:

$$\text{Cancer risk (CR)}_{\text{ingestion/dermal}} = \text{CDI}_{\text{ingestion/dermal}} \times \text{SF}_{\text{ingestion/dermal}} \text{ (mg/kg/day)} \quad (4)$$

Where:
CDI = Chronic daily dose
SF = Cancer slope factor

Most regulatory authorities provide that cancer risk values between 10^{-6} and 10^{-4} indicate acceptable cancer risk. The United States EPA considers a risk level negligible when cancer risk is below 10^{-6}, while it becomes a serious or high priority when the level exceeds 10^{-4}.

RESULTS AND DISCUSSION

The soil sample that was obtained from the Royal salt was taken to the laboratory and properly analyzed to detect the levels of lead, chromium, and cadmium in the soil sample, respectively.

Table 1 shows the levels of heavy metals in the analyzed soil samples. One hundred soil samples were randomly taken from the mining site, and after analysis, it was found that Pb and Cr were present in all of the soil samples. However, Cd was not detected in any of the soil samples. The presence of these heavy metals can cause disturbances and have adverse effects on humans when they are exposed to them in high quantities.

Table 2 presents the concentrations of Lead (Pb), Chromium (Cr), and Cadmium (Cd) at different sample points (A to E), expressed in milligrams per kilogram (mg/kg). The Pb and Cr concentrations show a progressive increase, starting at 0.021 mg/kg at Point A and reaching 0.127 mg/kg at Point E. Both metals follow a similar trend, with their concentrations rising consistently across the sample points. In contrast, Cd levels remain undetectable (0.00 mg/kg) at all locations, indicating its absence or below-detection limits in the analyzed samples.

Lead (Pb) levels in Royal Salt mining site soil samples compared with local and international standards: Soil sample value (Fig. 3) for Pb is below the standard limits set by Local and International Organizations (NESREA, WHO, EU and US EPA), which implies that the level of Pb in the soil is within the acceptable limits.

Chromium (Cr) levels in Royal Salt mining site soil samples compared with local and international standards: Chromium (Fig. 4) does not exceed the maximum standard recommended by both national and international bodies, indicating that chromium is within the minimum range provided by regulatory bodies. The level of chromium in the soil sample is within the acceptable limits set by local and international organizations (NESREA, WHO, EU and US EPA).

Chronic daily intake (CDI): Table 3 and 4 show the chronic daily intake of Pb and Cr for adults and children via ingestion and dermal routes.

Table 3 presents the chronic daily intake (CDI) values for Lead (Pb) through ingestion and dermal exposure for adults and children. The ingestion CDI for adults is 0.08, while for children, it is 0.04, indicating that adults have a higher intake through ingestion. In terms of dermal exposure, the CDI values are significantly lower, with 1.20×10^{-7} for adults and 4.06×10^{-8} for children, suggesting minimal absorption of Pb through the skin compared to ingestion.

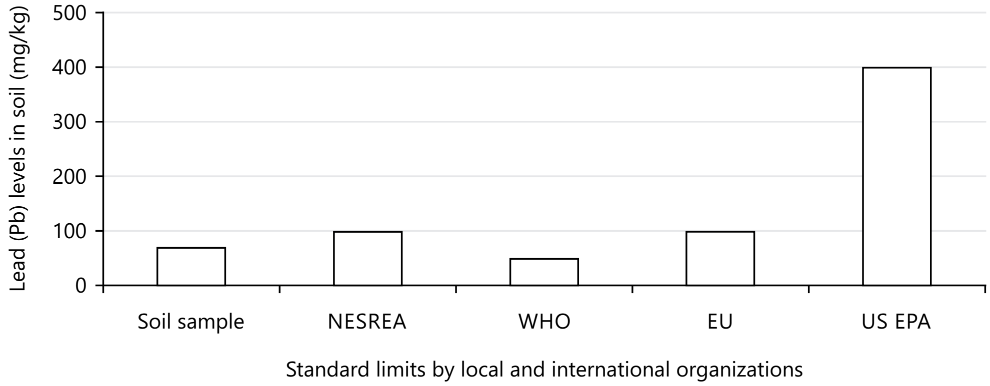

Fig. 3: Level of lead contamination in the soil sample compared by local and international organizations
NESREA: National Environmental Standards and Regulations Enforcement Agency, WHO: World Health Organization, EU: European Union and US EPA: United States Environmental Protection Agency

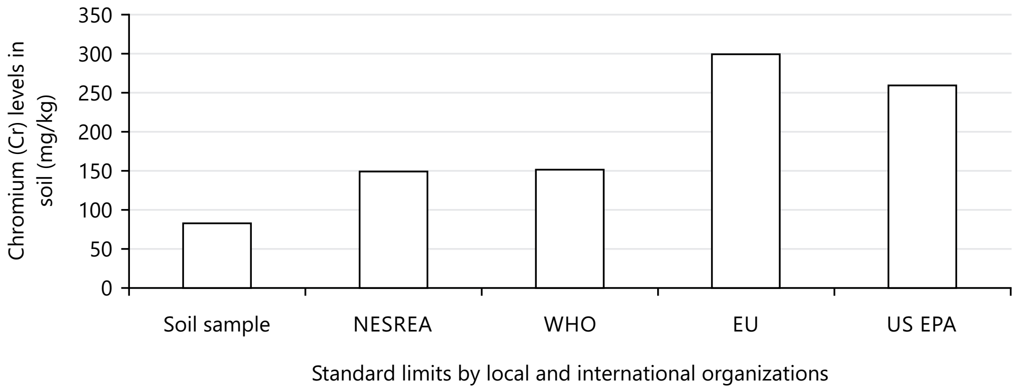

Fig. 4: Level of chromium in the soil sample compared with national and international organizations
NESREA: National Environmental Standards and Regulations Enforcement Agency, WHO: World Health Organization, EU: European Union and US EPA: United States Environmental Protection Agency

Table 1: RFD (reference doses) for selected heavy metals

Heavy metals	Ingestion	Dermal
Lead	3.5 E-3	5.3 E-4
Chromium	3.0 E-3	3.0 E-5

Table 2: Level of metals in soil samples from Royal Salt mining site

Sample points	Pb (mg/kg)	Cr (mg/kg)	Cd (mg/kg)
A	0.021	0.021	0.00
B	0.029	0.094	0.00
C	0.071	0.071	0.00
D	0.105	0.105	0.00
E	0.127	0.127	0.00

Table 3: Chronic daily intake (CDI) of lead in both adults and children

	Pb	
CDI	Adult	Child
Ingestion	0.08	0.04
Dermal	1.20×10^{-7}	4.06×10^{-8}

Table 4: Chronic daily intake (CDI) of chromium in both adults and children

	Cr	
CDI	Adult	Child
Ingestion	9.81×10^{-5}	4.6×10^{-5}
Dermal	1.42×10^{-4}	1.0×10^{-5}

Table 5: Hazard quotients of Pb in adult and children

	Pb	
Hazard quotient	Adult	Child
Ingestion	22.86	11.43
Dermal	2.26×10-4	7.64×10^{-5}

Table 6: Hazard quotient of Cr in adults and children

	Cr	
Hazard quotient	Adult	Child
Ingestion	6.54×10^{-5}	3.07×10^{-5}
Dermal	4.73×10^{-2}	3.33×10^{-3}

Table 4 presents the chronic daily intake (CDI) values for Chromium (Cr) through ingestion and dermal exposure for adults and children. The ingestion CDI for adults is 9.81×10^{-5}, while for children, it is 4.6×10^{-5}, indicating a higher intake for adults. In contrast, dermal exposure values are relatively higher, with 1.42×10^{-4} for adults and 1.0×10^{-5} for children, suggesting that Cr absorption through the skin is more significant than ingestion, particularly in adults.

Hazard quotients of Pb and Cr: Table 5 shows the hazard quotients of Pb for adults and children via ingestion and dermal routes. The hazard quotient value underlined is above 1 and may be a major potential health concern in association with exposure of humans to the contaminants. The hazard quotient of Pb for adults and children via the dermal route is below 1, and it is assumed to be safe.

Table 5 presents the hazard quotient (HQ) values for Lead (Pb) through ingestion and dermal exposure for adults and children. The ingestion HQ is 22.86 for adults and 11.43 for children, indicating a significant health risk associated with Pb ingestion, especially for adults. In contrast, the dermal HQ values are considerably lower, with 2.26×10^{-4} for adults and 7.64×10^{-5} for children, suggesting minimal health risks from dermal exposure compared to ingestion.

Table 6 presents the hazard quotient (HQ) values for Chromium (Cr) through ingestion and dermal exposure for adults and children. The ingestion HQ is 6.54×10^{-5} for adults and 3.07×10^{-5} for children, indicating a negligible health risk from ingestion. However, dermal HQ values are relatively higher, with 4.73×10^{-2} for adults and 3.33×10^{-3} for children, suggesting that dermal exposure poses a slightly greater health risk compared to ingestion, particularly in adults.

Table 6 shows the hazard quotients of Cr in adults and children via ingestion and dermal routes, which are assumed to be safe since they are below 1.

Carcinogenic risk index in soil samples: Carcinogenic risk values between 10^{-6} and 10^{-4} indicate acceptable cancer risk (Table 7 and 8). The World Health Organization considers a risk level negligible when the cancer risk is below 10^{-6}, while it becomes serious or high priority when the level exceeds 10^{-4} [6]. Therefore, the carcinogenic risk values of Pb and Cr for adults and children via ingestion and dermal routes indicate acceptable cancer risk.

Table 7 presents the carcinogenic risk (CR) values for Lead (Pb) through ingestion and dermal exposure for adults and children. The ingestion CR is 6.8×10^{-4} for adults and 3.4×10^{-4} for children, indicating a higher potential cancer risk from ingestion, particularly for adults. In contrast, the dermal CR values are significantly lower, with 1.92×10^{-6} for adults and 6.5×10^{-7} for children, suggesting minimal carcinogenic risk through skin exposure compared to ingestion.

Table 7: Carcinogenic risk levels of Pb in adults and children

	Pb	
Carcinogenic risk	Adult	Child
Ingestion	6.8×10^{-4}	3.4×10^{-4}
Dermal	1.92×10^{-6}	6.5×10^{-7}

Table 8: Carcinogenic risk levels of Cr in adults and children

	Cr	
Carcinogenic risk	Adult	Child
Ingestion	2.58×10^{-4}	1.21×10^{-4}
Dermal	3.73×10^{-4}	2.63×10^{-5}

Table 8 presents the carcinogenic risk (CR) values for Chromium (Cr) through ingestion and dermal exposure for adults and children. The ingestion CR is 2.58×10^{-4} for adults and 1.21×10^{-4} for children, indicating a moderate cancer risk from ingestion, with adults being more affected. In contrast, dermal exposure shows relatively higher CR values, with 3.73×10^{-4} for adults and 2.63×10^{-5} for children, suggesting that dermal exposure poses a slightly greater carcinogenic risk than ingestion, particularly in adults.

In addition to natural processes like soil erosion and crustal weathering, human activities, including mining, industrial effluents, urban runoff, and sewage discharge, also release heavy metals into the environment[14]. While heavy metals are naturally found in the earth's crust, human activities have considerably altered the geochemical cycles and the biological equilibrium of these elements. As a result, these metals have accumulated in plant parts that contain secondary metabolites, which possess distinct pharmacological properties. According to Drevnick *et al.*[15], continuous contact with heavy metals, including lead, chromium, and mercury, can hurt one's health, in addition to several other acute and long-term harmful effects on various body organs. The three heavy metals that have caused human poisoning most frequently are mercury, lead, and chromium[16]. Complications from the harmful effects of heavy metals include birth defects, cancer, vascular damage, nervous system abnormalities, skin lesions, immune system dysfunction, and malfunctions of the digestive and kidney systems. Exposure to two or more metals simultaneously may have compounding effects[17].

Given their toxicity, extended durability, and ability to bioaccumulate and biomagnify in the food chain, increasing quantities of heavy metal and metalloid contamination in soil, water, and sediment pose a severe danger[18]. Research from both field and lab settings indicates that exposure to food, water, and air can result in either acute or chronic poisoning. These heavy metals bioaccumulate and have a wide range of harmful effects on different body tissues and organs. The concentration of metals in water and the length of exposure determines how much metal accumulates in a tissue[19]. However, other environmental factors, including water, temperature, oxygen content, pH, hardness, salinity, alkalinity, and dissolved organic carbon, can also have a significant impact on the accumulation and toxicity of metals[20,21]. The production of free radicals, which results in oxidative stress, damages biological molecules such as proteins, lipids, enzymes, and nucleic acids and causes damage to DNA, which is essential to carcinogenesis, as well as neurotoxicity. These are the primary mechanisms of heavy metal toxicity[16]. Pollutant accumulation mostly occurs in fatty tissues, such as the liver, and its effects become apparent when concentrations in these tissues reach a threshold[22].

As a result, metals with high uptake and low elimination rates in tissues are more likely to accumulate to higher levels within the organs[23,24]. However, the buildup of heavy metals depends upon their intake, storage, and elimination from the body[25]. Fish can absorb heavy metals through their digestive tracts or by consuming polluted food[26,27]. The bloodstream effectively carries these heavy metals to the organs and tissues, where they accumulate upon absorption[28]. Furthermore, through the mediation of free radicals and reactive oxygen species, heavy metals have been shown to cause oxidative damage and/or carcinogenesis[29].

CONCLUSION

The study evaluated the contamination levels and human risk occasioned by heavy metals in soil samples from the Royal Salt mining site, Ikwo, Ebonyi State, Southeastern Nigeria. The results showed that Cd was not present in every soil sample. The soil samples' mean concentration of Pb and Cr was 70.6 and 83.6 mg/kg, respectively. The evaluation of Pb's chronic daily intake (CDI) for both adults and children by ingestion and dermal routes revealed the following amounts: DERMAL: 1.20×10^{-7} (adult), 4.06×10^{-8} (children), and INGESTION: 0.09 (adult), 0.04 (children). The evaluation of the chronic intake of Cr by ingestion and dermal routes for both adults and children revealed the following values: DERMAL: 1.42×10^{-4} (adult), 1.0×10^{-5} (children), and INGESTION: 9.81×10^{-5} (adult), 3.07×10^{-5} (children). Both adults (22.8) and children (11.43) had hazard quotients (HQ) of Pb via ingestion routes that were greater than one, indicating that residents may be at risk for health problems due to lead exposure. The Cr had a hazard quotient that was less than one. The Pb and Cr hazard quotient results via dermal were less than one, indicating no possible damage to health. Through ingestion and dermal routes, the cancer risk values for adults and children were found to be between 10^{-6} and 10^{-4}, indicating an acceptable level of cancer risk. The outcome of the present study indicates that residents of royal salt are not at risk for cancer.

SIGNIFICANCE STATEMENT

This study highlights the potential health risks associated with heavy metal contamination in soil from the Royal Salt Mining Site, Ikwo, Ebonyi State, Southeastern Nigeria. The findings indicate that lead (Pb) ingestion exceeds the safety threshold, posing a significant risk to residents, particularly through oral exposure. Additionally, the absence of cadmium (Cd) in all samples provides insight into the site's contamination profile. By assessing chronic daily intake levels of Lead (Pb) and chromium (Cr) for both adults and children, this study underscores the urgent need for monitoring and remediation efforts to mitigate heavy metal exposure and protect public health.

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