International Journal of Functional Research in Science and Engineering
e-ISSN: 2814-0923
www.ijfrse.com
Volume 3; Issue 4; December 2025; Page No. 132-142.

HEAVY METAL CONTENT & HEALTH RISK ASSESSMENT OF BEEF AND CHICKEN SAMPLES SOURCED FROM LOCAL RESTAURANTS IN MINING AREAS OF EBONYI AND ABIA STATE

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Abstract

This study was carried out to assess the levels of heavy metal contamination in giblets sourced from local restaurants in Southeastern Nigeria. The research employed atomic absorption spectrophotometry (AAS) for heavy metal analysis, followed by health risk assessments. The results revealed that copper (Cu) had the highest concentration among the metals detected, with a peak value (1.89 mg/kg) seen in the beef from Ishiagu, while cobalt (Co) had the lowest concentration, recorded at 0.02 mg/kg in the beef from Leru. In the Liver, iron (Fe) was the most abundant metal, with a maximum concentration (1.12 mg/kg) in Ishiagu, whereas arsenic (As) and lead (Pb) had the lowest concentrations (0.01 mg/kg) in Leru. The EDI analysis showed that Cu had the highest daily intake value (3.1002×10^{-3} and 2.8598×10^{-3} mg/kg/day) in the beef from Leru and Nkalagu, respectively, while Pb and As recorded the lowest EDI (1.86×10^{-5} and 3.71×10^{-5} mg/kg/day) in the Liver and Gizzard, respectively, across all locations. The THQ values indicated that Cu posed the highest non-carcinogenic risk, with a THQ (6.2004×10^{-2}) in the beef from Leru, while Co had the lowest THQ (1.114×10^{-4}) seen in the Liver .The HI values exceeded the safety threshold of 1 in Ishiagu, with a total HI of 1.1574, while the lowest HI was recorded in Nkalagu (5.84×10^{-1}). The CR analysis showed that nickel (Ni) had the highest carcinogenic risk, with a peak CR of 2.8412×10^{-3} in the beef from Nkalagu, whereas arsenic (As) had the lowest CR (1.58×10^{-7}) in the Liver from Leru. Based on these findings, stricter monitoring and control measures are recommended to reduce heavy metal contamination in poultry products, ensuring food safety and protecting public health.

Keywords: Heavy metals; Beef; Chicken; Ebonyi State; Abia State; Public health.

Introduction

Heavy metals are persistent environmental contaminants that can bioaccumulate through trophic transfer, posing serious human health risks when present in food sources (Orisakwe *et al*., 2012). Mining activities, particularly in artisanal and small-scale operations, are well-known to release trace metals

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such as lead (Pb), cadmium (Cd), chromium (Cr), and arsenic (As) into surrounding ecosystems. These metals may deposit in soils, vegetation, water bodies, and ultimately enter the food chain (Yebpella *et al*., 2023). In regions where agriculture and livestock rearing coexist with or are adjacent to mining, animals may ingest contaminated feed or water, leading to accumulation of heavy metals in edible tissues.

In Nigeria, the nexus between mining and food contamination has drawn increasing attention. Studies in the Niger Delta region have shown elevated levels of As, Cd, Pb, vanadium (V), and zinc (Zn) in soils, fodder, and food items including beef, goat meat, cow meat, and chicken (Okoye et al., 2022). These findings suggest that populations consuming meat from animals raised in or near mining-impacted zones may be exposed to non-trivial metal burdens (Okoye *et al*., 2022). Indeed, risk assessment using margin-of-exposure (MOE) and benchmark dose (BMD) approaches has identified potential carcinogenic and non-carcinogenic risks associated with arsenic and cadmium intake, especially in vulnerable subpopulations like children (Okoye *et al*., 2022).

While much of the existing literature focuses on heavy metal contamination in fish or plant-based foods, less is known about the accumulation of metals in terrestrial meat derived from animals reared in mining environments. This knowledge gap is particularly salient for beef and chicken — two widely consumed proteins in Nigeria — because their tissues may integrate metals over time through ingestion of contaminated feed, water, and soil. For example, Edet *et al*. (2024) documented unsafe concentrations of chromium, manganese, cobalt, cadmium, nickel, and zinc in chicken organs (liver, gizzard) from a commercial poultry farm, attributing sources of contamination to soil, diet, and water. Such accumulation not only threatens animal health but also represents a direct route of exposure for human consumers.

Moreover, the risk posed by heavy metals in meat is not only chronic but also cumulative. Health risk assessment frameworks such as the target hazard quotient (THQ), hazard index (HI), and carcinogenic risk (CR) are routinely used in food toxicology to estimate the probability of adverse outcomes. For instance, in poultry meat sampled in Pakistan, the cumulative HI for children exceeded 1.0, indicating potential chronic toxicological risk; likewise, arsenic-associated CR values were above acceptable thresholds (Arshad *et al*., 2025). These risk metrics emphasize that even when individual metals may be within accepted limits, their combined effect can pose a greater health burden.

Ebonyi and Abia States in Nigeria are known for diverse mining operations, including quarrying and mineral extraction, which may influence the heavy metal load in local food systems. Livestock in such regions may be exposed continually to environmental metals, raising the possibility that local restaurants serving beef and chicken might be an unrecognized exposure pathway for heavy metal intake by consumers. Considering the socio-economic reliance on locally sourced meat, especially in semi-urban and rural sectors, there is an urgent need for systematic investigation of the heavy metal content in these foodstuffs coupled with risk assessment for human health.

The present study, therefore, aims to evaluate the concentrations of selected heavy metals (e.g., Pb, Cd, Cr, As, Zn, etc.) in beef and chicken samples collected from local restaurants in mining areas of Ebonyi and Abia States. We further conduct a human health risk assessment using standard toxicological indices (e.g., THQ, HI, CR) to quantify the potential impact of meat consumption on local populations. This

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research provides critical data to inform food safety policy, public health protections, and guidelines for safe meat production in mining-impacted regions.

Materials and Methods

Studied Area

Major mining sites will be chosen from Abia and Ebonyi: Leru mining site of Ummuneochi LGA of Abia State with coordinates (6o 01'46.7N, 7o 23'11.1E), Ishiagu (latitudes 5°51′ N-5°59′ N and longitudes 7°24′ E-7°40′E), Ezzainyimagu in Izzi LGA and Nkalagu mining site of Ishelu LGA of Ebonyi state with coordinates (6o 28' 45.1N, 7o 46'32.4E).

Sample Collection

Beef samples were collected at mining regions of Nkalagu, Ishiagu and Ezzainyimagu of Ebonyi state and Leru, Abia State. Beef samples were also collected from local restaurants at Nsukka, Enugu State. Beef collected were divided into 5 groups: Group A to D: beef from local restaurants from the mining locations, Group E: beef samples from Nsukka local restaurants. Four (4) restaurants per location were used and 10 beef samples were obtained from each restaurant making it a total of 200 beef samples collected.

Digestion of Beef Samples

3g of each of the samples were weighed into the digestion flask and 30cm3 of aqua regia was added and digested in the fume cupboard, for the evaporation of HCl until a clear solution was obtained, it was cooled, filtered and then made up to 100ml mark in a standard volumetric flask with de-ionised water. The digested samples were analysed for Arsenic (As), chromium (Cr), Nickel (Ni), copper, Lead (Pb), Zinc (Zn) and Mercury (Hg) using atomic absorption spectrophotometer (AAS) at respective wavelengths.

AAS Configuration

A four-lamp turret Varian 200 flame AA spectrometer was optimized for the determination of arsenic (As), Chromium (Cr), Nickel (Ni), Copper (Cu), Lead (Pb), Zinc (Zn). The concentra-tions were measured in parts per million (ppm). The instrument mode was absorbance. The sampling mode of the instrument was manual, set at the prompt measurement mode. The photomultiplier voltage was set at 330 V. Precision of the standard, sample and expansion factor was 1%. A background correction factor was not used in the determination of any of the metals. The reslope was carried out after every 12 samples and the reslope standard was 2.0. The reslope lower limit was 75% and upper limit 125%. The lamp current for all the metals were set between 5-8 mA.

Human Health Assessment

Human risk assessment was conducted using the modules stipulated by USEPA in order to ascertain the risk of developing health complications from ingesting cooked beef and with additives. Human health risk from exposure to heavy metals through consumption of singed giblets and beef was evaluated. The estimated daily intake (EDI) concentration of Heavy metals from consumption of unwholesome beef were evaluated. Determination of the carcinogenic or mutagenic potency, increment life-time cancer risk and toxic equivalency quotient/ index were used to evaluate the carcinogenic risks of consuming beef. Furthermore, the toxicological/carcinogenic/mutagenic risk associated with the concentration of Heavy

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metals detected in the beef was evaluated by comparing the level obtained in this study with the regulatory standards limits and guidelines.

Probabilistic Risk Assessment Model
Human Health Risk Assessment
Estimated Daily Intake (EDI)
This was carried out to evaluate the specific daily consumption of PAHs via ingesting smoked giblet and beef and juxtapose it with the acceptable limits provided by USEPA. The EDI is usually expressed in mg/person/day. The assumptions such as the daily ingestion of meat and adult body weight were referenced properly
Estimated Daily Intake of metals for adults and children will be determined by the equation

$$EDI = \frac{Concentration\ of\ Metals\ x\ Daily\ beef\ Intake}{Average\ Body\ Weight}$$

The non-carcinogenic risks
The non-carcinogenic risks associated with consuming beef and chicken samples were determined using the hazard quotient formula expressed in mg/kg/day. This was derived by finding the ratio between the ingested heavy metals in the smoked beef or chevon and the oral reference dose as stated by USEPA.
Note:
A hazard quotient that is greater than 1 suggests the possibility of health hazards from heavy metals in beef, while when it is less than 1, it puts forward that it is safe to consume for life. (USEPA, 2011). This does not necessarily say that consumers will develop health issues directly by ingesting smoked chevon or beef but informs on the risks that may develop by consuming them
Toxic Hazard Quotient (THQ)
Toxic Hazard Quotient was calculated using the equation below

$$THQ = \frac{Concentration\ of\ Metals\ x\ Daily\ beef\ Intake}{RfD \times Average\ Body\ Weight}$$

Where RfD is the Oral / Ingestion Reference Dose

Incremental Lifetime Carcinogenic Risk (ILCR)
The life-time probability of cancer or carcinogenic risk was estimated according to the formula
CR = Estimated Daily Intake x Ingestion Carcinogenic Slope Factor (mg/kg/day) (mg/kg/day)-1.
A slope factor and the accompanying weight of evidence determination are the toxicity data most commonly used to evaluate potential human carcinogenic risks. The slope factor is a plausible upper-bound estimate of the probability of a response per unit of a chemical over a lifetime. The slope factor is used in risk assessments to estimate an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen. Cancer slope factors are estimates of carcinogenic potency and are used to relate estimate daily dose of a substance over a lifetime exposure to the lifetime probability of developing tumors. The Ingestion cancer slope factors are expressed in units of (mg/kg/day)-1.

Statistical Analysis:
Data obtained were expressed as mean ± SD and test of statistical significance were carried out using one-way analysis of variance (ANOVA). Mean with p values < 0.05 were considered as significant. All values for different model parameters estimated were compared to the standards and permissible limits of the updated versions of the United States Environmental Protection Agency

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Results

The level of heavy metals obtained from beef of chicken samples gotten from Southeast

The total concentration of heavy metal identified in beef samples (Figure 2) obtained from Leru was 2.60424 mg/kg. The highest concentration was Cu (1.67 mg/kg). While the metal with the least concentration is Co (0.02 mg/kg). The highest recorded from those obtained from Ishiagu town was also Cu (1.89 mg/kg). However, the metal with the least concentration is As (0.09 mg/kg). Also, those obtained from Nkalagu showed more concentration of Cu (1.54 mg/kg) and the least concentration was also As (0.05 mg/kg). They all recorded Cu as the metal with highest concentration, Ishiagu and Nkalagu recorded As as the metal with least concentration.

Table 1: Heavy metals in beef samples obtained from different restaurants sold around the mining areas

	Leru	Ishiagu	Nkalagu
Cu	1.67	1.89	1.54
Pb	0.08	0.12	0.05
Fe	1.4	1.92	1.43
Zn	1.02	1.61	1.33
As	0.03	0.09	0.05
Co	0.02	0.1	0.08
Ni	0.8	1.02	0.9

The level of heavy metals obtained from Gizzard of chicken samples gotten from Southeast

The heavy metals identified in Gizzard sample (Figure 3) obtained from Leru recorded Cu (1.3 mg/kg) as the highest metal concentration while As (0.02 mg/kg) was the least. However, the sample obtained from Ishiagu recorded Cu (1.58 mg/kg) also as the highest and Co (0.1 mg/kg) the least metal concentrations. Samples obtained from Nkalagu recorded Cu (1.21 mg/kg) as the highest and As (0.02 mg/kg) as the least metal concentration. They all recorded Cu to be the metal with highest concentration, whereby Leru and Nkalagu recorded As as the metal with least concentration.

Table 2: Heavy metals in beef samples obtained from different restaurants sold around the mining areas

	Leru	Ishiagu	Nkalagu
Cu	1.3	1.58	1.21
Pb	0.02	0.05	0.03
Fe	1	1.42	1.09
Zn	0.7	1.3	1.03
As	0.02	0.05	0.02
Co	0.09	0.1	0.08
Ni	0.03	0.06	0.05

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The level of heavy metals obtained from Liver of chicken samples gotten from Southeast

The heavy metals identified in Liver sample (Figure 4) obtained from Leru recorded Fe (0.78 mg/kg) as the metal concentration with the highest concentration while As and Pb (0.01 mg/kg) respectively, were the least. However, the sample obtained from Ishiagu recorded Fe (1.12 mg/kg) also as the highest and Pb and As (0.03 mg/kg) the metals with the least concentration. Samples obtained from Nkalagu recorded Fe (0.71 mg/kg) as the highest, recording As and Pb (0.02 mg/kg) as the least metal concentration. They all recorded Fe to be the metal with highest concentration and also had Pb and As as the least metal concentration.

Table 3: Heavy metals in Gizzard samples obtained from different restaurants (10) sold around the mining areas

	Nsukka	Ishiagu	Nkalagu
Cu	0.61	1.04	0.67
Pb	0.01	0.03	0.02
Fe	0.78	1.12	0.71
Zn	0.3	0.7	0.5
As	0.01	0.03	0.02
Co	0.03	0.07	0.05
Ni	0.07	0.06	0.05

Estimated daily intake (EDI) of heavy metal composition on giblets from Southeast Nigeria

The EDI of the samples (Table 1) obtained from Leru recorded the highest value to be Cu (3.1002×10^{-3} mg/kg/day) seen in gizzard, and the least EDI was Pb and As (1.86×10^{-5} mg/kg/day) in the Liver. Samples gotten from Ishiagu recorded Fe (3.5654×10^{-3} mg/kg/day) to have the highest EDI seen in gizzard, and the least EDI was also Pb and As (5.57×10^{-5} mg/kg/day) seen in the Liver. However, the samples gotten from Nkalagu recorded the highest EDI to be Cu (2.8598×10^{-3} mg/kg/day) seen in gizzard, and the EDI of the sample obtained from Nkalagu for As and Pb was seen in the Gizzard (3.71×10^{-5} mg/kg/day) and Liver (3.71×10^{-5} mg/kg/day) respectively. The highest EDI in the investigated samples was observed to be Cu in samples obtained from Leru and Nkalagu. Iron recorded the highest EDI from Ishiagu while Pb and As recorded the lowest EDI across all locations.

Discussion

Heavy metal contamination in the environment poses a significant threat to ecosystems, animals, and human health. These toxic metals, often introduced through industrial activities, agricultural practices, and improper waste disposal, can persist in soil and water, creating a cycle of bioaccumulation in plants and animals (Briffa *et al*., 2020; Angon *et al*., 2024). In Southeast Nigeria used as a case study in this research, specifically in Leru, Ishiagu, and Nkalagu, where industrialization, agriculture and poultry farming are key economic activities. Poultry, often reared in free-range systems, are highly susceptible

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to environmental contaminants as they forage freely, increasing their exposure to soil, water, and feed contaminated with heavy metals (Aljohani, 2023).

Beef and the edible organs of poultry, giblets, which include the Gizzard and Liver, are considered delicacies in many Nigerian communities. However, these organs are also primary sites for the accumulation of heavy metals. In giblets, given their physiological roles in digestion, detoxification, and circulation can also accumulate metals (Briffa *et al*., 2020). These metals can have long-term harmful effects on people when consumed, the consequences of this contamination in beef and giblets are significant for both public health and food safety (Emurotu *et al.,* 2024).

The beef samples from Leru, Ishiagu, and Nkalagu as seen in Table 2 showed variations in heavy metal concentrations. Notably, copper (Cu) levels ranged from (1.54 to 1.89 mg/kg), with Ishiagu having the highest concentration. Lead (Pb) levels were relatively low (0.12 mg/kg) in Ishiagu. Zinc (Zn) concentrations varied between 1.02 and 1.61 mg/kg, reflecting higher levels in Ishiagu compared to Leru and Nkalagu. Arsenic (As) and cobalt (Co), though present in minimal amounts, showed slightly elevated levels in Ishiagu. These findings suggest that environmental or anthropogenic factors might contribute to higher metal deposition in gizzards from Ishiagu. For instance, some locations in Ishiagu like Ezzamgbo where a very big abattoir is located. Regularly, they burn animal bones and skin in an open environment and deposit some of waste materials into the river close to that area. This same river can be used for poultry farming due to water shortage in that location, heavy metals can easily be accumulated through that exposure and again they are numerous mining sites (About 5 different sites) located around that geographical entity.

The gizzard, a muscular organ responsible for grinding food, acts as a site where ingested particles, including contaminants, can accumulate (Pain *et al.,* 2019). Free-range poultry in the study areas often roam freely, foraging for food and inadvertently ingesting soil, stones, and other environmental materials. In regions like Ishiagu, known for extensive mining activities and agricultural practices, the soil is more likely to contain higher concentrations of heavy metals, which are then transferred to the poultry through ingestion.

The Gizzard samples as seen in table 3 also revealed notable variations in heavy metal concentrations. Copper levels were highest in Ishiagu (1.58 mg/kg), aligning with trends observed in the beef samples. Lead concentrations were below 0.05 mg/kg across all locations, while zinc levels showed a peak of 1.3 mg/kg in Ishiagu. Noteworthy is the elevated cobalt level of 0.1 mg/kg in both Leru and Ishiagu. These patterns suggest that the Gizzard accumulates certain metals in response to environmental exposure, possibly reflecting the metal bioavailability in these areas. The health implications of heavy metals in the Gizzard are critical, given its role in detoxification and metabolism. Chronic exposure to metals such as Cu and Co in high quantities could impair Gizzard function. A study by Okoye *et al*. (2022) demonstrated similar findings in poultry Gizzard, linking high metal levels to compromise metabolic

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health in consumers. Consequently, consistent monitoring and implementation of stringent environmental controls in the regions under study are necessary to mitigate such risks.

The Liver samples in table 3, exhibited lower heavy metal concentrations compared to the beef and gizzard. Copper levels ranged from 0.61 to 1.04 mg/kg, with Ishiagu again recording the highest values. Lead and arsenic concentrations were below 0.03 mg/kg, while zinc levels peaked at 0.7 mg/kg in Ishiagu. These lower concentrations suggest that the Liver may not serve as a primary site for heavy metal accumulation in poultry, reflecting its distinct physiological role. Despite the lower levels, the presence of heavy metals in the Liver cannot be disregarded. Continuous exposure, even at low levels, may pose long-term health risks, particularly due to bioaccumulation. A report by Igwe *et al*. (2019) supports these findings, showing a correlation between environmental pollution and trace metal accumulation in poultry organs.

Health risk assessments revealed that Cu (3.1002×10^{-3} mg/kg/day) had the highest Estimated Daily Intake (EDI), particularly in BEEF samples from Leru, suggesting a high level of exposure through consumption. The Target Hazard Quotient (THQ) analysis showed that Cu also posed the highest non-carcinogenic risk (THQ_{Cu} 0.062004), especially in gizzards from Leru, indicating potential health concerns. A similar study by Kia et al. (2024) found that Cu had the highest EDI and THQ in poultry samples from Iran, exceeding safe limits and posing health risks to consumers. Nickel had the highest Carcinogenic Risk (CR), with the highest values (2.5255×10^{-3}) recorded in gizzards samples from Leru, suggesting a long-term cancer risk for consumers. Rajeshkumar & Li (2018) also reported elevated CR values for Ni in fish species, linking long-term exposure to an increased risk of cancer. The Hazard Index (HI) further confirmed that Ishiagu had the highest cumulative risk (1.1574), exceeding the safety threshold of 1, highlighting possible health concerns and the need for stricter monitoring and regulatory measures. Thus, the observed results emphasize the need for routine environmental assessments and control measures to ensure food safety.

Conclusion

This study assessed heavy metal contamination in chicken giblets from southeastern Nigeria, with higher levels observed in Ishiagu due to environmental factors like mining. Copper and iron were the most abundant, while toxic metals like lead and arsenic were present in smaller amounts. The results show that in order to reduce contamination and safeguard public health, more restrictions are required.

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Amalunweze A.E. etal, (2025). Heavy Metal Content & Health Risk Assessment of Beef and Chicken Samples Sourced from Local Restaurants in Mining Areas of Ebonyi. *International Journal of Functional Research in Science & Engineering,3*(4), 132-142.

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