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Assessment Of Heavy Metal Contamination In Broiler And Domestic Chicken Meat: A Review Of Analytical Findings, Toxicological Risks, And Food Safety Standards

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Abstract
Heavy metal (HM) contamination in poultry meat poses significant public health challenges due to bioaccumulation in edible tissues. This review synthesizes findings from studies assessing the presence of Pb, Co, Mn, Fe, and Cu in broiler (BC) and domestic chickens (DC), emphasizing data from Quetta, Bangladesh. Atomic Absorption Spectroscopy (AAS) results demonstrated that Pb levels exceeded permissible WHO and EU limits (0.2 mg/L and 0.1 mg/L, respectively), while Cu, Mn, Co, and Fe were within acceptable ranges. The comparative tissue analysis revealed organ-dependent variation, with BC exhibiting higher Pb concentrations and DC higher Fe levels. Data suggest contamination sources include polluted water, feed ingredients, and environmental emissions. The review highlights the need for systematic monitoring of poultry feed and urban agricultural practices to ensure meat safety.

Keywords: *Heavy metals, broiler chicken, domestic chicken, AAS, feed contamination, food safety*

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I. Introduction

The poultry sector has emerged as a cornerstone of global food security, supplying a substantial share of animal protein due to its economic accessibility, nutritional adequacy, and efficient production systems. In both developed and developing regions, poultry meat plays a pivotal role in bridging the nutritional gap by providing high-quality proteins, essential amino acids, and micronutrients required for human growth and health. However, the rapid pace of industrialization, intensive agriculture, and expanding urbanization has contributed to the proliferation of environmental pollutants, among which heavy metals (HMs) represent one of the most critical threats to food safety and public health (Ogunwale et al., 2022; Akinyele & Shokunbi, 2015).

Heavy metals such as lead (Pb), cobalt (Co), manganese (Mn), iron (Fe), and copper (Cu) are naturally occurring elements that can enter the food chain through contaminated feed, water, soil, and atmospheric deposition. While trace quantities of these metals are physiologically indispensable for enzymatic and metabolic functions, their accumulation beyond permissible limits disrupts biological homeostasis, leading to toxicological manifestations including neurotoxicity, oxidative stress, and organ dysfunction (Korish & Attia, 2020).

In Bangladesh, the poultry industry serves as a vital component of the agricultural economy, contributing approximately 25.8% of the nation's total meat output and providing a major source of affordable protein for its population (Hussain et al., 2015). Nevertheless, the intensification of poultry farming practices, coupled with inadequate regulation of feed composition and environmental management, has heightened the potential for heavy metal exposure in poultry products. Recent research, notably that of Hakeem et al. (2025), has documented detectable variations in the accumulation of Pb, Co, Mn, Fe, and Cu in both broiler and domestic chicken tissues, reflecting disparities in feed quality, environmental conditions, and husbandry systems.

Given these concerns, this review seeks to synthesize existing analytical evidence, elucidate patterns of heavy metal distribution in poultry tissues, and assess their broader implications for food safety, toxicology, and human health. The discussion also emphasizes the need for stringent monitoring frameworks, sustainable feed management, and targeted policy interventions to mitigate heavy metal contamination in poultry production systems.

II. Literature Review

Numerous global studies have confirmed that poultry meat can accumulate hazardous metals such as Pb, Cd, As, and Hg through contaminated feed and water (Hu et al., 2018; Ersoy et al., 2020). Akinyele and Shokunbi (2015) compared digestion methods to improve HM detection accuracy, while Ghimpețeanu et al. (2012) employed ICP-MS for trace metal quantification.

Korish and Attia (2020) reported significant heavy metal residues in feed and liver samples, aligning with Hakeem et al. (2025), who found Pb concentrations in broilers exceeding permissible limits. The WHO and FAO have proposed tolerable intake thresholds to minimize dietary exposure

(FAO/WHO,2000). Furthermore, research by Rehman et al. (2013) and Khan et al. (2016) emphasized geographical variation, showing higher Pb in regions near industrial activities. Studies in China and Nigeria corroborate similar contamination pathways from feed ingredients and water used for poultry rearing (Qin et al., 2021; Orisakwe et al., 2017).

III. Research Methodology

Hakeem et al. (2025) utilized Atomic Absorption Spectroscopy (AAS) for quantifying Pb, Co, Mn, Fe, and Cu in five tissues (liver, kidney, heart, gizzard, muscle) of BC and DC collected from Quetta. Samples were oven-dried at 120°C, digested using a mixture of HNO and HClO (4:1), and diluted to 50 mL for analysis. Standard curves were prepared using 1000 mg/l stock solutions, and Limit of detection/Limit of quantification (LOD/LOQ) were calculated using the calibration slope and standard deviation formulae. Quality assurance was ensured through blanks, reference standards, and triplicate analysis.

IV. Results And Discussion

Comparative Concentrations of Heavy Metals

The comparative analysis of heavy metal concentrations, specifically lead (Pb), cobalt (Co), manganese (Mn), iron (Fe), and copper (Cu), revealed distinct patterns of bioaccumulation across various tissues in both broiler and domestic chickens (Tables 1–2). The observed variations in concentration levels can be attributed to several physiological, environmental, and dietary factors influencing metal uptake and metabolism in the avian systems.

Lead (Pb) exhibited notably higher concentrations in the organs of broiler chickens compared to their domestic counterparts. This elevation may stem from intensive commercial feed formulations, potential contamination of drinking water, and exposure to industrial or vehicular emissions in poultry-rearing environments. The elevated Pb levels in vital organs such as the liver, kidney, and muscle tissues are of serious concern, as they surpassed the permissible thresholds recommended by both the World Health Organization (WHO) and the European Union (EU) for safe human consumption. Chronic ingestion of Pb-contaminated poultry products could pose significant health risks, including neurotoxicity, renal impairment, and hematological disturbances in consumers.

Cobalt (Co) concentrations showed moderate variability, likely reflecting differences in dietary mineral supplementation practices and the mineral composition of soil and water sources used for rearing. Although Co is an essential trace element required for vitamin B synthesis and erythropoiesis, excessive accumulation may interfere with enzymatic activities and cause metabolic imbalances.

Manganese (Mn) and iron (Fe) were detected in physiologically acceptable ranges, yet notable fluctuations were observed between tissues, with liver and kidney tissues generally exhibiting higher accumulation due to their central roles in metal metabolism and detoxification. Mn, being a cofactor for numerous enzymes, is vital for growth and skeletal development; however, its excessive presence may induce oxidative stress and disrupt neurological functions. Fe, essential for hemoglobin synthesis and cellular respiration, may accumulate differentially depending on dietary intake and metabolic demand, with higher levels in broiler chickens suggesting fortified feed inputs.

Copper (Cu) concentrations were comparatively stable but demonstrated tissue-specific accumulation trends, with higher levels in hepatic tissues, consistent with its function in enzymatic oxidation processes. Although Cu is an indispensable micronutrient, surpassing safety limits could lead to hepatotoxic effects and gastrointestinal distress in both poultry and humans consuming contaminated meat.

Overall, the data emphasize that broiler chickens, often subjected to intensive rearing and high-nutrient feed regimes, tend to bio accumulate higher levels of heavy metals than domestic or free-range chickens. This pattern underscores the need for stringent monitoring of feed quality, water purity, and environmental exposure to mitigate the entry of toxic metals into the poultry food chain, ensuring both animal welfare and consumer safety.

Table 1. Mean Heavy Metal Concentrations in Broiler Chicken Tissues (mg/L)

Organ	Pb	Co	Mn	Fe	Cu
Liver	**0.41**	**0.33**	**0.21**	**6.51**	**4.03**

Gizzard	0.45	0.35	0.16	2.42	4.39
Muscles	0.43	0.33	0.11	1.22	4.04
Heart	0.83	0.31	0.12	1.32	3.79
Kidney	0.68	0.31	0.11	4.43	4.22

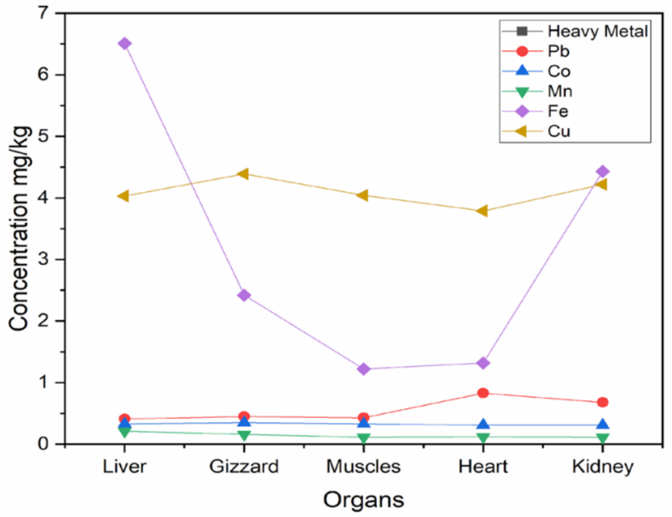

Fig-1: Comparative Concentrations of Heavy Metals in Different Chicken Organs

Table 2. Mean Heavy Metal Concentrations in Domestic Chicken Tissues (mg/L)

Organ	Pb	Co	Mn	Fe	Cu
Liver	0.30	0.25	0.17	9.26	4.18
Gizzard	0.25	0.21	0.10	4.21	4.32
Muscles	0.48	0.27	0.11	1.44	4.36
Heart	0.26	0.18	0.12	3.44	4.51
Kidney	0.28	0.19	0.11	12.70	3.85

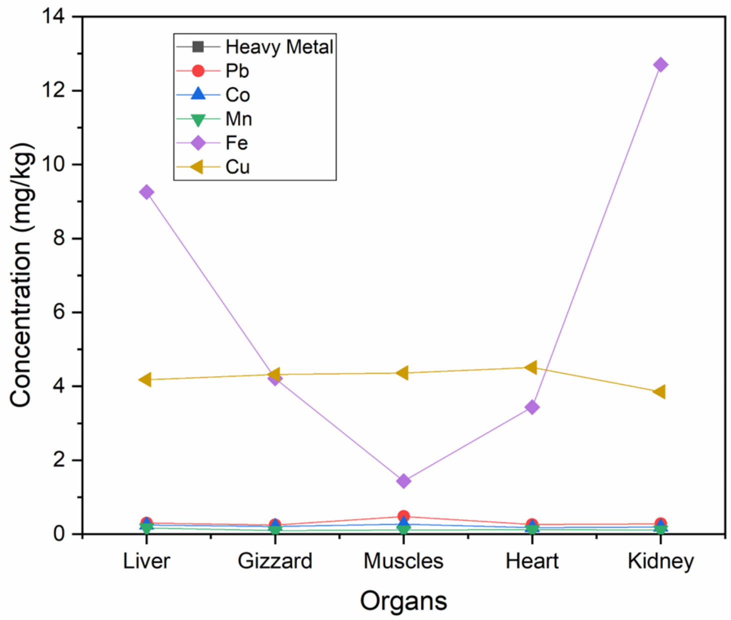

Fig-2: Comparative Concentrations of Heavy Metals in Different Chicken Organs

Analytical Performance of AAS

Table 3. Analytical Evaluation Parameters

Metal	LOD (mg/L)	LOQ (mg/L)	RSD (%)	R^2
Co	0.06	0.20	1.7	0.9998
Cu	0.05	0.20	1.4	0.9999
Fe	0.80	2.80	3.6	0.9993

Mn	**0.05**	**0.20**	**1.4**	**0.9999**
Pb	**0.07**	**0.20**	**1.9**	**0.9998**

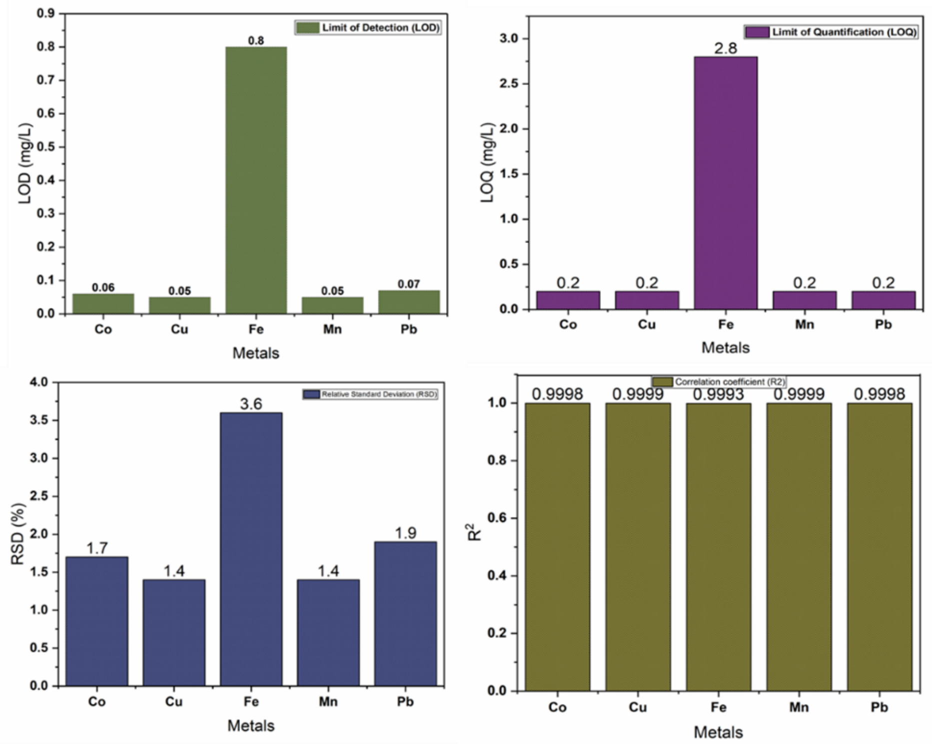

Fig-3: Analytical Performance of Metal Determination

Comparison with Global Standards

Table 4. Comparison of Mean Concentrations with WHO and EU Standards

Metal	Mean (mg/L) in BC	Mean (mg/L) in DC	WHO Limit	EU Limit	Status
Pb	**0.56**	**0.31**	**0.20**	**0.10**	**Exceeds**
Co	**0.32**	**0.22**	**1.50**	**1.50**	**Safe**
Mn	**0.14**	**0.12**	**0.50**	**0.50**	**Safe**
Fe	**3.18**	**6.00**	**40.00**	**40.00**	**Safe**
Cu	**4.10**	**4.24**	**10.00**	**10.00**	**Safe**

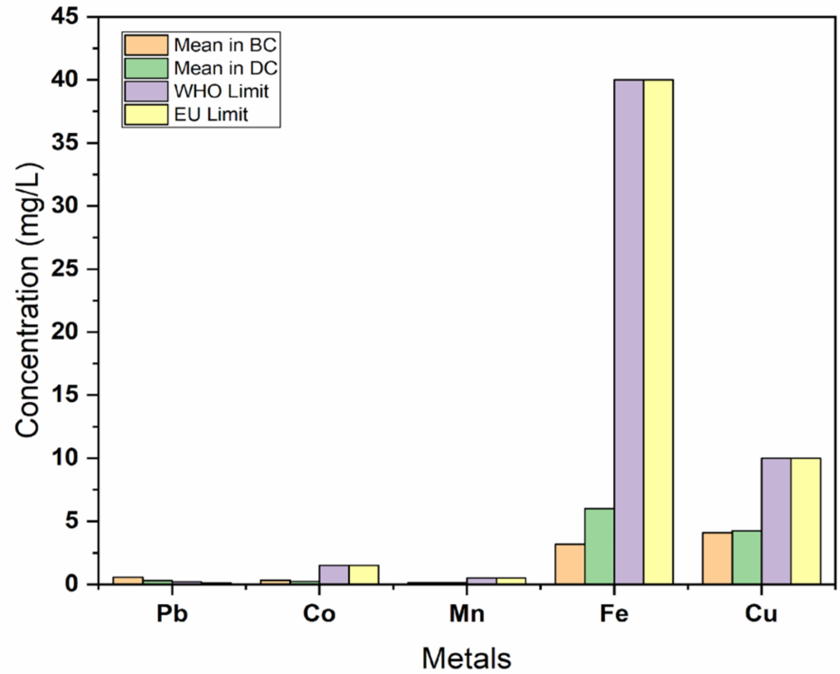

Fig-4: Comparison of Metal Concentrations in BC & DC with WHO and EU Limit

Risk and Toxicological Assessment

Lead (Pb) exposure that exceeds internationally recognized safety thresholds poses a significant threat to human health, with well-documented associations to neurological impairment, renal dysfunction, and hematological abnormalities (Johri et al., 2010). Chronic ingestion of Pb-contaminated meat can result in bioaccumulation within vital organs, potentially triggering long-term pathophysiological effects, including carcinogenic transformations and developmental disorders. In contrast, elements such as iron (Fe), copper (Cu), and cobalt (Co) are indispensable micronutrients that participate in numerous enzymatic and metabolic pathways-governing oxygen transport, redox balance, and cellular respiration. However, when present in excessive concentrations, these essential metals may shift from their physiological roles to pathological agents, contributing to oxidative stress, lipid peroxidation, and tissue degeneration (Menezes et al., 2018).

Table 5. Health Risk Evaluation of Heavy Metals in Chicken Meat

Metal	Function	Toxic Effect (if excess)	Observation in Study
Pb	Non-essential	Carcinogenic, neurotoxic	Above limits
Fe	Essential	Oxidative stress	Within limits
Cu	Essential	Liver dysfunction	Within limits
Mn	Essential	Neurological damage	Within limits
Co	Essential	Vitamin B12 cofactor	Within limits

V. Conclusion

This review underscores that, although the concentrations of most heavy metals-particularly Fe, Cu, Mn, and Co-identified in broiler and domestic chicken tissues remain within the permissible thresholds established by the World Health Organization (WHO) and the Food and Agriculture Organization (FAO), lead (Pb) contamination persists as a critical and recurrent issue. The elevated Pb levels detected in edible tissues pose a serious public health challenge, as lead is a non-essential and toxic metal with no known biological function. Its persistence in poultry meat implies sustained environmental exposure, most plausibly originating from contaminated feed ingredients, polluted drinking water, and atmospheric deposition derived from industrial emissions, vehicular exhaust, and improper waste disposal.

The findings highlight the urgent need for a comprehensive and integrated approach to mitigate heavy metal contamination in poultry production. Regulatory bodies and agricultural authorities should implement stringent feed quality assurance protocols, enforce regular surveillance of environmental contaminants, and prohibit the use of untreated wastewater for irrigation of feed crops. Moreover, the adoption of cleaner feed formulations, utilization of bio-sorbent materials, and development of environmentally sustainable rearing systems could substantially reduce metal uptake in poultry tissues.

To advance food safety and public health protection, future research should emphasize multi-factorial risk assessment models, examining the cumulative and synergistic effects of heavy metals on human consumers.

Investigations into the pathways of bioaccumulation, feed-to-tissue transfer kinetics, and regional variations in contamination levels are essential to inform targeted policy interventions. Establishing a robust monitoring framework, coupled with public awareness initiatives and international standardization of feed and meat quality parameters, will be pivotal in ensuring the long-term safety, nutritional integrity, and sustainability of poultry-based food systems.

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