INSIGHTS-JOURNAL OF

HEALTH AND REHABILITATION

ASSESSMENT OF HEAVY METALS IN TABLE EGGS: SOURCES OF CONTAMINATION, ASSOCIATED HEALTH RISKS, AND POTENTIAL OUTCOMES

Original Research

Muhammad Usama Aslam[1]*, Hafiz Muhammad Zeeshan[1], Waqar Mehdi[2], Dua Tariq[2], Ghulam Husnain[1], Esha Aslam[1]*, Umar Mushtaq Ahmad[1]

[1]Department of Food Safety and Quality Management, Bahauddin Zakariya University, Multan 60800, Pakistan.

[2]Department of Human Nutrition and Dietetics, Bahauddin Zakariya University, Multan 60800, Pakistan.

Corresponding Author: Muhammad Usama Aslam, Department of Food Safety and Quality Management, Bahauddin Zakariya University, Multan 60800, Pakistan, ua6965300@gmail.com

Esha Aslam, Department of Food Safety and Quality Management, Bahauddin Zakariya University, Multan 60800, Pakistan, iameshaaslam@gmail.com

Acknowledgement: The authors gratefully acknowledge the support of the Food Safety and Microbiology Laboratory, Bahauddin Zakariya University, Multan.

Conflict of Interest: None

Grant Support & Financial Support: None

ABSTRACT

Background: Poultry eggs serve as an essential source of protein, vitamins, and minerals, particularly for vulnerable populations like children and the elderly. With Pakistan's poultry industry witnessing an annual growth rate of 8–20%, egg production continues to rise in response to increasing dietary demands. However, the presence of heavy metals in eggs poses a significant threat to food safety and public health. This study was conducted to assess and compare the concentration of toxic metals in eggs sourced from domestic and commercial poultry systems in Multan, Pakistan.

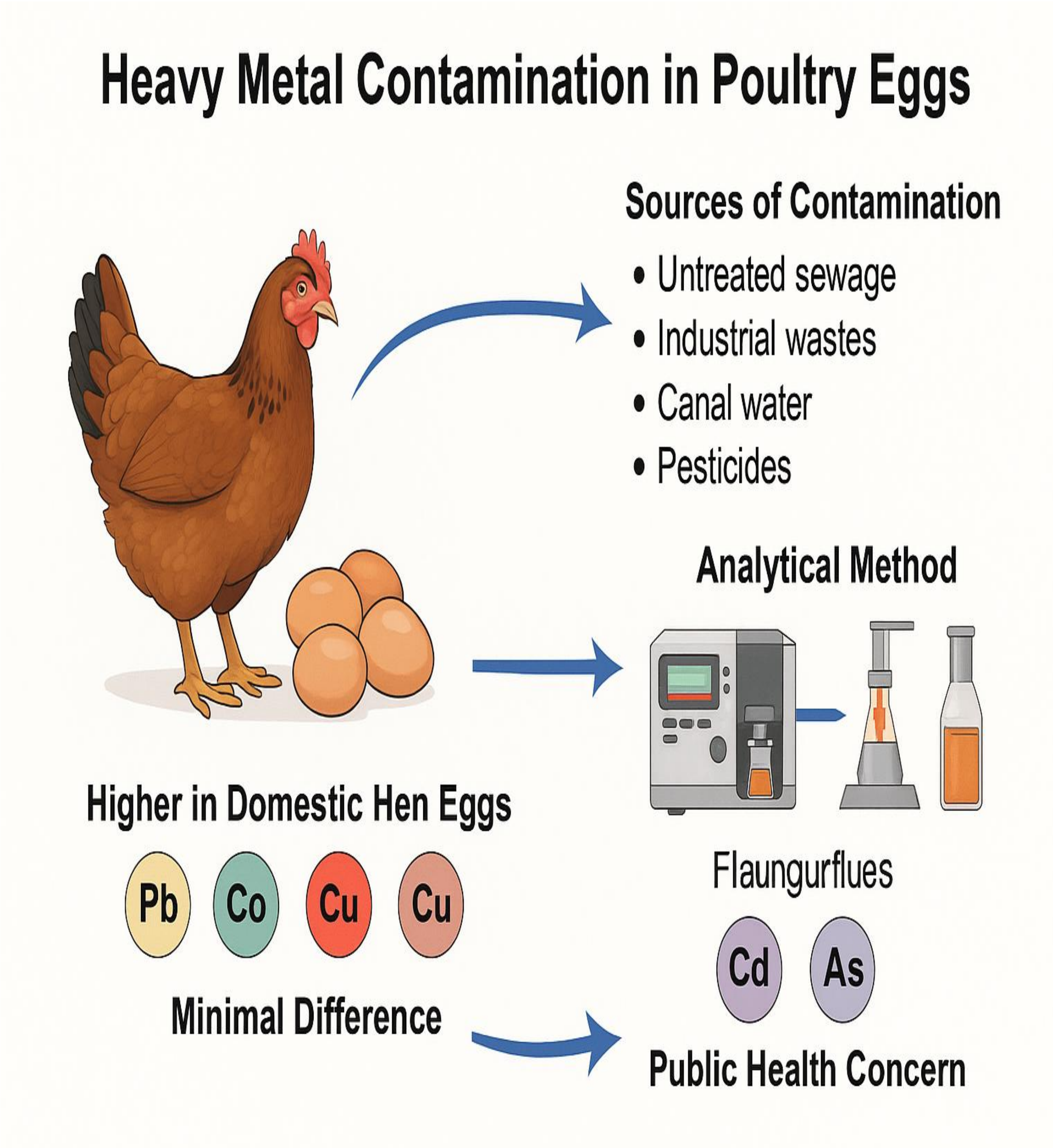
Objective: To evaluate and compare the levels of heavy metals—specifically lead (Pb), cadmium (Cd), zinc (Zn), cobalt (Co), arsenic (As), iron (Fe), and copper (Cu)—in layer and domestic hen eggs to determine their safety for human consumption.

Methods: This cross-sectional laboratory study was carried out at Bahauddin Zakariya University, Multan. Egg samples were collected randomly from domestic and commercial sources. Each sample underwent wet digestion using concentrated nitric and perchloric acid followed by analysis through Flame Atomic Absorption Spectrophotometry (FAAS). The concentrations of heavy metals were measured separately in egg whites and yolks.

Results: Lead levels in domestic hen egg whites (0.830 ± 0.011 µg/g) and yolks (0.668 ± 0.214 µg/g) were significantly higher compared to commercial layers (white: 0.043 ± 0.014 µg/g; yolk: 0.024 ± 0.006 µg/g). Cobalt concentrations were also higher in domestic whites (2.369 ± 0.302 µg/g) versus layers (1.138 ± 0.023 µg/g). Copper levels peaked in domestic yolks at 0.360 ± 0.027 µg/g. Cadmium, arsenic, and iron levels showed minimal variation across all samples. Zinc was highest in domestic whites (0.968 ± 0.085 µg/g) and in layer yolks (0.863 ± 0.076 µg/g).

Conclusion: Eggs from domestic poultry showed higher contamination with toxic metals, particularly Pb, Co, and Cu, raising serious public health concerns. These findings highlight the urgent need for regulatory oversight, environmental monitoring, and public awareness to ensure food safety and reduce exposure risks.

Keywords: Cadmium, Cobalt, Egg Contamination, Food Safety, Lead, Poultry Products, Zinc.


Heavy Metal Contamination in Poultry Eggs
Sources of Contamination
• Untreated sewage
• Industrial wastes
• Canal water
• Pesticides
Analytical Method
Higher in Domestic Hen Eggs
Pb
Co
Cu
Cu
Flaungurflues
Cd
As
Minimal Difference
Public Health Concern

INTRODUCTION

Eggs, long regarded as a superior source of animal protein, play a critical role not only in nutritional security but also in contributing to national economies through agriculture and export. In Pakistan, poultry farming has emerged as a significant sector, offering employment to over 1.5 million individuals and demonstrating remarkable export growth, with the value of poultry exports rising from Rs.27 million in 2009–10 to Rs.1.08 billion in 2010–11 (1). Despite surpassing targeted egg production volumes by 6.5% in the fiscal year 2012–13, concerns regarding the safety of poultry products have intensified due to environmental pollutants and the potential for contamination, especially with heavy metals (1). The quality and safety of these products are increasingly being scrutinized within the broader framework of global food safety concerns. Foodborne illnesses remain a global public health issue, claiming approximately 420,000 lives annually, with children under five disproportionately affected (2). The World Health Organization estimates that around 33 million disability-adjusted life years (DALYs) are lost each year due to consumption of unsafe food, underscoring the magnitude of the issue (2). Among the emerging concerns are contaminants like heavy metals, which pose a silent but severe risk to food security, particularly in widely consumed products such as eggs and chicken (3). These elements, including cadmium (Cd), lead (Pb), mercury (Hg), and arsenic (As), are known for their non-biodegradable and thermodegradable properties, enabling them to persist in the environment and bioaccumulate through the food chain (4,5). Mineral elements like iron (Fe), zinc (Zn), nickel (Ni), and copper (Cu) also pose toxicological risks when present beyond permissible limits (6). Chronic exposure to these metals has been associated with a range of debilitating health outcomes, including organ failure, developmental disorders, metabolic dysfunctions, and certain cancers (7-9).

Multiple pathways facilitate the entry of heavy metals into poultry products, including the use of contaminated water for irrigation, industrial effluents, and poor farming practices, such as using untreated sewage and canal water in rural areas (10-12). Furthermore, inadequate food handling, contaminated feed, and lack of awareness among poultry workers aggravate the situation (13). Numerous studies have documented widespread environmental contamination in countries like Pakistan and India, with notable detection of heavy metals in soil, plants, and poultry tissues (11,12). Poultry raised near industrial zones or highways tends to show higher contamination levels compared to those farmed in more remote rural areas (12). Improper processing practices, such as the use of contaminated containers and farm infrastructure, further amplify the risks (14). Globally, developing nations report higher incidences of heavy metal contamination in eggs and chicken meat, often due to lax regulatory enforcement and infrastructural deficits. While countries like Egypt, Serbia, and Poland have reported Pb concentrations in poultry products well above permissible limits, developed nations with stricter food safety protocols generally show significantly lower levels (15,16). Similarly, cadmium contamination has been found to exceed safety thresholds in eggs from Pakistan, Nigeria, and the Philippines, placing consumers at heightened risk of kidney and liver damage (17). Arsenic, although less frequently detected at high levels globally, has been found at alarmingly high concentrations in Pakistani poultry products, indicating a pressing need for tighter regulation of poultry feed and water quality (18). Mercury, particularly in its toxic methylmercury form, poses severe neurotoxic and immunotoxic risks and has also been shown to impair poultry reproductive health and egg integrity (19-21). The cumulative effect of such contamination not only compromises public health but also threatens economic stability by eroding consumer confidence and reducing market viability for poultry exports. In light of these findings, the present study aims to investigate the prevalence and sources of heavy metals in eggs and poultry products, particularly within the context of Pakistan's growing poultry sector. The objective is to identify key risk factors contributing to contamination and provide evidence-based recommendations to enhance food safety, safeguard consumer health, and strengthen the sustainability of poultry production systems.

METHODS

This cross-sectional laboratory-based study was conducted after the approval from Institutional Review Board (IRB) to assess the concentration of heavy metals in poultry products, particularly eggs, and potential environmental sources, including feed and water, in the Multan district of Pakistan. Egg samples were randomly collected from various locations such as local markets, shops, and residential homes. Water samples were procured from poultry farms where birds were actively reared, specifically to examine potential heavy metal exposure through drinking water. Feed samples were obtained from students working on heavy metal contamination within the same department. All samples were appropriately sealed in zipper polyethylene bags or transparent glass bottles and stored at room temperature in the Food Safety and Microbiology Laboratory (FFSN), Bahauddin Zakariya University (BZU), until further analysis. The study adhered to institutional ethical standards. The primary analytical technique used to detect heavy metal concentrations in samples was Atomic Absorption Spectrophotometry (AAS), specifically flame atomic absorption spectrophotometry, due to its cost-

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

effectiveness, operational simplicity, and suitability for developing country laboratories (11-13). Before AAS analysis, all biological samples underwent a standardized wet digestion process to break down organic matter, as egg matrices contain high levels of such materials (20-22).

Wet digestion process

Wet digestion was employed to effectively decompose the organic matrices in the egg, feed, and water samples prior to metal analysis. This method involved treating samples with strong acids under controlled heat conditions to obtain a clear, analyzable solution suitable for Atomic Absorption Spectrophotometry.

Sample Preparation for Heavy Metal Analysis

The high organic content in eggs necessitated a predigestion step before analyzing heavy metals. Acid digestion, also known as wet digestion, was used as the preferred method over dry ashing, ensuring effective decomposition and minimal sample loss (17-19).

Wet Digestion Process:

Sample Measurement: Each biological sample was precisely measured using a micropipette to collect exactly one milliliter. The aluminum foil used to seal the digestion flasks was also weighed to ensure accurate quantification and reproducibility.

Nitric Acid Digestion: Ten milliliters of concentrated nitric acid (HNO_3) were added to each sample flask. The flasks were then sealed with pre-weighed aluminum foil and incubated in the dark at room temperature for 24 hours.

Perchloric Acid Digestion: After 24 hours of nitric acid digestion, five milliliters of perchloric acid ($HClO_4$) were added to each flask. The flasks remained undisturbed for an additional four hours to complete secondary digestion.

Hot Plate Digestion: The samples were subsequently placed on a hot plate at 200°C. Heating continued until the sample solutions became translucent, indicating the effective breakdown of remaining organic material (23).

Dilution and Filtration: Post-digestion, the samples were diluted to a final volume of 50 mL using double-distilled water. Once cooled, the samples were filtered using Whatman No. 42 filter paper to remove any undigested particulates.

Storage for Analysis: The filtered, diluted samples were transferred to clean, sealed glass bottles and stored at room temperature in the laboratory until heavy metal analysis could be performed using flame atomic absorption spectrophotometry.

RESULTS

The concentration of heavy metals in eggs varied significantly between layer and domestic hens, particularly for lead (Pb), cobalt (Co), and copper (Cu), while cadmium (Cd), arsenic (As), iron (Fe), and zinc (Zn) showed relatively consistent trends. Notably, lead levels were markedly elevated in domestic hen eggs, with a concentration of 0.830 ± 0.011 µg/g in the egg white and 0.668 ± 0.214 µg/g in the yolk, compared to significantly lower levels in layer hens, where the white contained 0.043 ± 0.014 µg/g and the yolk 0.024 ± 0.006 µg/g. Similarly, cobalt was considerably higher in domestic hens, with 2.369 ± 0.302 µg/g in the white and 1.651 ± 0.107 µg/g in the yolk, as opposed to 1.138 ± 0.023 µg/g and 1.901 ± 0.081 µg/g in layers respectively. Copper concentrations followed a similar trend, showing elevated levels in domestic eggs (0.302 ± 0.048 µg/g in white and 0.360 ± 0.027 µg/g in yolk) compared to layer eggs (0.149 ± 0.011 µg/g in white and 0.176 ± 0.013 µg/g in yolk). In contrast, cadmium levels remained fairly consistent across both poultry types and egg parts, ranging between 0.021–0.033 µg/g. Arsenic values also showed minimal variation, with the highest level recorded in the white of layer eggs at 0.061 ± 0.010 µg/g and identical values of 0.013 ± 0.004 µg/g in both yolk samples.

Zinc concentrations were highest in the white of domestic hen eggs (0.968 ± 0.085 µg/g) and in the yolk of layer eggs (0.863 ± 0.076 µg/g), indicating variable bioaccumulation patterns. Iron levels were comparable between egg types, with the yolk consistently showing higher values—0.919 ± 0.044 µg/g in domestic and 0.636 ± 0.036 µg/g in layer eggs—while the white showed 0.790 ± 0.042 µg/g and 0.492 ± 0.054 µg/g, respectively. These differences in elemental profiles indicate heightened environmental exposure among domestic hens, potentially due to less controlled feeding and living conditions. The elevated levels of Pb, Co, and Cu in domestic eggs emphasize the need for stricter environmental and feed monitoring in non-commercial poultry setups to minimize public health risks.

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

Table 1: Comparative Analysis of Heavy Metal Concentrations in Egg Whites and Yolks of Layer and Domestic Hens

	Egg Part	Pb	Cd*	Zn	Co	As	Fe*	Cu
Layer	White	0.043±0.014[c]	0.030±0.015	0.763±0.097[c]	1.138±0.023[d]	0.061±0.010[a]	0.492±0.054	0.149±0.011[d]
	Yolk	0.024±0.006[c]	0.021±0.010	0.863±0.076[b]	1.901±0.081[b]	0.013±0.004[c]	0.636±0.036	0.176±0.013[c]
Domestic	White	0.830±0.011[a]	0.033±0.012	0.968±0.085[a]	2.369±0.302[a]	0.033±0.010[b]	0.790±0.042	0.302±0.048[b]
	Yolk	0.668±0.214[b]	0.027±0.014	0.738±0.101[c]	1.651±0.107[c]	0.013±0.004[c]	0.919±0.044	0.360±0.027[a]

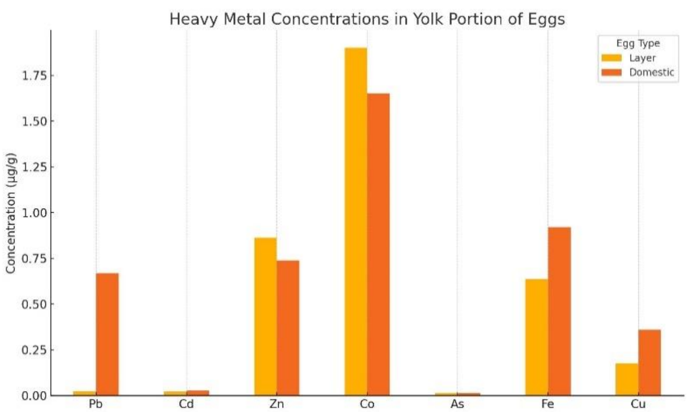


Figure 1 Heavy Mental Concentrations in Yolk Portion of Eggs

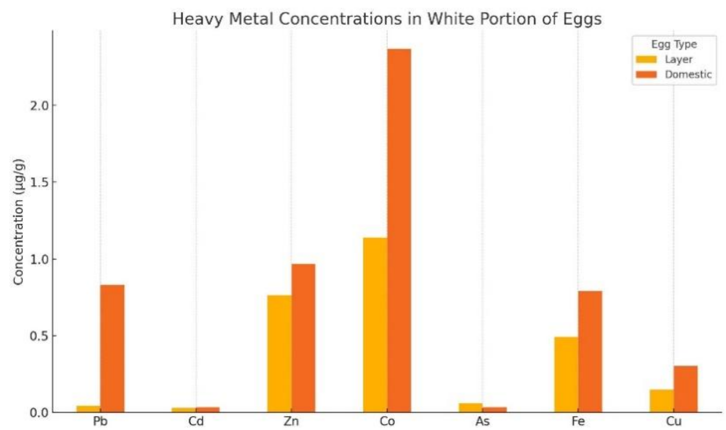


Figure 2 Heavy Mental Concentrations in White Portion of Eggs

DISCUSSION

The findings of this study highlight significant discrepancies in the concentrations of heavy metals in eggs derived from domestic hens compared to commercial layers. Particularly concerning were the elevated levels of lead (Pb), cobalt (Co), and copper (Cu) in eggs from domestically reared poultry. These observations align with previous research indicating that free-range or domestically managed poultry are more vulnerable to environmental contaminants due to increased exposure to unregulated feeding sources, contaminated water, and inadequate biosecurity protocols (11,13). The consistently higher Pb concentrations observed in domestic hen eggs raise serious public health concerns, as chronic lead exposure is strongly associated with neurological, renal, and reproductive toxicities, especially among vulnerable populations such as children and pregnant women (2,14). The comparative uniformity in cadmium (Cd) and arsenic (As) levels across both egg types is consistent with findings from regional studies in South Asia, which suggest that these metals may be present at baseline levels in the broader environment due to widespread contamination of irrigation sources and industrial runoff (15,16). However, the presence of these metals even within acceptable thresholds warrants continuous surveillance given their cumulative toxic potential and established link to carcinogenicity and organ dysfunction (17). Zinc (Zn) and iron (Fe), although essential for human nutrition, showed variability between egg types, yet remained within safe consumption limits. These elements, when exceeding their physiological thresholds, can also contribute to adverse metabolic interactions (18). The distribution pattern—elevated Zn in the albumen of domestic eggs and higher Fe in yolks—points to differential mineral absorption pathways that may be influenced by feed composition, metabolic stress, and breed-specific physiology.

The implications of these findings underscore the need for stringent environmental and production-based regulations. Despite growing awareness of food safety, developing nations continue to struggle with effective implementation of contamination control strategies, partly due to inadequate infrastructure and lack of policy enforcement. This is particularly concerning given the projected rise in egg and dairy consumption driven by urbanization, rising incomes, and nutritional transitions in low- and middle-income countries (19). Studies have emphasized that the adoption of Good Agricultural Practices (GAP), Good Manufacturing Practices (GMP), and Hazard Analysis and Critical Control Point (HACCP) systems is critical to minimizing contamination across the poultry value chain (20,21). Moreover, feed and water sources remain the primary vectors for heavy metal exposure in poultry. This necessitates routine quality control screening and strict regulation of feed ingredients, particularly in informal or small-scale operations that often lack standardized supply chains. Another salient point from this research is the heightened risk associated with domestic poultry production. While promoting backyard farming contributes to food security, especially in rural and peri-urban areas, it simultaneously increases the risk of exposure to unmonitored environmental toxins. Unlike commercial poultry farms, which often operate under certified conditions, domestic setups may rely on contaminated groundwater, untreated feed, and substandard housing conditions—all of which contribute to the bioaccumulation of heavy metals in poultry tissues and byproducts (22,23). These findings call for community-level interventions, including farmer education and subsidized access to tested feed and water supplies, to bridge the gap in food safety standards between commercial and non-commercial producers.

The study's strengths lie in its comparative analysis of domestic and layer poultry, using validated analytical methods such as flame atomic absorption spectrophotometry, which offers reliability and accessibility in resource-limited settings. Furthermore, the use of both yolk and albumen fractions provides a comprehensive view of heavy metal distribution within the egg matrix. However, some limitations must be acknowledged. The sample size and geographical coverage were limited to a single district, which restricts generalizability. In addition, while the study assessed several key heavy metals, it did not include mercury (Hg), one of the most toxic elements relevant to poultry contamination and a stated objective of the investigation. Future research should incorporate broader geographical sampling and include a more exhaustive panel of contaminants, including emerging pollutants such as microplastics and persistent organic pollutants (POPs), which are increasingly being detected in animal-derived foods (24). In conclusion, this study confirms the presence of varying levels of toxic metals in eggs, particularly from domestically reared hens, and highlights the critical need for regulatory oversight, environmental remediation, and farmer education to safeguard public health. The data reinforce the argument for enhancing food safety infrastructure, particularly in developing countries, through robust monitoring of feed, water, and production environments. These efforts are vital not only for preventing heavy metal-related illnesses but also for sustaining consumer confidence in locally produced animal-based food products.

CONCLUSION

This study underscores the pressing need for systematic monitoring and regulation of heavy metals in eggs, particularly in developing countries where environmental pollution, weak policy enforcement, and poor industrial oversight contribute to elevated contamination levels. The findings highlight that, children and the elderly are especially vulnerable to the adverse health effects of heavy metal exposure through common dietary sources like eggs. In contrast, industrialized nations benefit from stronger regulatory frameworks and lower contamination risks, offering a benchmark for best practices. Strengthening the role of food safety authorities, refining permissible thresholds, and ensuring strict enforcement are critical steps toward protecting public health. Ultimately, enhancing awareness and transparency around heavy metal presence in food products will be essential for ensuring safer consumption and guiding informed policy decisions.

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

AUTHOR CONTRIBUTION

Author	Contribution
Muhammad Usama Aslam*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Hafiz Muhammad Zeeshan	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Waqar Mehdi	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Dua Tariq	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Ghulam Husnain	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Esha Aslam*	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Umar Mushtaq Ahmad	Contributed to study concept and Data collection Has given Final Approval of the version to be published

REFERENCES

1. Shehzad MT, Sabir M, Zia-Ur-Rehman M, Zia MA, Naidu R. Arsenic concentrations in soil, water, and rice grains of rice-growing areas of Punjab, Pakistan: multivariate statistical analysis. Environ Monit Assess. 2022;194(5):346.
2. FAO. *World Food and Agriculture – Statistical Yearbook 2023*. Rome: Food and Agriculture Organization; 2023.
3. Islam MS, Mustafa RA, Phoungthong K, Islam A, Islam T, Choudhury TR, et al. Arsenic in the foodstuffs: potential health appraisals in a developing country, Bangladesh. Environ Sci Pollut Res Int. 2023;30(10):26938-51.
4. Munir MA, Khan B, Mian IA, Rafiq M, Shahzadi S, Naeem K, et al. Assessment of Hg accumulation in fish and scalp hair in fishing communities along river Swat, Pakistan. Environ Sci Pollut Res Int. 2021;28(47):67159-66.
5. Younis H, Ullah MM, Khan MA, Ahmad F, Azeem U, Waseem M, et al. Assessment of natural radioactivity levels in rice samples and their implications for radiological protection. Isotopes Environ Health Stud. 2024;60(6):615-27.
6. Afzal W, Habib SS, Ujan JA, Mohany M, Bibi H. Assessment of pesticide residues: a comprehensive analysis of seasonal trends and health implications. J Environ Sci Health B. 2024;59(10):642-53.
7. Mielech A, Puścion-Jakubik A, Socha K. Assessment of the Risk of Contamination of Food for Infants and Toddlers. Nutrients. 2021;13(7).
8. Kabeer MS, Hameed I, Kashif SU, Khan M, Tahir A, Anum F, et al. Contamination of heavy metals in poultry eggs: a study presenting relation between heavy metals in feed intake and eggs. Arch Environ Occup Health. 2021;76(4):220-32.
9. Rashid S, Shah IA, Supe Tulcan RX, Rashid W, Sillanpaa M. Contamination, exposure, and health risk assessment of Hg in Pakistan: A review. Environ Pollut. 2022;301:118995.
10. Riaz S, Khan MJ, Rani I, Ali A, Qazi MA, Sameer M, et al. Heavy metal contamination in some commercial marine fishes of Pakistan. Food Addit Contam Part B Surveill. 2025;18(2):135-42.
11. Kaur N, Singh J, Sharma NR, Natt SK, Mohan A, Malik T, et al. Heavy metal contamination in wastewater-irrigated vegetables: assessing food safety challenges in developing Asian countries. Environ Sci Process Impacts. 2025;27(7):1747-67.
12. Naz S, Rind KH, Afzal W, Ujan JA, Mohany M. Heavy metal pollution in commonly consumed fish species: seasonal variations and health risks. J Environ Sci Health B. 2024;59(10):678-85.
13. Draz A, Qazi MA, Hussain T, Ahmad O, Nazir MM, Bhatti MB, et al. Heavy metals concentration and human health risk assessment in selected shrimp species of Pakistan. Food Addit Contam Part B Surveill. 2025;18(1):78-85.
14. Aslam A, Naz A, Shah SSH, Rasheed F, Naz R, Kalsom A, et al. Heavy metals contamination in vegetables irrigated with wastewater: a case study of underdeveloping regions of Pakistan. Environ Geochem Health. 2023;45(12):8911-27.

15. Collado-López S, Betanzos-Robledo L, Téllez-Rojo MM, Lamadrid-Figueroa H, Reyes M, Ríos C, et al. Heavy Metals in Unprocessed or Minimally Processed Foods Consumed by Humans Worldwide: A Scoping Review. Int J Environ Res Public Health. 2022;19(14).
16. Khatoon N, Ali S, Hussain A, Huang J, Li Z, Yu Z, et al. Human health risks of heavy metals in water and vegetables: a deterministic and probabilistic study in Gilgit-Baltistan, Pakistan. Environ Geochem Health. 2025;47(3):88.
17. Akhtar S, Muneeb A, Khan ZI, Saba I, Ahmad K, Faisal M, et al. Long term urban wastewater irrigation drives zinc bioaccumulation and health risks in contaminated vegetables. Sci Rep. 2025;15(1):21290.
18. Ashfaq A, Khan ZI, Ahmad K, Raza H, Nazim M, Ahmad A. Multivariate analysis of potential health hazards of manganese via dietary exposure of widely consumed vegetables amended with municipal solid waste. Environ Geochem Health. 2025;47(7):247.
19. Iftikhar Ul H, Ahmed M, Aslam AA, Aftab F, Sanaullah M, Hussain R, et al. Multivariate analysis of potentially toxic metal contents in soil and vegetables: Enrichment, bioconcentration, translocation from soil to vegetables, and assessment of human health toxicity. Food Chem Toxicol. 2025;200:115413.
20. Xia W, Ghouri F, Zhong M, Bukhari SAH, Ali S, Shahid MQ. Rice and heavy metals: A review of cadmium impact and potential remediation techniques. Sci Total Environ. 2024;957:177403.
21. Chowdhury, M. A. Z., et al. (2021). "Assessment of toxic heavy metals and trace elements in poultry feeds, consumer chickens and eggs in Bangladesh." Asian-Australasian Journal of Bioscience and Biotechnology 6(3): 128-141
22. Samad, A., Roy, D., Hasan, M. M., Ahmed, K. S., Sarker, S., Hossain, M. M., & Shajahan, M. (2023). Intake of toxic metals through dietary eggs consumption and its potential health risk assessment on the peoples of the capital city Dhaka, Bangladesh. Arabian Journal of Chemistry, 16(10), 105104.
23. Wang, M., Chen, Z., Song, W., Hong, D., Huang, L., & Li, Y. (2021). A review on cadmium exposure in the population and intervention strategies against cadmium toxicity. Bulletin of environmental contamination and toxicology, 106, 65-74.
24. Muhammad J, Xu P, Khan S, Su JQ, Sarwar T, Nazneen S, et al. Arsenic contribution of poultry manure towards soils and food plants contamination and associated cancer risk in Khyber Pakhtunkhwa, Pakistan. Environ Geochem Health. 2022;44(10):3321-42.