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Dietary Exposure Assessment of Potentially Toxic Elements in Armenian Honey

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Conflict of Interest
The authors declare no conflict of interest concerning the research, authorship, and/or publication of this article.

ABSTRACT

The study aimed to assess the contents of potentially toxic elements (Cu, Mo, Pb, As) in honey and associated health risks in Armenia. To assess dietary exposure and characterize potential health risks, the estimated daily intake (EDI) and margin of exposure (MOE) of these elements were calculated. The assessment was carried out considering honey consumption patterns among the Armenian adult population. The outcomes of the health risk assessment reveal that the EDI of the investigated elements were notably lower in comparison to the health-based guidance values. Overall, the study findings suggest that the levels of potentially toxic elements in Armenian honey are within acceptable limits, and there are no health risks to consumers. However, future research could expand to include a larger number and variety of honey samples, as well as additional elements.

Introduction

Honey remains a staple in diets worldwide, valued not only for its organoleptic properties but also for its potential health benefits, including immune support and its role as a natural alternative to refined sugars. However, with increasing environmental pressures from industrialization, urbanization and intensive agricultural practices, this seemingly pure and wholesome product may contain various chemical hazards. Among these are environmental contaminants such as potentially toxic elements (PTEs), raising concerns for food safety and public health (Godebo, et al., 2025; Fakhri, et al., 2025; Mititelu, et al., 2023).

PTEs, commonly known as heavy metals or trace elements, include both essential and non- essential elements that can accumulate in biological systems, potentially causing adverse health effects (Fakhri, et al., 2025, Morariu, et al., 2024). These elements enter the honey production chain through various pathways, primarily via environmental contamination and agricultural practices. Major sources of possible contamination include industrial emissions and agricultural practices involving pesticides, fertilizers, and herbicides containing metal impurities. Additionally, the geographic origin of honey significantly influences PTE levels, with samples from industrialize or intensively farmed regions typically showing higher concentrations than those from non-polluted areas (Godebo, et al., 2025; Ligor, et al., 2022; Pipoyan, et al., 2020, Thrasyvoulou, et al., 2018).

Recent studies have reported varying levels of PTEs

in honey originated from different countries, reflecting differences in environmental contamination, agricultural activities and regulatory control (Bartha, et al., 2020; Casula, et al., 2024; Mititelu, et al., 2023). Regulatory bodies in different countries set maximum allowable levels for elements in food, including honey, to mitigate risks (European Commission, 2023; Morariu, et al., 2024; Thrasyvoulou, et al., 2018; TR CU 021/2011). Monitoring and controlling these elements is crucial to ensure the safety of honey for human consumption. At the same time, it is important to conduct risk assessments that consider not only contamination levels but also population-specific consumption patterns and the toxicological characteristics of the elements, including relevant health-based guidance values (HBGVs).

A recent study conducted in Armenia on locally produced honey of two regions (Shirak and Syunik) highlighted the importance of monitoring trace element levels and assessing dietary exposure via honey consumption (Pipoyan, et al., 2020). Therefore, the present study aimed to assess the contents of potentially toxic elements (Cu, Mo, Pb, As) in honey and associated health risks in Armenia. Given the rising global demand for honey as a natural and healthy product, a better understanding of the occurrence and possible health risks due to PTE contamination is essential.

Materials and methods

Sampling and analysis

60 samples of Armenian multifloral honey were collected in the frame of the state residue monitoring program on honey. Preparation and further chemical analysis of honey samples was carried out at the Republican Center for Veterinary and Sanitary and Phytosanitary Laboratory Services, accredited according to ISO 17025 standard. The contents of potentially toxic elements: copper (Cu), molybdenum (Mo), lead (Pb) and arsenic (As) were determined using atomic absorption spectrometry (AAS, Thermo Fisher iCE-3500).

Dietary exposure assessment

To assess dietary exposure and characterize potential health risks, the estimated daily intake (EDI) and margin of exposure (MOE) of the potentially toxic elements were calculated. The EDI of potentially toxic elements through Armenian multifloral honey consumption was calculated using the following equation:

$$EDI = \frac{C * IR}{BW},$$

where, EDI (mg/kg/day) is the estimated daily intake of the potentially toxic element through honey consumption, C is the content (mg/kg) of the investigated element in honey, and BW is the average body weight (kg) for the Armenian adult population (Pipoyan, et al., 2023b). IR is the average daily consumption of honey (kg/day).

Honey consumption data (Figure 1) were obtained through a food frequency questionnaire (FFQ), administered via in-person, interview-based surveys designed and conducted by the Informational-Analytical Center for Risk Assessment of Food Chain at the Center for Ecological-Noosphere Studies (CENS), NAS RA. Prior to implementation, the FFQ was pre-tested in a pilot phase (n=20) to assess its reliability and respondent understanding. The survey was conducted anonymously and included 1040 participants aged 18-65, selected using a stratified random sampling approach (with a 95% confidence level and a margin of error of ±3%) to ensure proportional representation of gender and age groups within each administrative district of Yerevan, the capital city of Armenia. Since Yerevan accounts for about 30% of the national population, the study sample was considered representative of Armenian adult consumers. Further details on the FFQ methodology are described by Pipoyan et al. (Pipoyan, et al., 2023a; 2023b).

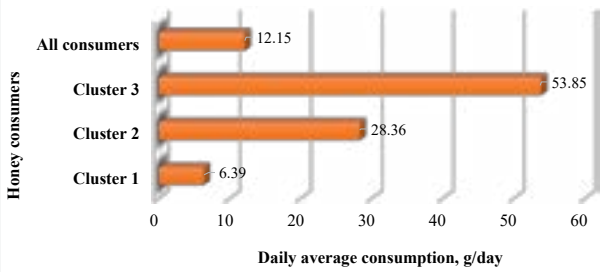


Figure 1. Daily average consumption of honey by the adult population in Armenia *(Pipoyan, et al., 2023b).*

The margin of exposure (MOE) for each detected element was calculated using the following equation:

$$MOE = \frac{HBGV}{EDI},$$

where, $HBGV$ is the health-based guidance values of each investigated potentially toxic elements. For risk

characterization, *HBGV*s set by the European Food Safety Authority were applied (EFSA, 2010; EFSA Scientific Committee, et al., 2023).

Results and discussions

Contents of potentially toxic elements in honey

Among the analyzed potentially toxic elements, molybdenum (*Mo*) was not detected (i.e., below the limit of detection of 0.008 mg/kg) in any of the investigated multifloral honey samples produced in Armenia. In contrast, copper (*Cu*) was detected in all samples, with contents ranging from 0.059 to 0.312 mg/kg, and an average content of 0.138 mg/kg (Figure 2).

Toxic element lead (Pb) was detected in 86.7% of the investigated multifloral honey samples, ranging from 0.021 to 0.046 mg/kg, with a mean content of 0.03 mg/kg (Figure 2). Importantly, all detected Pb contents were below the national (TR CU 021/2011) and EU (European Commission, 2023) maximum levels of 1 mg/kg and 0.1 mg/kg, respectively. Arsenic (As) was found in only one sample at a content of 0.025 mg/kg, which remains within the national maximum level of 0.5 mg/kg set by the Technical Regulation (TR CU 021/2011).

A comprehensive review on physicochemical properties, minerals, trace elements, and heavy metals in honey of different origins reported that chemical elements in honey samples throughout the world vary in terms of concentrations (Solayman, et al., 2016). A recent global systematic review conducted by Fakhri et al., reported pooled concentration of potentially toxic elements in honey as follows: *Cu* at 0.11 mg/kg, *Pb* at 0.0026 mg/kg and As at 0.00048 mg/kg. Notable, the higher concentrations were observed in honey from Brazil (*Cu*), Jordan (*Pb*) and Ethiopia (*As*) compared to the other countries (Fakhri, et al., 2025). Théolier et al. reported a regional pooled mean *Pb* concentration of 0.12 mg/kg in honey samples from Arab countries, based on a meta-analysis of 57 studies (Théolier, et al., 2024). Another study conducted by Mititelu et al. on heavy metals in various types of honey from different areas in Romania revealed that polyfloral (or multifloral) honey contained the highest level of *Pb* (0.52 mg/kg) compared to linden, acacia and rapeseed honey (Mititelu, et al., 2023). The mean concentrations of *Cu* in the studied polyfloral honey from three Romania areas were 0.47 mg/kg, 0.38 mg/kg and 0.46 mg/kg (Mititelu, et al., 2023).

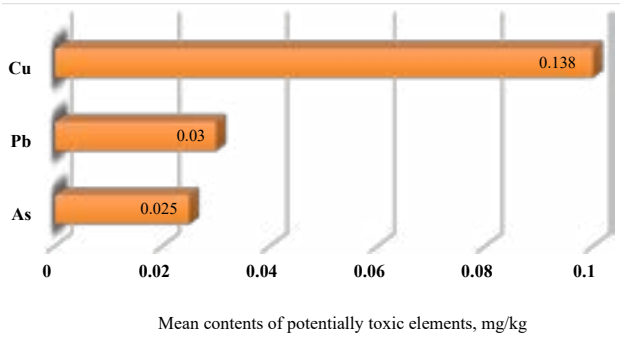


Figure 2. Mean contents of potentially toxic elements detected in Armenian multifloral honey.

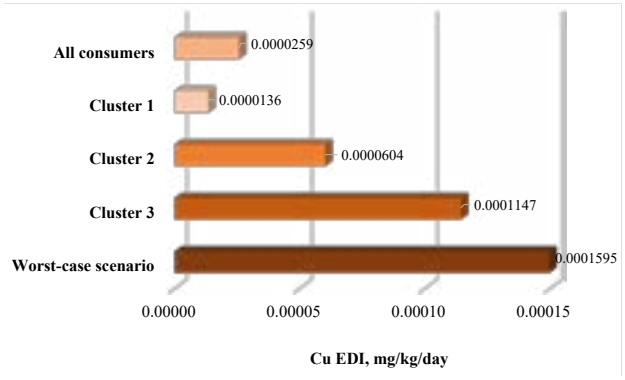
A study on toxic and essential elements in Serbian multifloral honey reported mean concentration of *As* at 0.00168 mg/kg (ranged from 0.001 to 0.0054 mg/kg), *Pb* at 0.0064 mg/kg (ranged from 0.002 to 0.0176 mg/kg), and *Cu* at 0.1939 mg/kg (ranged from 0.06535 to 0.407 mg/kg) (Spirić, et al., 2019).

A comparative study by Ligor et al. on potentially toxic elements in honey produced in Poland reported *Pb* levels below the background equivalent concentrations in all tested samples, while the mean contents of *As*, *Mo* and *Cu* were 0.00006 mg/kg, 0.00042 mg/kg and 0.136 mg/kg, respectively (Ligor, et al., 2022). It is important to note, that compared to other studied elements, *Mo* has not been as extensively investigated in honey, however, the study by Ligor et al. included Mo and detected its presence (Ligor, et al., 2022), in contrast to the finding of the present study in Armenia, where *Mo* was not detected.

Exposure assessment and risk characterization

Since copper (*Cu*) was detected in all honey samples and lead (*Pb*) in the majority of them, dietary exposure assessments were performed for these elements. The estimated daily intake (*EDI*) and margin of exposure (*MOE*) were calculated both for the overall population of honey consumers and for three clusters (Figure 1), which were defined according to consumption rates and reflect honey consumption patterns among the Armenian adult population. Moreover, a conservative worst-case scenario approach was applied, whereby the maximum detected concentration of each element in honey was assumed as its mean content. In this case, for estimating daily intake, consumption data of high consumers (i.e., Cluster 3), representing individuals with the highest honey consumption, were used. The calculated *EDI* values for *Cu* and Pb are shown in Figure 3.

a)



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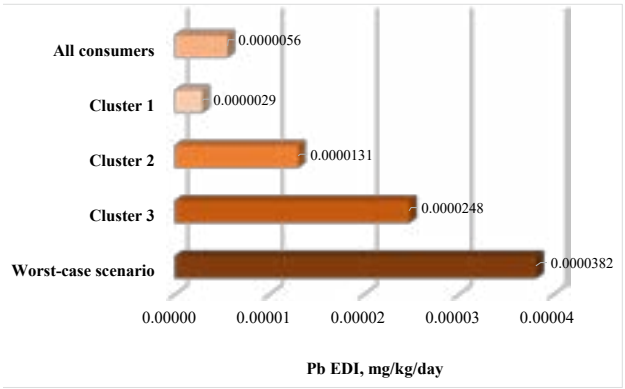
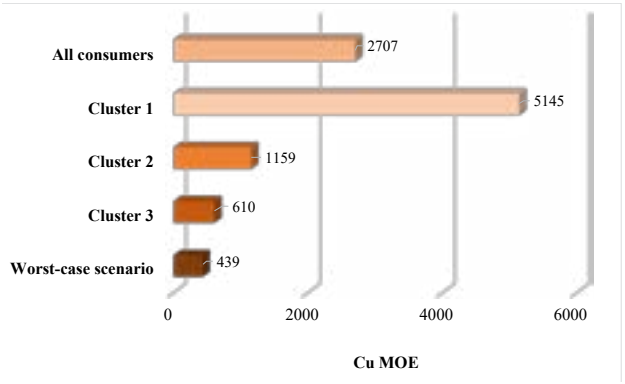


Figure 3. Estimated daily intake (*EDI*) of *Cu* (a) and *Pb* (b) through honey consumption (*composed by the authors*).

a)



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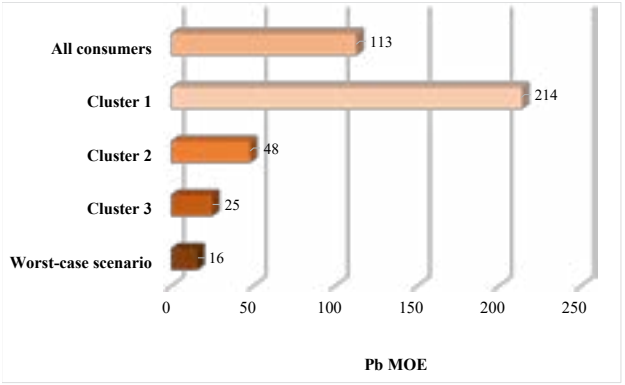

Figure 4. Margin of Exposure (*MOE*) of *Cu* (a) and *Pb* (b) through honey consumption (*composed by the authors*).

The obtained *EDI* values of *Cu* and *Pb* (Figure 3) were compared with the *HBGV*s established by *EFSA* (EFSA, 2010; EFSA Scientific Committee, et al., 2023). Specifically, *Cu EDI* values were compared with the Acceptable Daily Intake (ADI) of 0.07 mg/kg/day (EFSA Scientific Committee, et al., 2023), while *Pb EDI* values were compared with the benchmark dose level (BMDL10) of 0.00063 mg/kg/day (EFSA, 2010). In both cases, the *EDI* values from honey consumption were considerably lower than the established HBGVs.

For *Cu* and *Pb* risk characterization, the margin of exposure (*MOE*) was calculated based on the *HBGV*s (Figure 4). According to *EFSA* methodology, *MOE* values greater than 10 (*MOE>10*) indicate no risk to public health.

In the case of *Cu* and *Pb* detected in Armenian honey samples, the estimated *MOE* values (Figure 4) were significantly above 10, suggesting that the detected contents of these elements do not pose a health risk to the adult population in Armenia. Only in the worst-case scenario, which combines the highest honey consumption rate with the highest detected concentration of the element, the MOE of Pb (Figure 4, b) was the lowest and slightly above the threshold of 10, suggesting that continuous monitoring and control are essential to ensure consumer safety and minimize potential risks in the future.

Conclusion

In conclusion, this study provides important insights into the levels of potentially toxic elements (*Pb, As, Mo, Cu*) in Armenian multifloral honey and their possible risk to public health. The analytical results reveal that the levels of these elements are generally low and well below the available regulatory thresholds. The dietary exposure and associated risk assessment further showed with *EDI* values are significantly lower compared to the health-based guidance values. Furthermore, the estimated *MOE* values were above the threshold of 10, indicating no significant

public health concern associated with chronic exposure to studied elements through honey consumption. Overall, the study findings suggest that the levels of potentially toxic elements in Armenian honey are within acceptable limits, and there are no health risks to consumers.

While the current research data suggest no immediate public health concerns from dietary exposure to potentially toxic elements via honey consumption, the potential for variability due to factors such as agricultural practices and industrial activities highlights the need for continuous monitoring. Ongoing controls and compliance to best practices in honey production will be essential to safeguard the quality of Armenian honey and protect consumer health in the long term. Future research could expand to include a larger number and variety of honey samples, as well as additional elements.

References

1. Bartha, S., Taut, I., Goji, G., Vlad, I. A., Dinulică, F. (2020). Heavy metal content in polyfloralhoney and potential health risk. A case study of Copșa Mică, Romania. International Journal of Environmental Research and Public Health, 17(5), 1507.
2. Casula, M., Corrias, F., Atzei, A., Milia, M., Arru, N., Satta, A., ... & Angioni, A. (2024). Multiresidue Methods Analysis to Detect Contamination of Selected Metals in Honey and Pesticides in Honey and Pollen. Foods, 13(24), 4099.
3. EFSA (2010). Panel on Contaminants in the Food Chain (CONTAM). Scientific Opinion on Lead in Food. EFSA Journal 2010; 8(4):1570.
4. EFSA Scientific Committee, More, S. J., Bampidis, V., Benford, D., Bragard, C., Halldorsson, T. I., ... & Leblanc, J. C. (2023). Re-evaluation of the existing health-based guidance values for copper and exposure assessment from all sources. EFSA Journal, 21(1), e07728.
5. European Commission (2023). Commission Regulation (EU) 2023/915 of 25 April 2023 on maximum levels for certain contaminants in food and repealing Regulation (EC) No 1881/2006. Off. J. Eur. Union, 119, 103-157. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32023R0915. (Accessed on 08.09.2025).
6. Fakhri, Y., Esfandiari, Z., Mehri, F., Ranaei, V., Pilevar, Z. (2025). The concentration of potentially toxic elements (PTEs) in honey: Global systematic review and meta-analysis and risk assessment. International Journal of Environmental Health Research, 35(1), 37-55.
7. Godebo, T. R., Stoner, H., Taylor, P., Jeuland, M. (2025). Metals in honey from bees as a proxy for environmental contamination in the United States. Environmental Pollution, 364, 125221.
8. Ligor, M., Kowalkowski, T., Buszewski, B. (2022). Comparative study of the potentially toxic elements and essential microelements in honey depending on the geographic origin. Molecules, 27(17), 5474.
9. Mititelu, M., Udeanu, D. I., Docea, A. O., Tsatsakis, A., Calina, D., Arsene, A. L., ... & Ghica, M. (2023). New method for risk assessment in environmental health: The paradigm of heavy metals in honey. Environmental Research, 236, 115194.
10. Morariu, I. D., Avasilcai, L., Vieriu, M., Lupu, V. V., Ioniuc, I., Morariu, B. A., ... & Trandafir, L. (2024). A comprehensive narrative review on the hazards of bee honey adulteration and contamination. Journal of Food Quality, 2024(1), 3512676.
11. Pipoyan, D. A., Chirkova, V. I., Beglaryan, M. R. (2023a). Assessing Health Risks Associated with Antibiotic Residues in Armenian Honey. AgriScience and Technology, 2(82).
12. Pipoyan, D., Beglaryan, M., Chirkova, V., Mantovani, A. (2023b). Exposure assessment of nitrofuran metabolites in fish and honey produced in Armenia: A pilot investigation. Foods, 12(18), 3459 https://doi.org/10.3390/foods12183459.
13. Pipoyan, D., Stepanyan, S., Beglaryan, M., Stepanyan, S., Asmaryan, S., Hovsepyan, A., Merendino, N. (2020). Carcinogenic and non-carcinogenic risk assessment of trace elements and POPs in honey from Shirak and Syunik regions of Armenia. Chemosphere, 239, 124809 https://doi.org/10.1016/j.chemosphere.2019.124809.
14. Solayman, M., Islam, M. A., Paul, S., Ali, Y., Khalil, M. I., Alam, N., Gan, S. H. (2016). Physicochemical properties, minerals, trace elements, and heavy metals in honey of different origins: a comprehensive review. Comprehensive reviews in food science and food safety, 15(1), 219-233.
15. Spirić, D., Ćirić, J., Đorđević, V., Nikolić, D., Janković, S., Nikolić, A., ... & Teodorović, V. (2019). Toxic and essential element concentrations in different honey types. International Journal of Environmental Analytical Chemistry, 99(5), 474-485.

16. Théolier, J., Dominguez, S., & Godefroy, S. (2024). Lead exposure from honey: meta-analysis and risk assessment for the Arab region. Food Additives & Contaminants: Part A, 41(3), 271-286.

17. Thrasyvoulou, A., Tananaki, C., Goras, G., Karazafiris, E., Dimou, M., Liolios, V., ... & Gounari, S. (2018). Legislation of honey criteria and standards. Journal of Apicultural Research, 57(1), 88-96.

18. TR CU 021/2011. Technical Regulation of the Customs Union Concerning Safety of Food Products. https://www.rustandard.com/images/CU_TR/TR_CU_021.2011_Safety_of_Food_Products.pdf. (Accessed on 08.03.2025).

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