JEE Journal of Ecological Engineering

Journal of Ecological Engineering, 2027, 28(1), 529–535
https://doi.org/10.12911/22998993/242496
ISSN 2299–8993, License CC-BY 4.0

Received: 2026.10.26
Accepted: 2026.11.16
Published: 2026.12.01

Preliminary profiling of selected essential elements in *Salvia officinalis* and *Origanum vulgare* from Albania

Arvjola Hodaj[1*], Erjola Bej[1], Julian Shehu[2], Alma Shehu[3]

[1] Department of Chemical-Toxicological and Pharmacological Evaluation of Drugs, Faculty of Pharmacy, Catholic University "Our Lady of Good Counsel", Tirana, Albania
[2] Research Center of Flora and Fauna, Faculty of Natural Sciences, University of Tirana, Albania
[3] Department of Chemistry, Faculty of Natural Sciences, University of Tirana, Albania
* Corresponding author's e-mail: a.hodaj@unizkm.al

ABSTRACT

This study provides preliminary data on manganese (Mn), iron (Fe), zinc (Zn), and cobalt (Co) in 12 Albanian *Salvia officinalis* and *Origanum vulgare* samples, six per species. Concentrations were determined by graphite furnace atomic absorption spectrometry after duplicate hot-plate acid digestion and evaluated descriptively. Mean Mn, Fe, Zn, and Co concentrations were 24.05, 132.64, 4.52, and 0.28 mg/kg dry weight in *S. officinalis* and 20.95, 163.37, 6.40, and 0.36 mg/kg in *O. vulgare*, respectively. Fe predominated and showed the greatest absolute variation, while Co occurred at the lowest concentrations. Relative standard deviations between duplicate digestions ranged from 0.02% to 4.70%, supporting analytical consistency. These baseline data complement previously published measurements of other elements in the same samples. The patterns remain descriptive; larger, replicated studies with paired soil–plant analyses are needed to assess species-related and geographical variation.

Keywords: *Salvia officinalis*; *Origanum vulgare*; essential elements; GF-AAS; medicinal plants; Albania.

INTRODUCTION

Medicinal plants contain bioactive compounds that contribute to their nutritional characteristics (Novais et al., 2021). Mineral elements are also components of medicinal plant materials and contribute to their elemental profiles (Karahan, 2023). Among these elements, manganese (Mn), iron (Fe), zinc (Zn), and cobalt (Co) participate in numerous physiological and metabolic processes (Jomova et al., 2022; Zoroddu et al., 2019). Their concentrations in plant tissues may vary among plant species (Lavrinenko et al., 2024). Soil properties, environmental conditions, harvesting practices, and post-harvest processing may also influence these concentrations (Antoniadis et al., 2019; Kabata-Pendias, 2010). Elemental profiling can therefore provide complementary information for the characterization of medicinal plant materials, although it cannot independently establish their pharmaceutical quality, safety, or standardization. Previous investigations have examined differences in elemental composition among medicinal plants belonging to different botanical families (Arceusz et al., 2010). Studies of medicinal herbs and their infusions have also shown that elemental concentrations in plant material must be distinguished from those transferred into aqueous preparations (Başgel & Erdemoğlu, 2006; Pytlakowska et al., 2012). The determination of mineral elements alongside potentially toxic elements in commercial herbal products further highlights the importance of considering both composition and the form in which these products are consumed (Martín-Domingo et al., 2017).

Salvia officinalis L. and *Origanum vulgare* L. are medicinal and aromatic plants widely used in traditional medicine and in food, herbal, and nutraceutical preparations. Their biological properties have been mainly associated with phenolic compounds, flavonoids, terpenes, and essential oils (Ghorbani & Esmaeilizadeh, 2017; Soltani et al.,

2021). Compared with their phytochemical composition, information on the essential element profiles of these species in Albania remains limited.

Albania is characterized by diverse geological, topographic, climatic, and soil conditions (Zdruli & Lushaj, 2001). These conditions may influence the availability and uptake of elements by plants (Antoniadis et al., 2019; Kabata-Pendias, 2010). Nevertheless, reliable interpretation of geographical variability requires corresponding soil physicochemical and elemental measurements. Because such measurements were not included in the present study, the differences observed among sampling locations are considered descriptive and cannot be directly attributed to geographical or environmental factors.

Research on the elemental composition of medicinal plants has frequently focused on potentially toxic elements because of their implications for product safety and human exposure (Antoniadis et al., 2019; Karahan, 2023). Potentially toxic and trace elements in the same set of Albanian *S. officinalis* and *O. vulgare* samples were evaluated separately and reported in a previous publication (Hodaj et al., 2026). To avoid duplication of previously published results, the present study focuses exclusively on the essential elements Mn, Fe, Zn, and Co.

The objective of this preliminary study was to determine the concentrations of Mn, Fe, Zn, and Co in six *S. officinalis* and six *O. vulgare* samples collected from selected regions of Albania. The results are presented descriptively to provide baseline information on the elemental composition of these medicinal plants and to support the design of future studies involving larger and replicated sample sets, paired soil–plant analyses, and more comprehensive analytical validation.

MATERIALS AND METHODS

Sample collection and preparation

A total of 12 independent samples of wild-growing medicinal plants were included in the study, comprising six samples of *Salvia officinalis* L. and six samples of *Origanum vulgare* L. The *S. officinalis* samples were collected from Korçë, Berat, Tepelenë, Kukës, Pogradec, and Përmet, whereas the *O. vulgare* samples were collected from Berat, Pogradec, Korçë, Kukës, Ballsh, and Elbasan. Each sample represented independently collected plant material from one sampling location. The plants were collected during June-July 2025. For both species, the aerial parts were harvested by cutting the stems approximately 10-15 cm above ground level. The collected material was placed in clean polyethylene bags, appropriately labelled, and transported to the laboratory for further processing.

In the laboratory, the plant material was gently rinsed with deionized water to remove adhering dust and surface impurities. The samples were subsequently dried in a ventilated laboratory oven at 55 °C until constant weight was achieved. The dried plant material was ground into a fine homogeneous powder using a laboratory mill and stored in clean polyethylene containers at room temperature until analysis.

Acid digestion procedure

A conventional hot-plate acid digestion procedure employing an HNO_3-H_2O_2 reagent system adapted from EPA Method 3052 was used (U.S. Environmental Protection Agency, 1996). Because EPA Method 3052 specifies microwave-assisted digestion, the procedure employed in the present study should not be considered a complete implementation of that method.

Approximately 0.5–1.0 g of dried and homogenized plant material was accurately weighed into PTFE digestion vessels. Each test portion was treated with 8 mL of concentrated nitric acid (HNO_3, 65%) and 2 mL of hydrogen peroxide (H_2O_2, 30%) and left to predigest at room temperature for 24 h. The samples were then heated on a hot plate at approximately 150 °C until clear solutions were obtained.

After cooling, the digests were quantitatively transferred into 50 mL volumetric flasks and diluted to volume with deionized water. The resulting solutions were filtered through 0.20 µm membrane filters and stored at 4 °C until instrumental analysis. Each plant sample was digested independently in duplicate under identical experimental conditions. Sample handling and preparation followed general recommendations for medicinal plant materials (World Health Organization, 2011).

Elemental analysis

The concentrations of Mn, Fe, Zn, and Co were determined by graphite furnace atomic absorption spectrometry (GF-AAS) using an

Analytik Jena 800 G atomic absorption spectrometer. The analytical wavelengths were 279.5 nm for Mn, 248.3 nm for Fe, 213.9 nm for Zn, and 240.7 nm for Co. A spectral slit width of 0.2 nm was used for all four elements.

External calibration curves were constructed separately for each element using certified single-element standard solutions (Skoog et al., 2017; Welz & Sperling, 1998). The calibration ranges were 1–10 µg/L for Mn, 5–100 µg/L for Fe, 1–30 µg/L for Zn, and 0.2–0.6 µg/L for Co. The coefficients of determination (R^2) ranged from 0.9994 to 0.9997. The reported limits of detection (LODs), expressed on a dry-weight basis, ranged from 0.001 to 0.050 mg/kg.

Procedural blanks containing all reagents but no plant material were subjected to the complete digestion and analytical procedure. Blank results were below the corresponding LODs. Agreement between the two independently weighed and digested portions of each plant sample was evaluated using the relative standard deviation (RSD). Individual RSD values ranged from 0.02% to 4.70%, with an overall mean of 1.97%. These duplicate digestions represented analytical replicates rather than additional independent plant samples. Elemental concentrations were expressed as mg/kg dry weight. For each independent plant sample, the mean concentration obtained from the two separate digestions was used to calculate the descriptive statistics and construct Figure 1. Thus, the statistical summaries were based on six independent sample-level values per species.

RESULTS

Descriptive elemental profiles

Descriptive statistics for Mn, Fe, Zn, and Co concentrations in *Salvia officinalis* and *Origanum vulgare* are presented in Tables 1 and 2. Given the limited number of independent samples, the results are summarized using the mean, median, standard deviation, minimum, and maximum, and are interpreted descriptively. Iron was the predominant element in *S. officinalis*, with a mean concentration of 132.64 mg/kg DW and values ranging from 83.27 to 172.41 mg/kg DW. Manganese was the second most abundant element, with a mean concentration of 24.05 mg/kg DW, followed by Zn at 4.52 mg/kg DW. Cobalt occurred at the lowest concentrations, with a mean of 0.28 mg/kg DW. The widest absolute variation was observed for Fe.

Iron was also the predominant element in *O. vulgare*, with a mean concentration of 163.37 mg/kg DW and values ranging from 78.25 to 338.31 mg/kg DW. The comparatively high Fe concentration detected in one sample contributed to the large standard deviation observed for this element. The mean concentrations of Mn, Zn, and Co were 20.95, 6.40, and 0.36 mg/kg DW, respectively. The descriptive comparison indicated higher mean concentrations of Fe, Zn, and Co in *O. vulgare*, whereas the mean Mn concentration was slightly higher in *S. officinalis*. These observations represent descriptive patterns and were not evaluated as inferential differences between the two species.

Table 1. Descriptive statistics for selected essential elements in *Salvia officinalis* (mg/kg DW; n = 6)

Specification	Mn	Co	Fe	Zn
Mean	24.05	0.28	132.64	4.52
Median	24.17	0.21	137.07	4.75
Standard deviation	7.27	0.17	42.00	2.08
Minimum	14.77	0.14	83.27	0.85
Maximum	35.45	0.56	172.41	6.63

Table 2. Descriptive statistics for selected essential elements in *Origanum vulgare* (mg/kg DW; n = 6)

Specification	Mn	Co	Fe	Zn
Mean	20.95	0.36	163.37	6.40
Median	19.36	0.38	135.57	6.78
Standard deviation	7.31	0.10	98.39	2.81
Minimum	13.48	0.22	78.25	3.29
Maximum	31.88	0.46	338.31	9.20

Agreement between duplicate digestions

The agreement between the two independently weighed and digested test portions of each plant sample was evaluated using the relative standard deviation. The species-specific RSD ranges and mean RSD values are presented in Table 3.

Individual RSD values ranged from 0.02% to 4.70%, with an overall mean of 1.97%. The low variability observed between duplicate digestions indicated consistent analytical results under the conditions applied.

Descriptive comparison between species

The mean concentrations of the four investigated elements in the two species are presented in Figure 1. Because of the markedly different concentration ranges, Fe and Mn are displayed separately from Zn and Co.

Iron occurred at the highest mean concentration in both species and exhibited the greatest absolute variation among samples (Figure 1a). This variation was particularly pronounced in *O. vulgare*, where one sample had a comparatively high Fe concentration of 338.31 mg/kg dry weight, contributing to the higher mean and larger standard deviation. The overlap between the individual Fe concentrations of the two species shows that the difference in their means was accompanied by substantial within-species variation. Mn concentrations were much lower than Fe concentrations and showed a slightly higher mean in *S. officinalis*, with considerable overlap between species.

For Zn, *O. vulgare* showed a higher mean concentration and a wider absolute range than *S. officinalis* (Figure 1b), although individual values also overlapped. Co occurred at the lowest concentrations in both species, with a slightly higher mean in *O. vulgare*. Its relatively narrow absolute concentration range caused several individual points to overlap at the scale used. Overall, the figure shows differences in mean concentrations alongside variation among individual samples, supporting a descriptive interpretation of the elemental profiles.

DISCUSSION

This preliminary study describes the concentrations of Mn, Fe, Zn, and Co in *Salvia officinalis* and *Origanum vulgare* collected from selected locations in Albania. Fe was the most abundant of the four elements analyzed in both species, followed by Mn and Zn, while Co occurred at the lowest concentrations. *O. vulgare* showed higher mean concentrations of Fe, Zn, and Co, whereas *S. officinalis* showed a slightly higher mean Mn concentration. These differences describe the samples investigated and should not be interpreted as statistically established differences between species.

Fe showed the greatest absolute variability, particularly in *O. vulgare*, where concentrations ranged from 78.25 to 338.31 mg/kg dry weight. The comparatively high concentration in one sample contributed to the higher mean and standard deviation for this species. This finding highlights the importance of considering individual sample values alongside summary statistics. Elemental concentrations may be influenced by plant characteristics, soil properties, and environmental conditions (Antoniadis et al., 2019; Kabata-Pendias, 2010). However, the absence of corresponding soil data and independent replication within sampling locations prevents identification of the factors responsible for the observed variation.

The results can be considered in the context of previous studies on the elemental composition of medicinal and aromatic plants (Kostić et al., 2011; Özcan, 2004). Further investigations have contributed additional data on the elemental profiles of these plant materials (Juranović Cindrić et

Table 3. Agreement between duplicate digestions for Mn, Fe, Zn, and Co determination in *Salvia officinalis* and *Origanum vulgare*

Element	*S. officinalis* RSD range (%)	*S. officinalis* Mean RSD (%)	*O. vulgare* RSD range (%)	*O. vulgare* Mean RSD (%)
Mn	0.76–4.03	2.21	0.22–4.48	2.19
Fe	0.22–4.70	2.07	0.97–3.38	2.42
Zn	1.00–3.85	2.49	0.26–1.33	0.75
Co	0.36–3.71	1.84	0.02–2.98	1.77

Note: n = 6 independent plant samples per species; each sample was analyzed using two independently weighed and digested test portions.

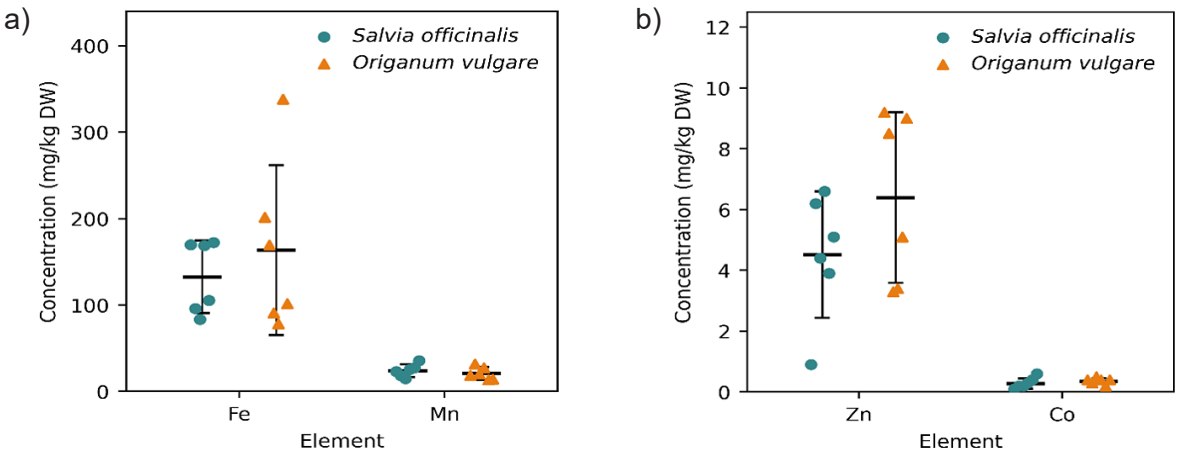

Figure 1. Distribution of Mn, Fe, Zn, and Co concentrations in *Salvia officinalis* and *Origanum vulgare*. Individual points represent independent plant samples (n = 6 per species), with each value corresponding to the mean of two separate digestions, horizontal lines indicate the means, and error bars represent the standard deviations. (a) Fe and Mn; (b) Zn and Co. Concentrations are expressed as mg/kg dry weight

al., 2013; Lavrinenko et al., 2024). More recent work provides additional context for comparison (Tinkov et al., 2025). Comparisons between studies nevertheless require caution because the analyzed plant parts, sampling conditions, digestion procedures, and analytical techniques may differ. The present dataset adds preliminary information on Albanian *S. officinalis* and *O. vulgare*, but it does not establish characteristic concentration ranges for either species at a national level.

Individual RSD values between duplicate digestions ranged from 0.02% to 4.70%, with an overall mean of 1.97%. This indicates low variability between independently prepared portions under the analytical conditions applied. Such agreement supports the consistency of sample preparation and measurement. Potentially toxic and other trace elements in the same sample set were reported separately (Hodaj et al., 2026). The present study complements that publication by focusing on Mn, Fe, Zn, and Co. These measurements provide compositional information but do not directly establish the nutritional contribution, pharmaceutical quality, or safety of the plants.

The small sample size, single collection period, and absence of paired soil–plant measurements limit the generalization of the findings. Nevertheless, the results provide a preliminary basis for further investigation. Future studies should include multiple independent samples from each location, repeated collection periods, paired soil–plant analyses, and comprehensive analytical validation to assess species-related patterns and environmental influences more reliably.

A similar study reported Mn and Zn concentrations of 24.05 and 63.16 mg/kg, respectively, in dried *Salvia officinalis* leaves cultivated in Turkey (Yaman, 2021). The mean Mn concentration in the present study (24.05 mg/kg dry weight) was numerically similar, whereas the mean Zn concentration (4.52 mg/kg dry weight) was lower. A study of cultivated *Salvia officinalis* from Jordan reported Fe, Mn, and Zn concentrations ranging from 524.67 to 935.40, 44.63 to 51.35, and 95.81 to 125.71 mg/kg, respectively (Abu-Darwish et al., 2011). The corresponding mean concentrations in the Albanian samples—132.64, 24.05, and 4.52 mg/kg dry weight—were below these reported ranges. These comparisons are descriptive and should account for differences in cultivation status, plant parts, harvesting stage, sample preparation, and analytical procedures.

CONCLUSIONS

This preliminary study provides baseline data on Mn, Fe, Zn, and Co concentrations in six *Salvia officinalis* and six *Origanum vulgare* samples collected from selected locations in Albania. Fe was the most abundant of the four elements analyzed in both species, while Co occurred at the lowest concentrations. *O. vulgare* showed higher mean concentrations of Fe, Zn, and Co, whereas *S. officinalis* showed a slightly higher mean Mn concentration. These observations describe the

samples investigated and do not establish statistically confirmed differences between species.

Low variability between duplicate digestions indicated consistent analytical results under the conditions applied. The small sample size, single collection period, and absence of paired soil data limit broader geographical interpretations. The findings should therefore be regarded as preliminary compositional data and cannot independently establish the nutritional contribution, pharmaceutical quality, or safety of these plants.

Funding

This research was financially supported by the Catholic University "Our Lady of Good Counsel" (UNIZKM), Tirana, Albania.

REFERENCES

1. Abu-Darwish, M. S., Al-Fraihat, A. H., Al-Dalain, S. Y. A., Afifi, F. U., & Al-Tabbal, J. A. (2011). Determination of essential oils and heavy metals accumulation in *Salvia officinalis* cultivated in three intra-raw spacing in Ash-Shoubak, Jordan. *International Journal of Agriculture and Biology, 13*(6), 981–985. https://api.fspublishers.org/viewPaper/75663_..pdf
2. Antoniadis, V., Shaheen, S. M., Levizou, E., Shahid, M., Niazi, N. K., Vithanage, M., Ok, Y. S., Bolan, N., & Rinklebe, J. (2019). A critical prospective analysis of the potential toxicity of trace element regulation limits in soils worldwide: Are they protective concerning health risk assessment? – A review. *Environment International, 127*, 819–847. https://doi.org/10.1016/j.envint.2019.03.039
3. Arceusz, A., Radecka, I., & Wesołowski, M. (2010). Identification of diversity in elements content in medicinal plants belonging to different plant families. *Food Chemistry, 120*(1), 52–58. https://doi.org/10.1016/j.foodchem.2009.09.068
4. Başgel, S., & Erdemoğlu, S. B. (2006). Determination of mineral and trace elements in some medicinal herbs and their infusions consumed in Turkey. *Science of the Total Environment, 359*(1–3), 82–89. https://doi.org/10.1016/j.scitotenv.2005.04.016
5. Ghorbani, A., & Esmaeilizadeh, M. (2017). Pharmacological properties of *Salvia officinalis* and its components. *Journal of Traditional and Complementary Medicine, 7*(4), 433–440. https://doi.org/10.1016/j.jtcme.2016.12.014
6. Hodaj, A., Domi, E., Puleri, G., Bej, E., Cascella, R., Hoxha, M., Shehu, J., & Shehu, A. (2026). Heavy metals contamination in Albanian *Origanum vulgare* L. and *Salvia officinalis* L. *Journal of Ecological Engineering, 27*(8), 303–318. https://doi.org/10.12911/22998993/220325
7. Jomova, K., Makova, M., Alomar, S. Y., Alwasel, S. H., Nepovimova, E., Kuca, K., Rhodes, C. J., & Valko, M. (2022). Essential metals in health and disease. *Chemico-Biological Interactions, 367*, 110173. https://doi.org/10.1016/j.cbi.2022.110173
8. Juranović Cindrić, I., Zeiner, M., Glamuzina, E., & Stingeder, G. (2013). Elemental characterisation of the medical herbs *Salvia officinalis* L. and *Teucrium montanum* L. grown in Croatia. *Microchemical Journal, 107*, 185–189. https://doi.org/10.1016/j.microc.2012.06.013
9. Kabata-Pendias, A. (2010). *Trace elements in soils and plants* (4th ed.). CRC Press. https://doi.org/10.1201/b10158
10. Karahan, F. (2023). Evaluation of trace element and heavy metal levels of some ethnobotanically important medicinal plants used as remedies in Southern Turkey in terms of human health risk. *Biological Trace Element Research, 201*(1), 493–513. https://doi.org/10.1007/s12011-022-03299-z
11. Kostić, D., Mitić, S., Zarubica, A., Mitić, M., Veličković, J., & Ranđelović, S. (2011). Content of trace metals in medicinal plants and their extracts. *Hemijska Industrija, 65*(2), 165–170. https://doi.org/10.2298/HEMIND101005075K
12. Lavrinenko, Y., Plieva, A., Chaligava, O., Grozdov, D., Frontasyeva, M., Tkachenko, K., & Zinicovscaia, I. (2024). Elemental analysis of five medicinal plants species growing in North Ossetia using neutron activation analysis. *Agronomy, 14*(6), 1269. https://doi.org/10.3390/agronomy14061269
13. Martín-Domingo, M. C., Pla, A., Hernández, A. F., Olmedo, P., Navas-Acien, A., Lozano-Paniagua, D., & Gil, F. (2017). Determination of metalloid, metallic and mineral elements in herbal teas. Risk assessment for the consumers. *Journal of Food Composition and Analysis, 60*, 81–89. https://doi.org/10.1016/j.jfca.2017.03.009
14. Novais, C., Pereira, C., Molina, A. K., Liberal, Â., Dias, M. I., Añibarro-Ortega, M., Alves, M. J., Calhelha, R. C., Ferreira, I. C. F. R., & Barros, L. (2021). Bioactive and nutritional potential of medicinal and aromatic plant (MAP) seasoning mixtures. *Molecules, 26*(6), 1587. https://doi.org/10.3390/molecules26061587
15. Özcan, M. (2004). Mineral contents of some plants used as condiments in Turkey. *Food Chemistry, 84*(3), 437–440. https://doi.org/10.1016/S0308-8146(03)00263-2
16. Pytlakowska, K., Kita, A., Janoska, P., Połowniak, M., & Kozik, V. (2012). Multi-element analysis of

mineral and trace elements in medicinal herbs and their infusions. *Food Chemistry, 135*(2), 494–501. https://doi.org/10.1016/j.foodchem.2012.05.002

17. Skoog, D. A., Holler, F. J., & Crouch, S. R. (2017). *Principles of instrumental analysis* (7th ed.). Cengage Learning.
18. Soltani, S., Shakeri, A., Iranshahi, M., & Boozari, M. (2021). A review of the phytochemistry and antimicrobial properties of *Origanum vulgare* L. and subspecies. *Iranian Journal of Pharmaceutical Research, 20*(2), 268–285. https://doi.org/10.22037/ijpr.2020.113874.14539
19. Tinkov, A. A., Korobeinikova, T. V., Baranova, O. V., Chang, J.-S., Chao, J. C.-J., Rylina, E. V., Prakash, N. T., Nemereshina, O. N., & Skalny, A. V. (2025). Trace element and mineral content in medicinal plants collected in the Altai Mountains foothills. *Biological Trace Element Research, 203*(12), 5999–6017. https://doi.org/10.1007/s12011-025-04620-2
20. U.S. Environmental Protection Agency. (1996). Method 3052: Microwave assisted acid digestion of siliceous and organically based matrices (Revision 0). In Test methods for evaluating solid waste, physical/chemical methods (SW-846).
21. Welz, B., & Sperling, M. (1998). *Atomic absorption spectrometry* (3rd ed.). Wiley-VCH. https://doi.org/10.1002/9783527611690
22. World Health Organization. (2011). *Quality control methods for herbal materials*.
23. Yaman, C. (2021). Effect of sample amount and application time on mineral content in herbal teas of sage (*Salvia officinalis* L.) (in Turkish). *Turkish Journal of Agricultural and Natural Sciences, 8*(2), 336–343. https://doi.org/10.30910/turkjans.828906
24. Zdruli, P., & Lushaj, S. (2001). The status of soil survey in Albania and some of its major environmental findings. In: P. Zdruli, P. Steduto, C. Lacirignola, & L. Montanarella (Eds.), *Soil resources of Southern and Eastern Mediterranean countries* (Options Méditerranéennes, Série B, No. 34, pp. 69–89). CIHEAM. https://om.ciheam.org/om/pdf/b34/01002086.pdf
25. Zoroddu, M. A., Aaseth, J., Crisponi, G., Medici, S., Peana, M., & Nurchi, V. M. (2019). The essential metals for humans: A brief overview. *Journal of Inorganic Biochemistry, 195*, 120–129. https://doi.org/10.1016/j.jinorgbio.2019.03.013