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GEOME 2
Manuscript received: July 7, 2025
Accepted: October 13, 2025

Geologica Macedonica, Vol. **39**, No. 2, pp. 127–138 (2025)
On print ISSN 0352 – 1206
On line ISSN 1857 – 8586
UDC: [549.25:582.32]:[502.175:622.34](497.115)
https://doi.org/10.46763/GEOL2539127l
Original scientific paper

ASSESSMENT OF HEAVY METAL ACCUMULATION IN MOSS SPECIES AS BIOMONITORS OF ATMOSPHERIC POLLUTION IN THE GOLESH Fe–Ni MINING AREA, REPUBLIC OF KOSOVO

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A b s t r a c t: The study aimed to assess the level of air pollution by heavy metals in the area around Golesh, near the iron–nickel (Fe–Ni) mines, using mosses as biomonitors (*Homalothecium lutescens* (Hedw.) Robins. At 20 selected sampling sites in this area, concentrations of 17 chemical elements were analyzed using the inductively coupled plasma with mass spectrometry (ICP–MS). This study assessed the elemental content, distribution, and level of heavy metal pollution in moss samples, serving as bioindicators in a potentially contaminated area. Statistical analysis revealed wide variations in metal concentrations, with elements such as Al, Fe, and Mg showing the highest average values. The Contamination Factor (CF) revealed extremely high levels of pollution for Cr, Cd, Co, Pb, and Ni, indicating a significant anthropogenic impact. Factor Analysis and Cluster Analyses confirmed the co–occurrence of toxic elements (As, Pb, Ni, Cd) likely originating from industrial and mining activities. The Pollution Load Index (PLI) also highlighted the overall high contamination status of the area. These findings confirm the presence of local pollution sources and reinforce the usefulness of mosses as biomonitors in environmental assessment.

Key words: mosses; heavy metal; mining Fe–Ni; ICP–MS

INTRODUCTION

Air pollution is one of the most worrying issues for human health and the environment on a global scale (Morera–Gómez et al., 2020; Ofremu et al., 2024). In developing countries, where advanced technologies for filtering and reducing emissions are lacking, the situation is even more alarming and dangerous (Pikula et al., 2021; Webb et al., 1992; Zhu et al., 2018). Undoubtedly, the study of atmospheric pollution has emerged as a critical and rapidly advancing domain within contemporary environmental science (Boev et al., 2022; Sopaj et al., 2021). Polluted air contains solid particles and hazardous gases, which are primarily released by industrial activities, road traffic, the burning of fossil fuels, agriculture, and natural processes such as rock erosion, as well as mining (Chen et al., 2023; Kapusta & Sobczyk, 2015; Pi et al., 2018).

A significant group of chemical pollutants is heavy metals, poses toxicity (Serafimovski et al., 2020), which possess high toxic potential and have a direct impact on living organisms (Bačeva et al., 2014; Bajraktari et al., 2019). Heavy metals are among the most problematic pollutants due to their ability to bioaccumulate in living organisms, causing irreversible biological damage. Some of them, such as nickel (Ni), chromium (Cr), copper (Cu), and zinc (Zn), can be particularly dangerous to human health when exposure is high (Paçarizi et al., 2021, 2024). Heavy metals represent only a subset of the many harmful compounds present in the atmosphere.

Heavy metals are stable in the environment and do not degrade easily, accumulating in soil, water, and the atmosphere (Dreshaj Lecaj et al., 2024). Increasingly, global studies have shown that mosses can monitor air pollution (Barandovski et al., 2020; Chaudhuri & Roy, 2023). Mosses are recognized as effective indicators of atmospheric pollution, with sources that can be transboundary (Chaudhuri & Roy, 2023; Oishi, 2021). Numerous studies have shown that different species of terestrial mosses are used as bioindicators of atmospheric metal deposition (Balabanova et al., 2014). These days, most European countries include moss biomonitoring in their pollution monitoring programs, since it provides an indicator of anthropogenic impact in urban areas, due to vehicular traffic and mining (Kastrati et al., 2021; Paçarizi et al., 2023).

In Kosovo, heavy metal pollution is a serious problem, especially in industrial areas and those near pollution sources, such as the metallurgical Ferronikeli (Gashi et al., 2016). Although there are several studies in Kosovo related to heavy metal pollution in potentially toxic elements such as soil and water, data on atmospheric pollution remain fragmented and sensitive. The findings of this study revealed high to excessive levels of heavy metal pollution, including Cd, Cr, Cu, Fe, Hg, Ni, Mn, Pb, and Zn, highlighting the major impact of anthropogenic sources on air quality in Kosovo (Maxhuni et al., 2016).

To monitor air pollution by heavy metals, a widely used method is biomonitoring with mosses (*Homalothecium lutescens*) (Chaudhuri & Roy, 2023). Mosses are non–vascular plants that absorb nutrients mainly from the air through their surface, making them particularly sensitive to atmospheric pollutants (Barukial and Hazarika, 2023). This characteristic makes mosses an effective tool for monitoring air pollution, as they act as accumulators of pollutants, reflecting the pollution present in the air environment over a long period of time (Balabanova et al., 2014). The use of mosses as bioindicators is widely accepted in Europe and has been applied in numerous studies for the assessment of air pollution by heavy metals in different countries (Balabanova et al., 2010).

In this study, 20 sampling points were taken including the Golesh area near the Ferronickel mine, the aim is to assess the level of air pollution in this area using mosses as bioindicators for heavy metals. In addition to identifying pollution levels, this study also aims to analyze the main sources of pollution through statistical methods such as factor analysis and principal component analysis. Also, a comparison will be made with data from regions unaffected by industrial pollution, such as Norway, to better understand the impact of anthropogenic pollution in Kosovo. The findings from this research will contribute to a better understanding of heavy metal deposition patterns and inform strategies for improving air quality in Kosovo.

MATERIALS AND METHODS

The Golesh magnesite mine is located near the village of Magura, in the municipality of Lipjan, about 3 km west of Prishtina International Airport (Çadraku, 2022). The area is located in the Golesh mountain massif, with a maximum altitude of 1019 m. The massif has a maximum length of 7 km and a width of 4.5 km and is formed by the surrounding villages: in the west the village of Sankovc, in the northeast the village of Harilaq, and in the southeast the village of Magura.

The Golesh magnesite deposit lies within the Golesh ultramafic massif, with an estimated area of about 15 km². The regional geology consists mainly of various types of peridotite, as well as remnants of erosional crust over peridotite with limited distribution. In the south of the deposit, peridotites are in contact with the diabase–chert formation, while in the eastern parts of the terrain, isolated Tertiary formations are observed. The dominant lithology consists of harzburgites and serpentinites.

The area belongs to the continental climate, with hot summers and cold winters, typical for this part of the region. The average annual temperature varies from 7.2°C to 12.8°C. The hottest months are July, ranging from 24.3°C to 37.4°C, and August, 21.4°C to 37.1°C, according to the relevant hydrometeorological points (IHHK, 2022).

In terms of air circulation, the dominant wind direction is from the northeast (NE), while less present from the north (N). The average annual rainfall is 597.6 mm, with a maximum in August (34.9 mm) and a minimum in February (4.0 mm).

Initially, the magnesite mine in Golesh operated as an open pit, later switching to an underground mine. According to Çadraku (2022), the mine was closed in 2002 and is currently in an unusable state. Its strategic location southwest of Prishtina (about 26 km away) and its geological composition make this area of particular interest for geochemical and environmental studies.

The climatic conditions of the area favor the dispersion of fine dust particles generated by mining activities and flotation tailings, contributing to envi–ronmental pollution. For this purpose, a sampling network has been designed, illustrated in Figure 1, where all the locations of the moss samples are marked.

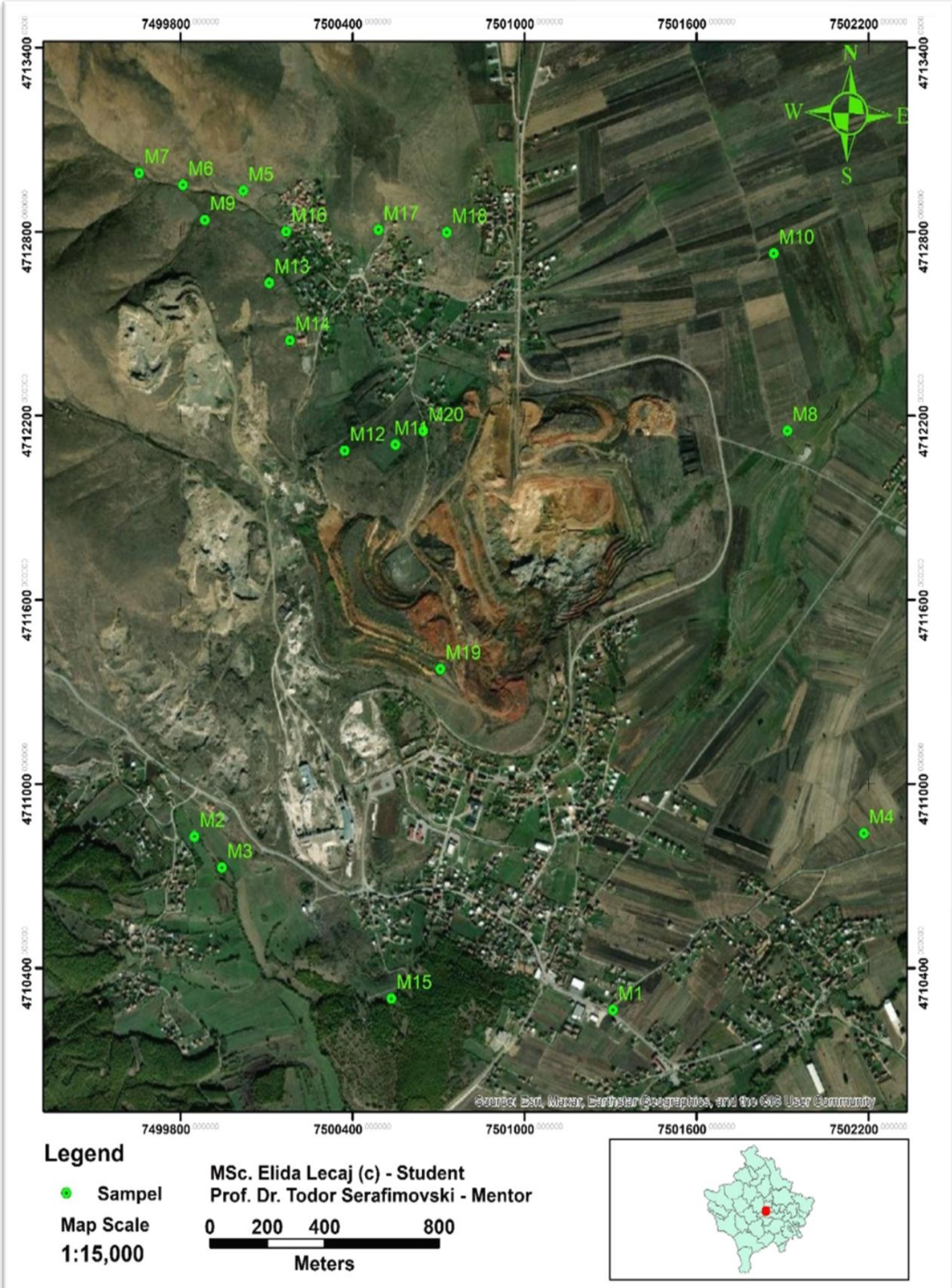

Fig. 1. Sampling network map of mosses

Species used in the study

One of the bryophyte species widely recognized as a bioindicator of heavy metal pollution is *Homalothecium lutescens* (family Brachytheci–aceae), which is common in temperate regions of Europe. This moss accumulates metals such as Pb, Cd, Zn, and Cu directly from the atmosphere, dust, and soil, making it an effective biomonitor (Quyet et al., 2021). Morphologically, it forms pale to yellow-green mats, with prostrate or ascending stems attached to substrates like grasslands, rocks, or soil. Its branches are relatively thick (1–2 mm), often curved when dry, while the lanceolate leaves measure 2.5 – 3 mm and taper to a fine point. The ability of *H. lutescens* to absorb pollutants through its leaves, rather than roots, highlights its sensitivity to environmental contamination and its value in long–term monitoring programs (Harmens, 2009).

Sampling of Homalothecium lutescens

Homalothecium lutescens samples were collected and identified from grass in the Golesh region of the state of Kosovo, where a collection from August to October 2024, all samples were collected from the ground. Samples were taken based on the identification of the species in different regions. They were taken using a plastic spatula and placing the moss samples in paper bags for transfer to the laboratory where a sample of about 300 grams of moss was taken. The sampling protocol has been adopted according to the European guidlines for moss sampling (Harmens, 2009).

Sample preparation protocol

The moss samples were subjected to physical pretreatment and homogenized which were stored for 5–7 days at ambient temperature (20 – 25 °C) before cleaning, to ensure uniform processing after drying the samples at ambient temperature, they were sent for analysis. Sample digestion was performed following the methodology described in EPA Method 3052 (Remeteiová et al., 2020).

Exactly 0.5 g of the sample was weighed to the nearest 0.001 g using an analytical balance, then the weighed samples were transferred to teflon dishes, 2 ml of hydrogen peroxide (H_2O_2) and 5 ml of nitric acid (HNO_3) 63% were added (Balabanova et al., 2010, 2014).

The teflon dishes were placed on a rack and inserted into a microwave–assisted digestion system (MARS 5 model, CEM Corporation). The mineralization process was performed at a maximum temperature of 180 °C.

After mineralization, the dissolved samples were analyzed using an inductively coupled plasma mass spectrometer (ICP–MS), model 7850, manufactured by Agilent Technologies. The analyses were performed at the UNILAB laboratory, Faculty of Agriculture, Agricultural University – Shtip.

The digests of the previously prepared samples were analyzed using the Inductively Coupled Plasma Mass Spectrometry (ICP–MS) analytical instrument, model 7850, manufactured by Agilent Technologies.

Method validation included key parameters such as LOD, LOQ, linearity, reproducibility, accuracy, precision, working range, and measurement uncertainty, supported by certified standards and reference materials.

The following calibration standards were used:

– ICP Calibration Standards at 100 mg/l from Agilent, containing elements such as Sb, As, Be, Cd, Ca, Co, Cr, Cu, Fe, Pb, Li, Mg, Mn, Mo, Ni, Se, Sr, Tl, Ti, V, and Zn.

– ICP Calibration Standard at 1000 mg/l from Agilent, including Al, Ba, Bi, B, Cd, Ca, V, Cr, Cu, Ga, In, Fe, Pb, Lo, Mg, Mn, Ni, K, Ag, Na, Sr, Tl, and Zn.

Instrument optimization was performed using PA Tuning solutions, and accuracy was verified with the certified reference material BCR–060 (*Lagarosiphon major*), confirming the ICP–MS method as reliable and reproducible.

RESULTS AND DISCUSSION

From the results obtained for the concentration assessment of the distribution of metals in the samples taken, statistical indicators such as: minimum value (Min), maximum (Max), arithmetic mean (Mean), standard deviation (SD), and coefficient of variation (CV) were analyzed. These results provide a clear picture of the concentration level and volatility of heavy metals in the environment, which are presented in Table 1.

Table 1

Statistical parameters of heavy metals in the analyzed samples of mosses (values in mg/kg)

Element	Min	Max	Mean	SD	CV
Na	8.1784	435.76	223.49	126.24	56.487
Mg	30.675	6238.7	2646.6	1577.6	59.609
Al	237.46	17349	3101.9	4454.8	143.61
V	0.001	23.475	3.738	6.2037	165.96
Cr	0.0597	198.46	31.733	48.248	152.05
Mn	0.9104	233.55	69.291	51.668	74.566
Fe	162.2	17349	3633	4180.8	115.08
Co	0.066	19.59	5.1763	4.7437	91.642
Ni	1.24	231.44	77.273	56.542	73.172
Ti	8.856	421.44	154.82	106.25	68.629
Cu	0.4028	121.42	30.97	36.404	117.55
Zn	0.9203	81.327	28.843	25.696	89.091
As	0.0010	5.9252	0.7131	1.2825	179.86
Cd	0.0010	4.023	0.4557	0.905	198.6
Sb	0.0073	1.332	0.2147	0.3404	158.53
Ba	0.1097	44.23	10.304	12.08	117.23
Pb	0.1146	41.2	6.1446	8.8447	143.94

The statistical data show that the concentrations of metals in the analyzed samples vary significantly, as Al (mean: 3101.88 mg/kg, *CV*: 143.6%), Fe (3633.03 mg/kg, *CV*: 115.1%), and Mg (2646.55 mg/kg, *CV*: 59.6%) show high values, reflecting significant inclusion in the sample matrix (Harmens et al., 2007). However, the high coefficient of variation (*CV*) percentages for Cd (198.6%), As (179.9%), V (165.9%), Cr (152.0%), and Pb (143.9%) suggest an uneven distribution and possible local contamination, with a clear influence of anthropogenic sources. Other elements such as Ni (77.3 mg/kg, *CV*: 73.2%), Mn (69.3 mg/kg, *CV*: 74.6%), and Cu (30.97 mg/kg, *CV*: 117.5%) also show high variability, highlighting the need for further investigation of their sources.

Contamination factor (CF)

The contamination factor (*CF*) is used to determine the level of contamination of each metal in that study area. It is mathematically expressed as:

$$CF = \frac{C\text{ (metal) sample}}{C\text{ (metal) background value}}$$

where *C*(metal) indicates the concentration of the metal in the tested sample and the background value *C*(metal), the natural concentration of the metal in an uncontaminated sample/area. The interpretation scale of the results will consist of different cate–gories according to the *CF* values. (Carballeira, 2001; Yushin et al., 2020).

According to the results for the contamination factor from Table 2, it can be seen that Na (*CF* mean = 1.064) and Mg (1.961) fall within the category of moderate contamination, indicating a limited but noticeable enrichment above background levels. Mn (*CF* mean = 0.173), Zn (0.902) and Ba (0.412) although present at low mean values, shows a *CF* close to the threshold, suggesting low to moderate contamination depending on local conditions. These elements suggesting that are present at natural levels in the geological matrix of the area.

The element Sb (3.067) is classified within the range of considerable contamination, while As (5.872) and Cd (5.995) approach the upper limits of this category, reflecting their elevated presence and the likelihood of anthropogenic influence.The elements Al, Cr, Fe, Co, Ni, Ti, Cu, and Pb present very high *CF* values (in some cases with a maximum of over

50 or even over 800), being classified in the category of very high pollution. In particular: Pb (*CF* mean = 122.66) and Ni (70.249) present alarming concentrations. Cr (45.332) and Co (25.881) are also above the critical thresholds for environmental impact, indicating strong anthropogenic pollution sources. Most elements show very high contamination, especially those with industrial use or occurring in mining contexts (Sopaj et al., 2022).

T a b l e 2

Contamination factor (CF) of heavy metals in moss samples from the study area

Element	Min	MaxF	Mean	Class	Contamination level
Na	0.040	2.070	1.064	2	Moderate
Mg	0.020	4.620	1.961	2	Moderate
Al	0.520	37.710	6.743	4	Very high
V	0.000	19.560	3.114	3	Considerable
Cr	0.090	283.500	45.332	4	Very high
Mn	0.000	0.580	0.173	1	Low
Fe	0.520	55.960	11.718	4	Very high
Co	0.330	97.950	25.881	4	Very high
Ni	1.131	210.400	70.249	4	Very high
Ti	0.369	17.560	6.451	4	Very high
Cu	0.096	28.900	7.364	4	Very high
Zn	0.029	2.5410	0.902	1	Low
As	0.488	45.580	5.872	3	Considerable
Cd	0.424	50.290	5.995	3	Considerable
Sb	0.104	19.030	3.067	3	Considerable
Ba	0.004	1.769	0.412	1	Low
Pb	2.292	824.00	122.66	4	Very high

Pollution load index (PLI)

The pollution load index (PLI), first introduced by Chaudhuri and Roy (2024), is a widely used method for determining pollution levels. A PLI value of less than 1 indicates good soil quality, a value equal to 1 suggests the presence of basic levels of contaminants, and a value greater than 1 signifies deteriorating soil quality (Ahmad et al., 2021). The PLI is calculated using the following formula:

$$\mathrm{PLI} = n\sqrt{(CF_1 \times CF_2 \times CF_3 \times \ldots \times CF_n)}$$

where CF_i represents the contamination factor for the i^{th} metal, and n is the total number of metals analyzed (Yushin et al., 2020). To assess pollution, the interpretation of the results will be based on the PLI values (Tomlinson et al., 1980), and all standards were analyzed based on Norwegian standards (Nekhoroshkov et al., 2022; NILU, 2016; Paçarizi et al., 2023).

In Table 3 we presented the results of factor analysis (FA), for four main groups. The first of four factors (F1–F4) explain most of the total variance of the data. The factor loadings show the contribution of each element to each component. From Table 3, from factor 1 we see that elements with high positive loadings are: Mg (0.965), As (0.961), Pb (0.945), Na (0.897), V (0.772).

These metals are closely linked by natural geochemical processes. The presence of high positive values implies that these elements follow the same distribution trend and are strongly correlated with each other (Doan et al., 2024).

T a b l e 3

Rotated factor loadings matrix of heavy metals in moss samples from the Golesh area

Element	F1	F2	F3	F4
Na	0.897	0.361	–0.12	0.161
Mg	0.965	–0.011	0.192	0.06
Al	–0.368	–0.233	0.094	–0.079
V	0.772	–0.091	0.018	–0.15
Cr	0.388	0.456	–0.027	–0.086
Mn	0.013	0.239	0.065	0.808
Fe	0.1	0.95	0.077	0.125
Co	0.205	0.015	0.088	0.551
Ni	0.149	–0.102	0.075	0.534
Ti	0.074	0.071	0.92	0.066
Cu	–0.014	0.82	–0.285	0–365
Zn	0.087	0.126	–0.81	–0.377
As	0.961	0.003	–0.048	0.02
Cd	0.045	0.079	–0.801	0.042
Sb	–0.006	0.916	0.032	0.104
Ba	0.21	0.147	–0.346	–0.632
Pb	0.945	–0.018	–0.054	–0.138

Factor 2 – from these data we conclude that elements such as Fe (0.950), Sb (0.916), Cu (0.820), Cr (0.456) related to industrial activity (e.g. metallurgy, technological waste), especially due to the high load of Sb and Fe, these two elements have the same source of pollution.

Factor 3 – element with a very high positive charge is also Ti (0.920). From this result we see that titanium is related to a specific source of pollution, perhaps from heavy minerals or land processing activities (Doan et al., 2024).

Pronounced negative charges, Zn (–0.810), Cd (–0.801), negative values show an inverse presence with Ti, implying that Zn and Cd have another source (often urban or agricultural pollution) and do not match the trend of Ti.

Factor 4 – high positive charges exhibits Mn (0.808). This element is a microelement that exhibits common behavior, indicating a common source or natural geochemical distribution, or influence from soil transformation processes. Negative charges exhibits Ba (–0.632); the presence of negative values indicates that this element is not related to the source of Mn, excluding a common distribution.

Figure 2 presents the pollution load index (PLI) for heavy metals accumulated in moss samples. The values were calculated in accordance with Norwegian background standards for metal concentrations in *Hylocomium splendens*, reflecting the relative pollution load for each station.

It is noted in Figure 2 that some stations (e.g., M1 to M7) have PLI values above 5, indicating possible heavy pollution from external anthropogenic or industrial sources. While stations such as M10, M20 show PLI values below or close to 1, implying less polluted conditions or close to background levels.

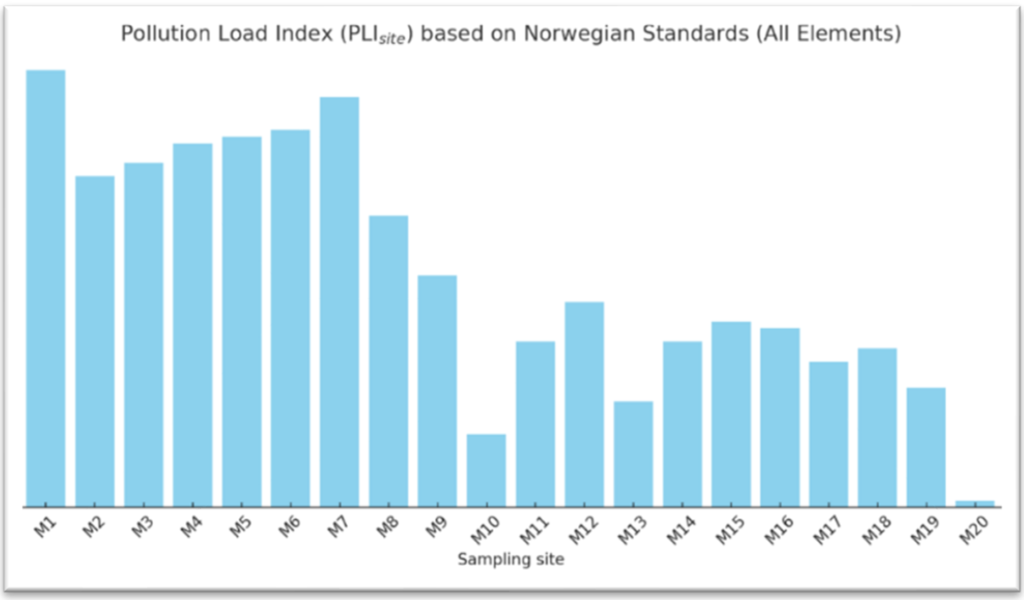

Fig. 2. Environmental pollutant load index of heavy metals in moss sample

From Table 4, for the correlation, we see that Na – Mg (r = 0.85) present a very strong correlation suggesting a common geogenic or anthropogenic source (Harmens et al., 2010). Both are macroelements and often occur together in soil distribution processes, while Na – V (r = 0.64) and V–Mg (0.73) suggests that V is strongly associated with Mg-rich parent material, characteristic of ultrabasic environments. Na – Cr (r = 0.50) show moderate correlation, suggesting a common influence from industrial or natural activities.

Na – Cu (r = 0.62) and Mg – Cu (r = 0.66): Strong correlations that can be related to the composition of ultramafic rocks or industrial pollution from metallurgical processes (Aničić et al., 2009). Cu – V (r = 0.62) and Cu – Cr (r = 0.54): High correlation between common metals of industrial and urban pollution (Weiss et al., 2002). Ba – Zn (r = 0.57) and Ba – Na (r = 0.59) have a moderate correlation, Pb – As (r = 0.91) has a very strong correlation, suggesting common contamination, potentially from mining activities or industrial discharges. Cd – Fe (r = 0.85) (Harmens et al., 2010). Very strong correlationoften suggesting retention of cadmium in fractions associated with iron oxides.

This method helps in assessing the common origin of pollution and the patterns of co–occurrence of metals, which we have presented in Figure 3. The main group distinguished which consists of Ni – As – Pb – Fe – Cd – Al, this community forms a compact cluster, showing high correlation between these elements, which are often linked to anthropogenic sources, especially metallurgical and industrial activities (Macedo–Miranda et al., 2024). All these elements are known as potentially toxic metals, linked to urban or agricultural pollution (fertilizers, pesticides, industrial waste). This division suggests that the pollution by Ni, As, Pb, etc. has a common origin, perhaps linked to the use of processed metal products, mining activities and industrial discharges in the study area, while in the secondary grouping which consists of Mg – V – Cu – Ti – Sb this grouping shows another functional community, linked to mixed natural and anthropogenic sources. Cu and Sb are common in agricultural and industrial activities, while Mg and V may have a more pronounced geological (ultramafic) origin (Paches et al., 2019).

T a b l e 4

Matrix of correlation coefficients (r)

Element	Na	Mg	Al	V	Cr	Mn	Fe	Co	Ni	Ti	Cu	Zn	As	Cd	Sb	Ba	Pb
Na																	
Mg	**0.85**																
Al	–0.42	–0.36															
V	**0.64**	**0.73**	–0.21														
Cr	**0.50**	0.36	–0.28	0.30													
Mn	0.23	0.06	–0.09	–0.08	0.04												
Fe	0.44	0.11	–0.28	–0.04	0.47	0.33											
Co	0.25	0.27	–0.24	–0.04	0.02	0.48	0.13										
Ni	0.18	0.19	–0.11	–0.04	0.03	0.42	–0.02	0.25									
Ti	–0.01	0.25	0.08	0.07	0.02	0.14	0.15	0.09	0.12								
Cu	**0.62**	**0.66**	–0.44	**0.62**	**0.54**	0.03	0.25	0.28	0.09	0.18							
Zn	0.71	0.40	–0.36	0.32	**0.55**	0.58	**0.66**	0.06	0.24	–0.06	0.47						
As	0.25	0.10	–0.18	–0.09	0.33	–0.12	0.30	–0.03	0.55	–0.14	–0.01	0.12					
Cd	0.49	0.19	–0.26	0.18	0.17	0.38	**0.85**	0.10	–0.04	0.04	0.28	**0.65**	0.08				
Sb	0.17	0.32	–0.22	0.16	0.10	–0.15	0.10	0.15	0.11	0.46	**0.71**	0.05	0.00	0.04			
Ba	**0.59**	0.32	–0.33	0.30	**0.61**	0.23	**0.50**	0.40	–0.01	–0.10	0.44	**0.57**	0.22	0.25	0.06		
Pb	0.35	0.21	–0.22	0.08	0.17	0.03	0.17	0.17	0.68	–0.24	0.04	0.17	**0.91**	0.08	–0.05	0.29	

∗Numbers in bold correspond to the correlation coefficients with a value over 0.5.

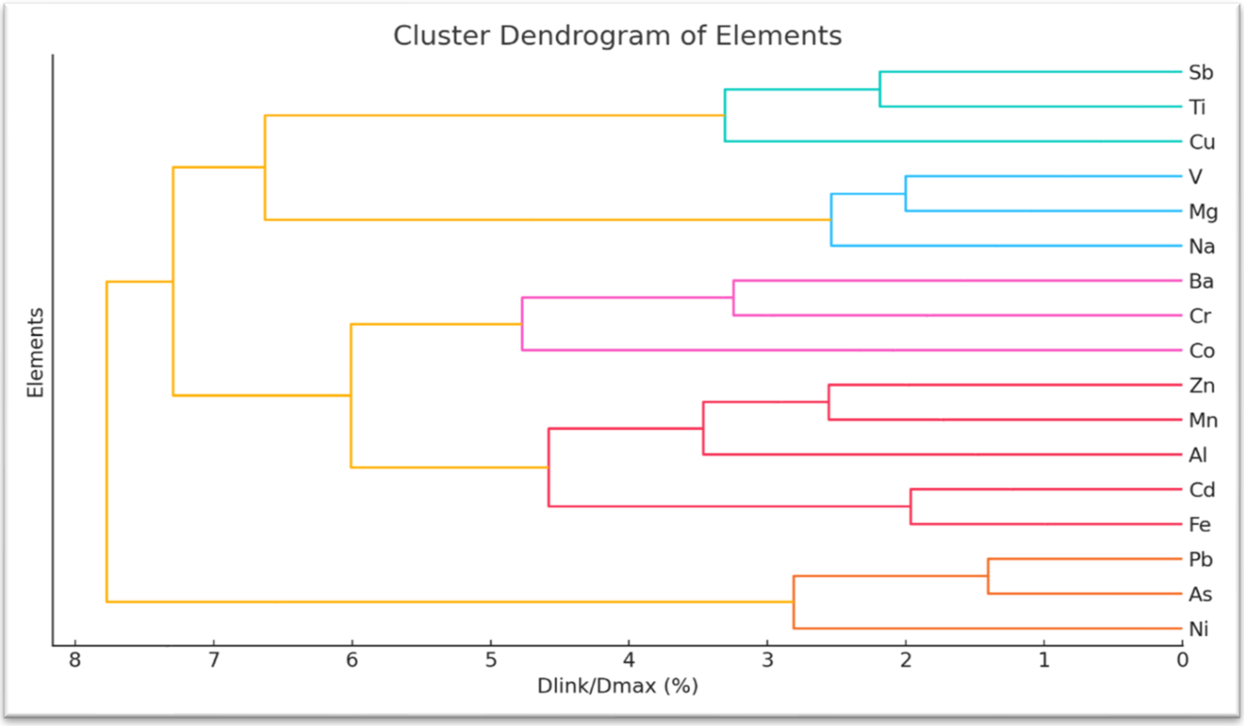

Fig. 3. Dendrogram of cluster analysis

CONCLUSION

From the results of this comprehensive analysis of heavy metals in moss samples, it is clear that the study area is exposed to significant pollution with a mainly anthropogenic source. Initial statistical analysis showed extremely high mean values for metals such as Al (3101.88 mg/kg), Fe (3633.03 mg/kg) and Mg (2646.55 mg/kg), which indicate a significant inclusion of these elements in the environmental matrix, while the coefficients of variation (CV) for Cd, Cr, Pb, and As exceed 140%, signaling uneven distribution and possible local pollution. These high values of variability are typical for areas with strong impact from industrial activities, mining, or urban waste streams.

The contamination factor (CF) significantly highlighted alarming concentrations of metals such as Pb (CF max = 824), Cr (283), Co (97.9), Cd (50.3), and As (45.6), placing the area in the very high contamination category. This metal load is a clear indicator of significant impact from anthropogenic sources such as mining, metallurgical processing, and industrial emissions.

Factor analysis (FA) and cluster analysis dendrograms helped identify common patterns of metal distribution. The first factor (F1) included metals such as Mg, As, Pb, Na, and V, suggesting a common natural or industrial impact. While the second factor (F2), dominated by Fe, Sb, Cu and Cr, is closely related to industrial activities and technogenic pollution. Another important group identified includes Ni, As, Pb, Fe, Cd and Al – a clear community of potentially toxic metals with a common source of pollution.

The pollutant load index (PLI) confirmed the total pollution of the environment, exceeding the critical limit of 1, which suggests that the quality of the environment is deteriorating. Strong correlations between pairs of metals, such as Na–Mg, Pb–As, Cu–Zn, and Cd–Fe, reinforce the hypothesis of common sources of pollution, mainly from industrial or urban activities.

Overall, the results confirm significant pollution of the area by heavy metals, many of which are toxic and persistent in the environment. Since the samples are representative of natural biomonitors such as mosses, this makes it possible to assess the real and sensitive environmental pollution.

***Acknowledgment*:** The authors gratefully acknowledge the support of the UNILAB laboratory (www.unilab.ugd.edu.mk) at the Faculty of Agriculture, Goce Delčev University in Štip, for providing scientific and technical assistance in conducting the analysis of the moss samples.

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Р е з и м е

ПРОЦЕНА НА АКУМУЛАЦИЈАТА НА ТЕШКИ МЕТАЛИ ВО ВИДОВИ МОВ КАКО БИОМОНИТОРИ НА ЗАГАДУВАЊЕТО НА АТМОСФЕРАТА ВО ОБЛАСТА НА РУДНИКОТ ЗА Fe–Ni ГОЛЕШ, РЕПУБЛИКА КОСОВО

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Клучни зборови: мовови: тешки метали; рударство на Fe–Ni; ICP–MS

Овие проучувања имаа цел да го проценат нивото на загадување на воздухот со тешки метали во областа околу Голеш, во близина на рудниците за железо–никел (Fe–Ni), користејќи мов (*Homalothecium lutescens* (Hedw.) Robins) како биомонитори. На 20 избрани места за земање примероци во оваа област беа анализирани концентрациите на 17 хемиски елементи со користење на масена спектрометрија со индуктивно поврзана плазма (ICP–MS). Овие проучувања ја одредија концентрацијата, дистрибуцијата и нивото на загадување со тешки метали во примероците од мов, кои служеа како биоиндикатори во потенцијално контаминираната област. Статистичката анализа откри големи варијации во концентрациите на металите, при што елементите Al, Fe и Mg покажаа највисоки просечни вредности. Факторот на контаминација (CF) откри екстремно високи нивоа на загадување со Cr, Cd, Co, Pb и Ni, што укажува на значително антропогено влијание. Анализите на главните компоненти и кластерите ја потврдија коегзистенцијата на токсични елементи (As, Pb, Ni, Cd) кои веројатно потекнуваат од индустриски и рударски активности. Индексот на загадување (PLI) исто така го истакна севкупниот висок статус на контаминација на областа. Овие наоди го потврдуваат присуството на локални извори на загадување и ја зајакнуваат корисноста на мововите како биомонитори во процената на животната средина.