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LICHEN DIVERSITY VALUE AND HEAVY METAL CONCENTRATIONS IN MOSSES AROUND THE LIGNITE POWER PLANTS 'KOSOVA'

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Abstract. Lichen and mosses are the most appropriate indicators for monitoring air pollution. To evaluate air quality in the Prishtina region, we determined lichen value diversity (LDV) and heavy metal concentrations in mosses at 20 sites around power plants 'Kosova A and B'. Twenty-three lichen species were recorded in the survey area. The lichen value diversity differed depending on the distance from the source of air pollution. Values ranged from 36.3 to 115.4, with the highest levels recorded in the cleanest area. This value decreased when moving towards the polluted areas. Concentrations of six heavy metals were measured in mosses (*Brachythecium rutabulum (Hedw.) Schimp*). Different concentrations of heavy metals in mosses were found during the investigation. The hot spots of heavy metals were associated with historical industrial activities, mining activities, and industrial centres. In addition, vehicle emissions near major roads were responsible for the high concentrations of trace elements in mosses in these areas. Zn was found in the highest concentration, and ranged from 56.5-136.6 $\mu g.g^{-1}$.
Keywords: *bioindicator, lichen value diversity, heavy metals, mosses*

Introduction

Humans generate large amounts of pollutants that reduce air quality. The air pollutants that originate from anthropogenic sources include heavy metals, CO_2, sulphur and nitrogen compounds (Pitcairn et al., 1995; Whelpdale et al., 1998; Pacyna et al., 2001). Air quality can be accurately estimated using lichens and mosses as bioindicators (Markert et al., 2003). The presence of air pollutants in a natural environment can cause changes in biochemical and physiological processes (Arb et al., 1990) and community structures. Lichens and mosses are cryptogams, which possess many properties that make them suitable for monitoring purposes: the cuticle is weakly developed, they do not have real roots, they are slow-growing and long-lived, they have an extremely broad distribution and they obtain nutrients from wet and dry deposition (Wolterbeek et al., 2003; Onianwa, 2001; Zechmeister et al., 2003). Lichens are highly sensitive to air pollution and have been identified as indicators of environmental quality, particularly air quality, since the 1800s (Nylander, 1866). Later, numerous of such studies have been conducted in industrial areas in a number of countries (Pejćinović and Hoxha, 1986, Sommerfeldt et al., 2001; Seaward, et al. 2004; Loppi, 2004; Bačkor, 2003; Munzi, 2007). In addition, mosses are highly efficient accumulators of many elements and are capable of accumulating persistent pollutants, such as heavy metals, in their natural environment (Rühling et al., 1994; Berg et al., 1996; Lepneva, 1987; Lippo et al., 2004). The aims of this study were to assess the air quality status by using lichens as

bioindicators and the deposition pattern of selected heavy metals by using mosses as bioaccumulators around lignite power plants located in the Prishtina region.

Materials and methods

Study area

The study area was located northwest of Kosovo and contained an area of about 200 km^2 around power plants 'Kosova A and B'. The study region is rich with natural resources, and there are large reserves of coal (lignite) and many mines (Stanterg mine (Pb, Zn); Magure mine (Mg, Fe, Ni); Hajvalia mine (Pb, Zn); Gllogoc mine (Fe, Ni)). The economy of the Prishtina region has been based mainly on the exploitation of these natural resources, such as electricity production (power plants that use coal as fuel), coal and mineral exploitation, and smelters (Ferronickel smelter). With the exception of Mitrovica, which was one of the largest industrial areas of the former Yugoslavia, the Prishtina region is considered to be the most polluted area in Kosovo. A major source of pollution in this region is the industrial complex in Obilic. This industrial complex consists of facilities that produce hazardous emissions in the area of Prishtina and beyond. The main sources of emissions from the industrial complex include open mining for lignite used as fuel in power plants, and lignite drying and heating plants. In the past, gasification and fertilizer plants were also sources of pollution, but these were permanently closed in 1988-89. With a total capacity of 1,478 MW (Gjendja e Mjedisit Raport 2008), the power plants 'Kosova A and B' are the major sources of pollution due to emissions of sulphur dioxide, nitrogen oxides, dust, fly ash, smoke, radioactive soleplates and carbon gases. 'Kosova B' discharges approximately *260 g/s SO_2, 556 g/s NO_x and 376 g/s dust* (Varjoranta and Pietarila, 2005). *O*ne unit of 'Kosova B,' with a capacity of 200 MW, emits about 25 tons of dust and ash per hour, which is 74 times more than the European standards (WHO, 2002). Currently, there are plans to build a new power plant, 'Kosova C,' in the same location. Chemical analysis of the dust particles which originated from the power plant contains different chemical elements including radio-nucleotides Pb^{214}, Ti^{218}, Cs137, U^{235} (Adrović et al., 1996) and toxic compounds as NO_x, SO_2, As, Pb, Cd, Ni, Cr, Co, etc., which have negative impacts on living organisms. The annual average temperature in the study region is 10.9 °C, the average annual rainfall is 638.3 mm and the annual average of insulation is 2,140 hours per year. The wind predominantly blows from north and northeast with an average velocity of 3 m/s (data from the Kosovo Meteorological Institute).

LDV determination

The standardized EU lichen recording method (Asta et al., 2002) was used to determine the lichen value diversity. The sampling units were selected in different sites around power plants to investigate the effects of environmental stress on lichens. This sampling strategy was designed to capture variation of the epiphytic lichen value diversity. Most of the sites were concentrated in southeast, south and south west of the power plants corresponding to the wind direction, where most of the changes were expected (*Table 1*). Within the study region, 20 sampling sites were randomly selected. Sampling was conducted exclusively in trees outside the woodlands. The size of the sample unit was 0.5 X 0.5 km. All sites were geo-referenced using GPS (Garmine-gekos 201).

Sampling units were selected based on the presence of suitable trees and no road disturbance. In six sampling units LDV was determined in oak trees, and in fourteen sampling units LDV was determined in the popular (Populus) species. Only trees of a single species were selected within a survey unit to determine LDV. The selected sampling units were divided into four equal quadrants, and within each of these quadrants, three tree trunks were selected according to the conditions listed above (Asta et al., 2002). To record the presence and frequency of each lichen species, we used a laddered quadrate comprising five quadrate squares (10cm × 10 cm). The lowest quadrate began at 100 cm above ground level on each aspect (N, S, E, W) of each tree. All lichen species present within the quadrates were recorded. Lichen value diversity was calculated for each sampling unit.

The sum of the frequencies of all lichen species for each aspect on each tree (i) was calculated in each sampling unit. For each tree there were four sums of frequencies (tree i: SFiN, SFiE, SFiS, SFiW). Then the arithmetic mean of the sum of frequencies (MSF) for the sampling unit j was calculated using the following formula:

$$MSFNj = (SF1Nj+SF2Nj+SF3Nj+SF4Nj+.....+SFnNj)/n \qquad (Eq.1)$$

Where:

MSFNj is the mean of the sum of the frequencies of all trees of unit j for each aspect (e.g. North)

SFiNj is the sum of the frequencies of all species recorded for each aspect (e.g. North) of tree in unit j

n is the number of surveyed trees with a given aspect in unit j

The lichen value diversity of the sampling unit j (LDVj) was calculated as the sum of the MSF-s of all aspects:

$$LDVj = (MSFNj+MSFEj+MSFSj+MSFWj) \qquad (Eq.2)$$

Heavy metal determination

In the same localities where we determined the LDV, we also collected mosses to measure the concentration of heavy metals. The moss samples were collected in sites that were located at least 300 m from the main roads, at least 100 m from any road or single house and 3 m away from the nearest tree. On each sampling site, 3 subsamples were taken within an area of 50m × 50m. *Brachythecium rutabulum (Hedw.) Schimp* was used to determine the concentration of heavy metals, as this species were present in the study area. All dead materials were cleaned from the samples and only the portion with green and green-brown mosses was included. The samples were dried to a constant weight at 40 °C. After being cleaned and dried, one gram of moss for each sample was burned in the temperature 450 °C for three hours. Heavy metal concentrations (Cd, Pb, Cu, Zn, CO and Ni) were determined by standard methods using AAS - atomic absorption spectroscopy (UNICAM 929 spectrometer) (Mendil et al., 2009). The concentrations of heavy metals were expressed in µg/g dry weight.

Data analysis

Data analysis was performed using SPSS 15. Lichen value diversities were used for multivariate analysis (Cluster Analysis) to cluster the sites based on the average linkage (Between Groups).

Species identification

Murati M. (1992, 1993) and Wirth (1995) were consulted for lichen determination. The moss species *Brachythecium rutabulum (Hedw.) Schimp* was identified by Beata Papp.

Results and discussion

Floristic data

During the investigation to determine the lichen value diversity around power plants 'Kosova A and B' we recorded 23 epiphytic lichen species, which are listed below. The majority were foliose species (11), 7 were crustose species, and 5 were fruticose species. The genera with the highest number of species were *Candelariella, Lecanora, Melanelia, Phaeophyscia Physcia* and *Ramalina.* Other genera had only one species per genera.

List of lichen species found around power plants.

1. *Anaptychia ciliaris (L.) Körb.*
2. *Arthrosporum populorum A. Massal.*
3. *Caloplaca holocarpa (Hoffm.) A. E. Wade*
4. *Candelariella aurella (Hoffm.) Zahlbr.*
5. *Candelariella cf. reflexa (Nyl.) Lettau*
6. *Evernia prunastri (L.) Ach.*
7. *Flavoparmelia caperata (L.) Hale*
8. *Lecanora carpinea (L.) Vain.*
9. *Lecanora subrugosa*
10. *Melanelia exasperata (De Not.) Essl.*
11. *Melanelia glabra (Schaer.) Essl.*
12. *Parmelia sulcata Taylor*
13. *Parmelina tiliacea (Hoffm.) Hale*
14. *Phaeophyscia nigricans (Flörke)*
15. *Phaeophyscia orbicularis (Neck.) Moberg*
16. *Physcia adscendens*
17. *Physcia stellaris (L.) Nyl.*
18. *Pleurosticta acetabulum (Neck.) Elix & Lumbsch*
19. *Pseudevernia furfuracea (L.) Zopf*
20. *Ramalina fastigiata (Pers.) Ach.*
21. *Ramalina fraxinea (L.) Ach.*
22. *Rinodina pyrina (Ach.) Arnold*
23. *Xanthoria parietina (L.) Th. F*

Table 1. *List of the main characteristics of the sample sites. Each locality was identified by number, name, GPS coordinate, tree species, number of lichen species, number of lichen species from above list and lichen diversity values*

No.	Localities	Longitude	Latitude	Orien-tation	Plant species	Nr. of species	Lichen sp. from above list of lichens.	LDV
1	Obiliq	21°04'1.8"	42°41'6.9"	CENTER	Populous	3	4, 15, 23	41.6
2	Shkabaj	21°06'24.5"	42°39'59.0"	E	Populous	5	4, 9, 14, 15, 23	49.4
3	Dragodan	21°09'5.7"	42°40'11.4"	E	Populous	7	4, 8, 15, 17, 18, 21, 23	58.7
4	Taukbashqe	21°10'55.6"	42°39'55.1"	E	Populous	5	4, 8, 15, 21, 23	64.7
5	Mramor	21°17'59.1"	42°39'7.7"	E	Quercus	8	4, 8, 10, 12, 15, 16, 21, 23,	96.2
6	Lagja e spitalit	21°10'1.4"	42°38'43.6"	SE	Populous	5	8, 14, 5, 16, 23	59.2
7	Graqanic	21°12'43.4"	42°36'6.1"	SE	Populous	5	8, 14, 15, 16, 23	78.1
8	Slivovë	21°20'28.1"	42°35'15.5"	SE	Quercus	15	1, 2, 4, 8, 10, 11, 12, 15, 16, 17, 18, 19, 20, 21, 23	115.4
9	Prelez	21°10'31.4"	42°27'36.6"	S	Populous	3	8, 15, 23	75.5
10	Ferizaj	21°11'1.3"	42°22'6.5"	S	Populous	4	4, 9, 15, 23	56.8
11	Lipjan	21°06'42.2"	42°30'55.1"	SSW	Populous	5	6, 8, 9, 15, 21, 23	70.0
12	Magure	21°00'49.3"	42°32'37.7"	SWW	Quercus	4	4, 14, 15, 23	79.2
13	Kroi i mbaretit	20°56'54.0"	42°36'8.06"	SW	Populous	6	4, 5, 8, 15, 21, 23	97.4
14	Sllatin	21°00'8.3"	42°35'44.8"	SWW	Quercus	4	4, 14, 15, 23	77.6
15	Lismir	21°04'19.5"	42°40'6.5"	W	Populous	3	4, 15, 23	36.2
16	Grabovc	20°59'29.4"	42°39'36.5"	W	Quercus	8	4, 11, 12, 15, 18, 19, 21, 22, 23	64.6
17	Drenas	20°54'14.8"	42°39'36.4"	W	Quercus	9	4, 5, 7, 8, 11, 13,15, 16, 18, 23	93.1
18	Vushtrri	20°59'46.0"	42°47'59.7"	NW	Populous	4	9, 14, 15, 23	76.8
19	Drenovc	21°03'38.7"	42°41'35.3"	N	Populous	2	15, 23	72.0
20	Bardhosh	21°08'59.1"	42°42'58.3"	NE	Populous	5	3, 4, 8, 15, 16, 23	70.5

Lichen diversity

The lichen value diversity results and characteristics of the study sites are shown in Table 1. Lichen value diversity was used to estimate the air quality, which ranged from 36.3 to 115.4. Lichen value diversity was compared with the LDV interpretation scale (Asta et. al., 2002), and our results are distinguished in six classes (*Table 2*).

Table 2. *Interpretation scale of lichen value diversity ranges of sampling units and the corresponding interpretation (Asta et al. 2002)*

LDV interpretation class	LDV interpretation subclass	Lichen value diversity	location numbers (see *Table 1*)
1. Very high	very high	>81	5, 8, 13, 17
2. High	high to very high	71- 80	7, 9, 12, 14,18,19
	high	61- 70	4, 11, 16.20
3. Moderate	moderate to high	51- 60	3, 6, 10,
	moderate	41- 50	1, 2,
4. Low	low to moderate	31- 40	15
	low	21- 30	-
5. Very low	very low	11- 20	-
	extremely low	0- 10	-

The LDV of different sites ranges from low to very high lichen value diversities, most sites range in subclass from high to very high LDV (*Table 2*). The highest number of lichen species was found in the cleanest sites. In polluted areas, the number of lichen species was very low (*Table 1*). *Candelariella aurella, Lecanora carpinea, Phaeophyscia orbicularis* and Xanthoria *parietina* were found in the majority of the sites, as they are toxitolerant species. Species with the lowest frequencies were *Anaptychia ciliaris, Flavoparmelia caperata, Parmelina tiliacea,* and *Pseudevernia furfuracea,* which are sensitive to air pollution.

A hierarchical cluster analysis was performed to group the various parameters (LDV) according to their values. Based on the average linkage (between groups), the results were grouped into six different groups, which were displayed in the dendrogram (*Fig. 1*). The groups in the dendrogram are quite similarly grouped, with groups interpolated according Asta et al.(2002) (*Table 2*).

Group A. Includes only one site, Slivovë, which is located in the SE area, is farther from power plants, and is characterized with the highest value of lichen diversity.

Group B. Includes sites that have high lichen value diversity (93.1 – 97.4), but this value was lower than in sites grouped into Group A.

Group C. Includes sites Obiliq and Lismir, which are the closest sites to the power plants and, consequently, are more polluted areas. The LDV fluctuate from 36.2 – 41.6.

Group D. Dragodan, Lagja e spitalit, Ferizaj, Shkabaj were included in this group. The LDV of these sites ranged from 49.4 to 59.2. These sites are characterized with higher LDV than sites grouped in group C.

Group E. Includes five sites that have a LDV from 75.5 to 79.3. They have higher lichen value diversity than sites in group D, and lower than sites in group B

Group F. Includes sites with lichen value diversity fluctuate from 64.7 to 72.0.
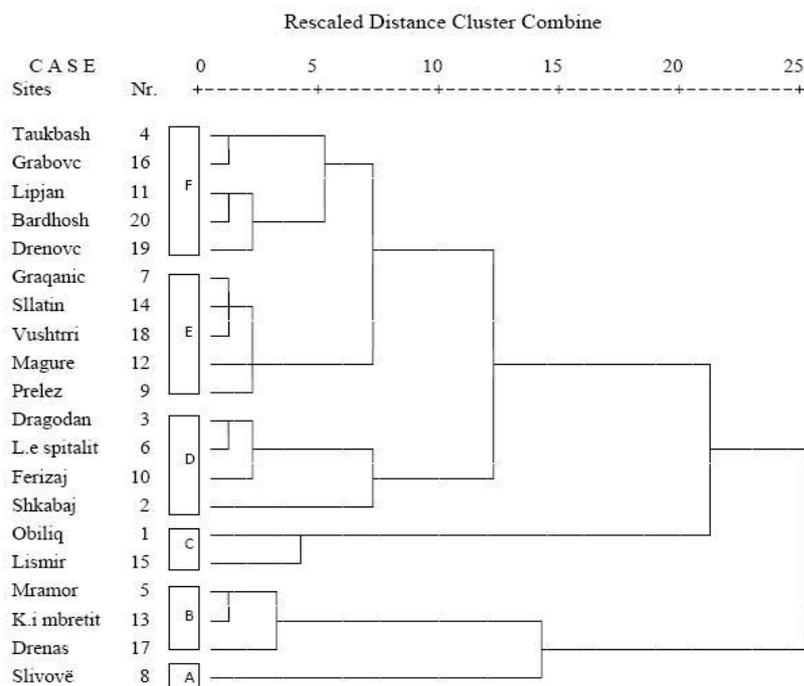
Figure 1. *Cluster analysis dendrogram. Cluster analysis of sites around power plants 'Kosova A and B' based on the average linkage (Between Groups) of lichen values diversity*

In most cases, lichen value diversity was low near the source of pollution and fell into the 'Low moderate and moderate' LDV class (*Table 2*). This value increased with increasing distance from the source of pollution, and fell into the higher LDV class. Higher LDV was recorded east and west of the source of pollution where localities had high vegetation richness. The lowest values were recorded near the power plants, main roads and mines which are characterized by higher levels of air pollution and poorness of vegetation. The influence of distance was found south of the power plant areas, which pollution dispersion by the wind, the presence of the main road, the lack of vegetation, and the presence of residents may have also played a role. Taking into consideration the presence of lichens and LDV, the air in the Prishtina region had a higher quality than the air around the Mitrovica region, which was the main industrial area in Kosovo and in former Yugoslavia. In the Mitrovica region, the air quality was very poor. In vast areas, there was an absolute 'lichen desert' (Pejqinoviq and Hoxha, 1986, Pejqinoviq and Hoxha, 1988), which still exists (Borgna, 2009), even though the industrial activities decreased rapidly after 1990 and nearly stopped completely in 2001.

Heavy metal concentration

Table 3 shows the minimum, maximum, median and average values for six trace element concentrations (Zn, Pb, Cu, Co, Ni, Cd) measured in moss samples from different sites. The concentration of trace metals differed depending on the distance from pollution sources. The hot spots were associated with historical industrial activities, mining activities, and industrial centres. Source pollution per locality is given in *Table 3*, and along the major roads, vehicle emission is responsible for the high concentrations of trace elements in the mosses. Zinc had the highest concentration and ranged from 56.5-136.6 $\mu g.g^{-1}$. This value decreased as follows: Pb: 2.10-66.3 $\mu g.g^{-1}$; Cu 10.10-27.00 $\mu g.g^{-1}$; Co 0.60-14.72 $\mu g.g^{-1}$; Ni: 1.29-10.59 $\mu g.g^{-1}$; Cd 0.32-1.69 $\mu g.g^{-1}$; (*Table 3*).

A wide range was observed for Zn concentrations in the survey region, with values from 56.50 to 136.47 $\mu g.g^{-1}$ (median = 81.1 $\mu g.g^{-1}$ *Table 3*). The highest median zinc concentration was found near the Hajvalia mine, with a median value 136.47 $\mu g.g^{-1}$. High levels of zinc were found near mines, power plants, and main roads. The concentrations of Zn significantly exceeded the average concentration of Zn in mosses from the Balkan region countries (Bulgaria 27.9 $\mu g.g^{-1}$; Serbia 29.0 $\mu g.g^{-1}$; Croatia 29.0 $\mu g.g^{-1}$; Slovenia 38.6 $\mu g.g^{-1}$; FYR of Macedonia 35.6$\mu g.g^{-1}$ (Harmens et al., 2008) and Bosnia and Herzegovina 23.8 $\mu g.g^{-1}$, (ESC, 2003)).

The Pb concentrations in the Prishtina region had a wide range (2.10 to 66.3 $\mu g.g^{-1}$) in mosses sampled, with a median value of 19.2 $\mu g.g^{-1}$. The concentration of Pb was higher compared to countries in the Balkan (Bulgaria 14.8 $\mu g.g^{-1}$; Croatia 2.57 $\mu g.g^{-1}$; FYR of Macedonia 7.62 $\mu g.g^{-1}$; Serbia 16.7 $\mu g.g^{-1}$; Slovenia 10.1 $\mu g.g^{-1}$ Harmens et al., 2008). Pb content was also higher compared to its concentration in vegetables from the Mitrovica region (pepper up to 4.86 $\mu g.g^{-1}$ and cabbage up to 7.56 $\mu g.g^{-1}$ Borga, 2009).

Copper concentrations in mosses varied between 10.1 to 27.0 $\mu g.g^{-1}$, with a median value 17.6 $\mu g.g^{-1}$ (*Table 3*). Compared with other countries in the Balkan region, the Cu median value in mosses from the Prishtina region was higher than Serbia 11.1 $\mu g.g^{-1}$, Croatia 7.54 $\mu g.g^{-1}$, FYR of Macedonia 6.65 $\mu g.g^{-1}$, Slovenia 8.17 $\mu g.g^{-1}$, Bulgaria 10.7 $\mu g.g^{-1}$ (Harmens et al., 2008).

Cadmium concentrations ranged from 0.32 to 1.69 $\mu g.g^{-1}$, with a median value 0.49 $\mu g.g^{-1}$ (*Table 3*). The content of cadmium had a higher concentration than other Balkan countries (Serbia 0.26 $\mu g.g^{-1}$; Croatia 0.28 $\mu g.g^{-1}$; Bulgaria 0.31 $\mu g.g^{-1}$; Slovenia 0.33 $\mu g.g^{-1}$ and FYR of Macedonia 0.29 $\mu g.g^{-1}$ Harmens et al 2008). The concentration of Cd in mosses was also lower than in maize (up to 1.67 $\mu g.g^{-1}$), Boletus edulis (16.0 $\mu g.g^{-1}$), from the Mitrovica region, which is located near the Prishtina region (Borga et al., 2009).

The Co concentration in mosses ranged from 0, 60 to 14.72 $\mu g.g^{-1}$ with a median value of 6.7 $\mu g.g^{-1}$.

Ni contents in mosses from the Prishtina region also showed wide ranges from 1.29 to 10.59 $\mu g.g^{-1}$ with a median value 3.90 $\mu g.g^{-1}$ (*Table 3*). The median value of Ni concentration in the Prishtina region was higher than in other countries in the Balkan region (Croatia 2.68 $\mu g.g^{-1}$ Slovenia 2.75 $\mu g.g^{-1}$ Bulgaria 2.99 $\mu g.g^{-1}$ Harmens et al 2008), but lower than in Bosnia and Herzegovina 4.85 $\mu g.g^{-1}$, Serbia 4.43 $\mu g.g^{-1}$, FRY of Macedonia 5.82 $\mu g.g^{-1}$ Harmens et al., 2008.

Table 3. *Concentrations of heavy metals (μg/g dry weight) measured in moss samples collected in different locations around power plants 'Kosova'*

Localities	Source of air pollution	LDV	Cd	Pb	Cu	Zn	Co	Ni
Lisnir	Power plant	36.2	0.33	2.10	16.2	58.16	1.06	2.15
Grabovc	Power plant. Coal mine	64.6	0.63	21.12	26.96	69.67	0.60	3.29
Drenovc	Traffic	72.0	0.46	26.80	22.40	84.00	6.45	10.59
Vushtrri	Stanterg mine	76.8	1.23	42.93	17.60	99.67	4.32	5.37
Obiliq	Power plant	41.6	0.62	19.00	15.40	66.33	7.60	4.50
Shkabaj	Power plant	49.4	0.41	5.87	15.67	64.56	1.19	6.87
Sllatin	Ferronickel factory, airport	77.6	0.66	9.25	10.45	56.50	11.5	6.87
Magure	Magure mine	79.2	1.69	18.00	10.10	89.00	9.36	10.46
Lipjan	Power plant, traffic	70.0	0.46	30.00	20.20	94.67	2.13	3.06
Kroi i mbaretit	Ferronickel factory, traffic	97.4	0.49	19.20	12.33	76.67	14.07	5.89
Drenas	Ferronickel factory	93.1	0.55	44.20	17.10	84.33	8.53	3.92
Dragodan	Power plant, traffic	58.7	0.35	21.73	19.73	69.89	8.61	4.12
Taukbashqe	Traffic	64.7	0.45	19.20	27.00	90.33	7.53	5.50
Graqanic	Hajvalia mine	78.1	0.40	66.36	25.04	136.47	2.59	4.19
Slivovë	Traffic	115.4	0.86	13.40	16.20	81.17	1.20	1.94
Mramor	Hajvalia mine	96.2	0.76	19.60	25.50	73.00	14.72	1.28
Prelez	Traffic	75.5	0.34	20.50	18.00	84.22	3.55	3.11
Bardhosh	Traffic	70.5	0.32	10.33	21.07	83.00	4.87	3.11
Lagja e spitalit	Traffic	59.2	0.34	17.90	17.87	80.22	6.73	3.71
Ferizaj	Traffic	56.8	0.34	14.00	14.80	65.33	8.77	1.55
	Mean	76.6	0.61	23.1	18.4	81.8	6.5	4.5
	Median	75.5	0.49	19.2	17.6	81.1	6.7	3.9
	Minimum	36.2	0.32	2.10	10.10	56.50	0.60	1.29
	Maximum	115.4	1.69	66.36	27.00	136.47	14.72	10.59

Conclusion

Taking into consideration the lichen value diversity and heavy metal concentration in mosses from Prishtina region, we can conclude that the lichen value diversity was influenced by different environmental factors acting in the same territory. Near the source of pollution, the lowest levels of LDV are found. There was a progressive increase of LDV with increasing distance from the source of pollution. Heavy metal concentrations in our moss samples varied greatly from the distance of sites from the source of pollution. High concentrations of heavy elements, such as Pb, Cd, Co, Ni, Zn and Cu, were found in the Prishtina region, which is connected with the former industrial activity of heavy metal pollution (e.g. mines, mine disposal sites, power plants, etc.). In all cases, a non-significant correlation was found between LDV and heavy metal, which suggests that other compounds like are NO_x and SO_2 seem to be responsible for the low level of LDV in these polluted areas. Further studies are required in the Prishtina region to determine what is contributing to the low levels of LDV.

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