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EPIPHYTIC LICHENS AS BIOINDICATORS OF AIR POLLUTION IN THE AREA OF BELGRADE

Epiphytische Flechten als Bioindikatoren für die Luftverunreinigung im Gebiet von Belgrad

by

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Key words: Epiphytic lichens, bioindicators, air pollution, Belgrade area.

Schlagwörter: Epiphytische Flechten, Bioindikatoren, Luftverunreinigung, Belgrad.

Summary: A total of 43 taxa of epiphytic lichens has been found at 103 stations in the investigated Belgrade area. The most frequent species, listed in decreasing order of frequency, were *Amandinea punctata* (the stations in the urban area accounting for 51% of the total number of its records), *Lecanora hagenii* (65% records from the urban area), *Physcia adscendens* (51%), *Phaeophyscia orbicularis* (33%), *Parmelia sulcata* (36%), *Lepraria incana* (29%), *Hypogymnia physodes* (26%), and *L. conizaeoides* (44%).

Three zones were established with regard to the distribution of the epiphytic lichens characteristic of urban areas: the area of lichen desert whose boundary was distinguished by the occurrence of *Lecanora hagenii* and *L. conizaeoides*, as well as the narrow and wide transitional zones.

Zusammenfassung: Im Stadtgebiet von Belgrad wurden an 103 untersuchten Stationen insgesamt 43 Taxa von epiphytischen Flechten gefunden. Die häufigsten Arten, aufgelistet in absteigender Reihe der Frequenz, waren *Amandinea punctata* (51% der Gesamtanzahl aller Angaben von den Stationen im Stadtgebiet), *Lecanora hagenii* (65 % der Angaben aus dem Stadtgebiet), *Physcia adscendens* (51 %), *Phaeophyscia orbicularis* (33 %), *Parmelia sulcata* (36 %), *Lepraria incana* (29 %), *Hypogymnia physodes* (26 %) und *L. conizaeoides* (44 %).

Entsprechend der Verbreitung der epiphytischen Flechten im Stadtgebiet wurden

drei Zonen unterschieden: Die Zone der Flechtenwüste wurde mit dem Auftreten von *Lecanora hagenii* und *L. conizaeoides* begrenzt, weiters wurden die innere und äußere Übergangszoge unterschieden.

Introduction

The oldest preserved lichen specimens from the wider Belgrade area are *Anaptychia ciliaris* and *Lobaria pulmonaria,* dating from 1899. They were also the first lichen specimens to be housed in the Natural History Museum in Belgrade BEO (the Balkan Peninsula Herbarium). Until the fifties, lichens on the territory of Belgrade were gathered sporadically and the data on lichens were first published in 1949 (SOŠKA). More extensive researches into epiphytic lichens were conducted during the last fifteen years (MILIĆ & BLAŽENČIĆ 1993, SAVIĆ in press).

The research carried out during 1993-95 was aimed at identifying the species of epiphytic lichens - air pollution indicators in the Belgrade urban area, as well as at determining pollution zones on the basis of these species.

Area and Methods

Belgrade, the capital of Yugoslavia, is situated at the confluence of the Danube and Sava rivers (44° 48′ N, 20° 28′ E). Belgrade has an average altitude of 132 m, with the altitudes ranging from 60 m on the banks of the Danube and Sava rivers to 253 m in the Zvezdara borough (Fig.1) which represents the highest point of the city proper. Although Belgrade has a moderately continental climate, it has acquired the climatic features typical of large cities and the city proper exhibits the characteristics of the so-called heat islands (RAKOČEVIĆ, 1990). Belgrade has the mean annual relative air humidity averaging 71% and the mean annual air temperature of 11,9° C for the period 1960-1990 (the Belgrade Meteorological Observatory).

Research was carried out from the centre to the periphery of the Belgrade urban zone. A total of 220 stations was investigated; the lichen specimens were obtained from 103 stations (Fig.1). The phorophytes, chosen selectively, were mostly comprised of old representatives of *Populus* L., *Quercus* L., *Tilia* L., *Acer* L. which were also the most frequent ones. The lichens found in the green areas and their occurrences up to the height of 0,5 m were noted separately. Relative lichen abundancy was marked by numbers **1-3**, where **1** signifies the occurrence of 1 to 5 thalli, **2** the occurrence of 5 to 10 thalli and **3** the presence of more than 10 thalli on a tree bark (Tab.1).

The Report of the City Institute of Public Health on the mean annual SO_2 values from 1983 to 1993 (Report 1983-1993) indicates only a slight reduction in the SO_2 levels (Fig. 2). For this reason we have taken into consideration the

Fig. 1: The distribution of the 103 stations in the Belgrade area and the annual SO_2 isolines for the 11 year period.

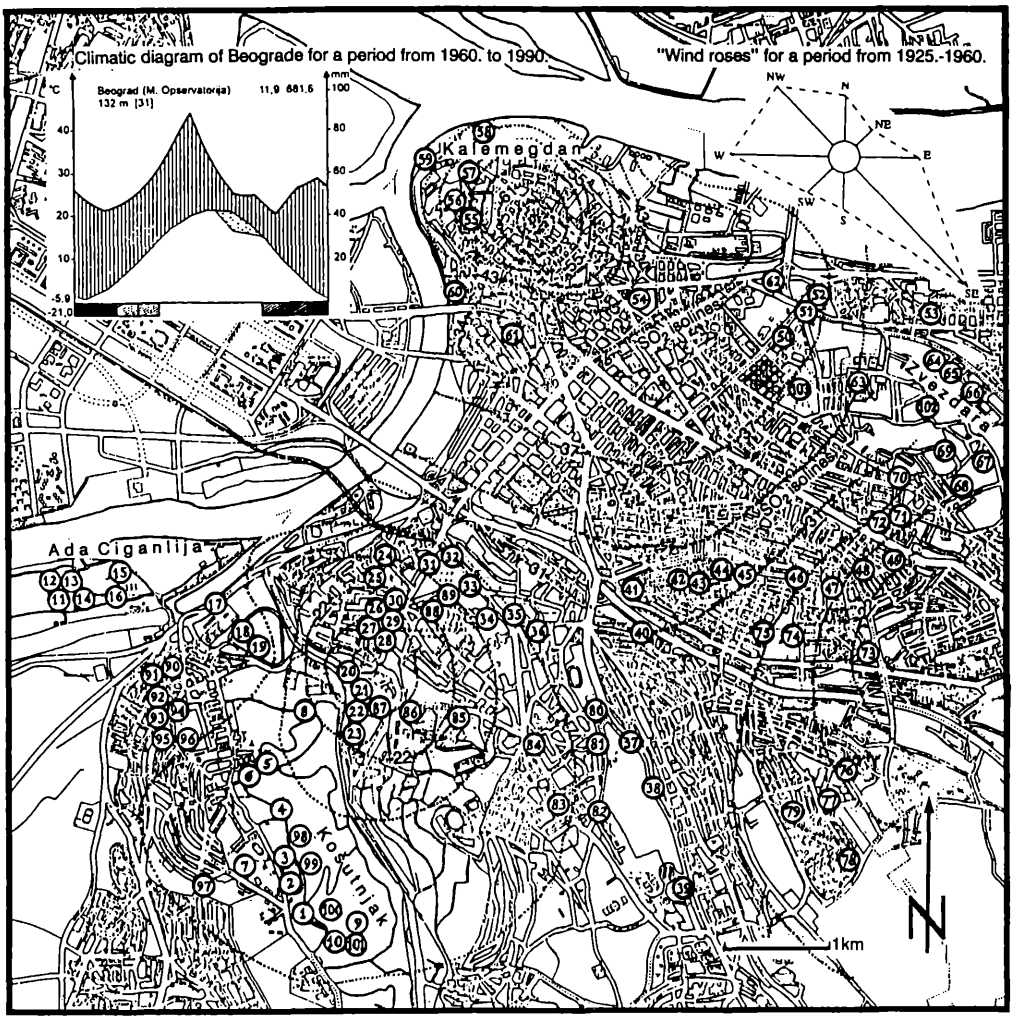
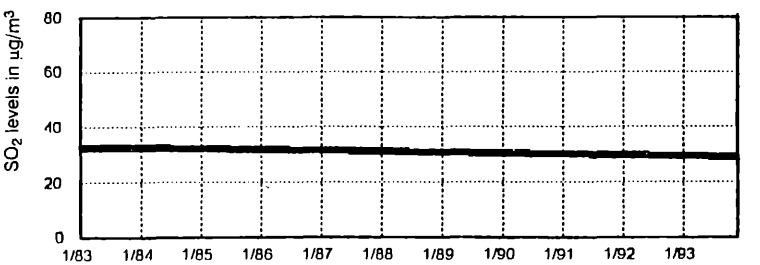


Fig. 2:



Mean annual SO_2 values from 1983 to 1993 in the Belgrade area

average winter and annual SO_2 values for the period of 11 years from the 13 monitoring stations situated within the area investigated. In the data analysis, we have used the computer program SURFER, by the help of which we have obtained the winter and annual SO_2 isolines.

Results and discussion

In the course of these investigations, a total of 43 lichen taxa was determined. The Table 1 gives a survey of the 22 epiphytic lichens observed more than once during the investigations.

The Belgrade lichens boast the greatest diversity in the park-forests Košutnjak and Ada Ciganlija, popular picnic grounds. The 21 species which occur only once have been listed separately in Table 2.

The most frequent lichens, likewise the most abundant ones within the typical urban regions, listed in decreasing order of frequency, were *Amandinea punctata,* (the stations in the urban area accounting for 51% of the total number of its records), *Lecanora hagenii* (65% records from the urban area), *Physcia adscendens* (51%), *Phaeophyscia orbicularis* (33%), *Parmelia sulcata* (36%), *Lepraria incana* (29%), *Hypogymnia physodes* (26%), and *L. conizaeoides* (44%). As these species were frequent both throughout the investigated area and in typically urban areas, and may comparatively easily be recognized *(L. hagenii* and *L. conizaeoides* excepted), they were used as indicators of the degree of air pollution, notably the sulphur dioxide levels.

The central city zone devoid of epiphytic lichens, but having the epilitic ones, represented the „central lichen desert" Its boundary area and the so-called „narrow transitional zone" were distinguished by the presence of three species of crustose lichens: *Amandinea punctata, Lecanora hagenii,* and *L. conizaeoides. A. punctata* was the most frequent species; exhibiting a noteworthy ecological valency, it inhabited various urban areas. *L. hagenii* chiefly occurred at the stations characterized by typical urban conditions. Compared to *L. conizaeoides,* its cover and frequency in the investigated urban area were by far greater. The species *L. conizaeoides,* whose cover was smaller at all sites, was most frequent in the SE boundary area of the lichen desert and the narrow transitional zone. *L. hagenii* and *L. conizaeoides* appeared together only on a few sites.

The species *Physcia adscendens, Phaeophyscia orbicularis* and *Parmelia sulcata* occurred in the areas with somewhat lower SO_2 levels and were characteristic of the „wider transitional zone" The clean-air zone was not observed within the studied urban area.

A comparison of the spatial arrangement of SO_2 isolines with the distribution of lichen taxa shows that the average annual SO_2 level isolines correspond closely with the lichen distribution, unlike the winter SO_2 level isolines.

The peak of the mean values for the 11 year period was in the NW part of the researched area, in Kalemegdan Park. The presence of as much as five epiphytic lichen species in that area may be accounted for by specific ecological conditions determined by the vicinity of rivers, green area, and the dominant NW-SE wind course.

The most drastic example of the consequences of microclimatic conditions was noted in the Botanical Garden at the station No. 54. The Botanical Garden, which covers an area of 8 ha, lies within the lichen desert characterized by a significant degree of air pollution. In 1993, six lichen species were observed on the dried remains of the tree *Prunus armeniaca* at the height of 0,5-2 m (this is an exception in this investigation, when the lichens found on tree remains were taken into consideration). Several months after a large-scale sanitary felling of the surrounding trees (within the Garden) in 1994, the lichen thalli were devastated and only the species *L. hagenii* and *Hypogymnia physodes* were noted in the winter of 1995.

Conclusions

The distribution of indicator-lichens provided the basis for establishing different air pollution zones in the studied Belgrade area. The main criterion for determining species-indicators was the frequency of epiphytic lichens both throughout the investigated area and in the typical urban areas. The division into three zones is comparatively rough, considering that only a small number of lichen representatives occurred in the urban area and that the local ecological conditions were dissimilar.

Acknowledgements

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Table 1: Distribution abundancy, and frequency of lichen species at 103 sites in the investigated Belgrade area.

Site (see Fig. 1)	*Amandinea punctata* (Hoffm.)Coppins &Scheideg.	*Lecanora hagenii* (Ach.) Ach.	*Physcia adscendens* (Fr.) Oliv.	*Phaeophyscia orbicularis* (Necker) Moberg	*Parmelia sulcata* Taylor	*Lepraria incana* (L.) Ach.	*Hypogymnia physodes* (L.) Nyl.	*Lecanora conizaeoides* Nyl. ex Crombie	*Physcia tenella* (Scop.) DC..	*Xanthoria parietina* (L.) Th.Fr.	*Evernia prunastri* (L.) Ach.	*Opegrapha herbarum* Mont.	*Physconia grisea* (Lam.) Poelt	*Candelariella xanthostigma* (Ach.) Lettau	*Parmelina tiliacea* (Hoffm.) Hale	*Parmelia saxatilis* (L.) Ach.	*Pertusaria coccodes* (Ach.) Nyl.	*Cladonia* Hill ex Browne	*Physcia stellaris* (L.) Nyl.	*Lecania dubitans* (Nyl.) A.L.Sm.	*Melanelia glabratula* (Lamy) Nyl..	*Physcia caesia* (Hoffm.) Furnr.	Number of species
1	-	-	1	2	2	1	1	-	-	2	-	-	-	-	-	-	1	-	-	-	-	-	7
2	2	2	-	3	3	3	3	-	-	1	-	-	3	2	2	-	-	1	-	-	-	1	12
3	3	-			2	1	1	1	-	2		2	3	2		-	-	-	1	-	-	-	15
4	-	-	-	-	1	1	1	-	-	-	-	-	-	1	-	-	1	1	-	-	-	-	6
5	1	-	2	1	1	1	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	7
6 •	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	1
	1	-	2			1	1	1	1	-	-	-	-	-	-	-	-	-	3	-	-	-	10
8 •	1	-	1	1	-		-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	5
9 •	3	1	1	-	2		-	-	-	-	-	2	3	3	1		1	-	-	-	1	-	12
10	2	1	-	-	2	1	2	1	-	-	-	-	-	-	-	-	1	1	-	-	-	-	8
11	1	-	2	1		-	-	1	1	1	-	-	-	-	-	1	-	-	-	1	-	-	9
12	1	-	2	1	2	1	1	-	-	1	2	-	-	-	1	1	-	1	-	-	1	-	12
13	3	-	3	3	3	2	1	-	-	-	2	-	-	-	-	-	-	1	-	1	-	-	9
14	-	-	2	1	2	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	5
15	2	-	2	-	-	1	2	-	-	-	1	1	-	-	-	1	-	-	-	-	-	-	7
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17	-	3			-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
18	2	-	2	-	-	-	-	1	2	1	-	-	-	-	-	-	-	-	-	-	-	-	5
19		-	2	2	1	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	6
20	1	-	1	1	-	-	-	1	2	1	-	-	-	-	-	-	-	-	-	-	-	-	6
21	1	-	1	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
22	1	-	2	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
23	-	1	-	-	-	2	2	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	4
24	-	2	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2
25	-	1	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	3
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30	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
31	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
32			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
33				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
34	1	1	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
35	1	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
36	1		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
37 •	1	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
		-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
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41	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
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68		-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		2
69		-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		1
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84 •		-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		2
85		1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		1
86		1	-	1	-	-	2	2	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-		5
87		3	-	1	-	-	-	-	-	1	-	1	2	-	-	-	-	-	-	-	-	-	-	-		5
88		-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		1
89 •		-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		1
90		1	-	1	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		3
91		2	1	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		3
92 •		-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		1
93		1	-	1	2	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-		5
		-	1	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		4
		2	1		2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		5
96 •		1	-		-		-	2	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-		5
97		2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		2
98		1	1	2		-	2	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-		6
99		1	-	-	-	1	2	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		5
100		1		1	-	2	-	-	-	-	-	-	-	-	1		-	1	-	-	-	-	-	-		7
101 •			-	-	-	-	-	-	1	-	-	-	2		-	1	1	-	-	-	-	-	-	-		6
102 •		1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		1
103		1	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		2

Species frequency

65	48	48	31	26	23	20	18	12	12	8	8	7	6	6	5	5	5	2	2	2	2

The stations in the urban milieu accounting for % of the total number of its records),

51 %	65 %	51 %	33 %	36 %	29 %	26 %	44 %	50 %	25 %		13 %	14 %

	Dark cells show the number of the stations lying in green areas
•	Dot-marked num. signify the stations where ep.lichens were found up to the height of 0,5m only

Table 2:

Caloplaca cerinella (Nyl.) Flagey	13
Candelariella aurella (Hoffm.) Zahlbr.	12
Candelariella vitellina (Hoffm.) Mull. Arg.	15
Chrysothrix candelaris (L.) Laundon	39
Cladonia coniocraea (Flk.) Vain.	12
Cladonia fimbriata (L.) Fr.	12
Flavoparmelia caperata (L.) Ach.	12
Hypogymnia tubulusa (Schaerer) Havaas	13
Lecanora carpinea (L.) Vainio	13
Lecanora varia (Hoffm.) Ach.	58
Lecidea Ach.	11
Melanelia exasperatula (Nyl.) Essl.	101
Melanelia glabratula (Lamy) Essl.	9
Pertusaria amara (Ach.) Nyl.	12
Physcia dubia (Hoffm.) Lettau	98
Physconia distorta (With.) Laundon	7
Physcia aipolia (Ehrh. ex Humb.) Furnr.	9
Punctelia subrudecta (Nyl.) Krog	9
Ramalina Ach.	99
Scoliciosporum chlorococcum (Graewe ex Stenh.)	56
Xanthoria candelaria (L.) Th. Fr.	3