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Air quality lichen monitoring at three selected urban areas in the Southern Serbia

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***Abstract*:**

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The results of a study using epiphytic lichens as bioindicators, on teritory of three different urban areas in the Southern Serbia (Leskovac, Vlasotince, Lebane) are reported. The analysis of samples from 142 investigated points indicates presence of 53 lichens taxa. The aim of the study is to present the difference in air quality over a certain time interval. Using the Index of Atmospheric Purity- IAP values, it has been found that there are different air pollution zones: „normal" zone, „struggle" zone and „lichen desert" zone. The comparison of the results obtained in 2002 and 2013 in Vlasotince indicates the presence of „normal" zone in 2002 but, in 2013, the „normal zone" area was completely replaced with the „struggle" zone. In Leskovac, unlike the previous studies, a slightly narrowing "lichen desert" zone is noticed. In Lebane, there is a presence of all lichen zones.

Key words: Biomonitoring, Serbia, Leskovac, Vlasotince, Lebane

***Apstrakt*:**

Stamenković, S., Djekić, T., Ristić, S., Novković, V., Mitrović, T., Marković, M.: ***Lišajski monitoring kvaliteta vazduha određenih urbanih područja južne Srbije. Biologica Nyssana, 7 (1), Septembar 2016: 19-29.***

Istraživanja kvaliteta vazduha korišćenjem lišaja kao bioindikatora sprovedena su na teritoriji tri različita urbana područja južne Srbije- Leskovac, Vlasotince i Lebane. Analiza uzoraka sa 142 istraživane tačke, ukazuje na prisustvo 53 lišajskih taksona. Cilj ovog istraživanja je da prikaže promene kvaliteta vazduha koje su nastale u određenom vremenskom periodu. Korišćenjem vrednosti indeksa atmosferske čistoće, konstantovano je prisustvo različitih zona zagađenja vazduha: „normalna" zona, zona „borbe" i zona „lišajske pustinje". Poređenje rezultata dobijenih 2002. i 2013. godine u Vlasotincu, ukazuju na prisustvo „normalne" zone u 2002. godini, međutim 2013. godine oblast „normalne" zone je u potpunosti zamenjena zonom „borbe". Na području Leskovca, razlika se ogleda u blagom suženju zone „lišajske pustinje". U Lebanu je uočeno prisustvo sve tri zone lišajske indikacije.

Key words: Biomonitoring, Srbija, Leskovac, Vlasotince, Lebane

Introduction

The air quality is getting worse all over the world. The strongest effects are felt in urban areas. Air pollution continuously increases, suggesting the need for timely detection, quantification and determination of levels of atmospheric pollution and introduction of monitoring system. Biological monitoring is based on the assumption that changes in the environment affect the indicator organisms and these changes can be effectively used as an early warning signal for detecting of environmental changes (Garty, 2001). Lichens are used in the biomonitoring studies because they are one of the most sensitive and valuable biomonitors of atmospheric pollution (Sujetoviene, 2015).

Lichens are symbiotic organisms composed of a fungus and an alga, usually either a cyanobacterium or green algae. It is estimated that there are approximately 25000 species of lichens (Chapman, 2009). These unique organisms have a number of specific properties and therefore can be used for different purposes. Changes in epiphytic lichen diversity are used as indicators of environmental conditions and have been widely applied in air quality assessments and monitoring programs around the world (Llop et al., 2012). They are very good indicators of air quality. In the last decade of the twentieth century, a more intense use of epiphytic lichens as bioindicators on the territory of the Republic of Serbia began (Milić, 1980; Savić, 1991; 1997; 1998; Stamenković, 1992; Milić & Blaženčić, 1993; Todorović, 1995; Cvijan et al., 1995; 1997; 2008; Stamenković, 1995; 1996; 1997; 1998; 2002; Cvijan & Stamenković, 1996a; 1996b; Stanković et al., 1999; Pejčinović, 2000; Stamenković & Cvijan, 2002; 2003; 2004; 2010; Stamenković et al., 2010; 2012; Stamenković et al., 2013a; 2013b; Jevtić, 2013; Novković, 2013).

This research is intended to present the results of the air quality on selected urban ecosystems and contribute the knowledge in biogeography and diversity of lichens on the territory of the Republic of Serbia and create the basis for the evaluation of lichens as indicators of the investigated urban territory. This is of great importance because there are no continuous physical and chemical measurements of air quality in these areas and this kind of monitoring is the only indicator of the air quality in urban conditions in the selected territory.

Material and methods

Sample location

The Southern Serbia includes Jablanica district. The administrative centre of the district is the town of Leskovac, the biggest settlement in the Southern Serbia. This is the town with around 65289 inhabitants. The mean annual temperature is 10.7 °C and the mean annual rainfall is 591.6 mm. The most frequent winds are north, northwest and south (Republic Hydrometeorological Service of Serbia). Leskovac has got a developed textile, chemical and pharmaceutical industry.

The town of Vlasotince is located in the southeastern part of Serbia, in the area of middle and bottom basin of the river Vlasina. The town has a population of 15882 people. The mean annual temperature is 11.8 °C and the mean annual rainfall is 724.3 mm, which is much higher than in the surrounding towns. East – west is the most common direction of movement of the winds (Republic Hydrometeorological Service of Serbia).

Fig. 1. Geographical position of investigated region - investigation region is framed.

The town of Lebane is an area which is characterized by extremely poor infrastructure, financial, economic and human resources. This is a small town having about 9272 inhabitants. The climate is moderate continental. The mean annual temperature is 10.2 °C and the mean annual rainfall in the vegetation period is 349 mm. The highest mean

Table 1. Substrates in the three different surveys (the cells are filled with serial number of the investigated points)

	Location and time of collection			
Supstrate (Plant species)	Vlasotince 2002	Vlasotince 2013	Leskovac 2002	Lebane 2013
Acer campestre	–	–	1	–
Carpinus betulus	–	2	–	–
Fraxinus excelsior	–	–	6, 29, 35	–
Fraxinus sp.	–	–	–	7
Juglans regia	2, 5, 8, 10, 11	7	3, 4, 11, 21, 22	6, 9
Malus domestica	–	10, 11, 13	15, 23	–
Morus alba	–	–	18, 34	17
Platanus acerifolia	–	–	33	–
Populus alba	1	–	–	–
Populus deltoides	4, 6, 7, 9, 13, 16	1, 4	5, 10, 19, 25, 30, 32, 36, 39	–
Prunus armeniaca	–	–	8, 13	–
Prunus avium	–	3, 12	20, 24	10
Prunus domestica	3	8, 14	–	4, 12, 16, 18, 19, 22
Pyrus communis	–	–	12, 28, 31	–
Quercus ceris	–	–	–	1, 2, 3, 8, 11, 14, 15, 24
Robiania pseudoacacia	–	–	7, 27	13, 20
Tilia argentea	–	–	–	–
Tilia plathyphyllos	12, 15	5, 6, 9	–	–
Tilia sp.	–	–	–	5, 21, 23

wind speed from the north-northwest is 3.5 m/s, and the least is 1 m/s, from the northeast direction (Republic Hydrometeorological Service of Serbia).

Bioindication of air quality using lichens, as well as the physical and chemical measuring of air pollution have not been done in Lebane until now. Bioindication in Vlasotince was made in 2002 and now.

The Institute of Public Health in Leskovac controls physicochemical measuring of the level of air pollution since 2004. Bioindication of air pollution in Leskovac was made in 2002 and 2008.

Sample collection

Epiphytic lichens are determined and collected from the bark of various species of trees at the level of 1.5- 2 m above the ground, exclusively from the trunks angled no higher than 5º. Lichens were collected from 142 investigated points on the territory of the Southern Serbia. Lichen materials were collected since 2002 to 2013. Points of investigation are located in urban part of three different towns in the Southern Serbia. Lichen samples were collected from the bark of various species of trees (**Tab. 1**).

The Voucher specimens of the lichens were determined and deposited in the lichenological herbarium (under designation L; 1-9 HMN) of the Department of Biology and Ecology, Faculty of Sciences and Mathematics, University of Niš, Serbia.

Determination of collected lichen species was done by using a few sources (Dobson, 2005; Wirth, 1995). Determination of plant species was done by using "Flora of Serbia" (Josifović, ed., 1970-1977). The nomenclature of plant species follows Euro+Med Plant Base (http://www.emplantbase.org).

Method description

The method of lichen indication of air quality means identifying, collecting, detecting and mapping the lichens and calculation of the Index of Atmospheric Purity (IAP) and it is based on determination of the zones of different degrees of air quality. Investigation points have been noted and IAP values for each point calculated.

In this research, we were using the numeric method known as the **I**ndex of **A**tmospheric **P**urity - IAP (Kricke & Loppi, 2002):

Table 2. Epiphytic lichen flora with values of frequency for each investigated point in the Southern Serbia

Taxon	Place/ Time	Investigated point	Frequency (%)
***Amandinea* sp.**	Leskovac/ 2002	28	2.56
Amandinea punctata (Hoffm.) Coppins & Scheid.	Leskovac / 2002	1, 8, 29, 30, 32, 33, 36	20.48
	Leskovac / 2008	25, 26, 28, 40, 41, 45, 46, 48, 49	18.37
	Vlasotince / 2002	7, 10, 12, 16	25.00
	Lebane / 2013	2, 11	8.33
Arthonia punctiformis Ach.	Lebane / 2013	19	4.16
Caloplaca cerina (Hedw.) Th. Fr.	Vlasotince / 2002	6, 10	12.50
***Caloplaca* sp.**	Leskovac / 2002	9, 14, 26	7.68
	Vlasotince / 2002	3, 16	12.50
Candelariella aurella (Hoffm.) Zahlbr.	Leskovac / 2002	11, 14, 19, 20, 32	12.80
Candelariella vitellina (Hoffm.) Müll.	Vlasotince / 2013	7	7.14
Candelariella xanthostigma (Pers. ex Ach.) Lettau	Leskovac / 2002	1, 4, 9, 19, 26, 28, 29	12.80
	Leskovac / 2008	2, 9, 15, 22, 25, 26, 27, 28, 31, 36, 40, 41, 45, 46,	34.69
	Vlasotince / 2002	2, 13, 14, 16	25.00
	Vlasotince / 2013	1, 9, 12, 13	28.57
	Lebane / 2013	1, 3, 4, 5, 9, 11, 12, 14, 16, 17, 19, 21, 23, 24	58.33
***Candelariella* sp.**	Vlasotince / 2002	2	6.25
Evernia prunastri (L.) Ach.	Leskovac / 2002	1, 29, 32	12.80
	Leskovac / 2008	27, 28, 29, 45, 46, 47, 48, 49	16.33
	Vlasotince / 2002	5, 9	12.50
	Vlasotince / 2013	2	7.14
	Lebane / 2013	1, 2, 8, 11, 12, 16, 19, 21, 22, 24	41.66
Flavoparmelia caperata (L.) Hale	Leskovac / 2002	37	2.56
	Leskovac / 2008	47, 48	4.08
	Lebane / 2013	1, 2, 8, 11, 12, 14, 16, 19, 21, 22	41.66
***Gyalecta* sp.**	Vlasotince / 2002	16	6.25
	Vlasotince / 2013	10	7.14
***Graphis* sp.**	Vlasotince / 2002	3	6.25
Hypogymnia physodes (L.) Nyl.	Leskovac / 2002	37, 38	5.12
	Leskovac / 2008	36, 48	4.08
	Lebane / 2013	4, 6, 12	12.50
Lecanora allophana (Ach.) Nyl.	Vlasotince / 2002	2, 5, 7, 8, 9, 10, 12	43.75
Lecanora argentata (Ach.) Röhl.	Leskovac / 2002	9, 34, 36	10.24
	Leskovac / 2008	28	2.04
	Vlasotince / 2002	2, 4, 9, 10	25.00
Lecanora carpinea (L.) Vain.	Vlasotince / 2002	4, 9, 10, 12	25.0
Lecanora glabrata (Ach.) Malme	Vlasotince / 2002	5, 10, 12	18.75
Lecanora intumescens (Rebent.) Rabenh.	Leskovac / 2002	3, 9, 10, 14, 30, 34	17.92
	Vlasotince / 2002	2, 4, 5, 7, 8, 9, 10, 12, 13	56.25
Lecanora muralis (Schreb.) Rabenh.	Vlasotince / 2002	2, 8, 9	18.75
Lecanora pulicaris (Pers.) Ach.	Leskovac / 2002	22	5.12
	Leskovac / 2008	28	2.04
	Vlasotince / 2002	2, 4, 5, 8, 9	31.25
***Lecanora* sp.**	Leskovac / 2002	1, 8, 11, 14, 18, 19, 26, 28, 29, 32, 35, 36, 37, 39	42.18
	Leskovac / 2008	22, 28, 39, 45, 46	10.20
	Vlasotince / 2002	3, 11	6.25
	Vlasotince / 2013	2, 7, 9	21.43
***Lecidea* sp.**	Leskovac / 2008	47, 48	4.08
Lecidella elaeochroma (Ach.) M. Choisy	Leskovac / 2002	1, 2, 6, 8, 16, 17, 24, 29, 30, 31	30.72
	Vlasotince / 2002	12, 13	12.50
***Lecidella* sp.**	Leskovac / 2008	47	2.04
Lepraria aeruginosa (Ach.) Turner	Lebane / 2013	11	4.16
Lepraria incana (L.) Ach.	Leskovac / 2008	28	2.04
	Lebane / 2013	10, 16, 22	12.50
Melanohalea elegantula (Zahlbr.) O. Blanco et al.	Leskovac / 2002	37, 38	5.12
Melanohalea exasperata (De Not.) O.Blanco et al.	Leskovac / 2002	38, 39	5.12
	Vlasotince / 2002	1, 2, 8	18.75
Melanohalea exasperatula (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch	Leskovac / 2002	1, 29	7.68
Melanelixia glabra (Schaer.) O. Blanco et al.	Leskovac / 2002	1	5.12
	Leskovac / 2008	36	2.04
Melanelixia glabratula (Lamy) Sandler Berlin & Arup	Leskovac / 2002	1, 2, 29	7.68
	Leskovac / 2008	27, 28, 47, 49	8.16
	Vlasotince / 2002	1	6.25

Continuation of ***Table 2***

Taxon	Place/ Time	Investigated point	Freque
Melanelixia subargentifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch	Lebane / 2013	18, 19, 21	12.50
Melanelixia subaurifera (Nyl.) O.Blanco et al.	Leskovac / 2002	1	5.12
	Leskovac / 2008	47, 48	4.08
	Lebane / 2013	1, 2, 8, 11, 12, 14, 16, 24	33.33
***Melanelia* sp.**	Leskovac / 2002	2, 20, 28	7.68
	Leskovac / 2008	4	2.04
	Vlasotince / 2002	1, 2	12.50
	Vlasotince / 2013	2, 6	14.29
***Ochrolechia* sp.**	Vlasotince / 2013	11	7.14
Parmelia sulcata Taylor	Leskovac / 2002	1, 2, 7, 8, 16, 20, 24, 27, 28, 29, 33	33.28
	Leskovac / 2008	15, 36, 39, 47, 48	10.20
	Vlasotince / 2002	1, 3, 5, 8, 9, 10, 16	43.75
	Vlasotince / 2013	2, 3, 4, 5, 13, 14	42.86
	Lebane / 2013	1, 4, 6, 17, 18, 19, 20, 21, 22, 23, 24	45.83
Parmelia tiliacea (Hoffm.) Ach.	Leskovac / 2002	1, 3, 32	7.68
	Leskovac / 2008	4, 14, 27, 28, 37, 48	12.24
	Lebane / 2013	5, 21, 23	12.50
Parmelina pastillifera (Harm.) Hale	Leskovac / 2002	37, 38, 39	7.68
	Vlasotince / 2002	8	6.25
Parmelina quercina (Willd.) Hale	Vlasotince / 2002	3, 13	12.50
	Lebane / 2013	3, 8, 14, 15	16.66
Phaeophyscia orbicularis (Neck.) Moberg	Leskovac / 2002	1, 2, 3, 4, 5, 6, 8, 10, 11, 12, 13, 15, 16, 18, 19, 20,	56.32
	Leskovac / 2008	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 14, 15, 16, 17, 19, 21,	79.59
	Vlasotince / 2002	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 14, 15	81.25
	Vlasotince / 2013	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	100.00
	Lebane / 2013	1, 2, 3, 5, 8, 9, 10, 14, 16, 19, 22	45.83
Physcia adscendens (Fr.) H. Olivier	Leskovac / 2002	1, 3, 8, 10, 11, 12, 19, 20, 28, 29, 30, 32, 33	40.96
	Leskovac / 2008	1, 2, 3, 4, 5, 6, 7, 8, 9, 12, 13, 14, 15, 16, 18, 19,	81.63
	Vlasotince / 2002	1, 4, 6, 8, 9, 10, 11, 13, 16	56.25
	Vlasotince / 2013	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	100.00
	Lebane / 2013	2, 5, 6, 9, 10, 11, 12, 13, 15, 17, 19, 22, 24	54.16
Physcia aipolia (Ehrh. ex Humb.) Fürnr.	Leskovac / 2002	29	5.12
	Vlasotince / 2002	8, 11	12.50
	Lebane / 2013	3	4.16
Physcia stellaris (L.) Nyl.	Leskovac / 2002	1, 3, 14, 20, 32	10.24
	Leskovac / 2008	28, 29, 48, 49	8.16
	Vlasotince / 2002	6, 8, 13	18.75
Physcia tenella (Scop.) DC.	Leskovac / 2002	1, 7, 20, 28, 29	17.92
	Leskovac / 2008	48	2.04
	Vlasotince / 2002	4, 8, 11	18.75
Physconia enteroxanta (Nyl.) Poelt	Leskovac / 2002	1	7.68
	Leskovac / 2008	48	2.04
	Vlasotince / 2013	6	7.14
	Lebane / 2013	2, 4, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 19, 21, 23	62.50
Physconia grisea (Lam.) Poelt	Leskovac / 2002	1, 25	10.24
	Leskovac / 2008	27, 28	4.08
	Vlasotince / 2002	1, 4, 5, 6, 10	31.25
	Lebane / 2013	2	4.16
Pleurosticta acetabulum (Neck.) Elix & Lumbsch	Leskovac / 2002	39	2.56
	Leskovac / 2008	28	2.04
	Lebane / 2013	7, 24	8.33
Ramalina calicaris (L.) Röhl.	Lebane / 2013	12, 19, 22	12.50
Ramalina farinacea (L.) Ach.	Leskovac / 2002	38	2.56
***Ramalina* sp.**	Leskovac / 2002	38, 39	5.12
Usnea hirta (L.) Weber ex F.H. Wigg.	Leskovac / 2002	37	2.56
Xanthoria parietina (L.) Th. Fr.	Leskovac / 2002	1, 2, 5, 8, 10, 14, 16, 19, 20, 25, 29, 36	35.84
	Leskovac / 2008	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 18,	83.67
	Vlasotince / 2002	1, 4, 5, 6, 7, 8, 10, 12, 14, 16	62.50
	Vlasotince / 2013	1, 3, 4, 5, 6, 8, 9, 10, 13, 14	71.43
	Lebane / 2013	1, 2, 3, 4, 5, 6, 8, 9, 10, 12, 13, 14, 15, 17, 18, 20,	83.33

$$IAP = \frac{1}{10}\sum_{i=1}^{n}(Q_i \times f_i)$$

where ***n*** = a number of species on the spot, ***f*** = coefficient which represents the frequency and cover of each species, and ***Q*** = the ecological index of each species, i.e. the mean value of other lichen species growing with the species under study within the surveyed area.

Results and discussion

The analysis of samples from the described localities indicate the presence of 53 lichen taxa on 142 investigated points from the territory of the Southern Serbia (**Tab. 2**). The most frequent species were: *Phaeophyscia orbicularis*, *Xanthoria parietina*, *Physcia adscendens* and *Parmelia sulcata.* The highest frequency of these lichen species were found in all three investigated urban ecosystems. The least frequent species were: *Amandinea* sp., *Ramalina farinacea* and *Usnea hirta.* These lichen species were found on only one of all investigated localities, in Leskovac in 2002, having a low frequency 2.56%.

The calculated IAP values are very variable and they are between 0 and 47 **(Tab. 3)**.

According to the calculated IAP values, we got borders of the lichen zones of different air pollution levels in Lebane (**Fig. 2**). Also, we got a picture which presents a comparison of moving the lichen zones in relation to the time of the survey in Leskovac (**Fig. 3**) and Vlasotince (**Fig. 4**).

On the basis of these results and according to Schulze (S c h u l z e et al., 2005), we can see that the investigated points in central part of urban ecosystems are included in "lichen desert" zone, characterized by the presence of species that are good indicators of air pollution**.** This indicates a high level of air pollution. The presence of this zone is recorded in most parts of urban areas of the Southern Serbia. In Leskovac, we found presence of this zone in 2002 and 2008 (**Fig. 3**). In Lebane, three points belong to the "lichen desert" zone. In Vlasotince, this zone did not exist in the year of 2002, but it is present in the year of 2013. (**Fig. 4**).

Many investigated points belong to the "struggle" zone. In this zone, the air quality is slightly better than in the previous one. The maps clearly show that this zone usually includes peripheral parts of the city.

Smaller parts of the towns belong to "normal zone" which is detected in Lebane and Leskovac in the years of 2002 and 2008. We can also notice an interesting situation in Vlasotince, where we detected the "normal zone" in the year of 2002 but, after eleven years, this zone does not exist anymore.

Such a picture of the different air pollution levels in the investigated areas is a logical consequence of air pollution and the mutual influence of microclimate, substrate and geophysical features, as well as the distribution of areas and objects. Composition of lichens community shows certain deviations.

The urban area of Lebane includes all air quality zones. There is a relatively high level of air pollution, caused by the main road intersecting the center of the town and the former textile factory. Agricultural land occupies 53% of the total area of the municipality of Lebane, so, in this area, the presence of lichen is less probable.

In 2002 and 2008, the bioindication of air quality by using lichens, in the area of Leskovac was analyzed and compared. Unlike in 2002, the boundaries of the "lichen desert" moved in 2008. There was a slight reduction of "lichen desert" zone. However, comparing to the year of 2002, in 2008, we can see a reduced number of lichen species of all types of the thallus morphology. Other zones did not show significant changes in their limits, but the composition of the lichen species shows discrepancies.

In Leskovac concentrations of sulfur dioxide (SO_2), nitrogen oxides (NOx), aero sediments and heavy metals (Cd, Pb, Zn) in the suspended particles have been decreasing (Institute of Public Health Leskovac), which might have to do with the closing down of many industrial facilities.

The reduction of the "lichen desert" zone might be correlated with a decrease of pollutants (sulfur dioxide, nitrogen oxides, aero sediments and heavy metals in suspended particles), while the reduced number of registered taxa might be linked to an increasing concentration of soot and heavy metals in the sediments.

By comparing the results of bioindication of air quality by using lichens, in the Vlasotince area in 2002 and in 2013, we found that the borders of the zones with different levels of air pollution using lichens as bioindicators in Vlasotince are different in 2002 and 2013. Investigation conducted in Vlasotince in 2002 showed the presence of "struggle zone" and "normal zone". Eleven years later, in the investigated area, there aren't any records of the presence of "normal zone". "Normal" zone from 2002 is commuted into a "struggle zone" in 2013, and the "struggle zone" area has changed into "lichen desert" zone **(Fig. 4)**. Compared to 2002, the absence of a number of taxa in 2013 provides the evidence for a considerably reduced diversity, which is supported by the altered frequency of some species' presence.

This indicates that, in relation to the resistant species, coverage of the sensitive ones is reduced. Domination of the more resistant species and a reduced total diversity of the lichen flora are indicating an increased air pollution ratio in Vlasotince within the last 11 years.

Tabele 3. Values of IAP for every investigated point in the Southern Serbia

L/t	Ip	IAP	L/t	Ip	IAP	L/t	Ip	IAP	L/t	Ip	IAP
	1	**38**		1	**6**		1	**17**		1	**4**
	2	**4**		2	**6**		2	**19**		2	**5**
	3	**3**		3	**6**		3	**7**		3	**3**
	4	**1**		4	**7**		4	**19**		4	**4**
	5	**3**		5	**7**		5	**14**		5	**5**
	6	**1**		6	**8**		6	**14**		6	**3**
	7	**2**		7	**3**		7	**7**		7	**2**
	8	**4**		8	**10**		8	**24**		8	**2**
	9	**4**		9	**9**		9	**17**		9	**4**
	10	**8**		10	**5**		10	**28**		10	**3**
	11	**6**		11	**7**		11	**3**		11	**2**
	12	**1**		12	**7**		12	**11**		12	**3**
	13	**0**		13	**4**		13	**8**		13	**3**
	14	**9**		14	**7**		14	**3**		14	**3**
	15	**0**		15	**5**		15	**1**			
	16	**2**		16	**6**		16	**11**			
	17	**1**		17	**7**						
	18	**3**		18	**4**						
	19	**7**		19	**8**						
	20	**6**		20	**2**						
	21	**0**		21	**18**						
	22	**0**		22	**5**						
	23	**/**		23	**5**						
	24	**1**		24	**9**						
	25	**2**									
	26	**3**									
	27	**1**									
	28	**21**									
	29	**39**									
	30	**3**									
	31	**1**									
	32	**12**									
	33	**6**									
	34	**1**									
	35	**1**									
	36	**4**									
	37	**35**									
	38	**23**									
	39	**47**									

Leskovac/2002 | **Lebane/2013** | **Vlasotince/2002** | **Vlasotince/2013**

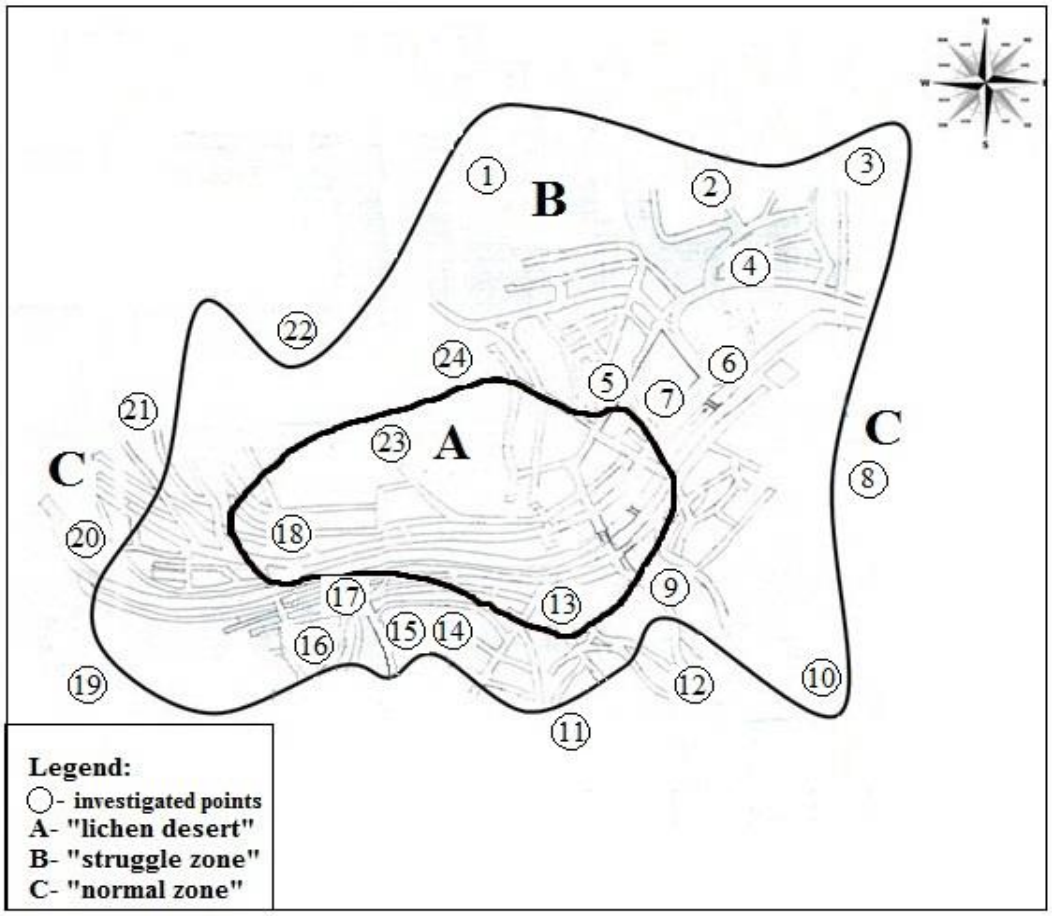

Fig. 2. Zones of different levels of air pollution in Lebane using lichens as bioindicators (Novković, 2013).

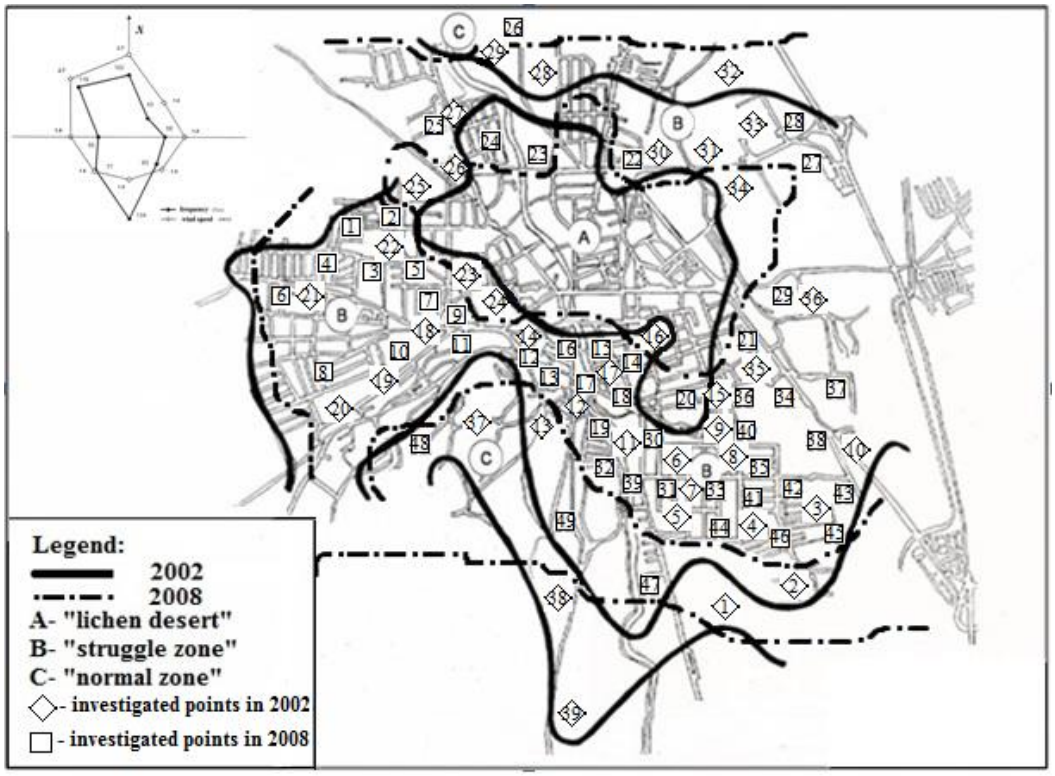

Fig. 3. Borders of the zones with different levels of air pollution using lichens as bioindicators in 2002 (Stamenković, 2002) and 2008 (Nikolić, 2008), with "wind rose" in Leskovac.

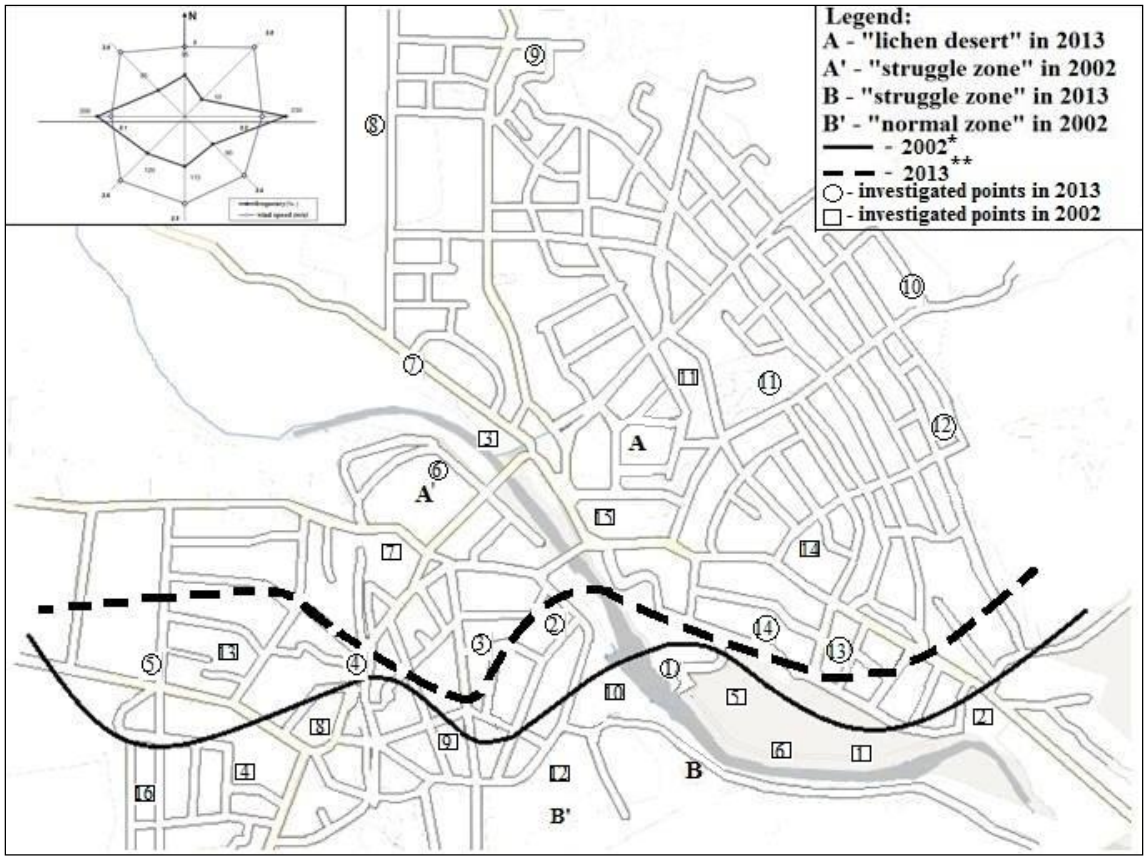

Fig. 4. The "wind rose" with the delimitation of different lichen indication zones in Vlasotince from investigations in 2002 (Stamenković, 2002) and 2013 (Jevtić, 2013).
*Delimitation of different lichen zones of indication in 2002; **Delimitation of different lichen zones of indication in 2013

Conclusion

The method used in this research on relatively simple and quick way provides an insight into the quality of the air on investigated area by calculating the index of atmospheric purity (IAP) based on the lichen diversity and abundance.

According to the calculated IAP values, we created a map of the zones of different air pollution levels in Lebane and maps which present comparison of lichen zones movement in different time periods in Vlasotince and Leskovac.

Due to the fact that during the last 11 years the level of air pollution has increased so, if we do not take measures of protection, it can be assumed that the trend of the further growth of pollution will continue.

This work is a mere contribution to the biomonitoring of air pollution i.e. air quality on the territory of the Southern Serbia.

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References

Chapman, A.D. 2009: Numbers of living species in Australia and the world. Australian Biological Resources Study (ABRS). Canberra. 80 p.

Cvijan, M., Todorović, B., Joksimović, V., 1995: Lichens as bioindicators of air pollution in the towns of Mali Zvornik and Aranđelovac, *Glasnik Instituta za botaniku i Botaničke bašte univerziteta u Beogradu*, 29: 175-186, Beograd.

Cvijan, M., Stamenković, S., 1996a: Bioindication of air pollution in the Niš area by use of lichens. *Ekologija* 31 (1), 151-157.

Cvijan, M., Stamenković, S., 1996b: Lignicolous lichens in the urban area of Niš town. *Archive of Biological Sciences*, 48 (3-4): 115-118, Belgrade.

Cvijan, M., Savić, S., Szabados, K., 1997: Lichens as bioindicators of air pollution in Belgrade area. *Ekologija*, 32 (1): 99-106.

Cvijan, M., Subakov-Simić, G., Krizmanić, J. 2008: Monitoring of the «lichen desert» in the Belgrade area (1980/81, 1991 and 2007). *Archive of Biological Sciences*, 60 (2), 215-222.

Dobson, F. S. 2005: Lichens. Richmond, Richmond Publishing Co. Ltd.

Garty, J., Tamir, O., Hassid, I., Eshel, A., Cohen, Y., Karnieli, A., Orlovsky, L. 2001: Photosynthesis, chlorophyll integrity and spectral reflectance in lichens exposed to air pollution. *Journal of environmental quality*, 30: 884-893.

Gombert, S., Asta, J., Seaward, M. R. D. 2004: Assessment of lichen diversity by index of atmospheric purity (IAP), index of human impact (IHI) and other environmental factors in an urban area (Grenoble, southeast France). *Science of the total environment*, 324: 183-199.

Hawksworth, D. L. and Rose, F. 1970: Qualitative scale for estimation sulfur dioxide air pollution in England and Wales using epiphytic lichens. *Nature*, 227: 145-148.

Institute of Public Health Leskovac. http://www.zzjzle.org.rs/

Jevtić, M., 2013: Promene lišajskih zona biološke indikacije kvaliteta vazduha u Vlasotincu u periodu 2002 – 2013. god. Master thesis (*in Serbian*). Prirodno-matematički fakultet. Niš.

Kricke, R., Loppi, S. 2002: Bioindication: the IAP approach. In: Nimis, P., Scheidegger, C. & Wolseley, P. (Eds.) Monitoring with lichens-monitoring lichens. Dordrecht, Kluwer Academic.

Llop, E., Pinho, P., Matos, P., Pereira, M.J., Branquinho, C. 2012: The use of lichen functional groups as indicators of air quality in a Mediterranean urban environment. *Ecological indicators*, 13: 215- 221.

Milić, M. 1980: BSc thesis - Lichens and air pollution in Belgrade. Senior Thesis *(in Serbian)*, Faculty of Biology, University of Belgrade.

Milić, M. and Blaženčić, J. 1993: The epiphytic lichenes in the city of Belgrade. *Glasnik Instituta za botaniku i Botaničke bašte Univerziteta u Beogradu*, 24-25: 83-96.

Nikolić, M. 2009: Monitoring životne sredine na urbanoj teritoriji grada leskovca u periodu od 2002 - 2008, Diplomski rad. Prirodno-matematički fakultet. Niš.

Novković, V. 2013: Lišaji kao pokazatelji kvaliteta vazduha u Lebanu. Master thesis (*in Serbian*). Prirodno-matematički fakultet. Niš.

Pejčinović, D. 2000: Lišajna flora Vranja i uže okoline, 6. Simpozijum o flori jugoistočne Srbije i susednih područja, Univerzitet u Prištini, Sokobanja, 39- 41 str.

Republic Hydrometeorological Service of Serbia. http://www.hidmet.gov.rs/

Savić, S. 1991: Promene u sastavu flore lišajeva kao bioindikatora aerozagadjenja na području Beograda za poslednjih deset godina. Senior Thesis *(in Serbian)*, Faculty of Biology, University of Belgrade, 87 pp.

Savić, S. 1997: Epifitski lišajevi kao bioindikatori aerozagadjenja na području Beograda. Master Thesis *(in Serbian)*, Faculty of Biology, University of Belgrade, 60 pp.

Savić, S. 1998: Epiphytic lichens as bioindicators of air pollution in the area of Belgrade. *Sauteria* 9, IAL 3 - Proceedings 331-340.

Schulze ED, Beck E, Muller-Hohenstein K. 2005. Plant ecology, Berlin⁄Heidelberg, Germany: Springer

Stamenković, S. 1992: Bioindikacija aerozagađenja lignikolnim lišajevima na području grada Niša. *Master thesis (in Serbian)*. Biološki fakultet. Beograd.

Stamenković, S. 1995: Lignikolna lišajska flora Prokuplja. *Ekologija*, 30(1-2): 41-46, Beograd.

Stamenković, S., 1996: Biological indication of air pollution in Vlasotince using lignicolous lichens. Acta biologica jugoslavica – serija D: *Ekologija*, 33 (1–2): 71–74. Belgrade.

Stamenković, S. 1997: Biological indication of air pollution in Prokuplje by means of lignicolous lichens. *Ekologija*, 32: 107-110. Belgrade.

Stamenković, S. 1998: Biological indication of air pollution in Vlasotince using lignicolous lichens, *Ekologija*, 33 (1-2): 71-74, Belgrade.

Stanković, S., Stanković, A., Pantelić, G. 1999: Zagađenost lišaja i mahovina Istočne Srbije prirodnim i veštačkim radionuklidima, Ekološka istina VII naučno-stručni skup o privrednim vrednostima i zaštiti životne sredine, Zaječar, 16. Zbornik radova.

Stamenković, S. 2002a: Indikacija aerozagađenja u urbanim centrima južne i jugoistočne Srbije korišćenjem lišajeva kao bioindikatora, *PhD Disseratation (in Serbian),* - Biološki fakultet, Univerzitet u Beogradu.

Stamenković, S. 2002b: Bioindication of air pollution in Pirot by use of lichens. *Ekologija*, 37 (1-2), 33-40, Belgrade.

Stamenković, S., Cvijan, M. 2002: Epiphytic lichens as bioindicator of air quality in Leskovac (southern Serbia). *Ekologija*, 37(1-2), 41-46, Belgrade.

Stamenković, S. and Cvijan, M. 2003: Bioindication of air pollution in Niš by using epiphytic lichens. *Archive of Biological Sciences*, 55: 133-140.

Stamenković, S., Cvijan, M. 2004: Using of epiphytic lichens for bioindication of air pollution in Vranje. *Archive of Biological Sciences*, 56 (3-4): 139-143. Belgrade.

Stamenković, S., Cvijan, M., 2010: Determination of air pollution zones in Knjaževac (southeastern Serbia) by using epiphytic lichens, *Biotechnology and Biotechnological equipment*, special edition-

online (2nd Balkan Conference on Biology, Plovdiv, Bulgaria, 2010), 278-283, Bulgaria

Stamenković, S., Cvijan, M., Aranđelović, M. 2010: Lichen as bioindicators of air quality in Dimitrovgrad (southeastern Serbia), *Archive of Biological Sciences*, 62 (3): 643-648, Belgrade, Serbia.

Stamenkovic, S., Djekić, T., Mitrović, T., Stojičić, D., Cvetković, V., Nikolić, M. 2012: Monitoring of air quality and „lichen desert" in the city of Leskovac (southeastern Serbia) in the period 2000-2011, Abstract book, IV congress of ecologists of the Republic of Macedonia with international participation, 106p, Skoplje, Makedonija (FYRM)

Stamenković, S., Mitrović, T., Cvetković, V., Krstić, N., Baošić, R., Marković, M., Nikolić, N., Marković, V., Cvijan, M. 2013: Biological indication of heavy metal pollution in the areas of Donje Vlase and Cerje (southeastern Serbia) using epiphytic lichens. *Archive of Biological Sciences*, 65(1): 151-159, Belgrade, Serbia.

Stamenković, S., Ristić, S., Đekić, T., Mitrović, T., Baošić, R. 2013a: Air quality indication in Blace (Southeastern Serbia) using lichens as bioindicators. *Archive of biological sciences*, 65 (3): 893-897.

Sujetoviene, G. 2015: Monitoring lichen as indicators of atmospheric quality. *Recent advances in lichenology*, 4: 87- 118.

Todorović, B. 1995: The lichens as bioindicators of air pollution in the towns Mali Zvornik and Aranđelovac. *Glasnik instituta za botaniku i botaničke bašte univerziteta u Beogradu*, 29: 175-186.

Vantova, I., Backor, M., Klejdus, B., Backorova, M., Kovacik, J. 2013: Copper uptake and copper-induced physiological changes in the epiphytic lichen *Evernia prunastri*. *Plant growth regulation*, 69: 1-9.

Wirth, V. 1995: Die Flechten Baden-Wurtembergs. Verbreitungsatlas, 1&2.

Wolterbeek, B. 2002: Biomonitoring of trace element air pollution: principles, possibilities and perspectives. *Environmental Pollution*, 120: 11-21.