

LICHENS AS BIOLOGICAL INDICATORS OF AIR QUALITY IN THE URBAN AREA OF KURŠUMLIJA (SOUTHERN SERBIA)

Svetlana S. Ristić^{1*}, Marijana M. Kosanić¹, Branislav R. Ranković¹,
Slaviša S. Stamenković²

¹University of Kragujevac, Faculty of Science, Department of Biology,
Radoja Domanovića 12, 34000 Kragujevac, Republic of Serbia

²University of Niš, Faculty of Sciences and Mathematics, Department of Biology and Ecology,
Višegradska 33, 18000 Niš, Republic of Serbia

*Corresponding author; E-mail address: risticsvetlanaaa@gmail.com

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ABSTRACT. In this work, we provided a first indication of Kuršumlja (town of Southern Serbia) air quality using epiphytic lichens known as bioindicators. The investigations were carried out from April to October 2014. The analysis of thalli samples (from 15 investigated points in Kuršumlja), indicates the presence of 42 lichens taxa from 23 genera. An assessment of air quality was made by using the Index of Atmospheric Purity (IAP) and Index of Human Impact (IHI). IHI values ranged between 15 and 36. IAP values ranged between 10 and 28. According to the IAP values, it has been found that there are three different air pollution zones: “normal“, “struggle“ and “lichen desert“. The latest characterize the majority of the urban area. The aim of this study is to formulate an indication of air quality using lichens as bioindicators on the basis of lichens diversity and frequency. This is of great importance because there are no continuous physical and chemical measurements of air quality in this area.

Key words: air quality, bioindication, lichens.

INTRODUCTION

Deterioration of air quality is noticeable worldwide. Air pollution is an essential problem in many urban areas in the world (EEA, 2014). European citizens often breathe air that does not meet European standards (EEA, 2014). Effects of air pollution are especially expressed in urban areas where there are the main sources of pollution (traffic, industry, anthropogenic activity etc.). Air pollution is the top environmental risk factor of premature death in Europe. Especially, it increases the incidence of a wide range of diseases and has many environmental impacts, damaging not only the population but also the vegetation and the ecosystem (EEA, 2014).

Lichens are cosmopolite, symbiotic organisms composed of fungi and photosynthetic organisms (generally green algae and cyanobacteria). About 17,000–25,000 species of known lichens species grow on Earth according to various estimations (cf. KIRK *et al.*, 2001; CHAPMAN, 2009). Lichens have a wide variety of proven and potential applications, that range

from their use as bioindicators to their use as possible sources of many bioactive compounds (KOSANIĆ and RANKOVIĆ, 2011).

The use of lichens as bioindicators provides a special viewpoint on the atmospheric environment (NIMIS *et al.*, 2002) and different bioindication methods are available based on their specific response (PAOLI *et al.*, 2015). A large number of species of these unique organisms is characterized by a great sensitivity to the impact of air pollution and for this reason, they can be used as indicators of air pollution.

Several studies have focused on the effect of pollution on urban areas (GOMBERT *et al.*, 2004; WASHBURN and CULLEY, 2006; BLASCO *et al.*, 2008; CALVELO *et al.*, 2009; KAEFFER *et al.*, 2011; STAMENKOVIĆ *et al.*, 2013a), using lichens as bioindicators especially in the southern and southeastern Serbia (CVIJAN and STAMENKOVIĆ, 1996; STAMENKOVIĆ, 1997; PEJČINOVIĆ, 2000; STAMENKOVIĆ and CVIJAN, 2002; STAMENKOVIĆ and CVIJAN, 2003; STAMENKOVIĆ and CVIJAN, 2004; STAMENKOVIĆ and CVIJAN, 2010; STAMENKOVIĆ *et al.*, 2010; STAMENKOVIĆ *et al.*, 2012; STAMENKOVIĆ *et al.*, 2013a; STAMENKOVIĆ *et al.*, 2013b).

The aim of this investigation is to (i) present the results of the air quality in an urban ecosystem and (ii) contribute to the knowledge in biogeography and diversity of lichens in the Republic of Serbia and (iii) create the basis for the evaluation of lichens as indicators of the investigated urban territory.

MATERIALS AND METHODS

Study area

This work was carried out in Kuršumlija (population 13,306, area of c. 952 km², SORS 2011), an urban area of Southern Serbia. Kuršumlija is a town located at an altitude of 383 m (above the sea level). The climate is moderate continental. The most frequent (prevailing) wind blows from the southwest direction of 310 ‰, followed by north 171 ‰ and the northeast direction 162 ‰. The “wind roses” in Kuršumlija area provides a graphical representation of these data (Fig. 1). The mean annual temperature is 11.6 °C. This value presents monthly average value for the year of 2014. The relative air humidity was 79%. The mean annual rainfall is 968.3 mm, which is much higher than in the surrounding towns (RHSS, 2014). The study area encompasses the urban part of Kuršumlija and a few agricultural fields remaining on the periphery of the city.

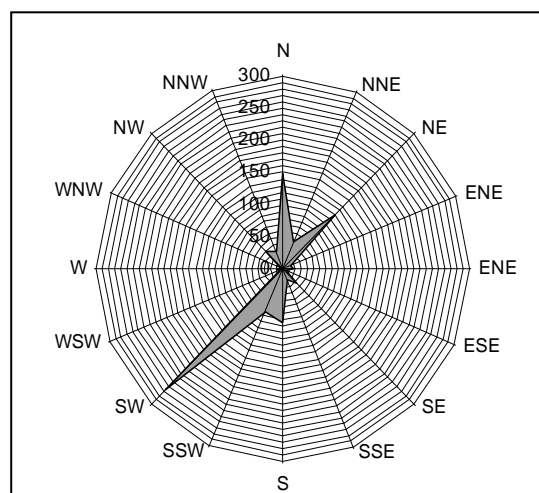


Figure 1. “Wind roses” in Kuršumlija area (RHSS, 2014).

Sample collection

The investigation was done from May 21 to September 8 in the year of 2014. Epiphytic lichens are determined and collected from the bark of various species of trees at 1.5-2.0 m above the ground, exclusively from the trunks angled no higher than 5°. The 15 investigated points were located exclusively in urban part of the in Kuršumlija town.

Lichen samples requiring microscopic observations were collected, cleared of substrate and then identified in the laboratory. Determining the essential characters of lichens was conducted using laboratory magnifying glass brand "PZO" (maximum magnification 85x, 10x minimum), and the light microscope brand "Biolam S-11" with the possibility of a maximum magnification of 1350x.

The voucher specimens of the lichens were determined and deposited in the lichenological herbarium of the Department of Biology and Ecology, Faculty of Science, University of Kragujevac, Republic of Serbia.

A few literature sources were used for identification of the collected lichen species (WIRTH, 1995; DOBSON, 2005), as well as indexfungorum.org and mycobank.org for arrangement of list of species.

Indication method description

The method of lichen indication of air quality consists of detecting, collecting, identifying and mapping the species and calculation of the Index of Atmospheric Purity (IAP). In this research the numeric method known as the **Index of Atmospheric Purity - IAP** (PIRINTSOS *et al.*, 1993; KRICKE and LOPPI, 2002) was calculated for each of investigated points:

$$\mathbf{IAP} = \sum f$$

where: f = coefficient which represents the frequency and the cover of each species studied within the surveyed area.

We also used method **Index of Human Impact - IHI** (GOMBERT *et al.*, 2004), which was proposed to characterize each investigated point by means of environmental parameters.

$$\mathbf{IHI} = \mathbf{U(T+D+E)}$$

where: **U**= urbanization (urban, suburban or rural areas); **T**= traffic (distance from a road); **D**= local developments (crop fields, green areas, housing sites, car parks); **E**= exposure (trees isolated, in rows or grouped).

Categories ('1' and '4') were established for each parameter to express a gradient of alteration (Tab. 1). IHI was calculated for each investigated point.

The aim of using these methods is to detect and quantify atmospheric pollution.

Table 1. Assessment of quantitative variables from general qualitative environmental variables (urbanization, traffic and local developments) by an increase of artificiality and from local environmental conditions (exposure) (GOMBERT *et al.*, 2004).

Parameters		
Urbanization (U)	Rural	Sub-urban and Urban
	1	4
Traffic (T)	Weak road exposure	High road exposure
	1	4
Local developments (D)	Crop fields, Green areas	Housing sites, Car parks, and roads
	1	4
Exposure (E)	Trees isolated or in rows	Trees grouped
	1	4

RESULTS AND DISCUSSION

Many authors in world have assessed air pollution effects indicated by epiphytic lichens in urban areas (PINHO *et al.*, 2008; 2009; PERLMUTTER, 2010; MUNZI *et al.*, 2014; PAOLI *et al.*, 2015). Our work is the modest contribution to this type of research carried out in Southern Serbia.

The research on 15 investigated points in Kuršumlija revealed the presence of 42 lichens taxa, from 23 genera:

Amandinea punctate (Hoffm.) Coppins & Scheid.
Candelariella vitelline (Hoffm.) Müll. Arg.
Candelariella xanthostigma (Ach.) Lettau
Evernia prunastri (L.) Ach.
Flavoparmelia caperata (L.) Hale
Graphis scripta (L.) Ach.
Hypogymnia physodes (L.) Nyl.
Hypogymnia tubulosa (Schaerer) Havaas
Lecanora allophana (Ach.) Nyl.
Lecanora argentata (Ach.) Malme
Lecanora carpinea (L.) Vain
Lecanora intumescens (Rebent.) Rabenh.
Lecanora pulicaris (Pers.) Ach.
Lecidella elaeochroma (Ach.) Choisy
Lepraria aeruginosa (F.H. Wigg.) Sm.
Lepraria incana (L.) Ach.
Melanohalea exasperate (De Not.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch
Melanohalea exasperatula (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch
Melanelixia fuliginosa (Fr. ex Duby) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch
Melanelixia glabra (Schaer.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch
Melanelixia subaurifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch
Melanelixia subargentifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch
Ochrolechia pallescens (L.) Massal.
Parmelia saxatilis (L.) Ach.
Parmelia sulcate Taylor

Parmelia tiliacea (Hoffm.) Hale
Parmelina pastilifera (Harm.) Hale
Parmeliopsis ambigua (Wulfen) Nyl.
Phaeophyscia orbicularis (Neck.) Moberg
Physcia adscendens (Fr.) H. Olivier
Physcia aipolia (Ehrh. ex Humb.) Fűrnr.
Physcia semipinnata (Leers ex J.F. Gmel.) Moberg
Physcia stellaris (L.) Nyl.
Physcia tenella (Scop.) DC.
Physconia distorta (With.) J.R. Laundon
Physconia enteroxantha (Nyl.) Poelt
Physconia grisea (Lam.) Poelt
Pseudevernia furfuracea (L.) Zopf
Ramalina farinacea (L.) Ach.
Usnea hirta (L.) Weber ex F.H. Wigg.
Xanthoparmelia stenophylla (Ach.) Ahti & D. Hawksw.
Xanthoria parietina (L.) Beltr.

The most frequent species (100%) were *Hypogymnia physodes* and *Physcia adscendens* (Tab. 2). *Parmelia sulcata* and *Xanthoria parietina* were characterized by frequencies of 93.33%. The rarest were *Lepraria* sp. and *Xanthoparmelia stenophylla*, which were found at only one of investigated localities, with a low frequency of 6.67%. Lichens were found mostly on different tree species - *Acer campestre* L., *Cornus mas* L., *Juglans regia* L., *Malus domestica* Borkh., *Robinia pseudoacacia* L., *Tilia platyphyllos* Scop. etc.

The calculated IAP values ranged between 10 and 28. IHI values ranged between 15 and 36 (Tab. 2). Based on calculated IAP, we established the distribution of the different air pollution zones in Kuršumlija (Fig. 2). The urban area of Kuršumlija includes all air quality zones: “lichen desert” zone, “struggle zone” and “normal zone”.

The presence of “lichen desert” zone indicates a high level of air pollution. The “lichen desert” zone included two investigated points (3 and 4) collocated in the central part of this urban ecosystem. These investigated points are characterized by low diversity of lichens and the lowest values of IAP. Lichen “struggle zone” included three investigated points (7, 8 and 9). The air quality is slightly better in this zone than in the previous one. It indicates that the air is moderately polluted in this zone. The greatest part of the town belongs to “normal zone”. This zone included ten investigated points (1, 2, 5, 6, 10, 11, 12, 13, 14 and 15). Lichen species noticed on these investigated points are distinguished by the higher diversity and IAP values.

Distribution of zones of different air pollution levels in the investigated area are a logical consequence of air pollution and the mutual influence of microclimate, substrate and geophysical features, as well as the type and distribution of urban areas and objects. The sources of air pollution in the town are relatively developed traffic in the centre of town and individual stakeholders. The Kuršumlija once had developed wood, textile and metal industry, which, which after a few decades of economic crisis got into a difficult situation and stopped working. Green areas are the best locations for lichens, therefore their diversity is the highest in the outskirts of town. Domestic activity, compared with the urbanization, may have some impact, but it can be almost negligible when compared to traffic (LLOP *et al.*, 2012). The lower lichen diversity in urban areas, is probably due to the drier city microclimate, compared to those of the rural and natural sites (LLOP *et al.*, 2012).

CONCLUSION

Kuršumlja is a small European town in Southern Serbia, without developed industry. Bioindication and physicochemical investigation of air pollution in Kuršumlja has not been done until now.

The method used in this research provides an insight into the quality of the air on investigated area by calculating IAP based on the lichen diversity and abundance. According to the calculated IAP values, we created the zones-map of different air pollution levels. The results indicate that it is necessary to reduce traffic in the downtown, redirect vehicles to transit routes which might contribute to improvement of air quality.

Our further investigations will be attended to the long-term air quality monitoring at local and regional level.

This work is a mere contribution to the biomonitoring of air pollution, i.e. air quality of Southern Serbia. Moreover, this work represents the only lichenological research conducted in this area.

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Table 2. Lichen species found on the researched area, the values of the coefficient *f*, the frequency (%) of each taxon and values of IAP and IHI on each of investigated points in Kuršumlja.

Taxon	Investigated point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	%
<i>Amandinea punctata</i>		0	1	0	0	1	0	1	0	1	0	0	0	0	0.3	0	33.33
<i>Candelariella vitellina</i>		0	0	0	0	1	0.4	0	0	0	0	0	0	0	0	0.4	20.00
<i>Candelariella xanthostigma</i>		1	0.3	0	0	1	1	1	0	0	1	0	1	1	1	0	60.00
<i>Evernia prunastri</i>		2	2	0	0	2	1	0	1	0	2	2	1	2	1	2	73.33
<i>Flavoparmelia caperata</i>		1	1	0	0	0	0.4	0	0.4	0	0	1	0	1	1	1	53.33
<i>Graphis scripta</i>		0	0	0	0	0	1	0	0.3	0	0	0	0	1	0	0.4	26.67
<i>Hypogymnia physodes</i>		3	3	1	1	3	2	1	1	2	2	2	1	2	2	2	100.00
<i>Hypogymnia tubulosa</i>		1	0	0	0	1	0	0	0	1	0.4	1	0	1	1	1	53.33
<i>Lecanora allophana</i>		0	0	0	0	0	0	0	0.4	1	0	0	0	0	0	0.3	20.00
<i>Lecanora argentata</i>		0	0	0	0	1	0.4	1	0	0	0	0	0	0	0	0	20.00
<i>Lecanora carpinea</i>		0	1	0	0.3	0	1	0	0	0	0.4	0	0	1	0	0.3	40.00
<i>Lecanora intumescens</i>		0	0	0	0.3	0	1	0	0.3	0	1	1	0.4	0	0.3	1	53.33
<i>Lecanora pulicaris</i>		0	0	0	0	1	0	0.4	0	0	0	0.4	1	0	0.3	0	33.33
<i>Lecidella elaeochroma</i>		0	1	0	0.1	0	0	1	0	0	1	1	1	1	1	0	53.33
<i>Lepraria aeruginosa</i>		0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	6.67
<i>Lepraria incana</i>		1	0	0	0	0	0	0	0	1	0	1	1	0	0	0	26.67
<i>Melanohalea exasperata</i>		0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	20.00
<i>Melanohalea exasperatula</i>		1	0	0	0	0	0	0	0	0	1	1	1	0	0	0	26.67
<i>Melanelixia fuliginosa</i>		0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	20.00
<i>Melanelixia glabra</i>		0	0	0	0	0	0.4	0	0	1	1	1	1	0	1	0	40.00
<i>Melanelixia subaurifera</i>		2	2	1	1	2	1	2	0	2	2	2	1	1	0	2	86.67
<i>Melanelixia subargentifera</i>		0	0	0	0	0	0	0	0	1	0.4	0.4	1	0	0	0.3	33.33
<i>Ochrolechia pallescens</i>		0	0	0	1	0.1	0	1	0.4	1	0	1	1	1	0	0.3	60.00
<i>Parmelia saxatilis</i>		0	0	0	0	0	0	0	0.4	0	0	0	0	1	0	0	13.33

Continuation of Table 2. Lichen species found on the researched area, the values of the coefficient **f**, the frequency (%) of each taxon and values of IAP and IHI on each of investigated points in Kuršumlija.

Taxon	Investigated point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	%
<i>Parmelia sulcata</i>		3	2	1	0	2	2	2	2	2	3	2	2	2	3	2	93.33
<i>Parmelia tiliacea</i>		0	0	0	0	1	0.3	0	0	0	0	1	1	1	1	1	46.67
<i>Parmelina pastilifera</i>		0	0	0	0	0	0	0	0	0	0.1	1	0.3	1	1	0.4	40.00
<i>Parmeliopsis ambigua</i>		0	0	0	0	0	0	0	1	0	1	0	0	0.4	0	0	20.00
<i>Phaeophyscia orbicularis</i>		0	2	0	2	2	1	2	2	1	2	2	1	2	2	1	86.67
<i>Physcia adscendens</i>		3	2	2	2	2	2	1	2	2	1	3	2	2	2	1	100.00
<i>Physcia aipolia</i>		1	0	1	0	1	1	1	1	1	1	0	1	0	1	1	73.33
<i>Physcia semipinnata</i>		0	0	0	0	0	0	0	0	0	0	0	0.4	0.4	0	0	13.33
<i>Physcia stellaris</i>		0	0	0	1	0	1	0	0	1	1	0	1	1	0.3	0.4	53.33
<i>Physcia tenella</i>		0	1	0	0	1	0.4	0	0	1	0.1	0	0.4	0	0	0	40.00
<i>Physconia distorta</i>		0	0	0	0	0	0	0	0	0	0.1	0	1	1	0.4	0.4	33.33
<i>Physconia enteroxantha</i>		0	1	0	0	0	0	0	0.3	0	0	0	1	1	1	1	40.00
<i>Physconia grisea</i>		2	1	1	1	0	1	1	1	0	1	0	2	0	2	1	73.33
<i>Pseudevernia furfuracea</i>		1	0	0	0	0	0.3	0	0	0	0.3	0	0	0.4	0.3	1	40.00
<i>Ramalina farinacea</i>		0	0	0	0	0	0.4	0	1	0	0.1	0	0	0.4	0	0	26.67
<i>Usnea hirta</i>		0	0	0	0	0	1	0	0	0	0.1	0	0.4	0	0	0	20.00
<i>Xanthoparmelia stenophylla</i>		0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	6.67
<i>Xanthoria parietina</i>		4	3	3	1	2	2	3	2	1	1	0	2	2	1	1	93.33
Index of Atmospheric Purity (IAP)		28	23	10	11	24	21	14	16	18	22	22	24	26	21	22	
Index of Human Impact (IHI)		18	24	36	32	24	21	36	28	28	21	21	15	15	18	18	

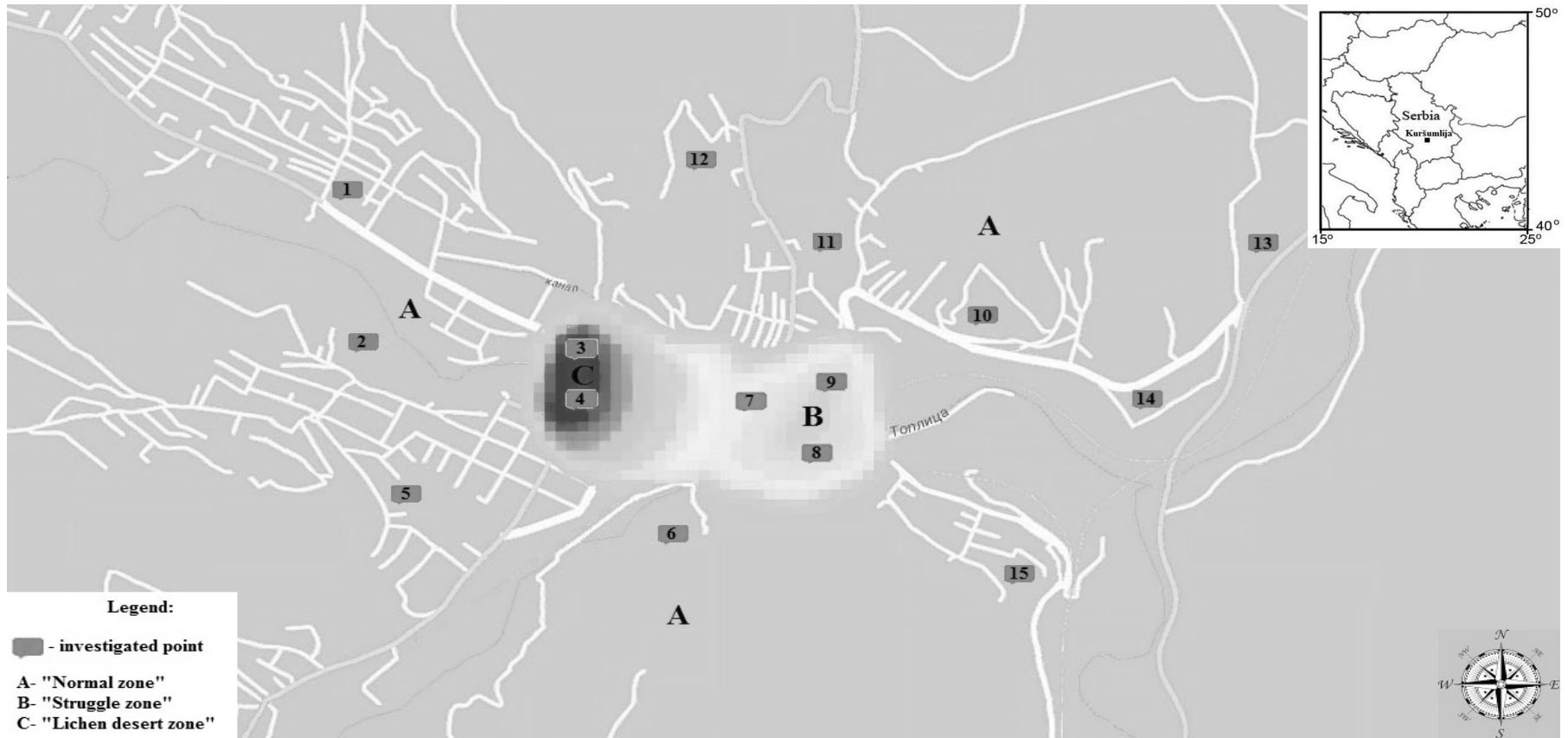


Figure 2. Zones of different levels of air pollution in Kuršumlija defined by using lichens as bioindicators.