

MONITORING OF THE «LICHEN DESERT» IN THE BELGRADE AREA (1980/81, 1991 and 2007)

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Abstract — This paper treats long-term changes in area of the «lichen desert», i.e., the region characterized (especially in the winter period) by average daily SO₂ concentration exceeding 150 µg/m³ of air, the maximum allowable concentration (MAC) for populated regions. Comparison of results obtained in 1980/81 and 1991 indicates that the “lichen desert” expanded (from 12 to about 13 km²) as a consequence of deterioration of the air quality in the Belgrade area. Comparing the results obtained in 1991 with investigations carried out in 2007, we found that «lichen desert” shrank substantially in the Belgrade area to a current size of about 11 km². The new boundaries of the «lichen desert» are presented, together with the main reasons for its shrinkage in the Belgrade area during the last 16 years and predictions of further alterations in the future.

Key words: «Lichen desert», monitoring, air quality, SO₂ concentration, Belgrade, Serbia

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INTRODUCTION

It is well known that organisms as open systems respond to detrimental external factors. The extent of the response of organisms is dependent on the intensity and duration of the factors. For this reason, many organisms are suitable objects for use in biological monitoring.

As for air pollution, bioindication ecology has enjoyed strong development due to recognition of the fact that lichens are highly susceptible to changes of air quality in the places where they live (Savić et al., 1995), particularly to SO₂ concentration in the air (Hawksworth and Rose, 1970).

With this in mind, workers at the Faculty of Biology in Belgrade have carried out many bioindication studies with lichens over the years (Cvijan and Stamenković, 1992, 1996a, 1996b; Cvijan et al., 1995, 1996, 1997; Milić and Blaženčić, 1993; Savić, 1991, 1996, 1997; Stamenković, 1992, 1995, 1997, 1998, 2002a, 2002b; Stamenković and Cvijan, 1993, 2002, 2003, 2004; Stamenković et al., 2003). An

attempt was made to establish relevant monitoring throughout the whole of Serbia (Cvijan, 1992), and significant results were achieved in the regions of Niš (Cvijan and Stamenković, 1992, 1996b; Stamenković, 1992, 2002b) and (especially) Belgrade (Cvijan et al., 1996, 1997; Milić and Blaženčić, 1993; Savić, 1991, 1996, 1997).

In the present paper, special emphasis is placed on defining the area and boundaries of the “lichen desert” in the region of Belgrade. The term “lichen desert” refers to the region in which lichens are not present on tree trunks. Their absence points to an average daily concentration of SO₂ above 150 µg/m³ of air, the maximum allowable concentration (MAC) for populated regions (Službeni Glasnik RS, 2006).

The results of previous studies conducted over a period of 10 years (1980/81; 1991) and investigations carried out at the start of 2007 provide a sound basis for comparison in further monitoring of the level of air pollution in the Belgrade region using lichens as bioindicators.

MATERIAL AND METHODS

The following tasks were performed:

1. Redefinition of the "lichen desert" on the basis of comparison with a study performed during 1980/81 and in accordance with altered limits of SO₂ concentration in the air;
2. Establishment of the presence/absence of lichens on tree trunks on both sides of the line which in 1991 marked boundaries of the "lichen desert" border;
3. The presence of lichens being considered relevant if lichens were found at chest height on tree trunks that were straight (with a slope of less than 5%);
4. Establishment of the presence/absence of lichens on tree trunks from the center of Belgrade to boundaries of the "lichen desert" as defined by the 1991 studies;
5. Precise mapping of the "lichen desert" and definition of its area and boundaries at the beginning of 2007; and
6. Comparison of currently obtained results with those obtained in 1991.

RESULTS

1. Studies performed in 1980/81

These studies dealt with analysis of specimens of lichens collected from 105 points in the wider region of the central part of Belgrade without its suburbs.

Analysis of the collected material indicated the presence of 13 genera of lichens with 29 species and one variety, as well as the existence of four zones with varying degrees of air pollution (Milić and Blaženčić, 1993).

The authors defined area of the "lichen desert" from the absence of epiphytic lichens and winter SO₂ concentrations in the air exceeding 200 µg/m³. The "lichen desert" encompassed the central zone of the city, covering an area of 8 km².

2. Studies performed in 1991

These were similar to previous studies, but differed from them in being more extensive. Thus, lichens from 144 points were analyzed, and the presence of 14 lichen genera with 32 species was established (Savić, 1991, 1996, 1997). Significant coincidence of these results with those obtained in 1980/1981 was observed. Certain differences in the qualitative composition of lichens were due to somewhat more detailed collecting of specimens.

Boundaries of the "lichen desert" (Fig. 1) were defined by a line extending clockwise along the following streets: Pariska - Tadeuša Koščuška - Dunavski Kej - Pristanište "Dunav" - Dunavska (up to the Pančevo Bridge) - Višnjička - Vojvode Micka Krstića (up to Marijane Gregoran) - Partizanski Put - Mije Kovačevića - Ruzveltova - Dimitrija Tucovića - M. Jankovića - Geršićeva - Bulevar Revolucije - Gospodara Vučića (up to Ustanička) - Stevana Prvovenčanog up to Tabanovačka - Tabanovačka (up to Bul. JNA) - Dr. Milutina Ivkovića (up to Bulevar Mira) - Bulevar Mira (up to Bulevar Vojvode Putnika) - Bulevar Vojvode Putnika (up to Topčiderski Venac) - corner of the streets P. Čajkovskog and Vase Pelagića - Vase Pelagića (up to V. Veličkovića) - V. Vučkovića (up to Koste Glavinića) - Radnička (up to the Topčider River) - the banks of the Sava River - Karadorđeva - Pariska.

Total area of the "lichen desert" amounted to about 13 km². Expansion of its area as compared to that established in the 1980/1981 studies was especially obvious in the southern part of Belgrade, moving from Trg Oslobođenja toward Senjak, with a marked discontinuity in Hyde Park. Another direction of expansion of the "lichen desert" was toward Karaburma through the region bounded by a contoured with line connecting the streets Višnjička, Vojvode Micka Krstića (up to Marijane Gregoran), and Partizanski Put.

It should be noted that these are streets with heavy traffic resulting from the construction of an ever greater number of residential buildings and extension of existing settlements, particularly in the zones of Karaburma, Višnjica, and Višnjička banja.

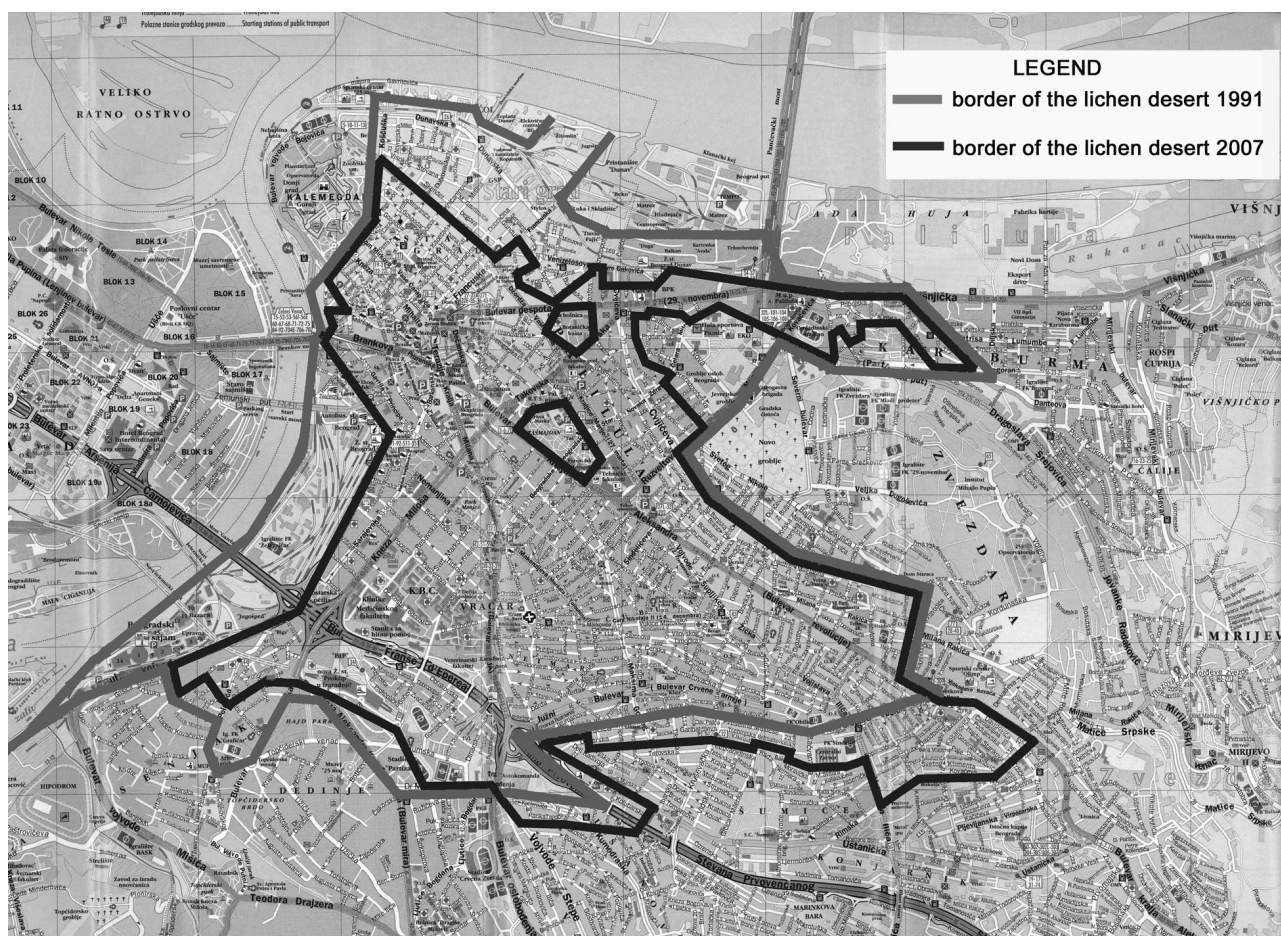


Fig. 1. Borders of the "lichen desert" in Belgrade area in the years 1991 (Savić 1991, 1996, 1997) and 2007

3. Studies performed in the period of October 1991 – March 1992

These studies dealt with a very narrow space of the central city area and involved a dense network of studied points (200).

Among other things the aim of these studies (Cvijan et al., 1996, 1997) was to check the results obtained in previous studies on the basis of extensive investigations in a confined space. The obtained results showed that the previous studies (Milić and Blaženčić, 1993; Savić 1991, 1996, 1997) were carried out properly and yielded results that were highly reliable, even though they were obtained on the basis of a comparatively small number of sampling points in relation to size of the zones studied.

This time the presence of six species of lichens

was recorded in the Jevremovac Botanical Garden, which represented an isolated island within the "lichen desert". All six species were found at only one point – on the trunk of a dried-up apricot, which after several years was uprooted.

Unexpectedly, lichens were found at one point in Karađorđeva Street (the species *Lecanora conizaeoides* Nyl.) and in Kamenička Street [the species *Buellia punctata* (Hoffm.)], i.e., within the area that was unequivocally defined as the "lichen desert".

4. Studies performed in 2007

The zone on both sides of the line which in 1991 marked the boundary of the "lichen desert" was surveyed in depth. In addition to this, the presence/absence of lichens was checked within the previ-

ously defined “lichen desert”. In the surveyed area, about 2,000 points, i.e., tree-trunks, were analyzed.

The results of the study were as follows:

I. Boundaries of the “lichen desert” were defined by a line extending clockwise along the following streets: Bulevar Kneza Aleksandra (former Bulevar Mira) through Bulevar Vojvode Putnika up to Kozjačka - Kozjačka up to Ljube Jovanovića (former Vasilija Gaćeše) - Ljube Jovanovića via Vase Pelagića up to Svetog Nauma - Svetog Nauma up to Koste Glavinića - Koste Glavinića up to Ruska - Ruska up to Bul. Vojvode Mišića - Savska (former Slobodana Penezića Krcuna) - via Savski Trg - Karadorđeva up to Branko's Bridge - Kosančićev venac from Brankov Bridge up to Zadarska - Zadarska up to Kneza Sime Markovića - Kneza Sime Markovića up to Pariska - Pariska - Tadeuša Koščuška up to Cara Dušana - Cara Dušana up to Francuska - Žorža Klemansoa (former Francuska) up to Gundulićev Venac - Gundulićev Venac up to Jelisavete Načić (former Pavla Papa) - Jelisavete Načić up to Đorđa Jovanovića - Đorđa Jovanovića up to Drinčićeva - Drinčićeva up to Carigradska - Carigradska up to Venizelosova (former Đure Đakovića) - Venizelosova up to Šajkaška - Šajkaška up to Vatroslava Lisinskog - Vatroslava Lisinskog up to Jovana Avakumovića (former Učiteljska) - Jovana Avakumovića up to Poenkareova (former Đure Đakovića) - Poenkareova up to the Pančevo Bridge - Višnjička from the Pančevo Bridge up to Vojvode Micka Krstića - Vojvode Micka Krstića up to Marijane Gregoran - Marijane Gregoran up to a point behind Triglavska and in the north through Vlade Ilića up to the beginning of Tina Ujevića - in the north-east up to Hvarska - Jastrebačka - Jastrebačka up to Levskoga - Levskoga up to Tina Ujevića - Tina Ujevića up to Sime Šolaje - Sime Šolaje up to Milice Janković - Milice Janković up to Generala Aračića - Generala Aračića up to Bata Lakina - Bata Lakina up to Sime Šolaje - Sime Šolaje up to Bore Vukomirovića - Bore Vukomirovića up to Dragoslava Srejševića (former Partizanski Put) - Dragoslava Srejševića up to Mitropolita Petra - Mitropolita Petra up to Sterijina - Sterijina up to Osmana Đikića - Osmana Đikića up to Čarlija Čaplina - Čarlija Čaplina up to Ljubomira Stojanovića - Ljubomira Stojanovića up to Zdravka

Čelara - Zdravka Čelara up to Hvarska - Hvarska - Vojvode Vuka up to Ruzveltova - Ruzveltova up to Dimitrija Tucovića - Dimitrija Tucovića up to Učitelja Miloša Jankovića - Učitelja Miloša Jankovića - Geršićeva up to Bulevar Kralja Aleksandra (former Bulevar revolucije) - Bulevar Kralja Aleksandra up to Mis Irbijeve (former Zage Malivuk) - Mis Irbijeve up to Vojislava Ilića - Vojislava Ilića up to Kralja Ostoje - Kralja Ostoje via Bačvanska up to Bakićeva - Bakićeva up to Dragačevska - Dragačevska up to Pašmanska - Pašmanska - Kolašinska - Miklošićeva - Rade Končara up to Pčinjska - Pčinjska via Debarska up to Gospodara Vučića - Gospodara Vučića up to Ustanička - Ustanička up to Milorada Bondžulića - Milorada Bondžulića via Stefana Prvovenčanog up to Ljube Nedića - Ljube Nedića via Kumodraška up to Admirala Vukovića - Admirala Vukovića via Vojvode Stepe up to Dr. Milutina Ivkovića - Dr. Milutina Ivkovića along the stadium of FC Partizan via Humska up to Stjepana Filipovića - Stjepana Filipovića up to Bulevar Kneza Aleksandra Karadorđevića (former Bulevar Mira) (Fig. 1);

II. Within the “lichen desert”, lichens were found in the Jevremovac Botanical Garden (with an area of about 0.05 km²) and in Tašmajdan Park (Large and Small Tašmajdan - with a total area of about 0.08 km²) (Fig. 1);

III. Total area of the “lichen desert” amounted to about 11 km²; and

IV. At many points located within the “lichen desert”, lichens were found at the base or in the lower parts of tree trunks.

DISCUSSION AND CONCLUSIONS

In 1980/81, 1991, and 2007, the boundaries and area of the “lichen desert” in the region of Belgrade without its suburbs were analyzed and compared.

The results of previous studies were considered separately for two reasons:

1. In the studies carried out in 1981/82, the “lichen desert” was defined on the basis of a SO₂ concentration of 200 µg/m³ of air. However, because we consider as relevant a SO₂ concentration of

150 $\mu\text{g}/\text{m}^3$ of air, the results obtained in 1980/81 were reexamined; and

2. In the study performed in 1991/92, lichens were recorded at three specific sites. Thus, lichens were found in the Jevremovac Botanical Garden, but they disappeared from this site later due to drying and uprooting of the single trunk on which they had developed. The other two sites were on Kamenička and Karađorđeva Streets which are located in the area unequivocally defined as the "lichen desert". Lichens were found in only one place on each street [*Buellia punctata* (Hoffm.) Mass on Kamenička Street; and *Lecanora conizaeoides* Nyl. on Karađorđeva Street]. **It was therefore concluded that the occurrence of one species or even a group of lichen species at one point only is a consequence of an array of accidental, strictly local factors.** The indicated presence of lichens and possible similar occurrences can only be recorded and their state monitored further, but they do not affect general conclusions about boundaries of the "lichen desert".

The results of studies performed during 1980/81 indicated that area of the "lichen desert" amounted to about 12 km^2 .

According to studies carried out in 1991, area of the "lichen desert" was about 13 km^2 .

Total area of the "lichen desert" in the spring of 2007 comprised about 11 km^2 , which indicates a decrease of about 15.38 % relative to the study performed in 1991 (Fig. 1).

The main reasons for decrease in area of the "lichen desert" are as follows:

- a. Connection of some parts of the city to district heating networks, which resulted in an improvement of air quality. The most prominent example is a considerable part of the Stari Grad municipality (the northern section of the city). In this way, a large number of small individual furnaces and fire-places in apartments and houses and large sources of air pollution during the winter period (e.g., the Jevremovac Botanical Garden)

were eliminated;

- b. Relocation of some railway traffic (particularly abolishment of the Dunav railway station in the northern part of the city) and complete replacement of steam engines by diesel/electricity-driven engines; and
- c. Considerable reduction in the use of firewood, fuel oil and coal for heating of residential and business premises, given that fees for electrical power consumption in Serbia were for a long time low and competitive with fossil fuels.

Meanwhile, traffic has become considerably heavier, but because the quality of vehicles and the fuel they use has also improved, this has not been a decisive factor in alteration of the boundaries of the "lichen desert". However, the increased traffic caused a certain number of the city's main traffic routes to become part of the "lichen desert" even when lichens were found in their side streets.

In the latest study, a certain discontinuity in the "lichen desert" was observed, since lichens were found in the Jevremovac Botanical Garden and Tašmajdan Park. Similar discontinuity was previously recorded in Hyde Park. All three of the mentioned sites underline the importance of green areas to air quality in urban/industrial environments.

Some smaller parts of the city only formally enter the "lichen desert", given that in newly built settlements lichens have not yet had a chance to develop on trees that were planted in the last two to four years. The most prominent example of this is the southern part of the "lichen desert", i.e., a zone which has significantly expanded in the last 16 years. It is realistic to expect that in the coming ten years, lichens will grow on the bark of tree trunks that will be mature at that time. Thus, this part of the current "lichen desert" will no longer exist.

At a large number of points within the newly defined boundaries of the "lichen desert", the presence of lichens was observed at the base or on the lower part of tree trunks. Although this does not shift the boundaries of the "lichen desert", it indicates a certain "encroachment" of lichens into the

space of the current "lichen desert". An additional decrease in area of the "lichen desert" can therefore be expected in the future.

The assumption that area of the "lichen desert" will further decrease in the future is unquestionably supported by activities planned at the level of the city of Belgrade and the Republic of Serbia as a whole which may result in a significant decrease of air pollution in the central part of Belgrade. Among them, the following activities should be mentioned:

- a) Further connection of some parts of the town to district heating networks;
- b) Further relocation of railway traffic away from the central part of the city;
- c) Gasification of the city itself (which has already been started and completed in some parts of the city);
- d) Construction of traffic beltlines Belgrade, including bridges over the Sava and Danube Rivers.
- e) Further subway construction and use of electrically driven public transport vehicles.

The mentioned activities will contribute to further direct decrease in the emission of pollutants during the winter period (notably those specified under item a and to some extent ones indicated under item c), i.e., at the most critical time relative to air pollution in the town. On the other hand, the activities specified under items b, d, and e will, thanks to lower traffic pressure in the city center, result in a reduction of harmful gas emission throughout the year.

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МОНИТОРИНГ «ЛИШАЈСКЕ ПУСТИЊЕ» НА ПОДРУЧЈУ БЕОГРАДА (1980/81, 1991 и 2007)

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У спроведеним истраживањима праћене су промене граница и површине «lišајске пустиње» на подручју Београда, а на основу поређења резултата истраживања из 1980/81, 1991 и 2007. године. При том се под изразом «lišајска пустиња» сматра подручје на којем често, посебно у зимском периоду, просечна дневна концентрација SO_2 прелази $150 \mu g/m^3$ ваздуха, тј. превазилази MDC за настањена подручја. Критичком анализом резултата истраживања из 1980/81. године, утврђено је да је тада површина «lišајске пустиње» износила око $12 km^2$. Поређењем резултата истраживања из 1991. са истима из 1980/81. године, установљено је ширење «lišајске пустиње» са 12 на око $13 km^2$. Њено ширење посебно је било изражено, уз дисконтинуитет исте који је чинио Хајд парк, у јужном делу градског под-

ручја (идући од Трга ослобођења ка Сењаку). У нешто мањем обиму наведена појава је била изражена и североисточном делу Београда (подручје од Панчевачког моста према Карабурми). У оба случаја ширење «lišајске пустиње» било је последица убрзане стамбене градње у тим деловима градског подручја и, последично, повећања загађивања ваздуха. Истраживања спроведена у пролеће 2007. године показала су да је дошло до смањивања укупне површине «lišајске пустиње» у односу на 1991. годину за око 15,38 % (са око 13, на око $11 km^2$). Смањивање је најизраженије у западном и северном делу градског подручја, као и североисточном делу «lišајске пустиње». Посебно је значајан дисконтинуитет «lišајске пустиње» које чине Ботаничка башта «Јевремовац» и Ташмајдански парк који не при-

падају «лишајској пустињи» иако се налазе унутар граница исте. Смањивање површине «лишајске пустиње» условљено је бројним факторима као што су даље проширивање мреже даљинског грејања, повећано коришћење електричне енергије за грејање, измештање дела железничког саобраћаја из централног дела градског подручја итд. Треба запазити да су у неким деловима градског подручја лишајеви населили кору дрвећа али још увек не на одговарајућој висини. С друге стране, у неким новоизграђеним насељима

(односно, деловима насеља) тек засађена стабла дрвећа још нису насељена од стране лишајева иако је извесно да ваздух није загађен изнад МДС. Имајући то у виду, као и даље ширење мреже даљинског грејања, измештање железничког саобраћаја из централног дела градског подручја, планирана побољшања у режиму саобраћаја и планирану гасификацију градског подручја може се у будућности очекивати даље смањивање површине «лишајске пустиње» на подручју Београда.