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Original article

Search of pattern in presence of epiphytic lichens growing in an urban environment – case study in Prešov city (Slovakia)

JOZEF OBOŇA[1*], LENKA DEMKOVÁ[1], LENKA BOBUĽSKÁ[1], TOMÁŠ LOŠÁK[2] & PETER MANKO[1]

[1] Department of Ecology, Faculty of Humanities and Natural Sciences, University of Prešov, 17. novembra 1, 081 16 Prešov, Slovakia,
[2] Department of Environmentalistics and Natural Resources, Faculty of Regional Development and International Studies, Mendel University in Brno, 613 00, Brno, Czech Republic

Abstract
Lichens are sensitive organisms, widely applied in air quality assessments and monitoring programs around the world. Traffic emissions or particulate matter influence the pattern in presence of lichens on roadside trees. The research of epiphytic lichens in Prešov city (Slovakia) was conducted in 17 near-road localities (three trees per locality). The traffic density, selected tree parameters, lichen density, and presence in research squares (15 x 15 cm) on 4 sides of the tree (side in the direction of traffic, in the opposite direction of traffic, the side facing towards the road and the side facing away from the road) were analysed. Three lichen species were most often determined on the trees: *Xanthoria parietina* (L.) Th. Fr., *Phaeophyscia orbicularis* (Necker) Moberg, and *Physcia adscendens* (Th. Fr.) H. Olivier. The most common lichen was the *Ph. orbicularis* accounted for up to 86% of all records. The highest presence was confirmed in localities with the highest traffic density. Based on the results it is obvious that atmospheric pollution alters lichen communities and therefore can be effectively used as biological indicator of air quality.

Keywords: urban area, *Phaeophyscia*, *Physcia*, *Xanthoria*, traffic density

Introduction

It is well established that lichens are sensitive to a wide range of habitat changes, most of them man-driven (Pinho et al. 2004). Changes in 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). In Europe is often used method LBI (evaluation of the lichen biodiversity index, e.g. Cioffi 2009; Giordani et al. 2002; Caoduro et al. 2014, etc.) and European guideline for mapping lichen diversity (e.g. Asta et al. 2002). The point quadrat method (e.g. Dunford et al. 2006; Martinez et al. 2006) or lichen based index (e.g. Will-Wolf et al. 2015) are used less often.

Tolerance to most of the heavy metals and the slow growth rate are the main factors which make lichens good indicators or/and monitors of metal pollution (e.g., Seaward & Letrouit-Galinou 1991; Paoli et al. 2019; Tarawneh et al. 2021). Biomonitoring with lichens can be done according Branquinho (2001) in three ways: using variations in diversity and/or abundance, using variations in physiological parameters, or using lichens as accumulators of pollutants. Lichen diversity has been used as an indicator for monitoring the effects of air pollution in urban areas since 20th century (Llop et al. 2012). Variations in lichen biodiversity may be due to changes in microclimatic conditions particularly light, water and nutrients. These alterations may be driven by local sources of disturbance, such as roads or farms, different land uses or habitat fragmentation (e.g., Jonsson & Jonsell 1999; Sillett & Goslin 1999; Moen & Jonsson 2003; Paoli et al. 2013; Asta et al. 2019).

It has been found in earlier studies that air quality in Central Europe has significantly deteriorated during second half of the 20th century (Lisowska 2011; Maňkovská et al. 2017). Traffic-related pollutants are considered one the biggest contributors to the urban air pollution (Stenson et al. 2021). The main pollutants in urban environments, roadsides and areas near the roads are the gases emitted from motor vehicles, such as sulphur dioxide (SO_2), carbon monoxide (CO) and nitrogen dioxide (NO_2) (e.g., Gilbert et al. 2007, Marmor & Randlane 2007). Traffic emissions or particulate matter influences the diversity and abundance of lichens on roadside trees. Non-tolerant lichens react to the presence of contaminants by inhibiting the growth, on the contrary pollution-tolerant species, thrive in such an environment (Marmor & Randlane 2007; Stapper 2012).

This study aims to i) determine the most frequently occurring epiphytic lichen taxa growing around the roads in the city of Prešov using modified quadrat method, ii) find out the relationship between the presence of epiphytic lichens and their orientation to the direction of traffic, iii) determine the relationship between the traffic density and the epiphytic lichens presence.

Materials and methods

A simple study of epiphytic lichens to assess the environmental quality of the Prešov (Slovakia) city during May 2019 for the first time was conducted.

The roads were selected for research as follows:

at least 3 trees had to grow by the road, ideally on each side of the road;

* Corresponding author: J. Oboňa. Email: jozef.obona@unipo.sk

the trees near road had to be of the same species and approximately the same size;
the minimum tree circumference had to be at least 80 cm (at a height of 1.3 m above the ground).
(note: The tendency should be to use only trees with acid bark, preferably of one species only; which was unrealistic for very specific urban conditions e.g. van Herk et al. 2002; Gombert et al. 2004).
A total of 17 near-road localities were selected for the research purposes. At each sampling locality three trees were randomly selected (if possible – on each side of the road – which was fulfilled only in 4 locations). For each tree, the genus of the tree, the perimeter of the trunk at 1.3 m height, and the radius of the crown were determined. Basic data on selected localities are given in Table 1.

Table 1. Basic information of sampled roads.

no.	GPS	traffic densities
001	48°59'27.3"N 21°14'02.9"E	LD
002	48°59'29.0"N 21°14'06.1"E	LD
003	48°59'29.5"N 21°14'11.0"E	LD
004	48°59'31.8"N 21°14'13.8"E	LD
005	48°59'29.5"N 21°14'14.3"E	MD
006	48°59'53.2"N 21°13'17.8"E	MD
007	48°59'41.4"N 21°13'40.2"E	LD
008	48°59'52.1"N 21°13'17.5"E	MD
009	48°59'58.9"N 21°13'33.2"E	HD
010	49°00'06.3"N 21°13'24.7"E	MD
011	49°00'14.7"N 21°13'16.3"E	HD
012	48°59'57.0"N 21°13'38.0"E	HD
013	48°59'41.5"N 21°13'54.8"E	MD
014	48°59'45.2"N 21°13'59.0"E	LD
015	48°59'42.5"N 21°14'06.6"E	LD
016	48°59'24.3"N 21°14'26.4"E	MD
017	48°59'18.9"N 21°14'12.2"E	HD

The traffic density was determined for individual roads as mentioned in Demková et al. (2019). Based on the results, the roads were divided into three traffic density categories: high traffic density (HD): > 600 cars per hour; medium traffic density (MD): 599 – 200 cars per hour; low traffic density (LD): < 199 cars per hour.

The coverage of each lichen was estimated by the modified quadrat method as follow. On each tree in 3 different heights (up to 40 cm from the ground, height approx. 130 cm from the ground and approx. 180 cm from the ground) were drawn squares measuring 15 x 15 cm. These squares were drawn on 4 sides of the tree (side in the direction of traffic (marked as 3), in the opposite direction of traffic (marked as 4), the side facing towards the road (marked as 1) and the side facing away from the road (marked as 2). A total of 12 squares were drawn on each tree (Figure 1). Overall, it was evaluated 756 squares on 63 trees near 17 roads.

Figure 1. Ash tree with drawn squares at locality 001 – Kúpeľná street.

Subsequently, the percentage coverage of the total square area by lichen species was determined at each square (whole area = 100%, Figure 2).

Figure 2. Example of a marked square with lichens.

All information was recorded and photographically documented directly in situ. Subsequently, they were digitized in the laboratory by estimation based on visual inspection and statistically analysed. Only those species of lichens whose coverage in the square was at least 1% were analysed. The possible influence of individual factors (e.g., traffic density, orientation to the road) was analysed using the nonparametric Kruskal-Wallis test in particular given that the distribution of data on the cover (representation) of individual species was not normal and Levene's test confirmed the inequality of deviations (inhomogeneity of variation). All statistical analyses and descriptive statistics were performed in the program JASP (2020), for creating box-diagrams (boxplots) program PAST (ver. 4.03, Hammer et al. 2001) was used.

Results

For the research purposes, following trees growing near the roads in the Prešov city were used: ash (*Fraxinus* spp.), boxelder maple (*Negundo* sp.), maple (*Acer* spp.), linden (*Tilia* spp.), chestnut (*Aesculus* sp.) and cherries (*Cerasus* spp.). Ash was found as the most frequently occurred tree accounting for about 27% of all examined trees, followed by maples (24%), chestnuts (19%), lindens (14%), boxelder maple (11%), and cherries (5%) (Table 2).

Table 2. Number and percentage of measurements on trees of different species.

tree-species	frequency	percent
Acer spp.	180	23.8
Aesculus sp.	144	19.0
Fraxinus spp.	204	26.9
Negundo sp.	84	11.1
Cerasus spp.	36	4.80
Tilia spp.	108	14.3
Total	756	100

The perimeter of the trunk at a height of 130 cm from the ground reached values from 68 cm to 205 cm. The average circumference of the trunk was 136 cm. The radius of the crown of the examined trees reached values from 2 m to 6 m. The average radius was 5 m (Table 3).

Table 3. Descriptive statistics of the properties of sampled trees – perimeter of the trunk and radius of the crown.

	perimeter of the trunk (cm)	crown radius (m)
Valid	756	456
Missing	0.00	0.00
Mean	136	4.97
Median	136	5.00
Std. deviation	33.1	1.05
Minimum	68.0	2.00
Maximum	205	6.00

Most of the measurements were performed at the low traffic density locations (43%), followed by medium traffic density locations (33%) and high traffic density locations (24%) (Table 4)

Table 4. Number and percentage of measurements in localities with different traffic density (LD – low traffic density; MD – medium traffic density, HD – high traffic density).

traffic intensity	number of measurements	percent
LD	324	42.9
MD	252	33.3
HD	180	23.8
Total	756	100

On the examined trees, most often 3 species of lichens were found (species with a coverage of less than 1% were not included in the analyses): Maritime sunburst lichen – *Xanthoria parietina* (L.) Th. Fr., *Phaeophyscia orbicularis* (Necker) Moberg, and *Physcia adscendens* (Th. Fr.) H. Olivier. The most common lichen growing on the evaluated trees was *Ph. orbicularis* (86% of records), followed by *Ph. adscendens* (12%) and *X. parietina* (2%). We also observed the highest proportion (average, median and maximum) in all recorded lichen species (Table 5).

Table 5. Descriptive statistics of the presence of individual lichen species.

	Ph. orbicularis	*Ph. adscendens*	*X. parietina*
Valid	756	756	756
Missing	0.00	0.00	0.00
Mean	19.8	2.81	0.34
Median	10.0	0.00	0.00
Std. Deviation	22.8	7.98	2.45
Minimum	0.00	0.00	0.00
Maximum	100	70.0	40.0

The possible influence of individual factors (the traffic density and orientation to the road) was analysed only for the most frequently occurring species *Ph. orbicularis.* We found that the presence of *Ph. orbicularis* was influenced by the density of traffic and the orientation of the measured area towards the road (Table 6, Figure 5). The highest presence of *Ph. orbicularis* was determined in the localities with the highest traffic density (Figure 3) and in the northern and western areas of the trunk. The lowest presence of *Ph. orbicularis* was found in the south-facing areas of the trunk (Figure 4).

Table 6. The results of nonparametric Kruskal-Wallis test expressing the differences in the presence of the *Ph. orbicularis* depending on the traffic density and orientation to the road.

factor	statistic
traffic intensity	41.654
orientation-road	14.739

As can be seen from Figure 3, the presence of *Ph. orbicularis* in localities with a low density of traffic represented approximately 12% to 17% of the records, at a medium traffic density of about 18% to 25% of the records. The highest presence (23 – 30%) was recorded at the localities with high traffic density.

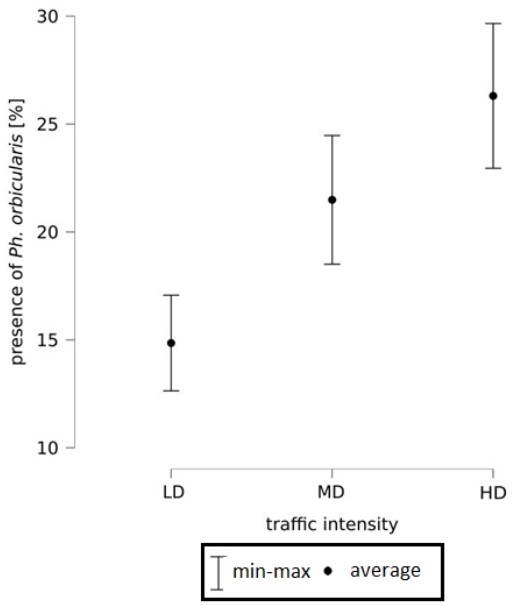

Figure 3. Presence of the species *Ph. orbicularis* in localities with different traffic density (x-axis, LD – low density, MD – medium density, HD – high density).

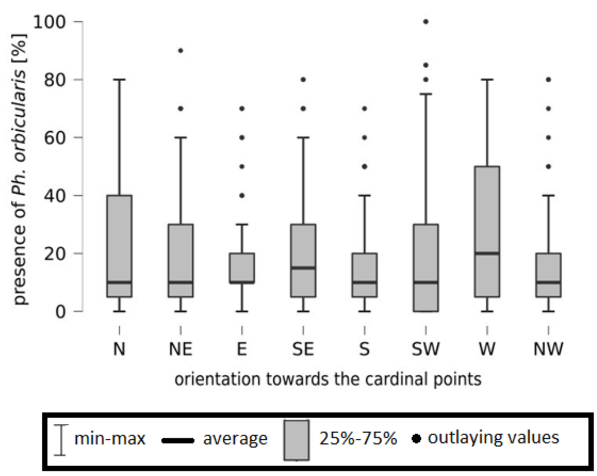

Figure 4. The presence of the *Ph. orbicularis* in squares with different orientations to the world sides (x-axis, sides of the world).

From the point of view of the presence of *Ph. orbicularis* in relation to the world sides (Figure 4), this species predominated in the west (W) and north (N), subsequently in the south-west (SW), south-east (SE) and north-east (NE). Less often *Ph. orbicularis* has occurred in the east (E), north-west (NW) and south (S), but these results are statistically insignificant.

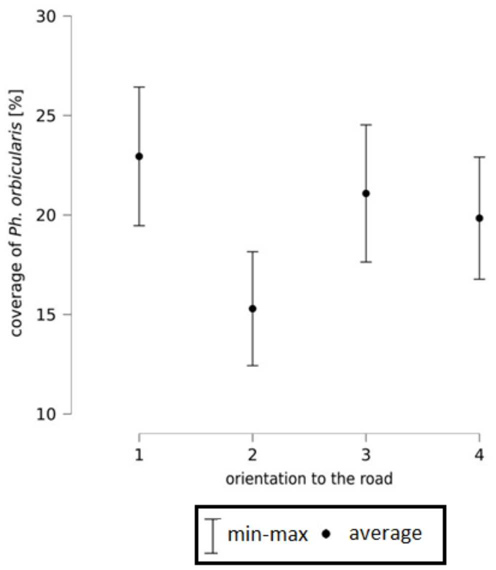

Figure 5. Coverage of *Ph. orbicularis* according to the orientation towards the road (diameters with standard error, 95% interval (side facing towards the road 1 and side facing away from the road 2, side in the direction of traffic 3, against the direction of traffic 4).

From the point of view of the cover of the species *Ph. orbicularis* and orientation to the road (Figure 5), we found, that this species grew most frequently on the side of the tree facing towards the road (19% to 27% cover), then on the side in the direction of traffic (18% to 25% coverage), followed by the opposite direction of traffic side (16% to 23% coverage). The lowest cover of this species was recorded on the side of the tree facing away from the road (12% to 18% cover).

Discussion

Atmospheric pollution alters lichen communities, and depending on the nature and concentration of pollutants, usually results in an impoverishment in terms of richness and/or abundance (Gries 1999). In many earlier studies, lichens have been recognized and successfully utilized as biological indicators of air quality (Shukla & Upreti 2012). Demková et al. (2019) confirmed a significant positive correlation between risk elements and the traffic density.

The species of lichens which were in greater numbers recorded in our study (namely *X. parietina*, *Ph. orbicularis*, and *Ph. adscendens*) were frequently represented in other European urban areas (Farkas et al. 2001; Matwiejuk & Chojnowska 2016; Djekic et al. 2017). Additionally, in the study of Piervittori & Maffei (2001) who evaluated the presence of lichens in the urban area in Italy (the city of Aosta), the species *Ph. adscendes*, *X. parientina* , and *Ph. orbicularis* were among the most frequently recorded. The species which were recorded as the most abundant along Prešov city streets, were in earlier studies rated as the most tolerant to environmental stress or air pollution (Elsinger et al. 2007; Dymytrova 2009; Vitali et al. 2019; Owczarek-Kościelniak et al. 2020).

The most common lichen growing on the road was *Ph. orbicularis* accounted for up to 86% of all records. According to Van Herk et al. (2001) and Loppi & Pirintos (2000) the rise in the number of necrophilous lichens especially members of the Physciaceae family (including *Phaeophyscia*) has been attributed to climate change and also to dry and dusty conditions in urban centres.

Gombert et al. (2005) found, that the presence of *Ph. orbicularis* was influenced by the density of traffic and the orientation of the measured area towards the road. From the point of view of the cover of the species *Ph. orbicularis* and orientation to the road, we found that this species grew most frequently on the side of the tree facing towards the road to the road. The lowest cover was recorded on the side of the tree facing away from the road. Gombert et al. (2005) use autecological and environmental parameters for establishing the status of lichen vegetation of urban areas in France and in agreement with our results he confirmed that *Ph. orbicularis* is frequent and tolerant species. Shukla & Upreti (2012) have designated this species as frequency and abundance thermophilus and poleotolerant lichens.

The highest presence was recorded in the localities with the highest traffic density and in the northern and western areas of the trunk. It is likely that the climatically less exposed sides (west, north), which have less light and more humidity, are more suitable for the growth of lichens (Gombert et al. 2005). But, the presence, absence and the diversity of lichen species is influenced by many other characteristics such as the tree size, tree age, diameter, branch density, bark chemical properties, bark structure, its water holding-capacity, and also the position of the tree in the stand (Raniu et al. 2008; Johansson et al. 2009; van Her et al. 2002; Bäcklund et al. 2016). Some authors have stated that the pH of the bark and susceptibility to toxic substances are among the most important properties affecting the presence and composition of lichens (Jüriado et al. 2012). Transport pollution substances (CO_x, NO_x, SO_2) causing acidification of the environment (Sebal et al. 2022), what can lead to the reducing bark pH. Since, according to our results, the highest presence of *Ph. orbicularis* was recorded on the high traffic density localities, with the highest abundance at the side facing the road, we assume that the recorded lichen belongs to pollution-resistant and favouring acidic environment species.

Conclusions

In Prešov city three lichen species that most often grow on the trees near roads are *Xanthoria parietina, Phaeophyscia orbicularis*, and *Physcia adscendens*. The most common lichen was *Ph. orbicularis* accounted for up to 86% of all records. We found that the presence of *Ph. orbicularis* was influenced by the density of traffic and by the orientation towards the road. The highest presence was confirmed in localities with the highest traffic densities. *Ph. orbicularis* grew most frequently on the side of the tree facing towards the road to the road, and the lowest cover of this species was recorded on the side of the tree facing away from the road.

We therefore conclude that presence and quantity of *Ph. orbicularis* growing on a tree may be a suitable indicator of traffic density, as well as traffic contamination.

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