NATURE JOURNAL VOL. 48: 83–94 (2015)
OPOLE SCIENTIFIC SOCIETY

AN ATTEMPT TO ASSESS THE AIR QUALITY IN THE OPOLE CITY USING THE EPIPHYTIC LICHEN DATA

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ABSTRACT: Authors present new data about the distribution of epiphytic lichen biota in Opole city (SW Poland). Lichenological study was conducted from the 2nd October 2013 to 22th October 2014 in areas lying within administrative boundaries of the city. The presence of epiphytic lichens was checked in 98 places, which have been established along 7 transects. Annotated lichen species were confronted with the lichen scale and air monitoring data. The level of SO_2 in the air drops to the low values; however, there is still an absence of vulnerable lichen species. In the different areas of the city the lack of lichens can be explained in several ways, e.g. by an absence of favorable habitats, high insolation, low humidity or the urban heat island effect.

KEY WORDS: biomonitoring, Poland, air pollution, lichen scale.

Introduction

The occurrence of lichens in cities have been of interest to scientists since 19th century (Nylander 1866). The lichen species composition was recognized as associated with sulphur dioxide air pollution levels. On this basis various so called lichen scales were created (Hawksworth and Rose 1970; Feige 1982; Kiszka 1990, 1999; Bielczyk 2001).

Lichens as bioindicators as well as changes in their species composition have been of interest to Polish scientists for many years. Investigations took place in many cities (e.g. Rydzak 1953, 1957a,b,c,d, 1959a,b,c; Kiszka 1977; Sokół 1978; Olech and Dudek 1981; Fałtynowicz et. al. 1991; Izydorek 2005; Kubiak 2007; Wieczorek and Durka 2009; Bielec 2011). Till now, lichen biota of Opole city was the subject of studies of Rydzak (1957a) and Leśniański (2010).

The aim of this paper is twofold. Firstly, the lichen scale and epiphytic lichen species were used to describe the air quality in Opole city. Secondly, information about lichen biota were compared to monitoring data with particular emphasis on the level of atmospheric SO_2. The influence of the city environment on lichens was determined.

Materials and methods

Opole is a city on the Odra River in a southern part of Poland. According to the physico-geographical division of Poland by Kondracki (2002) the city is localized in the North European Plain, in Silesian Lowland. Opole is located at the interface among of Wroclaw Glacial Valley, Opole Plain and Niemodlin Plain. In 1950s the city was much smaller than nowadays. Today, it has much larger surface area (97 km^2) with bigger population amounting to 125,710 persons (Budzyński et al. 2011). Inside its borders are: a typical urban area in the centre, spaces with single-family houses, agricultural fields and forest in the east part of the town. Bolko island is the only one place with numerous old trees. Coniferous trees are found mainly in home gardens (as ornamental plants) and in the mixed forests bordering Opole. In the city deciduous trees predominate. The communication traffic through the city is a potential source of negative impact on the environment. Annual average contamination of atmospheric sulphur dioxide was calculated and it varies from 4.8 to 9.5 $\mu g/m^3$ (Barańska et al. 2013). The amount of SO_2 loads varies depending on a place where was specified. Extreme average magnitudes were defined for the heating season and they were higher (7.5–12.85 $\mu g/m^3$), but according to lichen scales (Hawksworth and Rose 1970; Feige 1982; Kiszka 1990, 1999; Bielczyk 2001) still not threatening for lichen biota – areas with the level of SO_2 does not exceed 30 $\mu g/m^3$ are considered to be pure (Hawksworth and Rose 1970).

Lichenological study was undertaken from the 2nd October 2013 to 22th October 2014 and from 19th July 2015 to 10th August 2015 in areas lying within administrative boundaries of Opole. The presence of epiphytic lichens was checked in 98 sample plots, which have been established along 7 transects (Fig. 1). Middle parts of all transects coincide in the historical city centre (Main Market). The distance between adjacent plots was not greater than 1km. The occurrence of lichens was checked and photographs of their thalli were taken. The position of the thalli on tree trunks was determined.

Lichen species were identified using keys of Nowak and Tobolewski (1975). Although, lichens from the genus *Lepraria* were recognized as *Lepraria* sp. div. (Saag et al. 2009). The complicated determination of these species is not necessary for this study. The only one species (*L. incana*) is included in lichen scale, but it is sensitive only for more than 150μg/m^3 SO_2 in air. For identification of tree species the key of Rutkowski (2014) was used. The nomenclature of the tree species follows Mirek et al (2002). The names of lichens are given according to Fałtynowicz (2003). Lichen species were classified as rare (found in 1–5 localities), fairly rare (6–10 localities), common (11–20 localities), very common (21–30 localities), widespread (31 and more localities). The new lichen scale (Tab. 1) was created on the basis of two older scales elaborated by Hawksworth and Rose (1970) and Kiszka (1990). Thereby more species were included. It was the basis for the distinction bioindicators from other species (Tab. 2).

The collected material is housed in the herbarium of the Opole University (OPUN).

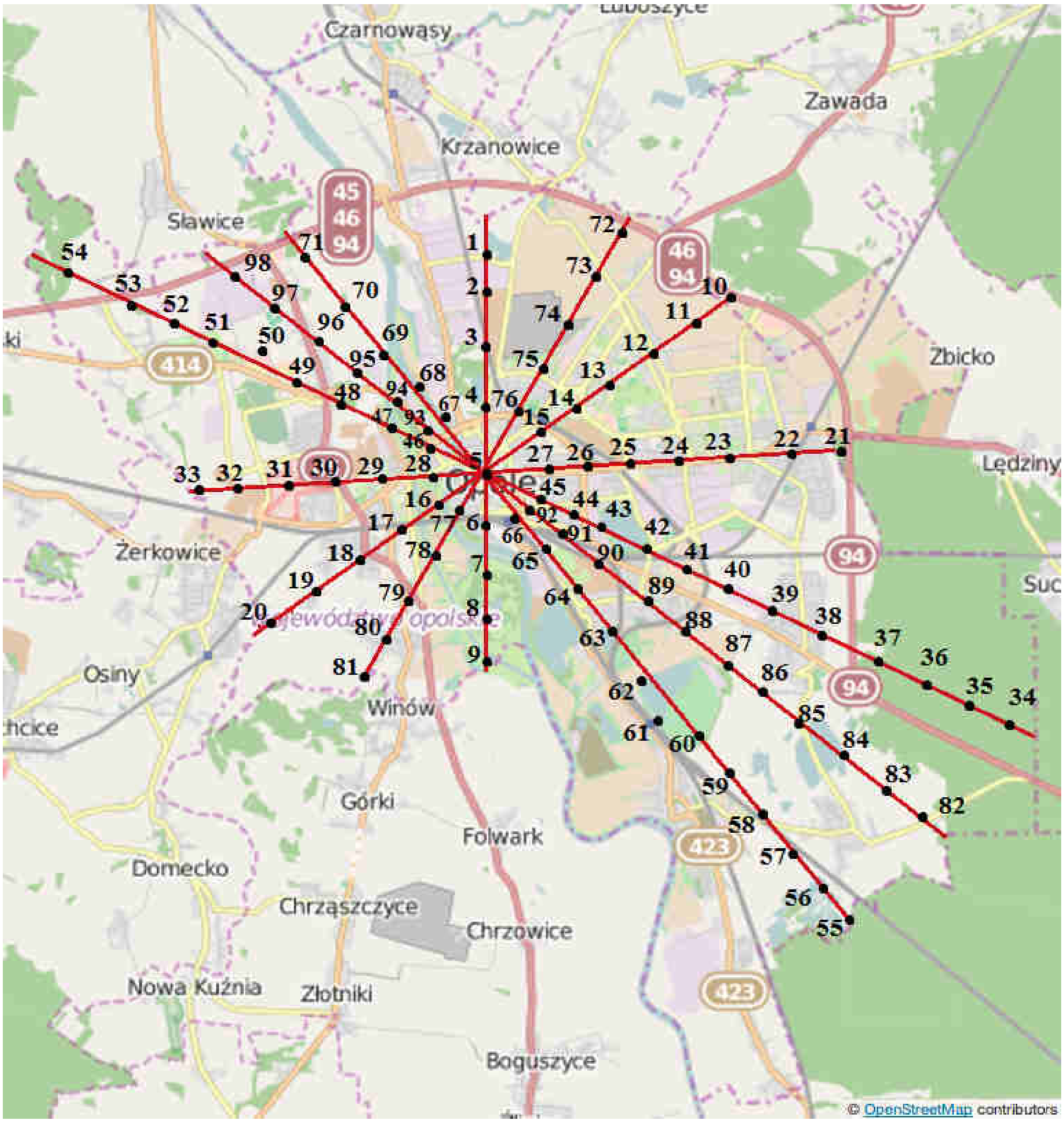

Fig. 1. The arrangement of transects and sample points in Opole City. Source: OpenStreetMap.org (modified): www.openstreetmap.org/copyright.

Results

In four a priori determined sample plots (11, 20, 49, 81) no epiphytic lichen individuals were noted due to of the lack of woody plants in agricultural areas. In 10 plots with woody plants (5, 33, 50, 53, 56, 57, 59, 60, 62, 83) no epiphytic lichens were found as well. However, in all of these 14 places no other lichens were found (5, 11, 20, 33, 49, 50, 53, 56, 57, 59, 60, 62, 81, 83). In the rest of the study area (84 plots) biodiversity of lichens was checked. 12 epiphytic lichen species belonging to 11 genera were found. Most of the thalli were damaged to the various degree (Fig. 2).

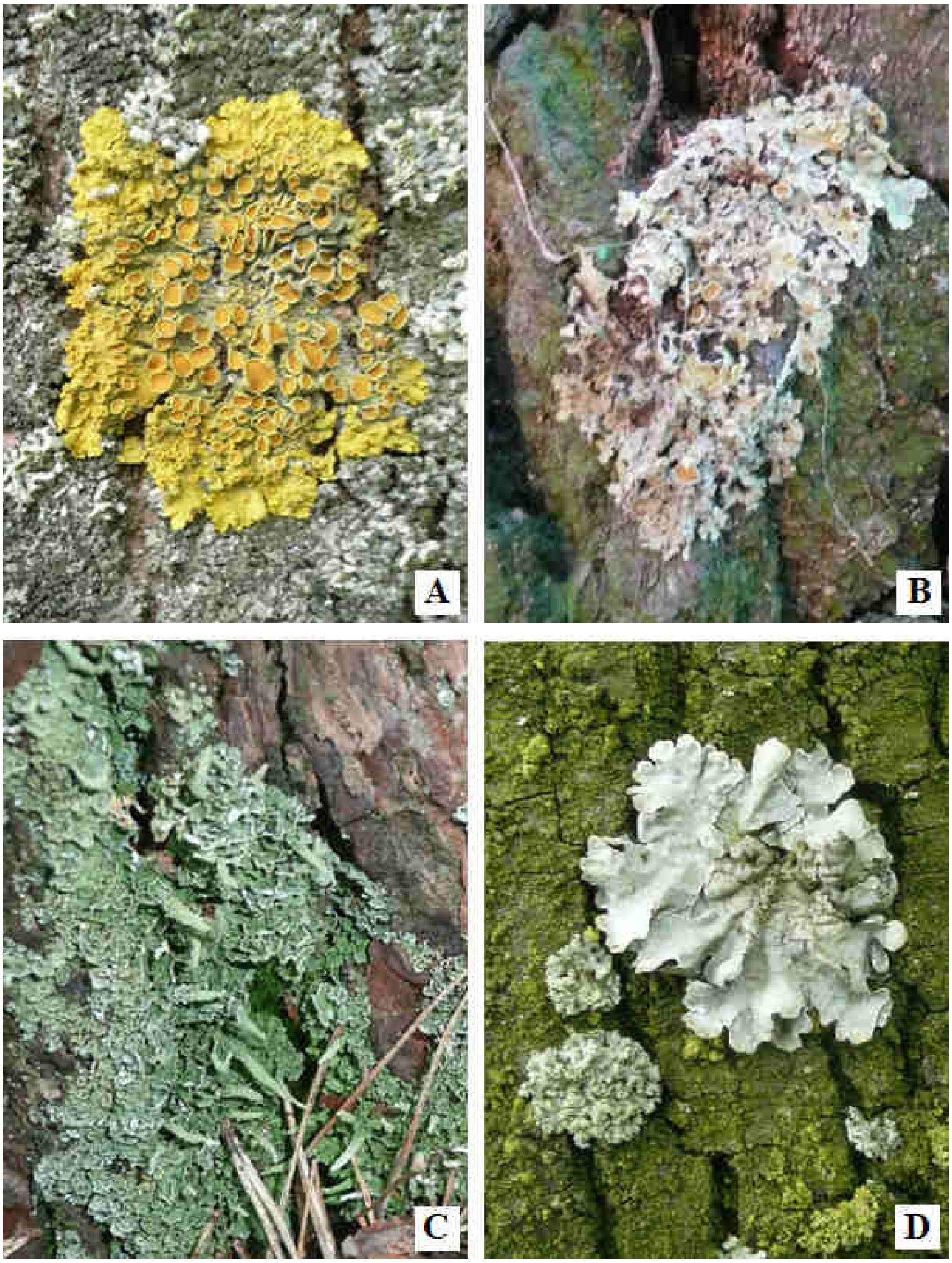

Fig. 2. A – *Xanthoria parietina*, B – the destroyed thallus of *Xanthoria parietina, C – Cladonia coniocraea*, D – *Parmelia sulcata.*

1. ***Amandinea punctata*** **(Hoffm.) Coppins & Scheid.** – widespread, 56 localities: 1 – *Populus nigra,* N; 2 – *Betula pendula,* N, NE; 6 – *Fraxinus excelsior,* E; 12 – *Ulmus leavis,* S, SW, W; 13 – *Robinia pseudoacacia,* N; 14 – *Tilia cordata,* S, SE; 15 – *Ulmus leavis,* NE; 16 – *Quercus robur*, N, NE; 17 – *Quercus robur,* S; 18 – *Fraxinus excelsior,* NE, S; 19 – *Populus balsamifera,* W, E; 21 – *Ulmus leavis,* S; 23 – *Acer platanoides,* N, S, E; 24 – *Sorbus intermedia,* N; 25 – *Acer platanoides,* S; 26 – *Tilia cordata,* N, NW; 27 – *Gleditsia triancanthos,* NE; 28 – *Acer platanoides,* NE; 30 – *Cerasus avium,* N, NE; 32 – *Sorbus aucuparia,* N; 34 – *Picea abies,* N; 36 – *Pinus sylvestris,* N, SE, E, W; 37 – *Quercus robur*, N, NW, NE, E; 39 – *Fraxinus excelsior*, E; 40 – *Robinia pseudoacacia,* N; 41 – *Sorbus intermedia*, S, SW; 42 – *Prunus serotina*, W; 43 – *Acer platanoides*, S, SE; 44 – *Fraxinus excelsior*, W; 45 – *Cerasus avium,* N, S; 46 – *Acer platanoides,* N, NE, NW; 47 – *Quercus robur,* NW, W; 52 – *Acer platanoides*, S; 58 – *Fraxinus excelsior,* W; 61 – *Quercus rubra*, NW; 63 – *Ulmus leavis,* SE, E; 64 – *Tilia platyphyllos,* W; 65 – *Tilia platyphyllos,* N, NW; 67 – *Sorbus aucuparia,* N, NW; 69 – *Sorbus aucuparia*, SW, W; 71 – *Salix sepulcralis,* N; 75 – *Tilia cordata*, N, W; 77 – *Quercus robur*, N, S; 79 – *Fraxinus excelsior,* SW; 84 – *Quercus robur*, NW, W; 85 – *Fraxinus excelsior,* NE; 86 – *Ulmus leavis*, S, SE; 88 – *Sorbus intermedia*, N, NW, NE; 89 – *Ulmus leavis*, NW; 90 – *Acer platanoides*, NE, E; 91 – *Fraxinus excelsior,* S, SW; 92 – *Tilia platyphyllos*, N; 93 – *Sorbus aucuparia,* N, NE; 94 – *Quercus robur*, NW, 95 – *Sorbus aucuparia,* SE, E; 97 – *Salix sepulcralis,* NW, W, SW.

2. ***Candelariella xanthostigma*** **Ach. (Lettau.)** – rare, 4 localities:
73 – *Ulmus leavis,* N, NW; 82 – *Quercus robur*, N, E; 86 – *Ulmus leavis,* S, SE; 97 – *Salix sepulcralis,* NW, W, SW.

3. ***Cladonia coniocraea*** **(Florke) Spreng.** – rare, at the base of the trunk, 5 localities:
34 – *Picea abies,* 35 – *Picea abies*, SE, E; N; 36 – *Pinus sylvestris,* N, SE, E, W; 37 – *Quercus robur*, N, NW, NE, E; 54 – *Picea abies,* S, SE, W.

4. ***Cladonia pyxidata*** **(L.) Hoffm.** – rare, at the base of the trunk, 3 localities:
36 – *Pinus sylvestris,* N, SE, E, W; 48 – *Betula pendula*, N, NE; 54 – *Picea abies,* S, SE, W.

5. ***Hypocenomyce scalaris*** **(Ach.) Choisy** – fairly rare, 6 localities:
1 – *Populus nigra,* N, 61 – *Quercus rubra*, NW; 63 – *Ulmus leavis,* SE, E; 72 – *Populus nigra*, SW, W; 87 – *Quercus rubra*, NW, E; 89 – *Ulmus leavis*, NW.

6. ***Lecanora conizaeoides*** **Nyl. in Cromb** – rare, 3 localities:
12 – *Ulmus leavis*, S, SW, W; 23 – *Acer platanoides,* N, S, E; 64 – *Tilia platyphyllos,* W.

7. ***Lepraria*** **sp. div.** – common, 12 localities:
1 – *Populus nigra*, N, 14 – *Tilia cordata*, S, SE; 34 – *Picea abies,* 35 – *Picea abies*, SE, N; 39 – *Fraxinus excelsior,* E; 51 – *Quercus robur,* S, SE; 52 – *Acer platanoides*, S; 72 – *Populus nigra,* SW, W; 73 – *Ulmus leavis*, N, NW; 75 – *Tilia cordata*, N, W; 93 – *Sorbus aucuparia,* N, NE; 98 – *Quercus robur,* N, NW W.

8. ***Parmelia sulcata* Taylor** – common, 17 localities:

6 – *Fraxinus excelsior,* E; 7 – *Salix sepulcralis,* SE; 8 – *Acer platanoides,* SW; 10 – *Quercus robur,* E; 14 – *Tilia cordata*, S, SE; 18 – *Fraxinus excelsior,* NE, S; 19 – *Populus balsamifera*, W, E; 38 – *Fraxinus excelsior*, S; 47 – *Quercus robur*, NW, W; 51 – *Quercus robur*, S, SE; 55 – *Quercus robur,* S; 75 – *Tilia cordata*, N, W; 78 – *Salix sepulcralis*, E; 79 – *Fraxinus excelsior,* SW; 82 – *Quercus robur*, N, E; 94 – *Quercus robur*, NW; 98 – *Quercus robur*, N, NW W.

9. ***Parmeliopsis ambigua* (Wulfen in Jacq.) Nyl.** – widespread, 33 localities:

3 – *Crataegus monogyna*, S, W, E; 4 – *Fraxinus excelsior,* S, N, W, E; 6 – *Fraxinus excelsior,* E; 9 – *Acer platanoides,* N, NE; 24 – *Sorbus intermedia*, N; 26 – *Tilia cordata*, N, NW; 27 – *Gleditsia triancanthos*, NE; 28 – *Acer platanoides,* NE; 30 – *Cerasus avium,* N, NE; 31 – *Sorbus intermedia*, NE, E; 32 – *Sorbus aucuparia,* N; 39 – *Fraxinus excelsior*, E; 40 – *Robinia pseudoacacia*, N; 41 – *Sorbus intermedia*, S, SW; 42 – *Prunus serotina,* W; 43 – *Acer platanoides*, S, SE; 44 – *Fraxinus excelsior,* W; 45 – *Cerasus avium,* N, S; 58 – *Fraxinus excelsior,* W; 63 – *Ulmus leavis,* SE, E; 64 – *Tilia platyphyllos,* W; 66 – *Tilia cordata*, N; 69 – *Sorbus aucuparia*, SW, W; 71 – *Salix sepulcralis,* N; 76 – *Fraxinus excelsior*, E; 80 – *Acer platanoides*, NE, E; 85 – *Fraxinus excelsior,* NE; 88 – *Sorbus intermedia*, N, NW, NE; 89 – *Ulmus leavis,* NW; 90 – *Acer platanoides*, NE, E; 91 – *Fraxinus excelsior,* S, SW; 95 – *Sorbus aucuparia*, SE, E; 97 – *Salix sepulcralis,* NW, W, SW.

10. ***Phaeophyscia ciliata* (Hoffm.) Moberg** – common, 18 localities:

1 – *Populus nigra*, N, 7 – *Salix sepulcralis*, SE; 12 – *Ulmus leavis*, S, SW, W; 16 – *Quercus robur,* N, NE; 22 – *Fraxinus excelsior,* N, S, W, E; 25 – *Acer platanoides,* S; 26 – *Tilia cordata*, N, NW; 28 – *Acer platanoides,* NE; 29 – *Acer platanoides,* S, SE; 32 – *Sorbus aucuparia,* N; 58 – *Fraxinus excelsior,* W; 65 – *Tilia platyphyllos,* N, NW; 72 – *Populus nigra*, SW, W; 73 – *Ulmus leavis*, N, NW; 77 – *Quercus robur*, N, S; 78 – *Salix sepulcralis,* E; 85 – *Fraxinus excelsior,* NE; 92 – *Tilia platyphyllos,* N.

11. ***Physcia adscendens* (Fr.) H. Olivier** – fairly rare, 10 localities:

15 – *Ulmus leavis,* NE; 17 – *Quercus robur*, S; 18 – *Fraxinus excelsior,* NE, S; 19 – *Populus balsamifera,* W, E; 21 – *Ulmus leavis,* S; 22 – *Fraxinus excelsior,* N, S, W, E; 23 – *Acer platanoides,* N, S, E; 24 – *Sorbus intermedia,* N; 46 – *Acer platanoides*, N, NE, NW; 79 – *Fraxinus excelsior,* SW.

12. ***Xanthoria parietina* (L.) Th. Fr.** – widespread, especially in parks and squares, 33 localities:

1 – *Populus nigra,* N, 2 – *Betula pendula*, N, NE; 4 – *Fraxinus excelsior,* S, N, W, E; 8 – *Acer platanoides,* SW; 10 – *Quercus robur,* E; 12 – *Ulmus leavis,* S, SW, W; 13 – *Robinia pseudoacacia*, N; 14 – *Tilia cordata*, S, SE; 15 – *Ulmus leavis*, NE; 17 – *Quercus robur*, S; 21 – *Ulmus leavis*, S; 22 – *Fraxinus excelsior,* N, S, W, E; 23 – *Acer platanoides*, N, S, E; 28 – *Acer platanoides*, NE; 30 – *Cerasus avium*, N, NE; 32 – *Sorbus aucuparia,* N; 44 – *Fraxinus excelsior,* W; 46 – *Acer platanoides*, N, NE, NW; 61 – *Quercus rubra*, NW; 67 – *Sorbus aucuparia*, N, NW; 68 – *Fraxinus excelsior*, S; 69 – *Sorbus aucuparia,* SW, W; 70 – *Fraxinus excelsior,* SW, S, SE; 72 – *Populus nigra*, SW, W; 73 – *Ulmus leavis*, N, NW; 74 – *Betula pendula,* NE, N, NW; 75 – *Tilia cordata*, N, W; 76 – *Fraxinus excelsior,* E; 87 – Q*uercus rubra*, NW, E; 91 – *Fraxinus excelsior,* S, SW;

93 – *Sorbus aucuparia*, N, NE; 95 – *Sorbus aucuparia*, SE, E; 96 – *Fraxinus excelsior*, N.

The most common species are: *Amandinea punctata, Parmeliopsis ambigua* and *Xanthoria parietina.* The least frequent species were found only in 3 plots: *Cladonia pyxidata* and *Lecanora conizaeoides. Candelariella xanthostigma* is an another rare species (found in 4 plots).

Discussion

The most comprehensive data about lichens occurring in the Opole Silesia were compiled by Leśniański (2010). About 30 species were mentioned to be known from the city of Opole, and 16 of them were epiphytes. The bigger number of species results from long research periods. Most of them was recorded in 1992–1997. Although, in this study 4 new species not listed by Leśniański (2010) were found: *Cladonia pyxidata, Lepraria* sp. div., *Parmeliopsis ambigua, Phaeophyscia ciliata.*

According to gradient zones Hawksworth and Rose (1970) and Kiszka (1990) areas with concentration of atmospheric sulphur dioxide at the level do not exceeding 30 $\mu g/m^3$ are consider to be pure and appropriate for even very sensitive lichen species, namely *Usnea* sp. div. Contamination of SO_2 in Opole is within this limits (Barańska et al. 2013), but no vulnerable species have been found during this study. The air quality seems to be unfavorable for lichens, and in consequence for other living organisms, for people too (Fałtynowicz 1991). Most of the species are classified as 3rd or 4th zone indicators. *Parmelia sulcata* is the least resistant lichen species, which can tolerate 50–60 $\mu g/m^3$ SO_2. However, the occurrence of even small, disposable increase of pollutants may be a threat to the lichen biota (Wieczorek and Durka 2009).

Sulphur dioxide seems then to be not the only one limiting factor, what is also consistent with observations made by Fałtynowicz (1995), but still is the main limiting pollutant (Giordani 2007). Rydzak (1957a) pointed to many limiting factors: a lack of water, an excessive insolation, development of urban infrastructure (buildings, sidewalks, routes, car parks), the urban heat island effect. Today, after 60 years and a significant expansion of the city, their impact still is noteworthy. The level of their influence depends on the way, how the city space is developed. The least number of species were found in agricultural fields outside the city centre. There was an absence of lichens despite the presence of trees. These places are localized far from river, and a low humidity, high insolation and the presence of trees that grow at a distance from each other may have unfavorable effect on lichen biota. The exception is Main Market where no lichens were found because of the lack of trees. At the adjacent streets occasionally grow young woody plants. At these places habitats are inappropriate.

Although, nearby city centre Odra River flow. It splits into 3 channels and their surroundings have high humidity. In the riverside lichen diversity is not higher than in other places. The same applies to the areas in close proximity to ponds. On the other hand the development of lichen biota is often limited along main communication roads (Rydzak 1957a; Fałtynowicz 1991), but areas near roads with heavy traffic in Opole city are not poorer in lichen species than the rest of urban area.

Conclusions

The epiphytic lichen biota of Opole city shows small diversity, in consequence the quality of air seems to be low. There is a lack of vulnerable species in Opole. *Parmelia sulcata* is the most sensitive biomarker in the city, but its resistance to SO_2 is quite high (60 μm/m^3). It is assumed that aside from pollutants, the most important limiting factors are: high insolation, the urban heat island effect, and in some places: low humidity or the lack of tree complexes. For sure, there is no zone of normal, unrestricted vegetation.

In conclusion, the analysis of the distribution of lichens in cities could be helpful for verifying some of the environmental variables, but their presence (or absence) should be interpreted in terms of all limiting factors and distributional changes over the previous decades.

Bibligraphy

Barańska B., Barbaruk G., Sobolewska A., Stęplewska S., Wylęgała L., Wróbel M., Zimolong Z., Karczyńska E., Lech E., Wyrozumski H., Kantorczyk-Gałkiewicz J., Gębala M., Olszanowska-Kuńka K., Szczepańska P. 2013. Stan środowiska w Opolu i powiecie opolskim w 2012 roku. Wojewódzki Inspektorat Ochrony Środowiska w Opolu, Biblioteka Monitoringu Środowiska, Opole. 116 pp.

Bielec D. 2011. Lichenoindykacja Bielska-Białej – syntetyczne strefy porostowe. Nauka Przyr. Technol. 5(4): 1–12.

Bielczyk U. 2001. Porosty. Ulotka. Instytut Botaniki im. W. Szafera PAN, Kraków. 10 pp.

Budzyński I., Taradejna U., Korczak–Żydaczewska K., Milusz M. Wójcikowska J, Sznejder A., Marczak M. 2011. Powierzchnia i ludność w przekroju terytorialnym w 2011r. GUS, Warszawa. 198 pp.

Fałtynowicz W. 1995. Wykorzystanie porostów do oceny zanieczyszczenia powietrza. Zasady, metody, klucze do oznaczania wybranych gatunków. Centr. Edu. Ekolog. Wsi, Krosno. 141 pp.

Fałtynowicz W. 2003. The lichens, lichenicolous and allied fungi of Poland – an annotated checklist. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków. 435 pp.

Fałtynowicz W., Izydorek I., Budzbon E. 1991. The lichen flora as bioindicator of air pollution of Gdańsk, Sopot and Gdynia. Monogr. Bot. 73: 3–52.

Feige G. B. 1982. Niedere Pflanzen – speziell Flechten – als Bioindikatoren. Decheniana – Beihefte 26: 23–30.

Giordani P. 2007. Is the diversity of epiphytic lichens a reliable indicator of air pollution? A case study from Italy. Envir. Pollut. 146: 317–323.

Hawksworth D. L., Rose F. 1970. Qualitative scale for estimating sulphur dioxide air pollution in England and Wales using epiphytic lichens. Nature 227: 145–148.

Izydorek I. 2005. The lichens of selected towns in a Polish coastline of the Baltic Sea. Acta Bot. Cassub. 5: 173–178.

Kiszka J. 1977. Wpływ emisji miejskich i przemysłowych na florę porostów (*Lichenes*) Krakowa i Puszczy Niepołomickiej. Prace Monogr. WSP w Krakowie 19: 5–132.

Kiszka J. 1990. Lichenoindykacja obszaru województwa krakowskiego. Studia Ośrod. Dok. Fizjogr. 18: 201–212.

Kiszka J. 1999. Porosty (*Lichenes*) oraz warunki bioekologiczne Przemyśla. Arbor. Bolestraszyce 6: 1–86.

Kondracki J. 2002. Geografia regionalna Polski. PWN, Warszawa. 440 pp.

Kubiak D. 2007. Zastosowanie porostów do oceny antropogenicznych przekształceń i waloryzacji przyrodniczej obszarów leśnych miasta Olsztyna. Stud. i Mat. Centr. Edu. Przyr.-Leś. 2/3(16): 303–316.

Leśniański G. Z. 2010. The lichen biota of Opole Silesia (South Poland). Pt. 1. The list of lichen species. Wyd. Uniw. Opolskiego, Opole. 162 pp.

Mirek Z., Piękoś-Mirkowa H., Zając A., Zając M. 2002. Flowering plants and pteridophytes of Poland. A checklist. vol. 1. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków. 442 pp.

Nowak J., Tobolewski Z. 1975. Porosty polskie. PWN, Kraków. 1177 pp.

Nylander W. 1866. Les lichens du Jardin du Luxemburg. Bullet. de la Soc. Botan. de France 13(7): 364–372.

Olech M., Dudek K. 1981. Epiphytic lichens of Skawina (southern Poland). Prace Bot. 8: 165–171.

Rutkowski L. 2014. Klucz do oznaczania roślin naczyniowych Polski niżowej. PWN, Warszawa. 816 pp.

Rydzak J. 1953. Rozmieszczenie i ekologia porostów miasta Lublina. Ann. UMCS (sec. C) 8(9): 233–356.

Rydzak J. [1956] 1957a. Wpływ małych miast na florę porostów. Część 1. Dolny Śląsk – Kluczbork, Wołczyn, Opole, Cieszyn. Ann. UMCS (sec. C) 10(1): 1–22.

Rydzak J. [1955] 1957b. Wpływ małych miast na florę porostów. Część 2. Beskidy Zachodnie – Wisła, Ustroń, Muszyna, Iwonicz, Rymanów, Lesko. Ann. UMCS (sec. C) 10(2): 33–66.

Rydzak J. 1957c. Wpływ małych miast na florę porostów. Część 3. Tatry. Zakopane. Ann. UMCS (sec. C) 10(7): 157–176.

Rydzak J. 1957d. Wpływ małych miast na florę porostów. Część 4. Lubelszczyzna, Kieleckie, Podlasie, Puławy, Zamość, Busko, Siedlce, Białowieża. Ann. UMCS (sec. C) 10(14): 321–398.

Rydzak J. 1959a. Wpływ małych miast na florę porostów. Część 5. Kotlina Kłodzka, Kłodzko, Kudowa Zdrój, Duszniki Zdrój, Lądek Zdrój, Stronie Śląskie. Ann. UMCS (sec. C) 11(2): 25–50.

Rydzak J. 1959b. Wpływ małych miast na florę porostów. Część 6. Region bałtycki – Międzyzdroje, Ustka, Łeba. Ann. UMCS (sec. C) 11(3): 51–72.

Rydzak J. [1958] 1959c. Wpływ małych miast na florę porostów. Dyskusja i wyniki. Część 7. Ann. UMCS (sec. C) 13(16): 275–323.

Saag L., Saag A., Randlane T. 2009. World survey of the genus *Lepraria* (Stereocaulaceae, lichenized Ascomycota). The Lichenol. 41(1): 25–60.

Seaward M. R. D., Letrouit-Galinou A. 1991. Lichen recolonization of trees in the Jardin de Luxembourg, Paris. Lichenol. 23(2): 181–186.

Sokół S. 1978. 'Porosty (*Lichenes*) wskaźnikami zanieczyszczeń środowiska w rejonie miast Ustroń i Wisła'. Master's thesis. Uniw. Śląski, Katowice. 157 pp.

Wieczorek A., Durka A. 2009. Ocena stanu środowiska przyrodniczego lewobrzeżnej części miasta Szczecina na podstawie reakcji porostu testowego *Xanthoria parietina* (L.) Th. Fr. Acta Biol. 16(581): 167–176.

Table 1. The combined lichen scale based on scale zones by Hawksworth and Rose (1970) and Kiszka (1990).

SO_2 concentration [µg/m^3]	Zone	Characteristic species
> 170	1	*Desmococcus viridis* only at the base of a trunk. No epiphytic lichens
170–150	2	*Desmococcus viridis* extend up the trunk. *Lecanora conizaeoides* only at the base of the trunk. Rare: *Lecanora conizaea, Bacidia chlorococca, B. albescens*
150–125	3	*Lecanora conizaeoides* extend up a trunk. Present: *Lecanora conizaea*, *Bacidia chlorococca* and *B. albescens, Lecidea flexuosa, Lepraria incana*
125–70	4	Damaged thalli of *Hypogymnia physodes, Parmelia saxatilis, P. sulcata* at the base of a trunk. *Buellia punctata, Cladonia coniocraea, Lecanora expallens, Lecidea scalaris, Chaenotheca melanophaea*. *Physcia adscendes*, *Hypogymia physodes*, *Xanthoria parietina, X. candelaria*, *Amandinea punctata*, *Hypocenomyce scalaris*. Species from 3rd zone prevail
70–60	5	*Parmelia saxatilis, P. sulcata* up to 2,5m from the base of a trunk. *Physcia stellaris, P. tenella, Hypogymnia physodes, Parmeliopsis aleurites, Lecanora pinastri, L. chlarona, L. carpinea, Xanthoria parietina.* Damaged and rare thalli of *Evernia prunastri, Ramalina farinacea, R. polinaria, Cetraria glauca* at the base of a trunk
60–50	6	*Physcia stellaris*, *Hypogymnia physodes*, *Parmelia sulcata, P. glabratula*, *Ramalina farinacea, Evernia prunastri.* Damaged thalli of *Parmelia caperata* at the base of trunk. *Pseudoevernia furfuracea, Evernia mesomorpha, Alectoria sp., Usnea hirta, U. dasypoga, Graphis scripts*, *Parmelia dubia* at various degrees of damage. Common: *Lecanora* sp., *Lecidea* sp., *Pertusaria* sp.
50–40	7	Very common: *Parmelia caperata, P. dubia, Pseudoevernia furfuracea, Evernia prunastri*, *Graphis ellegans.* Common: *Parmelia cetrarioides, P. revolta, Normandina pulchella, Anaptychia ciliaris*, *Usnea* sp., *Ramalina* sp., *Alectoria* sp.
40–30	8	Numerous species from 7th zone. *Anaptychia ciliaris, Usnea ceratina, U. hirta, U. subfloridana, Platismatia glauca, Bryoria fuscescens, Menegazzia terebrata, Hypogymnia vittata, Parmelia arnoldi, P. perlata, P. acetabulum, Ramalina fraxinea, Physcia pulverulacea, Ramalina fastigiata.* Rare: *Lobaria pulmonaria, Pachyphiale cornea*
Pure < 30	9	Numerous species from 8th zone. *Ramalina calicaris, R. fraxinea, Bryoria* sp., *Usnea* sp. Present: *Lobaria ampliseima, L. scrobiculata, L. pulmonaria, L. scrobiculata, L. amplissima, Parmelia plumbea, Sticta* sp., *Nephroma* sp., *Panaria* sp.

Table 2. Comparison of concentration of SO_2 in Opole (Barańska et. al. 2013) and concentration of SO_2 predicted by combined lichen scale zone based on scale zones by Hawksworth and Rose (1970) and Kiszka (1990).

Species	Zone	Concentration of SO_2 [µg/m^3] predicted by lichen scale	Annual average concentration of SO_2 [µg/m^3]
Amandinea punctata	4	125–70	4.8–9.5
Candelariella xanthostigma	Not included	–	
Cladonia coniocraea	4	125–70	
Cladonia pyxidata	Not included	–	
Hypocenomyce scalaris	4	125–70	
Lecanora conizaeoides	3	150–125	
Lepraria sp.div.	3	150 – 125	
Parmelia sulcata	5 and 6	70–60 and 60–50	
Parmeliopsis ambigua	Not included	–	
Phaeophyscia ciliata	Not included	–	
Physcia adscendens	4	125–70	
Xanthoria parietina	4 and 5	125–70 and 70–60	

Ocena jakości powietrza na podstawie bioty porostów epifitycznych Opola, skali porostowej i danych monitoringowych.

Badania zostały przeprowadzone w celu porównania danych o składzie flory porostowej w Opolu ze skalami porostowymi. Podczas badań terenowych stwierdzono 12 gatunków porostów epifitycznych, należących do 11 rodzajów. W Opolu średni roczny poziom zanieczyszczenia powietrza SO_2 jest niski i wynosi 4,8–9,5µg/m^3. Nieobecność wrażliwych gatunków porostów świadczy o słabej jakości powietrza i złych warunkach dla rozwoju porostów epifitycznych, które ograniczone są przez szereg czynników innych niż zanieczyszczenia (tj.: nadmierne nasłonecznienie, zbyt niska wilgotność, efekt miejskiej wyspy ciepła, czy też brak starych, zwartych zadrzewień).