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Research Article

Evaluation of a Method for the Reassessment of air Quality by Lichen Mapping in the City of İzmir, Turkey

Maja SOMMERFELDT
Hubert-Müller-Strasse 108, D-66115 Saarbrücken-GERMANY
Volker JOHN
Pfalzmuseum für Naturkunde, Hermann-Schäfer-Strasse 17, D-67098 Bad Dürkheim-GERMANY

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Abstract : The occurrence of lichens and air pollution in the city of İzmir were investigated according to VDI-Guideline 3799 Part 1. In all, 45 epiphytic lichen species were found in 1092 releves. Different distribution patterns discriminated in the study area were used to evaluate air quality. A predominant part of the city area is heavily polluted; this pollution decreases in green spaces and in the outer zone of the study area. The best air quality values were determined in the southern and western parts of the city zone. A value of 7.3 for the width of the air quality classes shows that the method is suitable for similar studies in Turkey.

Key Words: Lichens, air pollution, air quality, mapping method, İzmir, Turkey

İzmir'de (Türkiye), Liken Haritalaması ile Hava Kalitesinin Belirlenmesi İçin Kullanılan Metodun Değerlendirilmesi

Özet : İzmir ilinde liken varlığı ve hava kirliği VDI 3799-1 bölüm yöntemine göre incelenmiştir. 1092 karede toplam 45 epifitik liken bulunmuştur. Bu çalışmada bulunan farklı dağılım numuneleri hava kalitesinin değerlendirilmesinde kullanılmıştır. Şehirin büyük bir alanını kapsayan kısmı ağır kirliliğe maruz kalmıştır; bu kirlilik dış bölgelerde yer alan, yeşil alanları kapsayan çalışma alanlarında azalmıştır. Belirlenden en iyi hava kalitesi şehrin güney ve batı kısımlarında tespit edilmiştir. Hava kalitesinin 7.3 genişliğindeki bir değerde olması çalışma metodunun benzer şekilde Türkiye'de de kullanılabileceğini göstermektedir.

Anahtar Sözcükler: Likenler, Hava kirliği, Hava kalitesi, Haritalandırma metodu, İzmir, Türkiye

Introduction

In the mid-19th century the first observations on the correlation between air pollution and lichen vegetation in urban environments were made (Grindon, 1959; Nylander, 1866). In 1926, while mapping the lichen flora in Stockholm, Sernander (1926) formulated the "zone-theory", in which he divided the city according to the epiphytic lichens into the desert zone, struggle zone and normal zone. This division was the basis for mapping lichen floras in a large number cities and industrial touns in Europe. Further methods developed were based on this theory, e.g., the Index of Atmospheric Purity (De Sloover & Le Blanc, 1968). The VDI-Guideline (1995) is the most recent standardised method which has been devised for Central Europe. The question arises whether, and in which way, this method can be applied in Turkey.

Study area

The study area covers the city of İzmir, which has an area of ca. 475 km^2 and an extension of 28 km from north to south and of 41 km from east to west.

Geographically the area belongs to the Northern Menderes Massif (İzmir-Aydın yöresi), a unit of the Aegean Coast Subregion (Ege Kıyı Bölümü) which is part of the Aegean Region (Ege Bölgesi). The Aegean Coast Subregion is a landscape of mountains and basins in which the "ovas" and mountain ranges occur from NE to SW (Erol, 1982). While the basins unite towards the coastline to a broad plain, the mountain ranges approach each other towards the inland so that both basins and mountain ranges are linked together. In the study area, as for the whole Aegean coastal area, numerous east-west rift valleys and isolated massifs (up to more than 1500 m) are the result of elevation and subsidence movements in the Tertiary period. In the mountains of the İzmir region, limestones and marls of the Cretaceous and the Tertiary periods from the main exposures. The city of İzmir is situated in a valley that extends 60 km inland. In the north, İzmir Bay is characterized by the alluvial land of the Gediz river and the 5 km wide Bornova plain. The city is surrounded by several massifs, Yamanlar Dağları (1114 m) in the north, Sipil Dağı in the north-east, the limestone massif of Nif Dağı (1506 m) in the east and south-east, and Çatalkaya Dağı (1042 m) in the south-west. The massifs are divided by some streams whose alluvial land is occupied by settlements. The centre of İzmir, for example, is situated on the alluvial land of the Melez river. The gravel plain in the region north of the bay at Karşıyaka district was deposited by streams that rise on Yamanlar Dağı (Barth et al., 1988; Barth et al., 1989).

In Western Anatolia, a typical Mediterranean winter-rain climate (Figure 1) with hot summers and mild winters is found. In the region of İzmir there is an average annual precipitation of 719 mm, a maximum in December/January and a distinct minimum in July/August (Figure 1). The midday temperature has an annual average of 17.4°C, with 8.5°C in January and up to 27.6°C in July (Statistiches Bundesamt, 1994). In 5 months per year a total minimum of less than 0°C is to be expected (diagonal hatching). The coastal region is influenced by a north to north-west wind in the summer while the inland valleys are protected from the penetration of northern air masses by the mountain ranges (Erol, 1982). Figure 2 shows that winds from the west and south-east prevail.

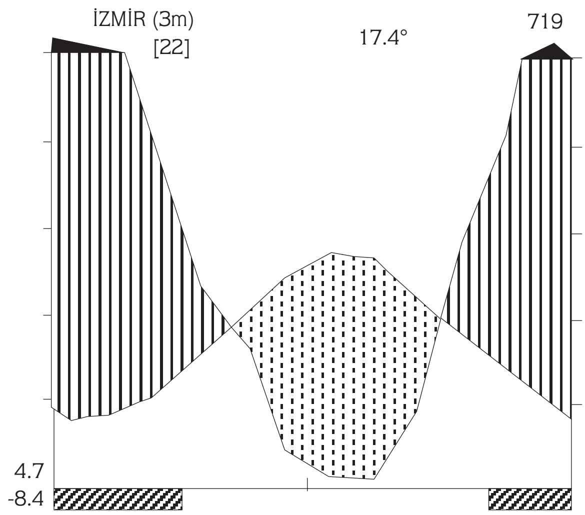

Figure 1. Climatic diagram of İzmir (Walther, Lieth, 1967)

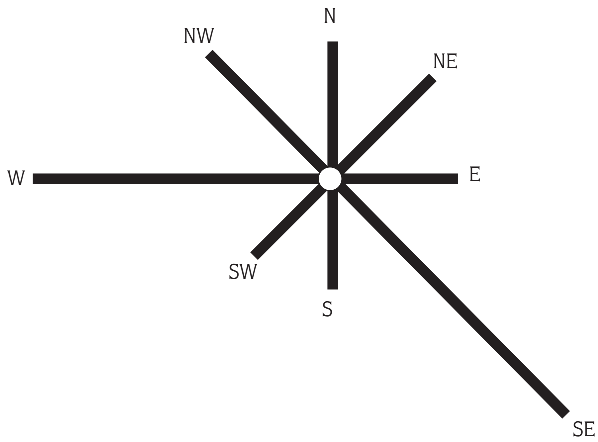

Figure 2. Wind frequencies 1938-1980 at the meteorological station in Güzelyalı, İzmir (Barth et al., 1988; Barth et al., 1989).

According to the figures of the national census of 1997 (Devlet İstatistik Enstitüsü, Internet page), the city of İzmir has a population of 2,081,551, which is at best an approximation. The largest park of the city is the Kültür Park which covers 46 ha. Other green spaces in the city centre are the parks in the districts of Buca and Bornova, and some large cemeteries.

The air pollution of the city of İzmir was researched in the 1980s (Barth et al., 1988; Barth et al., 1989). The concentration of SO_2, CO, NO, NO_2 and dust were measured at 81 locations across the city zone. The most serious were the high SO_2 concentration rates with recordings between the long term limit (0.14 mg/m^3) and the short-term limit (0.40 mg/m^3) of the TA Luft (German government regulation). Towards the west of the city (Güzelbahçe district) a lower population density correlates with a slight concentration reduction. The concentration of CO was also critical, most of the measurements being only a little below the long-term limit of the TA Luft (Erste allgemeine

Verwaltungsvorschrift zum Bundesimmissions-schutzgesetz, 1986) and at some locations this limit was exceeded. The air pollution was extremely high in areas of arterial roads and traffic junctions since CO is released mainly by traffic.

Materials and Methods

The mapping of the lichen vegetation and the evaluation of the results followed the instructions of VDI-Guideline 3799 Part 1 (VDI-guideline, 1995). A 1200 m x 1200 m grid served as the basis for the mapping. In each grid square the lichens of 6 trees were recorded. The study area was composed of 330 grid squares, in 185 of which 1092 trees were analysed (Figure 3). In 145 grid squares no data could be recorded since they were either not accessible (military area) or no appropriate trees were found (e.g., trees were too young, bark was absent, trees were injured). The latter were often in the outer zone of the study area where the mountains begin to rise. The mountain slopes in the north of the city are often barren or reforested with *Pinus* L. or *Eucalyptus* L. species. Those in the south and the east of the city are mostly covered with pines, which do not show any lichen vegetation up to 800 m above sea level.

According to VDI Guidelines, only tree species with comparable bark properties (e.g., pH-value, water storing capacity, nutrient content) should be examined. In the study area it was not easy to meet these requirements since in some districts only *Morus alba* L. and *Ficus carica* L. were present; other areas were covered with olive groves or orchards. Thus the choice of examined trees had to be adjusted to local conditions. Several deciduous tree species were selected for the study; conifers were not considered (except for *Juniperus* L.). Because of the selection of trees with different bark properties, it is not always possible to compare recorded data in totality.

For the examination, the side of the tree trunk was chosen where lichen growth was heaviest. There, a surveying grid, as shown in Figure 4, was attached to the trunk so that the lower edge of the grid was 1 m above

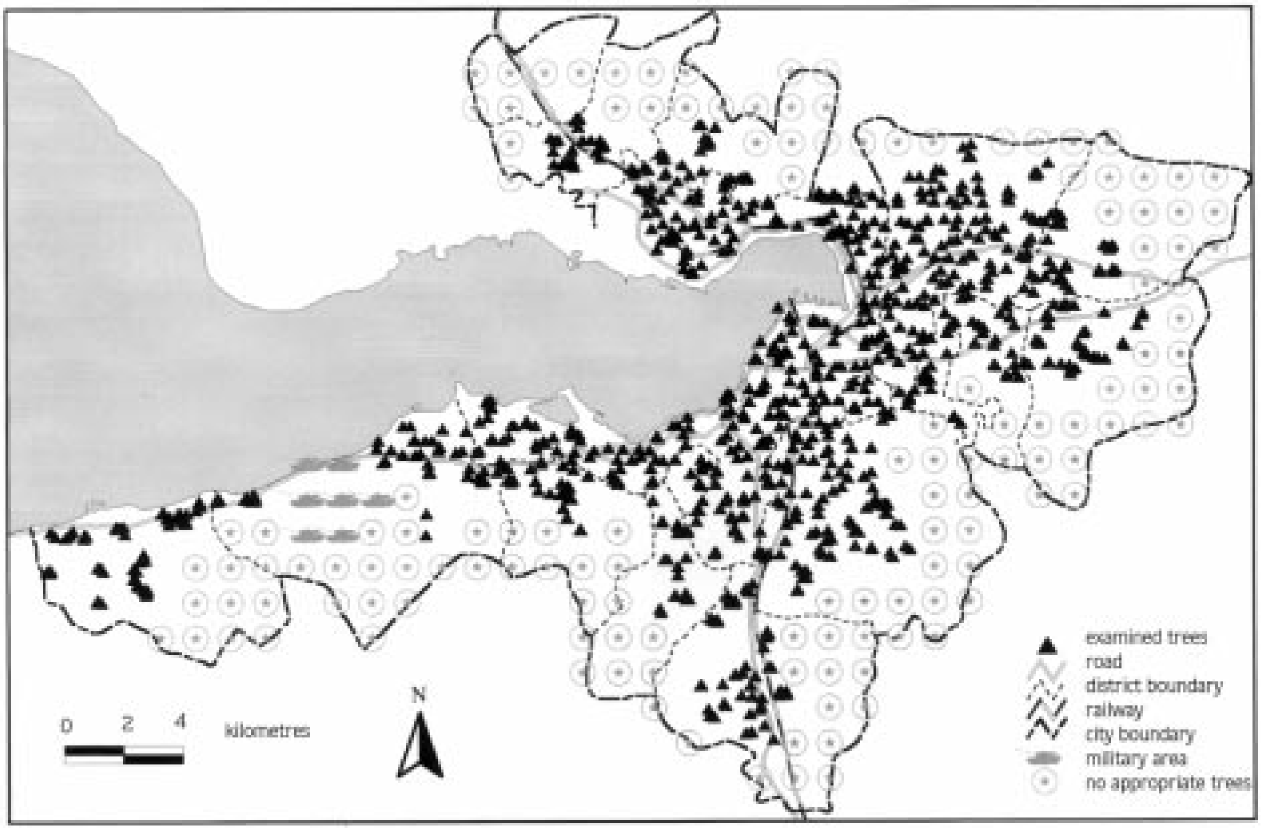

Figure 3. Examined trees

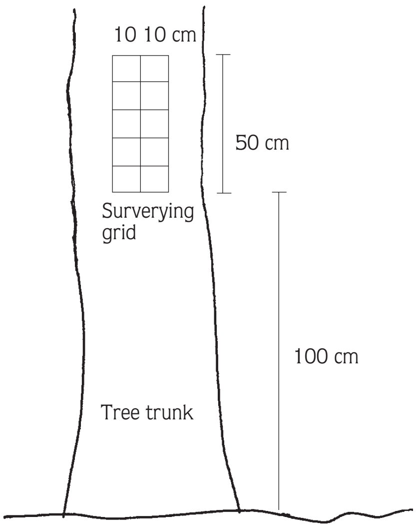

Figure 4. Lichen surveying grid

the ground. The 10 units within the grid were precisely examined with a magnifying glass. All lichen species present and the frequency of their occurrence were recorded. Species not present in any of the 10 uints but occurring just outside the grid were also recorded (and assigned a frequency of 1). In addition, properties of the examined tree (species, circumference, structure of bark, exposure of slope, land utilization, emission sources) were recorded.

If the lichen species could not be identified in the field, specimens were carefully removed and investigated in the laboratory with a stereomicroscope (magnified 6-70 times) and a microscope (magnified 40-1000 times). The colour reaction of the thallus or of the microscopic slide preparation was carried out with the usual reagents: K, C, I and P. The specimens are stored in the herbarium of the Faculty of Sciences at Anadolu University, Eskişehir (ANES).

Analysis of Data

Air quality values (LGW) were calculated according to the following equation:

$LGW_j = \Sigma F_{ij} / n_j$

where

i is the number of the individual tree examined in grid square j

j is the number of the examined unit

F_{ij} is the sum of the frequencies of occurrence on tree i in examined unit j

n_j is the number of surveyed trees within examined unit j

Air quality values (LGW) are assigned to classes which represent the different ranges of air quality, with the standard deviation of the results determining the class width. If the standard deviation is large, the air quality classes are broad and no fine differentiation between various degrees of air pollution is possible. If the standard deviation is small, a more differentiated distinction between the various degrees of pollution is possible. Factors influencing the standard deviation are, for example, the number of trees examined per square and the ecological homogeneity of the area investigated. The following equation is used to calculate the mean standard deviation of the project (VDI-guideline, 1995):

$s_p = \sqrt{\Sigma_j \Sigma_i (F_{ij} - LGW_j)^2 / m(n_p-1)}$

the width of each of the air quality classes = $t_p x s_p / \sqrt{n_p}$

where

s_p is the mean standard deviation of all examined grid squares for the entire study

n_p is the average number of trees examined per grid square for the entire study

m is the number of grid squares surveyed for the entire study

t_p is the critical value of the Student distribution for n_p-1 degrees of freedom.

The calculated width of the air qualityc lasses is the basis for the assignment of the air quality values to the corresponding air quality class:

class 1 $0 < LGW < t_p$

class 2 $t_p < LGW < 2t_p$

class 2 $2t_p < LGW < 3t_p$

etc.

For the evaluation, an exposure scale according to the VDI-Guideline is used (Figure 5). The threshold values of the exposure scale were derived from several extensive surveys in Central Europe. The air quality classes are assigned to the exposure scale such that they match the most suitable verbal expressions and colour codes. If the air quality class falls into two exposure categories, the evaluation of exposure is composed of both categories.

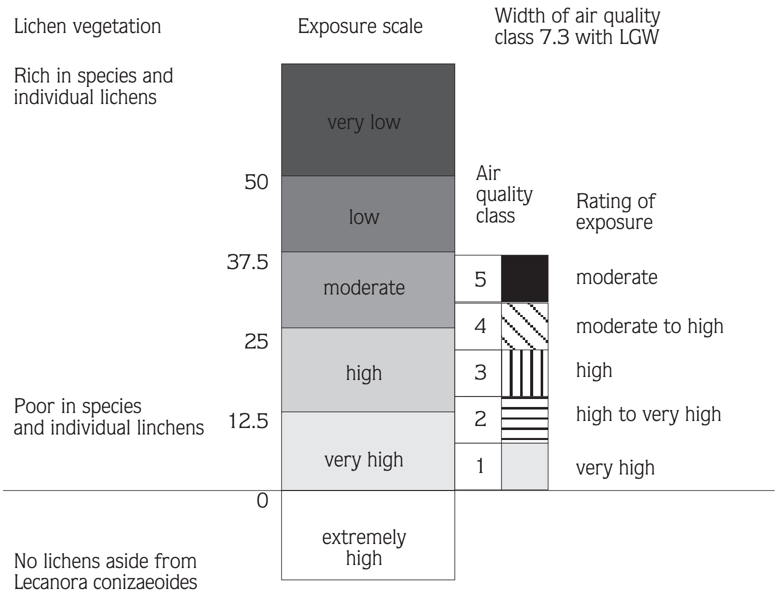

Figure 5. Exposure scale according to the VDI-Guideline (1995); the width of air quality classes is based on the data of the İzmir studies.

Results

Lichen species

During the mapping of the lichen vegetation from April to December 1997, 45 lichen species were found, of which 21 are new records for the province of İzmir, indicated by* in the following list, and 3 species are new records for Turkey, indicated by # in the list.

* *Amandinea punctata* (Hoffm.) Coppins & Scheideg.

Caloplaca cerina (Ehrh. ex. Hedw.) Th. Fr.

Caloplaca cerinella (Nyl.) Flagey

* *Caloplaca cerinelloides* (Erichsen) Poelt

* *Caloplaca flavorubescens* (Huds.) J. R. Laundon

Caloplaca haematites (Chaub. ex St. Am.) Zw.

Caloplaca holocarpa (Hoffm.) Wade

* *Candelaria concolor* (Dicks.) B. Stein

* *Candelariella reflexa* (Nyl.) Lettau

Candelariella viae-lactae Thor & V. Wirth

Candelariella vitellina (Ehrh.) Müll. Arg.

Candelariella xanthostigma (Ach.) Lettau

* *Catillaria nigroclavata* (Nyl.) Schuler

Diplotomma alboatrum (Hoffm.) Flot.

* *Lecania cyrtella* (Ach.) Th. Fr.

* *Lecanora albescens* (Hoffm.) Branth. & Rostr.

Lecanora carpinea (L.) Vain.

Lecanora chlarotera Nyl.

Lecanora hagenii (Ach.) Ach.

#**Lecanora persimilis* (Th. Fr.) Nyl.

Lecanora pulicaris (Pers.) Ach.

**Lecanora saligna* (Schrad.) Zahlbr.

**Lecidella achristotera* (Nyl.) Hertel & Leuckert

Lecidella elaeochroma (Ach.) M. Choisy

**Lepraria lobificans* Myl.

#**Leptogium microphylloides* Nyl.

**Melanelia glabratula* (Lamy) Essl.

**Pertusaria albescens* (Huds.) M. Choisy

Phaeophyscia orbicularis (Neck.) Moberg

Physcia adscendens (Fr.) Olivier

Physcia biziana (A. Massal.) Zahlbr.

Physcia leptalea (Ach.) DC.

Physcia stellaris (L.) Nyl.

Physcia tenella (Scop.) DC.

**Physconia distorta* (With.) J. R. Laundon

Physconia grisea (Lam.) Poelt

Ramalina fastigiata (Pers.) Ach.

**Rinodina colobina* (Ach.) Th. Fr.

Rinodina exigua (Ach.) S. F. Gray

Rinodina oleae Bagl.

#**Strangospora ochrophora* (Nyl.) R. Anderson

**Trapeliopsis flexuosa* (Fr.) Coppins & P. James

Xanthoria parietina (Ach.) Arnold

**Xanthoria polycarpa* (Hoffm.) Rieber

**Xanthoria ucrainica* Kondratyuk

Lichen distribution patterns

Some of the species have characteristic distribution patterns according to their sensitivity to a particular pollution level (Figure 6). The most frequent species in the study area, such as *Candelariella viae-lactae, Lecanora hagenii, Physcia biziana* and *Xanthoria parietina,* are extremely toxitolerant and reach the border of the desert zone. *Caloplaca cerina, Caloplaca haematites, Rinodina pyrina, Lecanora chlarotera* and *Lecidella achristotera* are slightly more sensitive; they are mainly distributed in the outskirts, but they are still frequent. In addition, there is a group of rare species registered almost exclusively in the south and west of the study area (*Caloplaca cerinella, Caloplaca holocarpa, Candelariella xanthostigma* and *Rinodina oleae*).

Frequencies of the most common lichen species

A comparison of the frequencies of the commonest lichen species in the study area (Figure 7) is also very instructive. It is striking that the foliose lichens *Physcia biziana* and *Xanthoria parietina* show their highest concentration in the less polluted areas in the south and the west of the city. In the heavily polluted areas the poor environmental conditions result in a low frequency and a degenerated outer appearance of these toxitolerant lichens. *Physcia biziana* is very common in the southern as well as in the western outer zone, while *Xanthoria parietina* has its highest frequencies in the western outer zone close to the sea. This could be explained by the salt-containing maritime air because *Xanthoria parietina* prefers nutrient-rich habitats. For *Physcia biziana,* the maritime air does not seem to be a decisive factor. The

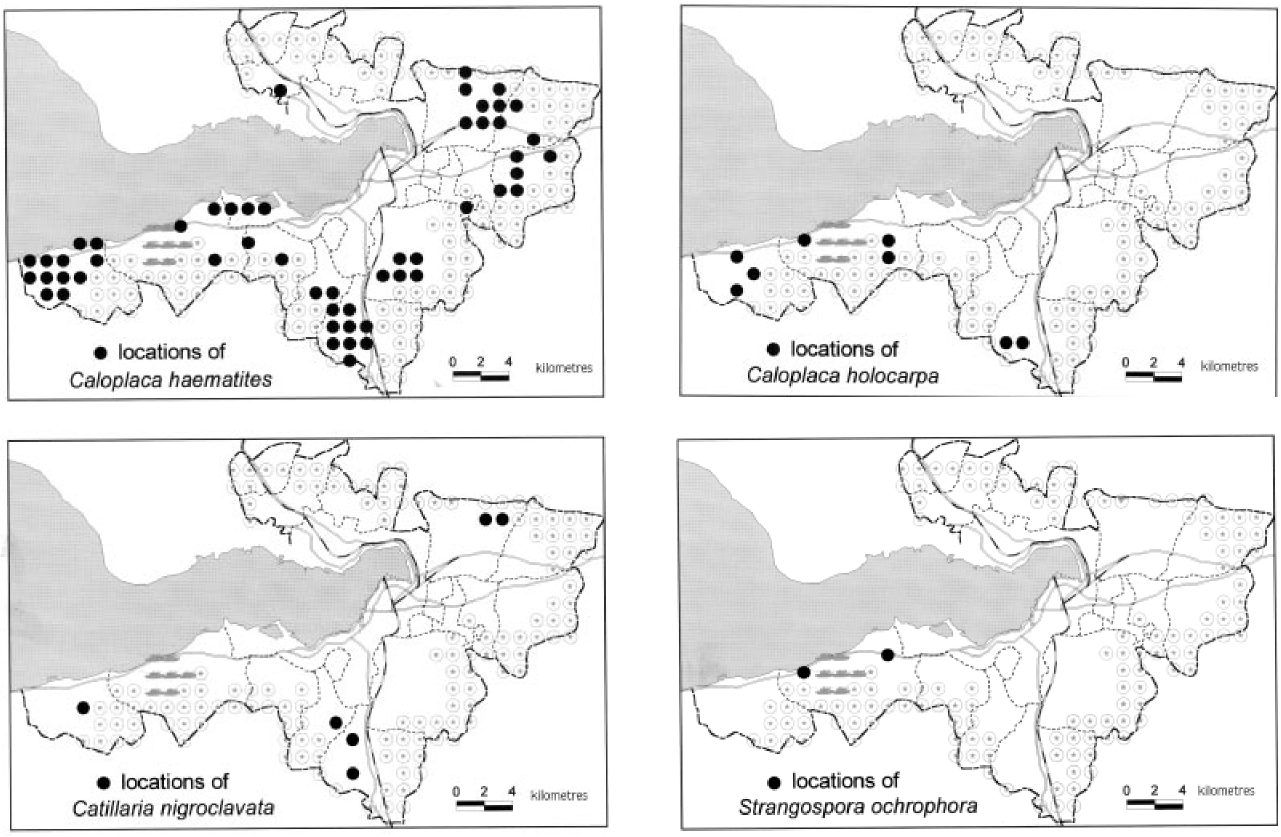

Figure 6. Examples for distribution patterns of crustose lichens that show different sensitivities to air pollution.

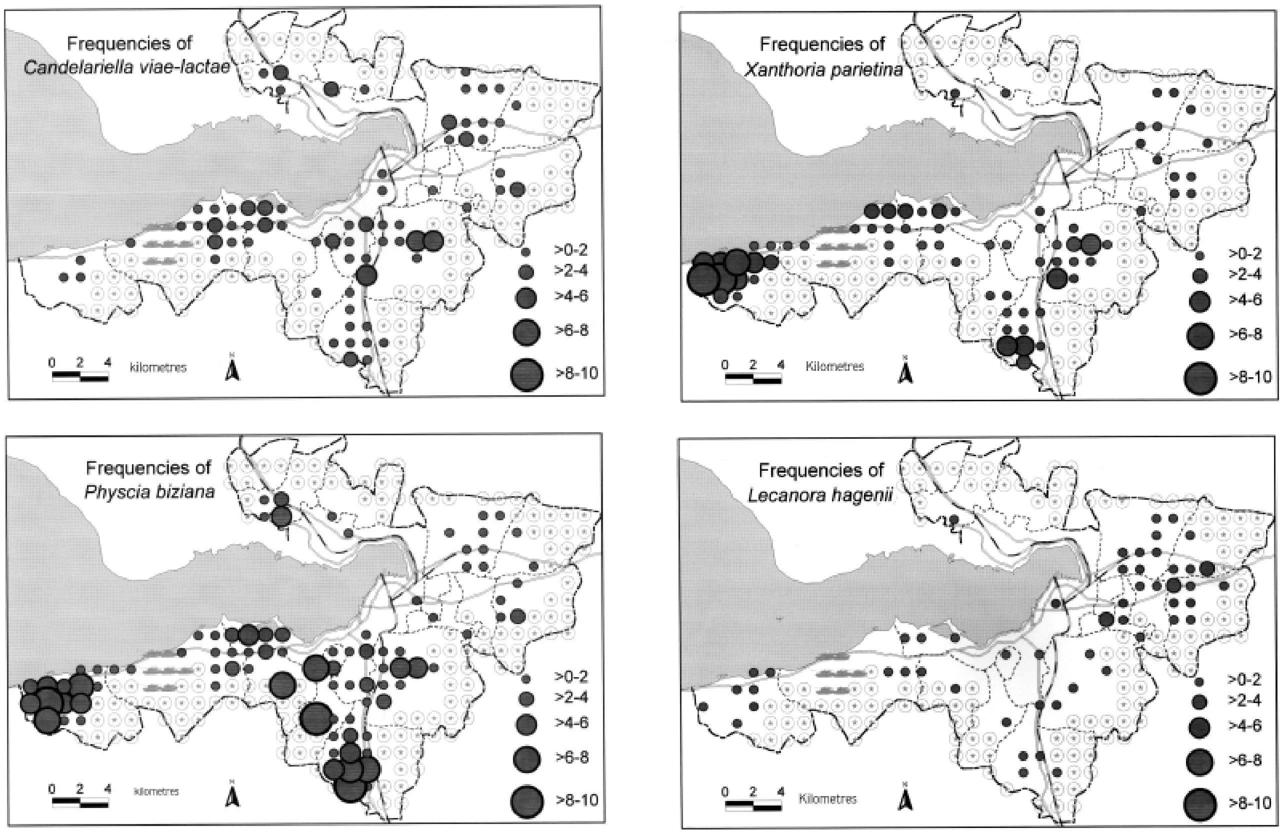

Figure 7. Frequencies of two common crustose and two foliose lichens.

crustose lichens *Lecanora hagenii* and *Candelariella viae-lactae* show different distribution patterns to the most frequent foliose lichens, which could be attributed to the pressure of competition. In the less polluted areas, the more competitive foliose lichens can replace the crustose ones up to a certain degree; in the more polluted areas, however, competition is lower, so these species can develop freely as long as the exposure to emissions is not too high to inhibit their growth. The distribution of both of these crustose lichens indicates that they also like to grow on dust impregnated bark. *Lecanora hagenii,* which has its highest concentration in the heavily polluted eastern part of the city, seems to be the most toxitolerant lichen species in the study area.

Lichen zones in the city of İzmir

According to the methods of the VDI-Guideline, a class width of 7.3 and five air quality classes were determined for the study area as follows:

class 1	0-7.3	very high exposure
class 2	7.3-14.6	high to very high exposure
class 3	14.6-21.9	high exposure
class 4	21.9-29.2	moderate to high exposure
class 5	29.2.36.5	moderate exposure

In the main part of the city of İzmir, the air is heavily polluted; in the outer zone (except for the northern and north-western outskirts), air quality is slightly better; the best air quality values were determined in the southern and western outer zone (Figure 8). In the north-west of the city (Balatçık, Büyükçiğli, Karşıyaka), heavy air pollution is caused by the dense population, the high volume of traffic and the industrial areas in Çiğli and Turan; this region also lacks green spaces. In the recently developed districts, there are almost exclusively young trees, inappropriate for examination, and the hills in the northern external zone are mostly barren. The green spaces in Büyükçiğli with some older trees showed the highest number of species in the north-western part of the city.

In the north-eastern part of the city (Bornova, Doğanlar/Naldöken) heavy air pollution was determined

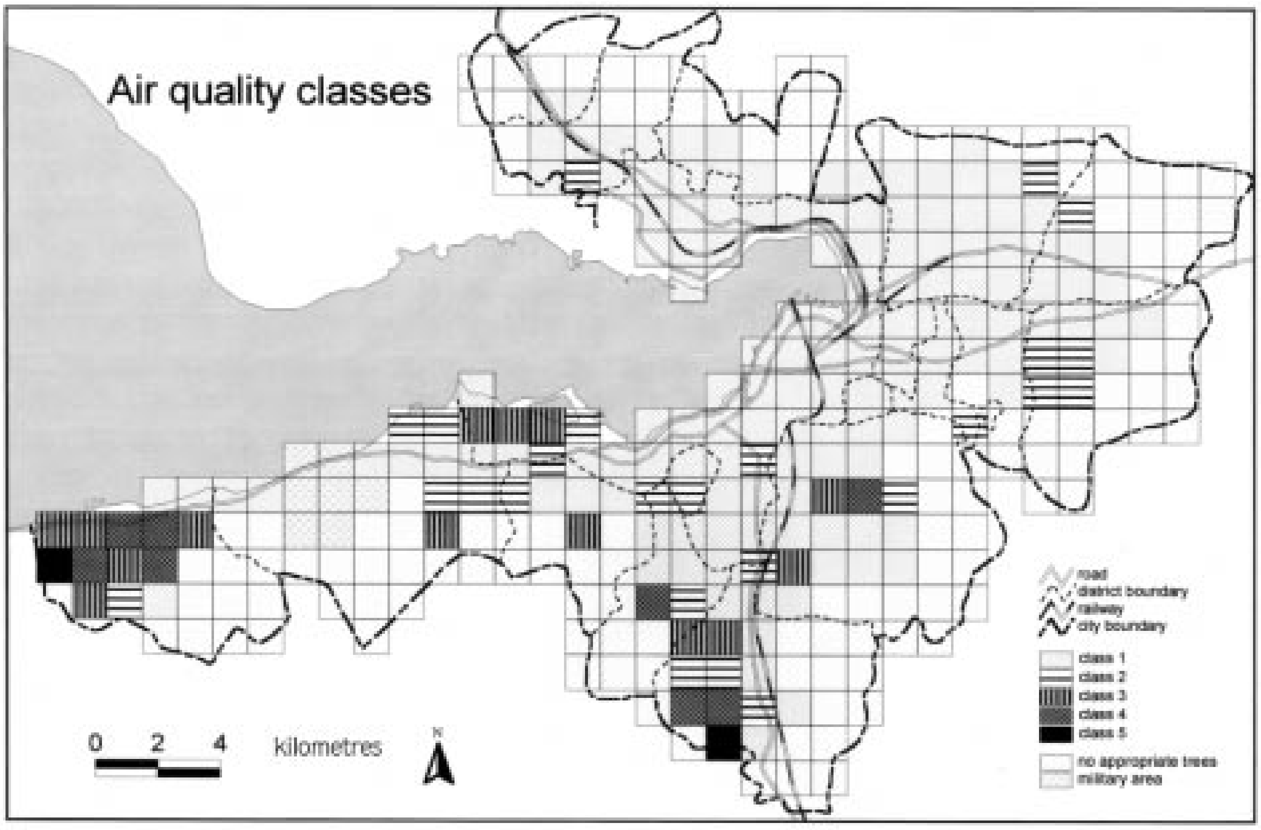

Figure 8. Air quality map

almost everywhere due to the dense population, the high traffic density and the industrial area along the arterial road, especially the emissions from a cement factory. In contrast to the north-western area, there are some larger green spaces in the north-eastern part of the city, e.g., Bornova Park, and the Ege University campus and olive groves, which are characterized by a high number of species (Figure 9) compared with their surrounding areas. In addition, air quality improves towards the outskirts at higher altitudes.

In the eastern part of the city (Çamdibi, Altındağ, Işıkkent, Pınarbaşı), heavy air pollution was also noticed, which can be attributed to industry, in particular a cement factory.

In the central part of the city (centre of İzmir, Yeşilyurt), high air pollution levels were also determined, which are related to the extremely dense population and the high volume of traffic. Furthermore, a small industrial area close to the port and a larger one in Karabağlar contribute to the pollution. The only large park is the 46 ha Kültür Park/Fair. The air quality of this green space differs little from its surrounding area, only a few lichen species being registered here. A little further to the south, an open space stands out due to its slightly better air quality. There are plans to convert this hilly area, with its many old lichen covered pistachio trees, into a picnic area with a lake. Such measures should be supported.

In the south-eastern part of İzmir (Buca) better air quality was detected; hardly any industry has been established here, and there are many green spaces, e.g., “Hasanağa Bahçesi”, an old cemetery, and parks of a college of education and of a hospital. Their positive effect on the air quality is evident, as there are much higher frequencies of lichens.

The southern part of the city (Gaziemir, Uzundere) is distinguished by a comparatively high air quality; in its northern part, industry has been established, but the large cemetery has a positive effect on the lichens.

In the districts Balçova and Narlıdere there are also some areas with a better air quality, e.g., the green spaces along the coast. The high lichen coverage in the olive groves south of the cemetery of Balçova is also striking, as is the valley of a stream coming from the mountains in

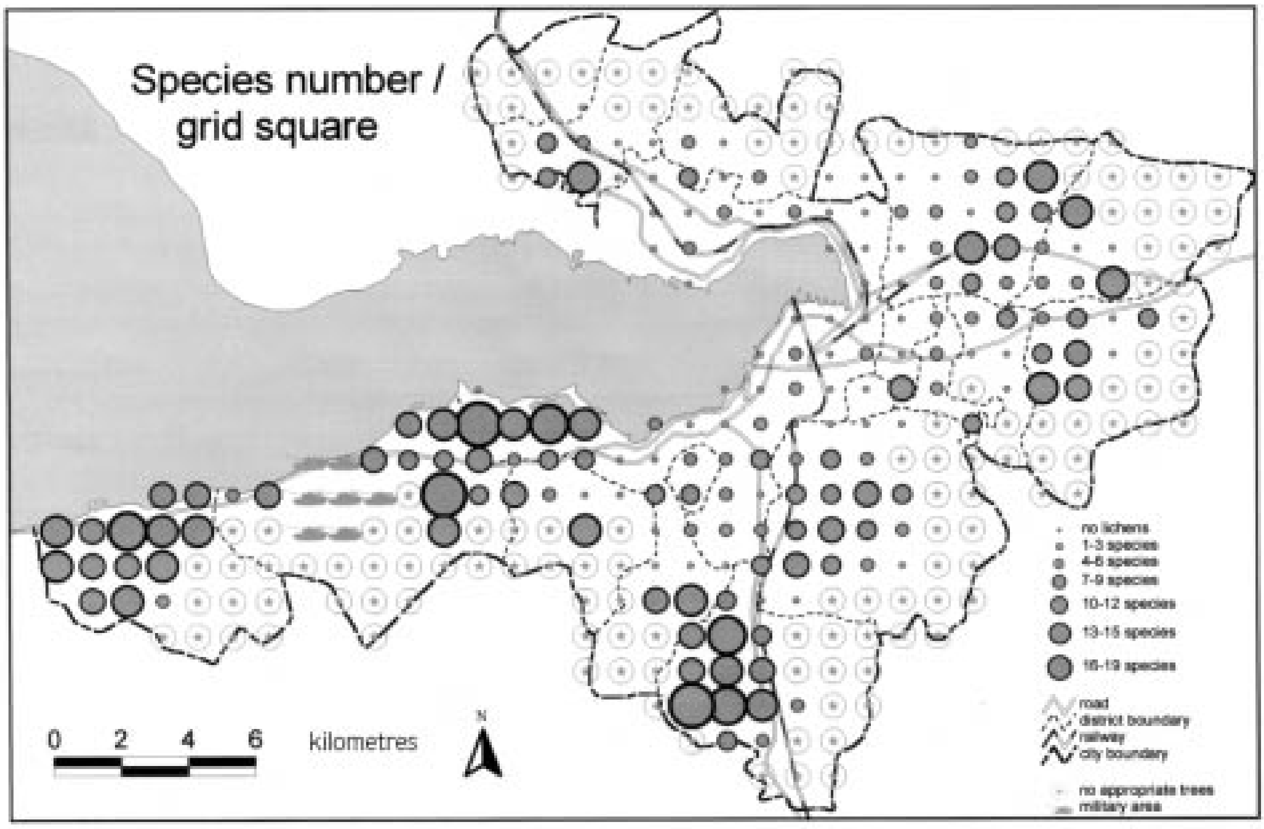

Figure 9. The species number is an appropriate measure of the air quality.

Narlıdere, which reflects the ecological significance of the mountains as places of origin of cold air.

In the part of İzmir furthest in the west (Güzelbahçe), the best air quality (even though it did not exceed a moderate level) of the study area was determined. The comparatively better air quality can be attributed to the lack of industry, the relatively low population density, the low volume of traffic and the many green spaces which are cultivated as orchards or olive groves, or lie fallow.

Since the city is surrounded by mountains, emissions cannot spread unhindered in all directions; the predominant west and south-east winds cause increased pollution exposure in the northern and eastern parts of the city.

Discussion

Growth-from of lichens in the study area

In the study area, the life-form is an appropriate parameter for determining the sensitivity of lichens to air pollution. Generally, fruticose lichens are very sensitive; crustose lichens, in contrast, are mainly resistant species. This is connected with increasing surface area from crustose, followed by foliose, up to fruticose lichens. The larger the surface area the more pollutants can be taken up, and the more eaisly the lichens can dry out. In the study area, most species found were crustose (67%), followed by foliose lichens (31%); fruticose and gelatinous lichens are represented by only one species of *Ramalina* Ach. and one of *Leptogium* (Ach.) S. F. Gray respectively. The predominance of crustose lichens is due to air pollution as well as to the arid and hot climate in İzmir.

Bioclimatic vegetation zones of the lichens in the study area

Figure 10 shows that most species have a large distribution area; in Europe they are present from the boreal conifer forest zone to the Mediterranean. Only a few species are restricted to the sub-Mediterranean/Mediterranean zone. With the exception of *Xanthoria polycarpa*, all species have a bioclimatic

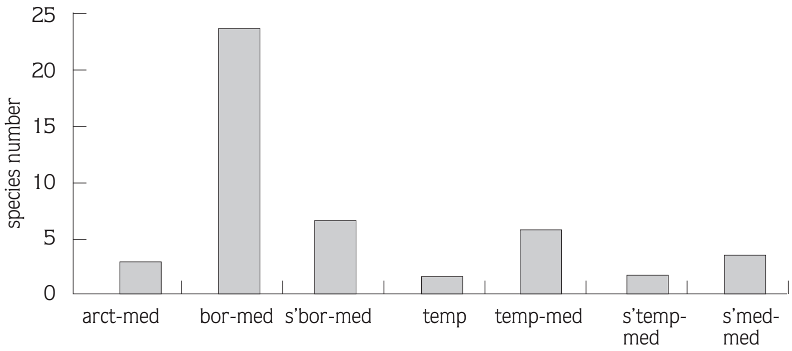

Figure 10. Bioclimatic vegetation zones of the lichens in the study area.

range that includes the Mediterranean region. In contrast to the bioclimatic range of the lichens in the city of İzmir, in the lichen flora in the province of izmir as a whole, many montane species are present.

Choice of trees

On *Pistacia* L. the highest frequencies of lichens were determined, followed by *Olea europaea* L. (Figure 11). While most *Pistacia* are covered with lichens, there are not many trees of *Morus* L. sp. on which lichens occur. Apart from the tree species, lichen coverage is influenced by the age of t he trees. Young *Juglans regia* L. ofter show a high lichen coverage, whereas old ones mostly have none at all. Likewise, on older specimens of *Pistacia* and *Prunus dulcis* (Miller) D.A.Webb, a much lower lichen coverage was registered. This is probably connected with the decreasing water storing capacity of the bark in its old age. Thus the lichen floras on the different tree species are only partially comparable. To be able to compare the results, different tree species were selected in one grid square, if possible, so that differences could, to a large extent, be evened out. If there were no species other than *Morus* and *Ficus carica* L. in one grid square, the results are not totally comparable to the other grid squares; this was the case only in "Gecekondu", because the high population density caused heavy air pollution. The sums of the frequencies of *Pistacia* and *Olea* L. generally correspond with each other and with the results of the air quality map (Figure 8).

The results of the present mapping correspond with those determined from emission measurements made in 1986. SO2-concentration is the main factor influencing epiphytic lichens, as proved by countless experiments (Wirth & Türk, 1975; Hawksworth, McManus,1989). It is not correct, however, to assume that SO2 is the only substance which affects lichens. The epiphytic lichen vegetation reflects long-term synergies of all the pollutants influenced by different locational factors.

Comparison with 1986 survey

The present grid square mapping is not totally comparable with the lichen vegetation survey in 1986 (John, 1988; John, 1989), since the scope and intensity of the mapping differ. In 1986, 81 locations were examined, while in 1997 the lichen vegetation of 1092

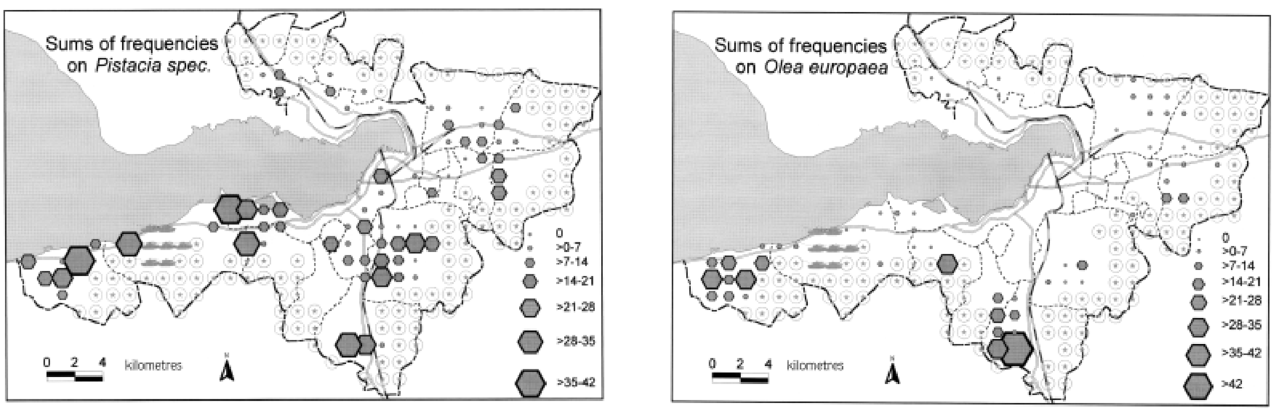

Figure 11. Sums of frequencies of Lichens on the most common tree species

trees was determined. The general picture of the lichen zones is similar in both surveys. At some locations where lichen coverage was registered in 1986, such as Eski İzmir and Kadifekale, no lichens were found in 1997. The disappearance of lichens indicates a worsening of the air quality between 1986 and 1997, undoubtedly as a consequence of increases in population and in traffic density.

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