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Accumulation of Heavy Metals from Motor Vehicles in Transplanted Lichens in an Urban Area

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Abstract: Thalli of the lichens *Pseudevernia furfuracea, Usnea longissima, Lobaria pulmonaria,* and *Peltigera praetextata* were taken from unpolluted areas and transplanted to a downtown site in Erzurum, Turkey. Heavy metals copper (Cu), chromium (Cr), zinc (Zn), lead (Pb), nickel (Ni), and iron (Fe) were measured after an 8 month exposure period. Changes in the heavy metal concentrations were observed during the exposure period in lichen species and in both locations. Heavy metal concentrations were significantly higher in *Peltigera praetextata* than the other species at the location nearest to the junction crossroads. *Peltigera praetextata* may be considered a good indicator. These results can be attributed to the effect of atmospheric pollutants on the transplanted lichens.

Keywords: Accumulation, Erzurum, Turkey, heavy metal, lichen

INTRODUCTION

Lichen species show differing degrees of sensitivity to air pollution but are generally affected adversely by sulfur dioxide, heavy metals, fluorides,

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nitrogen oxides, and peroxyacetyl nitrate (Canas, Orellana, and Pignata 1997). Lichens consist of both an alga and a fungus. The alga contains chlorophyll and provides the lichen with carbon compounds by photosynthesis, and the fungus absorbs water and nutrients from surroundings. As a result, lichens are self-sufficient and can grow on rocks, roofs, tree trunks, and similar surfaces. Because they have no roots, lichens absorb their nutrients from the air around them, instead of doing so from the soil as plants do. Consequently, when nutrients are absorbed into the thallus, other elements, not necessarily required for growth, are also absorbed. Heavy metal cations are absorbed, in part via exchange mechanisms, and the exchangeable fraction decreases when the thalli become air dried. It has been reported that in humid regions, a high correlation exists between levels of air pollutants and injury to the living cell and tissues of lichens (Bernasconi et al. 2000).

Lichens are an outstandingly successful group of symbiotic organisms exploiting a wide range of habitats throughout the world (about 20,000 species). Lichens have long been recognized as sensitive indicators of environmental conditions. Lichens are also good accumulators of many elements, particularly heavy metals and radionuclides (Nayaka et al. 2003).

Several studies on lichens in relation to air pollution and metal deposition in different regions of the world have been carried out (Garty, Kauppi, and Kauppi 1996; Bennett, Dibben, and Lyman 1996; Canas, Orellana, and Pignata 1997; Najera et al. 2002). Many studies used the technique of lichen transplantation to monitor air pollutants. Most studies implementing these technique were carried out for rather long periods to obtain definite changes in the elemental composition of the thallus. Short-term transplantations, on the other hand, would be an easy and economical means to monitor airborne pollutants (Garty, Kauppi, and Kauppi 1996). In Turkey, a large number of pollution-monitoring studies with biological and chemical methods are available. However, such studies utilizing lichens have started recently (Özdemir 1992; Öztürk, Güvenç, and Aslan 1997; Çiçek and Koparal 2003). The purpose of the present study is to provide information regarding the accumulation of six heavy metals in four lichen species exposed in urban sites subjected to vehicular traffic.

MATERIALS AND METHODS

Study Area

Erzurum city occupies 3.2% of the country's area with 25,066 km^2 surface and is located between 40° 15′ and 42° 35’ E longitudes and 40° 57′ and 39° 10′ N latitudes. Erzurum is established in the southeastern part of a high plateau and is the biggest city at an altitude of approximately 1950 m above sea level in Anatolia. The area is surrounded by the Dumlu Mountains to the north and Palandöken Mountains to the south. Spring is rainy, summer is hot and arid, and winter is cold and snowy. The annual mean temperature is 6°C, the coldest month mean is −8.3°C, and the warmest month mean is 20.2°C. Mean temperature is under 8°C approximately 220 days of the year. Relative humidity averages 60.3%.

Plant Cover

The plant cover of the province is scarce mainly because of destruction of natural plant cover around residences and agricultural areas. The major type of plant cover is steppe. Forests are located in the higher parts of mountains in the north and northeast. Forests include *Pinus sp., Picea sp., Fagus sp., Quercus sp., Juniperus sp., Abies sp., Ulmus sp.*, and *Fraxinus sp.* species and conifers, mostly at altitudes of 700–2500 m.

Lichen Sampling

Selected lichen samples were collected with part of their substrate in unpolluted areas (Table 1). The specimens were identified by studying their morphology, anatomy, and chemistry following recent literature (Purvis et al. 1992; Clauzade and Roux 1985; Wirth 1995; Brodo, Sharnoff, and Sharnoff 2001). Lichen species (*Pseudevernia furfuracea, Usnea longissima, Lobaria pulmonaria, Peltigera praetextata*) were attached to nonmetal cages (50 cm^2) avoid to metal contamination. The cages were mounted at a height of 10 cm on wooden stands and 5 m from road. Lichens were exposed to heavy metals from traffic sources in the city for 8 months (June–February). A total of four locations were selected. Properties of location are given Table 2. For distance and direction determination relative to the highway, Magellan GPS Color Track was used (MSC 1997).

Table 1. Properties of nonpolluted sites, lichen species, and substrates

Lichen species	Nonpolluted areas	Altitude	Latitude	Longitude	Substrate
Lobaria pulmonaria	Dereli/Giresun	1550 m	40°44″30″	38°20″15″	*Fagus orientalis*
Peltigera praetextata	Bulancak/Giresun	1700 m	40°38″30″	38°14″30″	Mosses
Pseudevernia furfuracea	Dereli/Giresun	1550 m	40°44″30″	38°20″15″	*Pinus sylvestris*
Usnea longissima	Dereli/Giresun	1550 m	40°44″30″	38°20″15″	*Picea orientalis*

Table 2. Properties of urban sites and vehicle quantities

Locality No.	Properties	Vehicles
1	Centre of city, Havuzbası Place, crossroads junction	19,872 vehicles/day
2	Main gate of Atatürk University	12,288 vehicles/day
3	Gate of Atatürk University on Istanbul Highway	8,640 vehicles/day
4	Erzurum–Istanbul Highway	7,056 vehicles/day

Chemical Analyses

The lichen samples were dried for 24 h at 105°C. One g from each sample was placed in Pyrex® reactors of a CEM Star 2 microwave digestion unit. Forty mL of Perchloric–nitric ($HClO_4$:HNO_3) acids of 1:4 proportions for samples were added to the reactors. Samples were mineralized at 140°C for 1 hour. Afterward, samples were filtered in such a way as to complete their volumes to 100 mL with 0.1 N hydrochloric acid (HCl). Heavy metal concentrations were determined by flame atomic absorption spectrophotometry (FAAS, Varian Spectra A 250 plus model) (ASTM 1985; APHA 1992). The FAAS detection limits (DL) are 10, 6, 3, 6, 10, and 10 mg kg^{-1} dry-weight tissue for nickel (Ni), iron (Fe), copper (Cu), chromium (Cr), lead (Pb), and zinc (Zn), respectively.

RESULTS AND DISCUSSION

Metal concentrations (Cu, Cr, Zn, Pb, Ni, and Fe) of *Pseudevernia furfuracea, Usnea longissima, Lobaria pulmonaria,* and *Peltigera praetextata* in Erzurum are shown in Figures 1–6. The concentrations given in the figures are the means of triplicate samples taken from same station.

The measured metals are likely to be emitted into the atmosphere by the wearing of engines and tires of vehicles in traffic and may be present in fuel composition or exhausted by vehicles. The results were interpreted for each metal, considering the sampling points where the lichens were exposed to traffic pollution. In addition, lichens located in the same point were also compared. The highest Fe concentration (2900 mg kg^{-1}) was detected in location 1, which is distinguished from other sampling locations by heavy traffic (19,872 vehicles/day). As shown in Figure 1, Fe concentrations tend to decrease from the high-density traffic points to low-density (7,056 vehicles/day) traffic points. Iron concentrations decrease down to as low as 150 mg kg^{-1}. This is due to the direct correlation between concentrations of metals trapped in lichen samples and the amount of metal in the air. A similar situation was observed in other metals as well. In location 1,

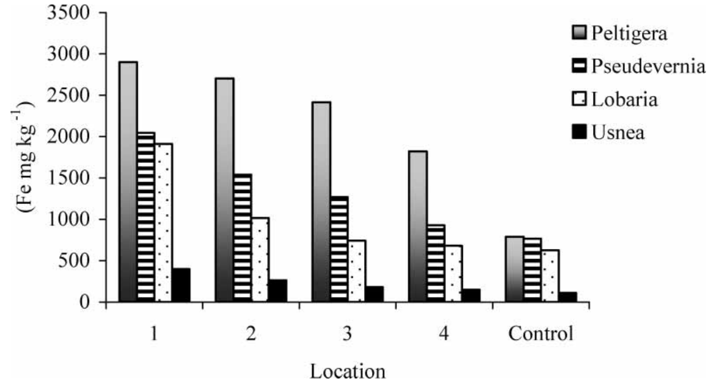

Figure 1. Iron concentrations of lichen species (mg kg^{-1} in dry weight).

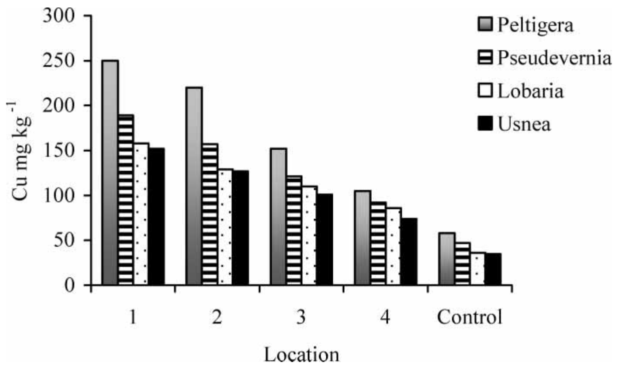

Figure 2. Copper concentrations of lichen species (mg kg^{-1} in dry weight).

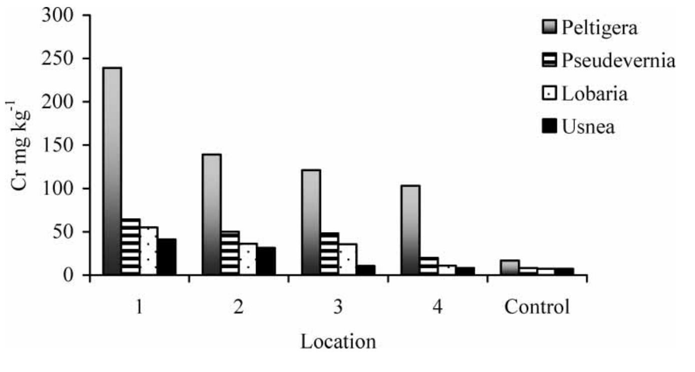

Figure 3. Chromium concentrations of lichen species (mg kg^{-1} in dry weight).

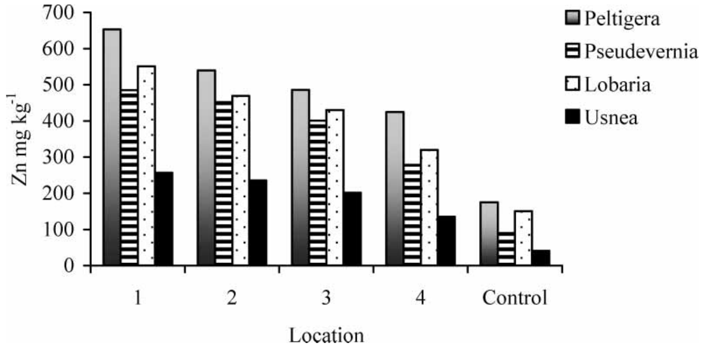

Figure 4. Zinc concentrations of lichen species (mg kg^{-1} in dry weight).

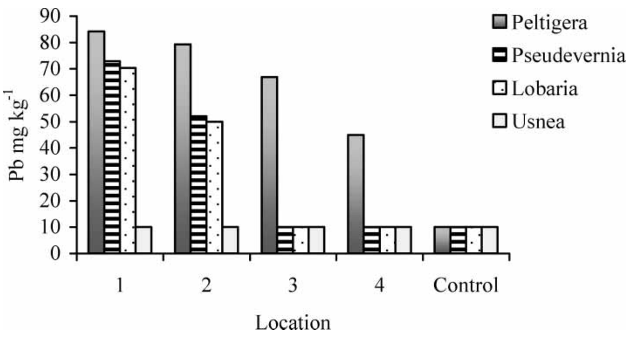

Figure 5. Lead concentrations of lichen species (mg kg^{-1} in dry weight).

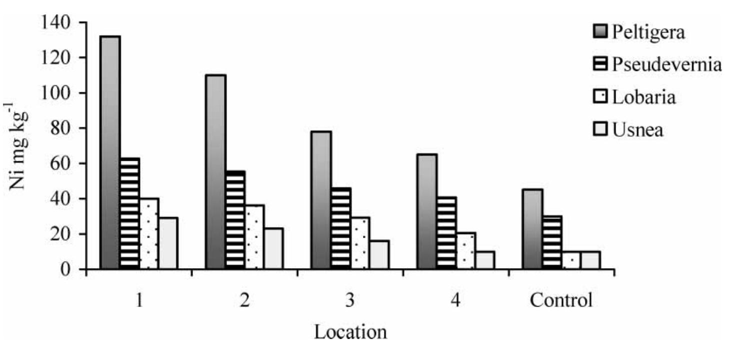

Figure 6. Nickel concentrations of lichen species (mg kg^{-1} in dry weight).

which has the highest traffic density, concentrations of heavy metals Cu, Cr, Zn, Pb, and Ni were found to be 250 mg kg^{-1}, 239 mg kg^{-1}, 653 mg kg^{-1}, 84.13 mg kg^{-1}, and 132 mg kg^{-1}. In contrast, in location 4, which has the lowest traffic density, concentrations were much lower: 74 mg kg^{-1}, 8.37 mg kg^{-1}, 135 mg kg^{-1}, 4.2 mg kg^{-1}, and 10 mg kg^{-1}, respectively. Similar behavior of all the heavy metals supports the idea that concentrations

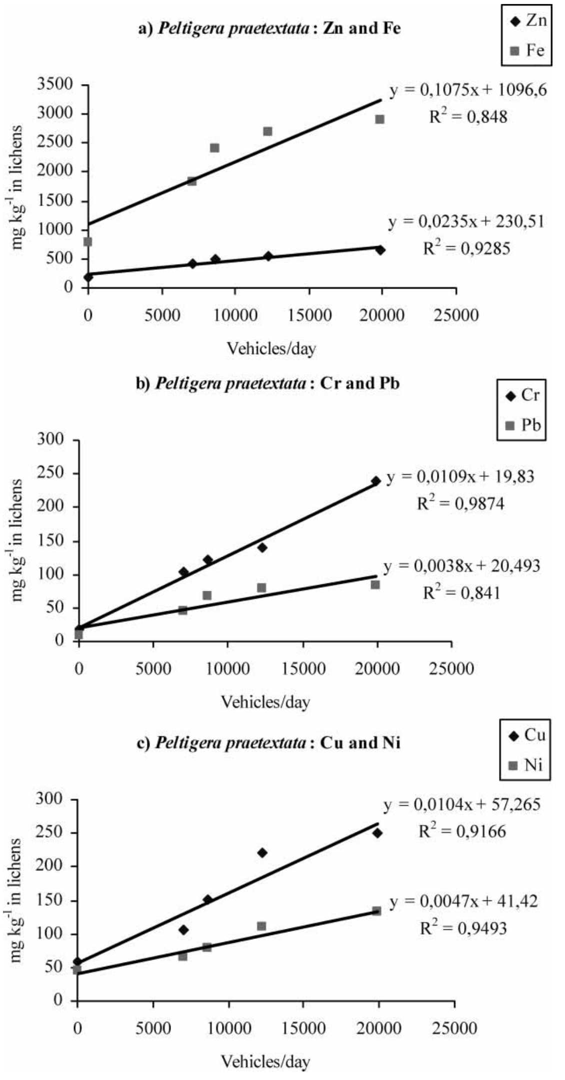

Figure 7. Relationship between heavy metal pollution in *Peltigera praetextata* and vehicle quantities.

of heavy metals trapped in lichens are directly related to the traffic density around.

There are considerable differences in heavy metal concentrations with regards to the different transplanted lichen species (Figures 1–6). Each lichen species includes different amounts of metals. In all locations, *P. praetextata* has the highest metal concentrations. Analyses of samples for Fe (Figure 1) indicate a lineup for location 1 as follows: *P. praetextata* 2900 mg kg^{-1}, *P. furfuracea* 2045 mg kg^{-1}, *L. pulmonaria* 1909 mg kg^{-1}, and *U. longissima* 396 mg kg^{-1}. The lowest Fe concentrations found in location 4 are as follows: *P. praetextata* 1820 mg kg^{-1}, *P. furfuracea* 928 mg kg^{-1}, *L. pulmonaria* 680 mg kg^{-1}, and *U. longissima* 150 mg kg^{-1}. Copper, Cr, Pb, and Ni concentrations are similar to Fe concentrations.

When one considers Zn concentrations (Figure 4), *L. pulmonaria* appears to have higher concentration values than *P. furfuracea* and *U. longissima* in all locations. This result is the reverse of to the other metals. This is probably due to the higher baseline values of Zn concentrations in *L. pulmonaria* when compared to those of *P. furfuracea* and *U. longissima*. When the initial values are considered, the lineup of specimens with regards to Zn concentration is in accordance with the lineup in other metals.

Concentrations of heavy metals found in samples indicate air pollution. As there is no industrial source for the heavy metals in the locations and because concentrations are well proportional to traffic density, it can be considered that traffic is the cause of the pollution. To support this result, metal accumulations in lichens versus vehicle traffic have been plotted, and linear regression has been conducted (Figure 7). As evident from the figure, linearity is observed between vehicle quantities and heavy metal pollution. When morphological features of lichens are examined, it seems that *P. praetextata* with broad leaves has the highest metal concentrations, whereas *U. longissima* with narrow leaves have the lowest concentrations, This indicates that surface area is an important factor in metal trapping of lichens. As mentioned in the literature, accumulated metal contents in lichens are well correlated with the real measurements of airborne heavy metals (Ferry, Boddeley, and Hawskworth 1973). This work is filling a gap about actual airborne heavy metal measurements in the study area.

CONCLUSIONS

Results indicate that there is air pollution of traffic origin in Erzurum. These findings suggest that lichen species *P. praetextata*, *P. furfuracea*, *L. pulmonaria*, and *U. longissima* present in the region can be used to monitor air pollution and that particularly *P. praextata* is a very good indicator of air pollution. Because lichens grow very slowly and are rarely encountered in polluted areas, lichen transplantation seems to be coming forward for air pollution monitoring. Transplantation of *P. praextata* could be an easy and cost-effective means of air pollution monitoring and could provide valuable data for preventive measures. In this work, our goal was to contribute to lichen transplantation studies, which are of great importance for bio-monitoring, and this article reveals traffic-originated metal pollution using structural features of lichens.

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