Title	**Air-quality biomonitoring: Assessment of genotoxicity of air pollution in the Province of Kayseri (Central Anatolia) by use of the lichen *Pseudevernia furfuracea* (L.) Zopf and amplified fragment-length polymorphism markers**
Author	Çiğdem Vardara, Esin Basarana, Demet Cansaran-Dumanb, Sümer Arasa
Journal	Mutation Research/Genetic Toxicology and Environmental Mutagenesis, Vol.759
Abstract	Mixed air pollutants are considered a major cause of DNA damage in living organisms. In this study, samples of the lichen *Pseudevernia furfuracea* (L.) Zopf were used as bioindicators to assess the genotoxicity of air pollutants in the province of Central Anatolia, Kayseri. The study area is characterized by the presence of numerous industrial activities, such as steel works, glassworks, and ship-building, metallurgical, mechanical and chemical industries. In the study, two biomonitoring experiments were performed during the dry and wet seasons of 2005. *P. furfuracea* lichen samples were exposed to various pollutants at 12 monitoring sites, distributed throughout the different parts of the province, and each experiment lasted for a period of four weeks. Genotoxic effects of environmental pollutants were evaluated with amplified fragment-length polymorphism (AFLP) molecular markers. The results indicate that the mixture of pollutants might have contributed to the changes in the band patterns obtained by AFLP analysis, reflecting the presence of DNA damage. The average value of polymorphism obtained from the amplification of the primers used was 45.0% for the wet period and 64.6% for the dry period. Genomic template stability (GTS) ratios revealed that the highest values belong to the *P. furfuracea* samples from Rural Site I and Rural Site II (97.9%, 99.3% respectively for the dry season), the lowest values were from Shanty II and Urban Road Site I (85.8%, 85.2%, respectively for the wet season). The present results indicate that the licxhen species *P. furfuracea*, which is known for its bioindicator–biomonitor capacity, also has a high capacity as indicator of genotoxicity AFLP markers are cheap, reliable and, therefore, an important tool for studying genotoxicity in lichen species.
Year	2014
Pages	43–50

keywords	Air pollution, Pseudevernia furfuracea, Lichen, AFLP, Genotoxicity

Title	Spatial dispersal of airborne pollutants and their effects on growth and viability of lichen transplants along a rural highway in Norway
Author	Olena A. Yemets, Knut Asbjørn Solhaug and Yngvar Gauslaa
Journal	The Lichenologist, Vol 46, Issue 06
Abstract	This study aims to quantify dispersal of airborne traffic-related elemental pollutants and concurring responses – relative growth rate (RGR), maximal quantum yield of PSII (F_v/F_m), and chlorophylls (Chl *ab*) – in four epiphytic lichens (*Lobaria pulmonaria*, *Parmelia sulcata*, *Ramalina farinacea*, *Usnea dasopoga*). Lichens were transplanted from 25 September to 26 March to 1·5 m tall stands in open farmlands at 10, 15, 30, 50 and 100 m from the E6 highway (SE Norway), along three transects on each side usnea dasopoga of the road. The concentrations of most elements (Ca, Mg, Na, Fe, Al, Zn, Ba, Cu, V, Cr, Ni, Co, Sn, As, Mo) significantly increased with increasing proximity to the road. Elements in bold had elevated concentrations relative to controls, at least in some species at 100 m. The heavy metal accumulation increased from foliose to fruticose lichens in the order: *P. sulcata>L. pulmonaria>R. farinacea≫U. dasopoga.* However, *L. pulmonaria* was the only species with strong pollutant-dependent reductions in growth, F_v/F_m, Chl *ab*, and Chl *a*/*b*-ratio. The RGR and viability parameters were adversely affected by the roadside environment near the road only (≤15 m), and only after substantial heavy metal accumulation. Measurement of metal accumulation in lichens is thus a far more sensitive way of monitoring road pollutants than recording growth and lichen viability. Despite strong species-specific contrasts in elemental concentrations, most road pollutant elements responded similarly to distance from the road in all species.
Year	2014
Pages	809-823

Keywords	Biomonitoring, epiphytic lichens, heavy metals, relative growth rate, salt

Title	**The spatial and seasonal variation of nitrogen dioxide and sulfur dioxide in Cape Breton Highlands National Park, Canada, and the association with lichen abundance**
Author	Mark D. Gibsona,Mathew R. Healb, Zhengyan Lic,James Kuchtaa,Gavin H. Kinga,Alex Hayesa, Sheldon Lambertd
Journal	Atmospheric Environment, Vol. 64
Abstract	Over 200,000 tourists per year visit Cape Breton Highlands National Park, Nova Scotia, Canada. The forests within the park are home to many rare epiphytic lichens, the species diversity of which has declined in some areas. The primary motivation for this study was to gain insight into the concentrations and potential local and long-range sources of air pollution, but its association with lichen species diversity was also examined. Ogawa passive diffusion samplers were used to measure nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) in the park at 19 sites in the winter and 20 sites in the summer of 2011. An improvement in the sensitivity of the sampler analytical protocol was developed. The mean concentrations in the park of winter and summer NO_2 (0.81 and 0.16 ppb) and SO_2 (0.24 and 0.21 ppb) are not at levels known to be phytotoxic to lichen. The NO_2 concentrations in winter were significantly ($p = 0.001$) higher than those in summer whilst the SO_2 concentrations did not differ significantly between winter and summer ($p = 0.429$). Highest NO_2 concentrations in both seasons were observed in the Grand Anse Valley, presumably due to the steep road, emissions from the Pleasant Bay community at the foot of the valley and the enclosed topography of this area reducing dispersion of primary emissions. The SO_2 concentrations in the park tended to be greater at elevated sites than valley sites, consistent with dispersion from long-range, rather than local, sources for this pollutant. Significant predictors in a multilinear regression for an index of air purity (lichen based measure of air quality) were lichen species number ($p = 0.009$), forest old growth index ($p = 0.001$) and distance from roads ($p < 0.001$) (model $R^2 = 0.8$, model $p = 0.004$). The study suggests that local sources of pollution (roads emissions) are adversely associated with lichen species diversity in this National Park, compared with long-range transport, and that monitoring programs

	such as a lichen-based ‘index of air purity’ can reveal locations where ambient air pollution, although low, is nevertheless at a level that may cause ecological detriment. The implications from this work could be applicable to national parks elsewhere.
Year	2013
Pages	303–311
keywords	Cape Breton Highlands National Park, Canada, NO_2, SO_2, Ogawa passive diffusion sampler, Lichen, Index of air purity

Title	**Does Impact of Point Polluters Affect Growth and Reproduction of Herbaceous Plants?**
Author	Mikhail V. Kozlov and Elena L. Zvereva
Journal	Water, Air, & Soil Pollution
Abstract	Investigation of nine herbaceous species collected around five polluters in northwestern Russia (nickel–copper smelters at Monchegorsk and Nikel, ore-roasting factory at Zapolyarnyy, aluminium smelter in Kandalaksha, and iron pellet plant at Kostomuksha) demonstrated that effects of pollution on plant growth were rarely significant in individual analyses. However, meta-analysis revealed decrease in plant size, in terms of height and leaf length; simultaneous increase in the number of leaves and flowers/inflorescences may compensate for this decline, thus the biomass of aboveground plant parts did not change. This result contrasts numerous experimental studies that generally demonstrate adverse effects of various pollutants on growth and reproduction of herbaceous plants, hinting that the effects detected in short-term experiments are of limited value for predicting performance of plant individuals surviving in polluted ecosystems. Changes in growth and reproduction of plants persisting under chronic pollution are minor presumably due to development of pollution tolerance and adaptation to altered environmental conditions.
Year	2007
Pages	183- 194

keywords	Herbaceous species, air pollution, impact

Title	**Is the diversity of epiphytic lichens a reliable indicator of air pollution? A case study from Italy.**
Author	Paolo Giordani
Journal	Environmental Pollution
Abstract	This work provided additional information for a better interpretation of lichen diversity values in biomonitoring studies of air pollution. The effects of 12 predictive variables were estimated for the Genova province (NW Italy) by means of a non-parametric model. The diversity of epiphytic lichens was strictly correlated with mean annual rainfall and mean annual temperature. Different variables were found to affect the lichen diversity in urban vs. forested areas. In urban areas, air pollutants, mainly SO_2, are still the main limiting factor, even if under ameliorating conditions this relationship becomes less significant. In forested areas, harvesting and forest fires showed a predominant effect, suggesting the need to develop a more defined sampling protocol to estimate atmospheric pollution in such ecosystems. Lichen diversity is a reliable tool to monitor atmospheric pollution, but care should be taken in forested areas, where other influencing factors occur.
Year	2007
Pages	317- 323
keywords	Air pollution, biomonitoring, lichen