Highway Exhaust Aerosols and Their Effects on Alpine Lichen Populations

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Abstract

The aim of this study was to investigate the particle inventory of airborne particles in the region of the Bluntau-Valley near Golling / Salzburg to find correlations between the existence of alpine lichen communities, particularly their vitality, and the exposure to exhaust emissions of the nearby Motorway E55 (Tauernautobahn). This motorway has been fitted with 4 m tall sound-shielding barriers to reduce noise levels of nearby residential areas.
The U-shaped Salzach-Valley is strongly influenced by oscillatory motions of air masses due to solar radiation and characteristic wind directions. This leads to a translocation of aerosol particles from vehicle exhaust across the sound-protection barriers and into the Bluntau-Valley. The examination of epiphytic lichen populations in this valley confirms the negative effect of vehicle exhaust pollution, displaying a strongly reduced diversity and a change in lichen communities.

Introduction

The Bluntau-Valley was chosen for these investigations because it was found that lichen population density and diversity have decreased under the influence of airborne pollutants (Christ & Türk, 1981). Hence it was the aim of this study to correlate particle exhaust load originating from this highway to verify the assumption that highway exhausts strongly affect lichen diversity in the Bluntau-Valley area in close proximity to the motorway E55 (Ellenberg, 1992; Kasperowski & Frank, 1989).

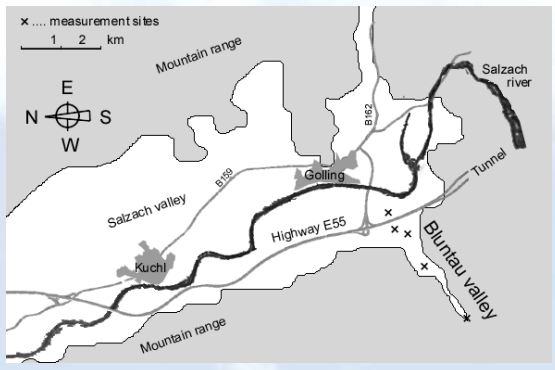

Fig. 1: Topographical setting of the Bluntau-Valley, Salzburg, AUT

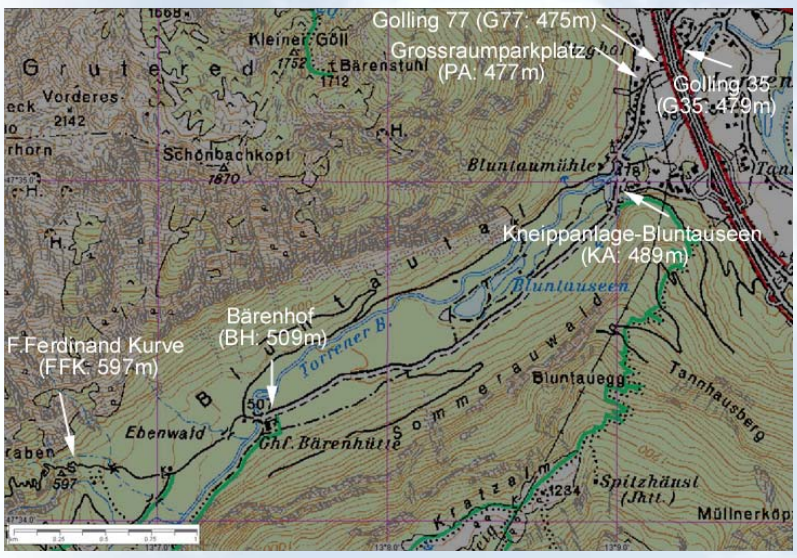

Fig. 2: Topographical setting of the Bluntau-Valley with measurement sites (elevation given in parenthesis)

Fig. 3: Heavily damaged lichen *Parmelia sulcata* (Wirth, 2002) found at site G77 on a coniferous tree.

Methods

SMPS measurements were carried out repeatedly on four days during a six-month-period from July to December 2006, to cover a wider range of prevailing meteorological conditions. However, monitoring was limited to dry days as this facilitated the dispersal of airborne particles. With regard to the prevailing wind conditions and the north-to-south orientation of the Salzach-Valley, measurement times were confined to the early morning or evening hours as this better redistributed the particle load originating from the motorway by thermal convection into or out of the Bluntau-Valley.

The census of the epibiotoc lichen species abundance was performed separately and always in close proximity to the actual SMPS-measurement sites. Sampling was limited to a stem-height window of 0.5 – 2 m, considering both relative coverage on the stem and the degree of damage of the individual lichen. Statistical diversification was obtained by exdending the sampling area in concentric circles away from the SMPS-measurementt site in steps of 10m (i.e. 1-10m, 11-20m, 21-30m, 31-40m, 41-50m). At all sites an individual species list was compiled to enable comparison and species associations. Being slow-growing organisms, the census was done in spring 2007.

Measurement sites used for both the census as well as for the particle inventory consisted of the following locations (see Fig. 2):

Golling 35	(G35,	20 m from motorway)
Golling 77	(G77,	20 m f. motorway)
Parking Area	(PA,	300 m f. motorway)
Kneippanlage	(KA,	500 m f. motorway)
Baerenhof	(BH,	2500 m f. motorway)
F. Ferdinand Kurve	(FFK,	4000 m f. motorway).

Results

Particle concentrations decrease with increasing distance to the source, i.e. the highway E55. Figure 3 reveals the characteristic dilution gradient within the Bluntau-Valley. This observation was consistent through the sampling campaign for all of the inbound wind conditions. However, it was observed that during inbound wind directions, the half-way site (BH) yielded lower aerosol counts than the remotest site (FFK). This is no surprise as the FFK-site is approx. 90 m higher in elevation and hence much more exposed to particle loads originating from the highway than the BH-site – the latter being well protected within a coniferous forest, whereas the FFK-site is an open location with direct view to the motorway. This correlates nicely with the species diversity found at the various locations, in that a higher diversity was documented at the BH-site and a slightly lowered one of the FFK-site.

In addition it was found that days with reversed wind conditions (outbound of the Bluntau-Valley), the average particle inventory was comparable to "purified" mountain air (FFK-site: approx. 1200 particles/cm^3) compared to particle loaded Salzach-Valley air measured during inbound wind conditions (FFK-site approx. 2600 particles/cm^3). During the half-year measurement campaign (from July till December 2006), we further documented a 30% decrease in particle inventory on all sites due to a reduced vehicle frequency on the motorway especially in the colder months – i.e., particle number concentration is almost twice as high in summer and correlates with the peak travelling time of major EU countries. It was also noted that characteristic and yet pollutant-sensitive lichen species of this climatic zone are displaced by mainly nitrophilous species (KRDL, 2007).

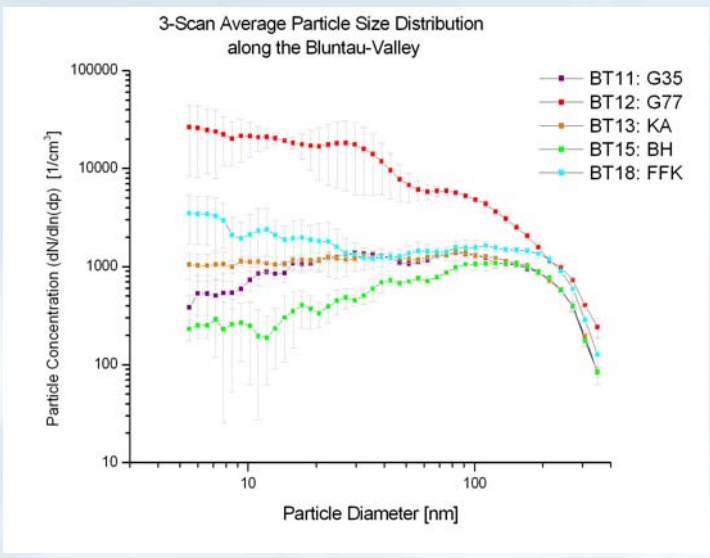

Fig. 3: Size distributions of exhaust particles originating from the Highway with predominantly easterly winds (inbound wind direction) for the summer months of 2006.

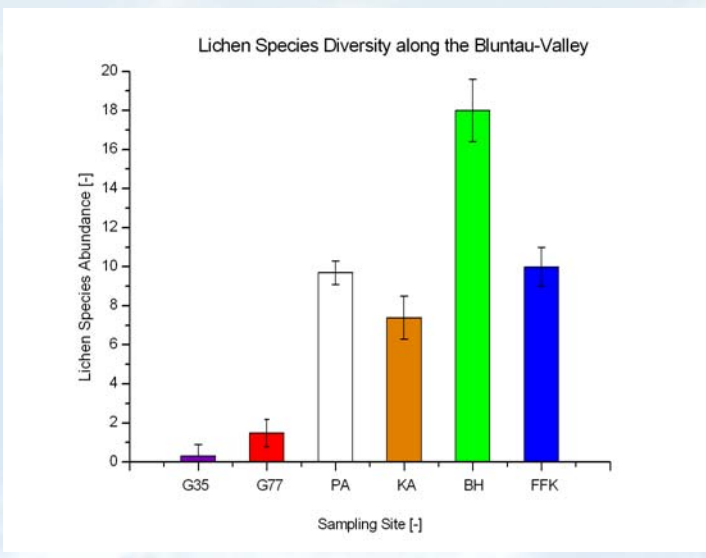

Fig. 4: Species diversity of lichens along the Bluntau-Valley at the various locations sampled with the SMPS-instrumentation.

Conclusions

The area of the Bluntau-Valley is predestined to be influenced by solar radiation and changing wind conditions due to meso-climatical processes and the topographical setting of the valley.

Measurement days in summer showed higher particle concentrations, which correlates with the peak vehicle frequencies during the summer-holiday season.

Measurement sites closer to the highway produced higher concentrations as a result of the constant mixing of exhaust particles and resuspension of larger aerosol-clusters and elevated vehicle density (Hofmann, 2005). Consequently, particles are easily relocated by wind and transported over the sound-protective barriers to finally settle in neighbouring land strips. As expected, sampling sites further away and deeper within the Bluntau-Valley yielded lower particle concentrations. However, long-distance relocation of exhaust particle-loads originating from the motorway does regularly occur, as lichen-populations on exposed sites such as the remotest site surveyed (FFK-location) do reveal a suppressed species diversity. This observation correlates with those made by other authors that associate these ecological changes to excess eutrophication and an elevated pollutant load (Masuch, 1993).

In particular, higher aerosol concentration results in lower species diversity by damaging the thalli of the lichens (Nimis, 2002). Therefore, measurement sites in close proximity to the E55 display a distinctive absence of species otherwise found in more pristine areas of similar geo-botanic character (Masuch, 1993).

Additionally, lichen associations near the highway tend to change to more nitrophilous lichen associations because of a higher amount of nitrogen available due to vehicle exhaust and being in a rural setting, the prevailing agricultural activities near the motorway along with the associated wind-related relocation of fertilizer. The dramatic reduction of lichen diversity observed at all measurement sites – with none to just a few in close proximity to the motorway backs up the hypothesis that certain particle sizes are able to enter the lichen thallus through pores of the polysaccharide layer of the epicortex thereby negatively affecting the fungi and in turn the symbiotic association between the mycobiont and the photobiont (Masuch, 1993).

Acknowledgment

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