NITROGEN ISOTOPE RATIOS IN PINE BARK AS AN INDICATOR OF N EMISSIONS FROM ANTHROPOGENIC SOURCES

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Abstract. The article describes the use of Scots pine bark to identify nitrogen sources in eastern Germany, as well as background areas in Russia and Bulgaria, by using natural isotope ratios of total nitrogen (N) and individual N compounds such as ammonium (NH4+), nitrate (NO3−) and amid nitrogen (amide-N). The samples collected were analysed using an elemental analyser in connection with a gas isotope mass spectrometer (EA-IRMS). Natural 15N abundances in pine bark from impact areas suggest that the ammonium accumulated on the surface of the bark is released from livestock management. Bark of Scots pines growing near agricultural land had highly depleted δ15N values (between –8 and –12‰), while bark from background areas (unpolluted areas) displayed slightly negative δ15N values (mean 15Nt = –3.8‰). It is assumed that part of the N adsorbed on the bark surface is mainly derived from ammonia (mean 15Nt = –40.3‰) escaping from livestock housing and during the application of manure. This assumption is confirmed by experiments under controlled conditions in which manure samples were spread on soil. In addition, temporal and spatial variations of 15Nt abundances in pine bark from various locations in eastern Germany as well as pine stands in Nature Park Dübener Heath are discussed.

Keywords: nitrogen isotope composition, pine bark, spatial patterns, temporal variations

1. Introduction

Anthropogenic emissions of air pollutants containing nitrogen cause excess N deposition in forest ecosystems (Aber et al., 1989). Determining the origin of nitrogenous pollutants in forests, including nitrogen oxides (NOx), ammonia (NH3) as dry deposition, and nitrate (NO3−) and ammonium (NH4+) as wet deposition, is thus a matter of general concern (United Kingdom Review Group on Impacts of Atmospheric Nitrogen, 1994). However, determining the origin of these N-containing compounds is difficult, as the N emissions usually originate from different anthropogenic sources, e.g. power stations, chemical plants, motorised traffic and livestock management (Fangmeier et al., 1994). In such cases, natural nitrogen isotope variations can often serve as an N-tracer. To ascertain the concentrations of individual N depositions in forests, bark from Scots pines was used as passive bioindicator because this matrix has shown by various groups to be an excellent adsorbent of airborne pollutants (Raunemaa et al., 1987; Stöcker, 1993; Hühn et al., 1995; Poikolainen, 1997; Loppi et al., 1997). When bark is exposed to airborne...
pollutants either directly from the atmosphere or from the rainwater trapped by or leached through the canopy (throughfall) as well as running down the stem, the chemical composition of the surface layers of the bark changes. Such changes can be utilised to investigate the extent of the area subjected to air pollutants (Poikolainen, 1997). Schulz et al. (1997) could be showed that a correlation exists between the concentrations of NO$_3^-$ and NH$_4^+$ in pine bark and the concentrations of throughfall. Therefore, the concentrations of NO$_3^-$ and NH$_4^+$ in Scots pine bark can be used to calculate throughfall rates in pine stands (Schulz et al., 1997) and have been employed to study temporal variations and spatial patterns in forest deposition (Schulz et al., 1999a). Moreover, Scots pine stands occur throughout Germany and are widespread in Central, Northern and Eastern Europe. In the present study we analysed the concentrations and natural isotope ratios of both N, and individual compounds (NH$_4^+$, NO$_3^-$, amide-N) in bark samples from various locations to obtain detailed information on the origin of atmospheric N depositions. The primary aim was to ascertain whether depositions of NH$_3$/NH$_4^+$ leave a recognisable nitrogen isotopic signal in pine bark.

2. **Material and Methods**

2.1. **Field sites and sampling conditions**

Bark samples from 60–80 yr old Scots pine (*Pinus sylvestris* L.) trees were sampled in October between 1988 and 1997 at three field sites in Russia (Lovozero: 67°55′N, 32°70′E, Kola Peninsula; Syktyvkar: 61°50′N, 50°50′E, Komi Republic; Tsentralnolesnoj: 57°35′N, 38°20′E, one site in Bulgaria (Rozen: 25°52′N, 41°50′E, Rhodopen) and six sites in Germany (Neuglobsow: 53°05′N, 13°02′E, Brandenburg; Jänschwalde: 51°86′N, 14°49′E, Brandenburg; Taura: 51°58′N, 13°25′E, Saxony; Rösa: 51°63′N, 12°40′E, Saxony-Anhalt; Lübbars:52°64′N, 11°31′E, Saxony-Anhalt; Lindau: 47°54′N, 9°68′E, Bavaria). For statistical calculations (homogeneity of the emission field), each of the sites was subdivided into five macro-plots (pine stands) with a minimum size of 0.4 km$^2$ and a maximum distance of 1000 m between the five macro-plots in each test area. In contrast to Germany, the field sites in Russia and Bulgaria are embedded in a forested region far removed from livestock housing and industrial plants and traffic. In addition, bark samples were collected in Nature Park Dübener Heath inside a 2.5×2.5 km grid of 53 test sites. The Nature Park Dübener Heath represents a forest area of 20×30 km, 20 km north-east of the industrial region of Bitterfeld: 51°63′N, 12°31′E (Saxony-Anhalt).

The external bark layer (profile depth exactly 1 mm) was sampled from the non-weather stem area (free of epiphytic organism) at a height of 1.5–1.70 m above the ground using a specially developed sampling device (Figure 1). Samples from at least 25 stems from each macro-plot were collected to produce a mixed sample weighing 60 g.