INTERACTIONS OF ATMOSPHERIC DEPOSITION WITH CONIFEROUS CANOPIES IN ESTONIA

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Abstract. Throughfall and open field bulk precipitation were measured at three coniferous sites during 1995–2002 in the framework of ICP Integrated Monitoring and at five coniferous sites during 1996–2002 in the framework of ICP Forests (Level II). The coniferous canopies acted as a sink for nitrate and ammonium and as a source for base cations: Ca2+, Mg2+ and K+. The estimated share of SO42− dry deposition from total deposition was 1.5–4 times higher for dormant period compared to growing period. During the study period average annual throughfall and bulk deposition of SO42− decreased significantly, 2.8 and 2.3 times, respectively.

Throughfall enrichment with base cations increased in the order Mg < Na < Ca < K. Using Na as a tracer ion, average dry deposition and canopy leaching were calculated. Leaching was the dominant process for TF enrichment by potassium. Leaching of base cations occurred during growing as well as dormant period.

The calculated internal flux of Ca2+ and Mg2+ varied in the range of 0.6–2.0 and 0.6–1.2 kg ha−1 per year in spruce and pine stands, respectively. The internal circulation of K+ was significantly higher (8.9–10.9 kg ha−1 per year) in spruce stands than in pine stands (2.7–4.4 kg ha−1 per year).

Keywords: bulk deposition, canopy leaching, pine and spruce stand, throughfall deposition

1. Introduction

Throughfall method has been approved as a reasonable method of estimating total and dry deposition of atmospheric pollutants to forest landscapes (Cape et al., 1992; Draaijers et al., 1996; Ferm and Hultberg, 1999; Rothe et al., 2002). Dry deposition measurements are difficult and expensive (Hicks and Meyers, 1988), while tree canopies serve as a natural surface and filter for trapping atmospheric pollutants, entering into the ecosystem.

Throughfall water is generally enriched in most chemical elements compared to bulk precipitation. Deposition of base cations, H+, Cl− and SO42− is significantly higher under canopies, while nitrogen (NH4+ and NO3−) is often retained in canopies (Bredemeier, 1988; Helmisari and Mäkönen, 1989; Potter et al., 1991; Hultberg and Grennfelt, 1992; Cappellato and Peters, 1995; Houle et al., 1999). Two primary mechanisms influencing throughfall water chemistry are (1) wash-off of dry-deposited elements, and (2) canopy exchange through leaching.
of plant nutrients and absorption of ions from rain water (Parker, 1983). Different approaches have been developed to separate these processes, for example, the multiple regression model (Lovett and Lindberg, 1984) and canopy budget model (Ulrich, 1983).

From studies comparing throughfall with deposition measurements, it is generally concluded that canopy exchange of sodium, chloride and sulphur is negligible. In many studies the contribution of dry deposition and canopy leaching has been estimated using Na$^+$ as a tracer ion (Bredemeier, 1988; Ferm and Hultberg, 1999; Houle et al., 1999; Lövblad et al., 2000; Ukonmaanaho, 2001; Rothe et al., 2002). This simplification is based on the assumption that Na is deposited only in particles (including cloud-water and fog droplets) and that interception ratio of Na in canopy is equal to other base cations.

Using throughfall method on coniferous trees has several advantages comparing to deciduous trees. Presence of needles all year round ensures comparable enrichment in dormant and growing period, but also, the interception of precipitation is greater in coniferous canopy because of its persistent foliage. Due to conifer morphology and disposition of branches, stemflow is usually less important (Houle et al., 1999).

It has been shown that needles are more efficient aerosol collectors than most leaves (Blood et al., 1989). Also, filtering surface of coniferous trees may exceed that of deciduous trees (Rothe et al., 2002).

On the other hand, there are certain factors that should be taken into consideration. Throughfall chemistry of coniferous stands could be affected by lichens and algae that are present in significant amounts on the branches of a coniferous stand. They may be responsible for part of N uptake attributed to the canopy (Lovett, 1992). Throughfall under conifers is commonly more acidic than under deciduous trees, which is probably due to organic acids leaching from living and dead tissues (Parker, 1983). The acid water film on spruce needles may be an effective sink for SO$_2$, which would explain the high values for sulphate and the protons (Rothe et al., 2002).

The Estonian National Environmental Monitoring Network (ENEMN) provides throughfall data from seven coniferous sites in the framework of two International Co-operative Programmes (ICP). Unfortunately, the measurements of dry deposition do not exist up to now.

The period of throughfall measurements in ENEMN has been relatively short to reflect the emission trends that have been shown earlier in bulk deposition (Treier et al., 2004; Frey et al., 2001, 2003).

Air pollution situation in Estonia is essentially connected with the use of oil shale in energy production (about 90%) causing large emissions of sulphur dioxide as well as fly ash. Local emissions of SO$_2$ have decreased by about 60% during 1990s. In 2001 the emission of SO$_2$ from Estonia was the highest (92 kt) compared to other countries in the Nordic-Baltic region (Vestreng, 2003). Because of the reduced