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The contribution of canopy exchange to differences observed between atmospheric deposition and throughfall fluxes

G.P.J. Draaijers[a], J.W. Erisman[a], N.F.M.van Leeuwen[b], F.G. Römer[c], B.H. Te Winkel[c], A.T. Vermeulen, G.P. Wyers[d], K. Hansen[e]

a) National Institute of Public Health and Environmental Protection (RIVM), Air Research Laboratory (LLO), P.O. box 1, 3720 BA Bilthoven, the Netherlands
b) University of Utrecht (UU), Department of Physical Geography, P.O. box 80.115, 3508 TC Utrecht, the Netherlands
c) Electric Power Research Institute (KEMA), Environmental Research Department, P.O. box 9035, 6800 ET Arnhem, the Netherlands
d) Energy Research Foundation (ECN), P.O. box 1, 1755 ZG Petten, the Netherlands
e) Danish Forest and Landscape Research Institute, Department of Forest Health and Forest Ecosystems, Skovbrynet 16, 2800 Lyngby, Denmark.

Introduction

For the evaluation of emission abatement measures it is essential that a relation can be established between emission of air pollutants and adverse effects as a result of exposure and deposition. Most adverse effects of air pollutants in forest ecosystems are found to occur due to changes in the soil system (Hey & Schneider, 1991). Critical loads are therefore directly referring to soil loads. The soil load (usually determined by measuring throughfall and stemflow) may differ from the deposition flux (determined by a combination of air concentration and meteorological measurements and inferential modelling) as a result of canopy exchange processes. The mechanisms of these processes are still not well known and debate continues on their contribution to the gap between soil loads and deposition fluxes (Draaijers et al., 1994).

Methods

Throughfall and precipitation fluxes were measured at the Speulder forest research site in the Netherlands with different time resolutions allowing the application of two canopy exchange models. Sequential sampling during throughfall events allowed a detailed study of the dynamic mechanisms of canopy exchange. Information on canopy exchange was also provided by comparing throughfall deposition estimates with estimates from micrometeorological measurements and inferential modelling, and by comparing deposition estimates from surface wash experiments using real and artificial twigs. Specific information on canopy exchange of root-derived sulphur at the Speulder forest was provided by a S^{35} nutrition experiment.

Canopy exchange rates at the Speulder forest

Sulphur was found to behave conservative within the canopy, with SO_2 uptake (35 mol/ha.year) more or less balancing leaching of soil-derived SO_4^{2-} (80 mol/ha.year). Stomatal uptake of NO_2 and HNO_2 amounted 130 mol/ha.year. Experiments did not indicate significant uptake of NO_3^- from water layers covering the tree surface, leaving an inexplicable gap of approximately 270 mol/ha.year between the NO_3^- soil load and the NO_y deposition estimate. Stomatal uptake of NH_3 amounted 140 mol/ha.year, whereas uptake of NH_4^+ in solution equalled 115 mol/ha.year. About 180-200 mol H^+/ha.year was retained within the canopy. Canopy uptake of H^+ and NH_4^+ was encountered by leaching of K^+ (270 mol/ha.year), Ca^{2+} (50-75 mol/ha.year) and Mg^{2+} (0-40 mol/ha.year). Part of the leaching of K^+, Ca^{2+} and Mg^{2+} (15%) took place along with weak organic acids. No significant canopy exchange was found for Na^+ and Cl^-.

Differences observed between atmospheric deposition and throughfall fluxes could almost completely be explained by canopy exchange. For closing the gap between the soil load of NO_3^- and the deposition flux of NO_y, additional research is necessary. More knowledge regarding canopy exchange of nitrogen compounds can be obtained by using radioactive tracers (^{15}N) in ecosystem studies. At the same time, NO_2, HNO_2, HNO_3 and NO_3^- dry deposition estimates from micrometeorological measurements and inferential modelling need to be improved.

Generalisation of measurement results

Field experiments at the Speulder forest were mainly performed in the winter period (November until May) when the vegetation is physiologically less active. As measurement results were scaled to one year, stomatal uptake as well as uptake and leaching in solution is most probably underestimated. During the measurement period no episodes with winter smog, frost, drought or an insect plague occurred. Such stress factors may intensify canopy exchange processes considerably. Canopy exchange rates derived for the Speulder forest may not be considered representative for other forests in the Netherlands as canopy exchange is found to depend strongly on tree species and ecological setting.

A canopy exchange model developed by Van der Maas & Pape (1991) has proven to be a useful tool for determining the impact of canopy exchange on throughfall fluxes. The combination of throughfall measurements and this model results in deposition estimates which are similar to deposition estimates derived from micrometeorological measurements and inferential modelling. Unfortunately, several basic assumptions in the canopy exchange model are not properly evaluated under different environmental conditions (ecological setting, pollution climate), which limits the models' utility up to now to forest stands growing on dry and sandy, nutrient poor podzolic soils under current air pollution levels. The model can be improved by taken into account the different mass median diameters of Mg^{2+}, Ca^{2+} and K^+ containing particles compared to Na^+ containing particles in the calculation of the dry deposition factors. Moreover, stomatal uptake of NO_2 and HNO_2 has to be included in the model (Draaijers et al., 1994).

References

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