GENERAL INFORMATION

author(s)	Adriaenssens S, Hansen K, Staelens J, Wuyts K, De Schrijver A, Baeten L, Boeckx P, Samson R, Verheyen K
year	2012
English title	Throughfall deposition and canopy exchange processes along a vertical gradient within the canopy of beech (*Fagus sylvatica* L.) and Norway spruce (*Picea abies* (L.) Karst)
original title	
reference	Science of the Total Environment 420
pages	168–182
type	article (a1)
ecosystem service	regulating – nutrient cycling
keywords	throughfall deposition, dry deposition, canopy exchange, N, S, canopy budget model
taxa	*Fagus sylvatica*, *Picea abies*
project	PhD Adriaenssens_2012
supervisor	Verheyen K, Boeckx P, Samson R
institution	Forest & Nature Lab, Laboratory of Applied Physical Chemistry, University of Antwerp
location	pdf, hardcopy
data	

MATERIALS & METHODS

study area	5n (measuring tower)
time period	2009–2010
goal	- Determination of the amount and chemical composition of throughfall water throughout the year within the canopy of a European beech (*Fagus sylvatica* L.) tree in Belgium and two Norway spruce (*Picea abies* (L.) Karst) trees in Denmark. - Distinguish dry deposition from canopy exchange by using a canopy budget model.
set-up	beech next to the measuring tower (scientific zone Aelmoeseneie)
data collection	water collection: two-weekly from 22/04/2009–21/05/2010 - 6 funnels (collecting area 0.0460 m^2) at each level (1.5, 15, 22 m) - 2 funnels at the top of the canopy (28 m) - 2 funnels on top of the tower (35 m, bulk deposition) - spiral gauge at 2 m above ground level (stem flow) - sample volume, pH, conductivity, NO_3^-, SO_4^{2-}, PO_4^{3-}, Cl^-, NH_4^+, K^+, Ca^{2+}, Mg^{2+}, Na^+ leaf collection: 09/06/2011 - at 3.5, 8, 10.5, 15, 17.5, 22, 24.5 and 28 m height - 4 twigs per height - analysis of leaf N content
remarks	In Denmark, data were collected in 1992 and 1993; see - Hansen K (1995) In-canopy throughfall measurements in Norway spruce: water flow and consequences for ion fluxes. Water Air and Soil Pollution 85, 2259–2264 - Hansen K (1996) In-canopy throughfall measurements of ion fluxes in Norway spruce. Atmospheric Environment 30, 4065–4076

ABSTRACT

To assess the impact of air pollution on forest ecosystems, the canopy is usually considered as a constant single layer in interaction with the atmosphere and incident rain, which could influence the measurement accuracy. In this study the variation of througfall deposition and derived dry deposition and canopy exchange were studied along a vertical gradient in the canopy of one European beech (*Fagus sylvatica* L.) tree and two Norway spruce (*Picea abies* (L.) Karst) trees. Throughfall and net throughfall deposition of all ions other than H+ increased significantly with canopy depth in the middle and lower canopy of the beech tree and in the whole canopy of the spruce trees. Moreover, throughfall and net throughfall of all ions in the spruce canopy decreased with increasing distance to the trunk. Dry deposition occurred mainly in the upper canopy and was highest during the growing season for H^+, $NH4^+$, $NO3^-$ and highest during the dormant season for Na^+, Cl^-, $SO4^{2-}$ (beech and spruce) and K^+, Ca^{2+} and Mg^{2+} (spruce only). Canopy leaching of K^+, Ca^{2+} and Mg^{2+} was observed at all canopy levels and was higher for the beech tree compared to the spruce trees. Canopy uptake of inorganic nitrogen and H^+ occurred mainly in the upper canopy, although significant canopy uptake was found in the middle canopy as well. Canopy exchange was always higher during the growing season compared to the dormant season. This spatial and temporal variation indicates that biogeochemical deposition models would benefit from a multilayer approach for shade-tolerant tree species such as beech and spruce.

RESULTS

Bulk deposition, throughfall deposition and leaf N content

The annual precipitation to the canopy was 647 mm (beech) and 693 mm (spruce), of which 40 % (beech) and 31 % (spruce) evaporated after canopy interception. The interception by beech was higher in the growing period (50 %) than in the dormant period (26 %). The stemflow volume for beech was 2 % of the total precipitation volume.

The bulk deposition of H^+, inorganic N (NH_4^+ and NO_3^-) and S (SO_4^{2-}) was 1.20, 63.7 and 24.3 mmolc m^{-2} yr^{-1} in Belgium (beech) and 26.7, 57.9 and 98.5 mmolc m^{-2} yr^{-1} in Denmark (spruce).

The throughfall fluxes of all ions were significantly influenced by sampling time and precipitation volume for both beech and spruce. For all ions except H^+ and NO_3^- (beech only), throughfall increased with canopy depth. Within the spruce canopies, throughfall was also influenced by the distance to the trunk.

For the <u>beech</u>, throughfall deposition was high for NH_4^+, H^+, Cl^-, SO_4^{2-} and Na^+ during leaf senescence and the leafless period; for K+ and weak acids during leaf development; and for K^+, weak acids, Ca^{2+} and Mg^{2+} during leaf senescence. The throughfall of NO_3^- was lower during leaf development and approximately constant during the rest of the year.

For the <u>spruce</u> trees, throughfall deposition was higher during the dormant season for Na^+, H^+, Ca^{2+}, Mg^{2+}, SO_4^{2-} and Cl^-; at the beginning of the growing season for NH_4^+, at the beginning and end of the growing season for K^+.

Leaf nitrogen content in the beech canopy increased significantly ($p<0.001$) from 2.25 % at 28 m height to 2.67 % at 3.5 m.

Net throughfall

<u>Beech</u>: significantly influenced by time and precipitation volume for all ions, and by canopy level for almost all ions.

Highest during leaf senescence, intermediate during the leafless period and lowest for the leaf development and fully leafed periods (opposite for H^+; NH_4^+ highest during the leafless period). During leaf development and the leafed period: negative net throughfall of NH_4^+ in the upper canopy. During leaf development: positive net throughfall of NO_3^- in the upper canopy.

Significant increase towards 1.5 m for all ions except H^+, NO_3^- and Na^+; significant increase for K^+ (28–22 m), for Mg^{2+} (22–15 m), for SO_4^{2-}, K^+, Ca^{2+} and Mg^{2+} (15–1.5 m). No significant changes for H^+, NO_3^- and Na^+ below 28 m.

Spruce: differences according to sampling time, precipitation volume, canopy level and distance to the trunk for all ions; significant effect of the interaction between canopy level and distance to the trunk for volume, H^+ and Cl^-. Patterns similar to throughfall, except for NH_4^+ (significant increase between 15–13 m and between 13–9.5 m).

Dry deposition and canopy exchange

Net throughfall fluxes of K^+, Mg^{2+}, Ca^{2+} and H^+ were mainly determined by canopy exchange processes; dry deposition was more important for the other ions.

Beech: Dry deposition of K^+, Ca^{2+} and H^+ was higher during the growing season; Na^+ was higher during the dormant season. Dry deposition of K^+, Mg^{2+}, Ca^{2+}, Cl^- and NH^{4+} was significantly higher at 1.5 m than at 15 m (for NH_4^+ also higher at 15 m than at 22 m). Canopy exchange was significantly affected by canopy level, for all elements, and by season, for all elements except NH_4^+. Canopy leaching was significantly different for K^+, Ca^{2+} and weak acids (28–22 m, 15–1.5 m), and for Ca^{2+} and Mg^{2+} (22–15 m). Canopy uptake was detected for NH_4^+, NO_3^- and H^+ (22–15 m).

Spruce: Dry deposition fluxes of NH_4^+, Cl^-, K^+, Ca^{2+}, Mg^{2+}, Na^+ and SO_4^{2-} were affected by canopy level and season; dry deposition of NO_3^- was only affected by season. For NH_4^+ and NO_3^-, the dry deposition was highest during the growing season; for the other elements in the dormant season. The largest differences were found between the upper two canopy levels (except for Na^+, Cl^- and Ca^{2+}, with a significant increase between 13–9.5 m). Only for NH_4^+, Cl^- and Na^+, dry deposition decreased with increasing distance to the trunk. Canopy exchange was affected by canopy level and season. Leaching of K^+, Ca^{2+}, Mg^{2+} and uptake of NH_4^+ occurred mainly in the upper and middle canopy (15–11 m) and decreased with increasing distance to the trunk. Uptake of H^+ and NO_3^- occurred in the middle and lower canopy (13–9.5 m).

CONCLUSIONS

The chemical composition of throughfall and net throughfall changed significantly between the different canopy levels of beech and spruce trees, linked to differences in dry deposition and canopy exchange. The patterns in throughfall, net throughfall, dry deposition and canopy exchange depended upon the ion considered, the season and the canopy structure of the studied tree species.

Dry deposition of ions originating from gases (NH_4^+, NO_3^- and SO_4^{2-}) and canopy uptake of inorganic N was concentrated in the upper canopy of both species and was linked to the higher physiological activity of this canopy layer (stomatal conductance and photosynthesis). Dry deposition of ions deposited as aerosols (K^+, Ca^{2+}, Mg^{2+}, Na^+, Cl^-) occurred mainly in the upper canopy for beech, but increased with canopy depth and decreased with distance to the trunk for spruce, which reflects the canopy structure of beech and spruce. Ions originating from the canopy (K^+, Ca^{2+}, Mg^{2+}) were found in the throughfall water at all levels; the contribution was low for beech in the dormant season.