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Comparative field study on precipitation, throughfall, stemflow, fog water, and atmospheric aerosol and gases at urban and rural sites in Japan

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Abstract

Precipitation collected by a wet-only sampler (WP), precipitation collected by a filtering-type bulk sampler (BP), throughfall (TF), stemflow (SF), fog water (FW), and atmospheric aerosol and gases were collected at two sites with different site classifications: an urban site (Mt. Rokko) and a rural site (Mt. Awaga) to investigate canopy–atmosphere interactions and to study the chemistry of precipitation in forested areas located in different atmospheric conditions. Compared to those at the rural site, the monthly volume-weighted pH values at the urban site were not significantly ($p>0.05$) different for WP, higher ($p<0.05$) for BP, not significantly ($p>0.05$) different for TF, lower ($p<0.01$) for SF, and lower ($p<0.01$) for FW. The order of mean pH values at the urban site was FW<SF<WP<TF<BP. In contrast, the order at the rural site was FW<SF<BP<WP<TF. Concentrations of chemical species at the urban site were higher than those at the rural site in all samples and all chemical species. In particular, higher NO_3^- concentrations at the urban site were observed in all samples. The amount of dry deposition on leaves at the urban site was approximately 1.17 times larger than that at the rural site. The monthly net TF (=TF − BP) in autumn seemed to be larger than that in summer; this trend was remarkable in K^+. The monthly NO_3^- deposition in the net TF was larger at the urban site than at other parameters and at the rural site. The concentrations of chemical species in aerosol and gases that were measured near the central part of Kobe City were ca. 3.4 times higher than those in the rural area. Mt. Rokko borders the central part of the city, which caused the concentrations at Mt. Rokko to be higher than those at Mt. Awaga. The deposition amounts at Mt. Rokko were larger than those at Mt. Awaga, which probably can be attributed to the higher concentrations of chemical species in atmospheric aerosol and gases.

Keywords: Aerosol; Bulk; Fog water; Gas; Stemflow; Site classification; Throughfall; Wet-only

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1. Introduction

Precipitation is one of the most important agents providing nutrients to forest ecosystems (Ukonmaanaho and Starr, 2002; Laclau et al., 2003). The chemistry of precipitation in a forested area is important in the study of the forest ecosystem and the mechanism for recovery from acidification in forests (Bini and Bresolin, 1998; Schrijver et al., 1998; Hill et al., 2002). Recently, throughfall, stemflow, fog water, stream water, groundwater, dry deposition, and precipitation have been investigated to estimate the input–output balance and to study forest ecosystems (Fenn and Kiefer, 1999; Castro and Morgan, 2000; Marcos and Lancho, 2002; Quilchano et al., 2002; Stachurski and Zimka, 2002; Rodrigo et al., 2003). Precipitation is a major contributor of input of materials to forest ecosystems. However, fog water and dry deposition also play important roles in the supply of materials. It has been reported that the input of chemical species into a forest ecosystem by fog water was equal to or larger than that by precipitation at mountain sites (Kobayashi et al., 1999).

There have been few comprehensive studies of precipitation (wet-only and bulk), throughfall, stemflow, fog water, and atmospheric aerosol and gases at two different sites with different site classifications. The aim of this study is to investigate comprehensively the chemistry of precipitation (wet-only and bulk), throughfall, stemflow, fog water, and atmospheric aerosol and gases that can provide input of materials to the forest ecosystem at two different sites with different site classifications.

2. Experimental

2.1. Monitoring site

A comparative field study was carried out at Mt. Rokko (elevation at the summit: a.s.l. 931 m) in Kobe City and Mt. Awaga (elevation at the summit: a.s.l. 962 m) in the town of Aogaki, Hyogo Prefecture, Japan. A location map of the monitoring sites, Kobe, and Aogaki is shown in Fig. 1. Mt. Rokko is bordered on the south by the central part of Kobe, while Mt. Awaga is located inland, where there are few industrial companies and, therefore, commerce is limited. Mt. Rokko is subject to influences of air pollutants derived anthropogenically, while Mt. Awaga is likely to be less influenced by such pollutants.

2.2. Sample collection

2.2.1. Method and period

Two kinds of precipitation samples were collected: one by a wet-only sampler (WP) and the other by a filtering-type bulk sampler (BP). The details about the wet-only sampler and the filtering-type bulk sampler were described by Tamaki et al. (2000) and Aikawa et al. (2003). The filtering-type bulk sampler was also used to collect throughfall samples. The BP collected by the filtering-type bulk sampler was used as the control sample for throughfall (TF). The bottles used in the filtering-type bulk samplers for BP and TF were covered with silver sheeting to prevent solar light from causing the samples to deteriorate. Stemflow (SF) was collected by a shampoo-hat stemflow sampler (Tamaki et al., 2000). *Cryptomeria japonica* (height of tree: approximately 16 m, diameter at breast height: 25 cm at Mt. Rokko; height of tree: approximately 15 m, diameter at breast height: 23 cm at Mt. Awaga) was selected for the collection of SF and TF. Fog water (FW) sampling was performed by using an active string-fog collector. The collector used at Mt. Rokko can collect fog water by volume separation and time separation. The details were described by Aikawa et al. (2005a). In contrast, the collector used at Mt. Awaga can collect fog water as one sample during each sampling period. The four-stage filter pack method (1st stage: PTFE filter, 2nd stage: polyamide filter, 3rd stage: 6% K_2CO_3–2% glycerin-impregnated filter, 4th stage: 5% H_3PO_4–2% glycerin-impregnated filter) was used to collect gases (SO_2, HNO_3, HCl, NH_3) and aerosol (SO_4^{2-}, NO_3^-, Cl^-, Na^+, NH_4^+, K^+, Ca^{2+}, Mg^{2+}) in the air (Karakas and Tuncel, 1997; Matsumoto and Okita, 1998; Sickles et al., 1999). The BP, TF, and SF samples at Mt. Rokko were collected at the Kobe Municipal Arboretum (a.s.l. 360 m), located at Mt. Rokko, the WP and FW samples were collected near the summit of Mt. Rokko (a.s.l. 800 m), and the aerosol and gases were collected on