Cloud Water in Southern Chile: Whence Come the Nutrients?

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Abstract: The chemical analysis of ground-level cloudwater samples collected over the past several years from remote sites in southern Chile suggests that cloudwater deposition may be a very important source of nutrients, especially nitrogen, to some near-coast ecosystems of the regions. Cloudwater from Torres del Paine, Punta Arenas, Chiloe Island, Chile was dominated by "seasalt" ions, such as calcium, magnesium, sodium and chloride, but had surprisingly high concentrations of inorganic nitrogen. When compared to rainwater from nearby locations, cloud water ranged from two to eighty times more concentrated. Nitrogen deposition via cloudwater may contribute up to 10 kg N/ha/yr to temperate forests of this region (Weathers and Likens 1997). In addition, at the Chiloe site, organic nitrogen, on average, accounted for 80% of the total nitrogen in these samples. Future research will address the sources of nitrogen in cloudwater deposited to these remote sites as well as the relative importance of cloudwater as a nutrient input to southern temperate forest ecosystems.

1. INTRODUCTION

Cloud and fogwater are known to be important sources of nutrients and pollutants in many ecosystems of the world, particularly coastal and montane regions (e.g. Lovett 1982, Waldman et al. 1982, Weathers et al. 1986, Vong et al. 1997, Kimball et al. 1988). Although much more is known now than a decade ago about the chemistry and deposition of cloudwater, few data exist from "background sites" where anthropogenic influence is minimal (Weathers and Likens 1997, Vong et al. 1997). Here we present some data on the chemistry of cloudwater from remote sites in the Southern Hemisphere, where anthropogenic influence on atmospheric chemistry is thought to be at a minimum (Galloway et al. in press, Hedin et al. 1995, Weathers and Likens 1997).

2. EXPERIMENTAL

2.1 Materials and Methods

Cloudwater samples were collected from three locations in southern Chile, including: Torres del Paine National Park, Magallanes Preserve (collections made 1987-1994), and Chiloe Island (1996- present). Samples were collected on an event basis in clean polyethylene bottles using CalTech Active Strand Collectors (CASC) (3.5 micron lower droplet size cut, (Weathers and Likens 1997)) and immediately fixed with 0.5 ml of reagent grade chloroform. They were then sent to the Institute of Ecosystem Studies (IES) in Millbrook, New York where they were analyzed for major inorganic cations and anions following the methods of Weathers et al. (1988). Total nitrogen was determined on the Chiloe samples using the persulfate digestion and standard wet chemical techniques (EPA 1987). Organic nitrogen was determined by subtracting the sum of measured inorganic nitrogen from total nitrogen.

3. RESULTS and DISCUSSION

Cloudwater from southern Chile was two to eighty times more concentrated than rainwater from Torres del Paine National Park (Figure 1). This result is consistent with other data showing that cloudwater is often many times more concentrated than rainwater (e.g. Weathers et al. 1988), however, the enhancement of nitrogen (N) in cloudwater versus rainwater is of particular interest, especially since nitrogen is often a limiting nutrient in terrestrial ecosystems. In our previous work, we have noted the potential significance of inorganic N in cloudwater as a source of nutrients to southern temperate ecosystems. We have estimated that N deposition via cloudwater may be as high as 10 kg/N/yr (Weathers and Likens 1997). While inorganic N concentrations were relatively high in cloudwater from southern Chile, organic N was the largest fraction of total nitrogen in cloudwater, contributing, on average,

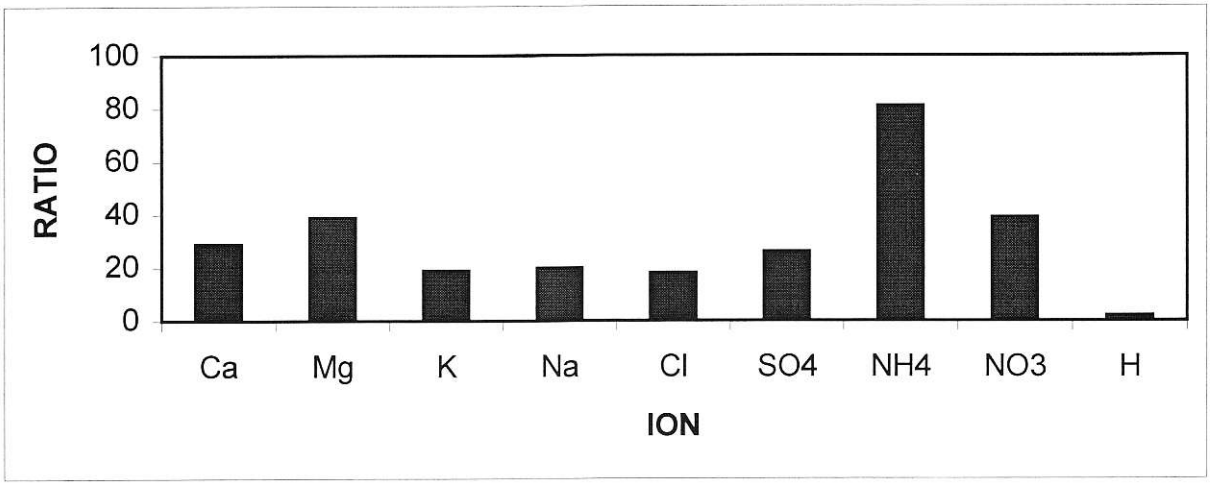

Figure 1: Ratios of average cloudwater to volume-weighted average rainwater chemistry for inorganic ions. The cloud water data are from Weathers and Likens 1997. The rainwater data are from Galloway et al, in press, Galloway et al. 1996.

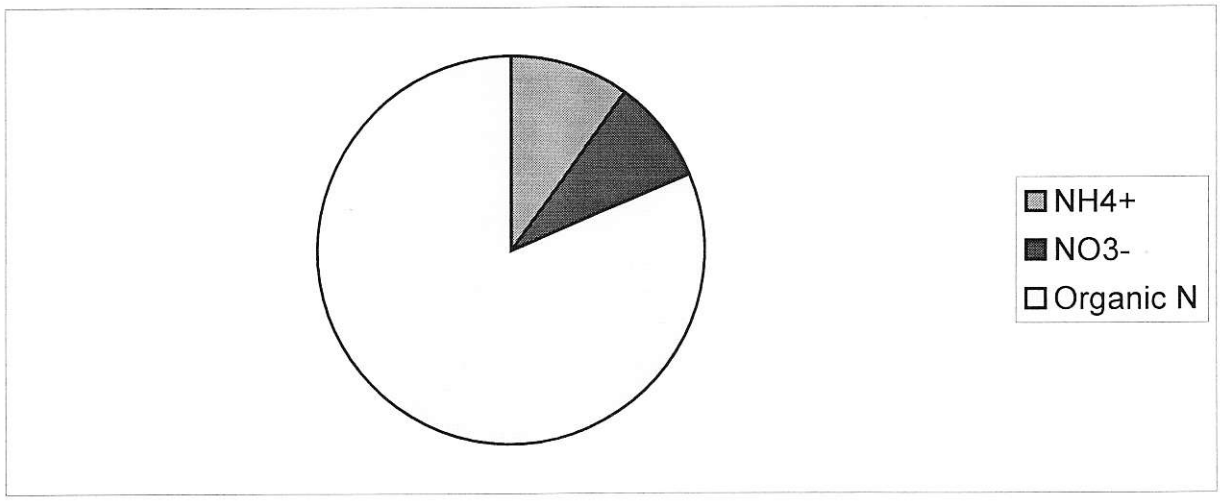

Figure 2: Average percent contribution of inorganic nitrogen (nitrate + ammonium) and organic nitrogen to total nitrogen in cloudwater samples from Chiloe Island, Chile.

80% (Fig. 2). In fact, our cloudwater organic N concentrations from southern Chile are up to forty times higher than those reported for rainwater collected from various sites in the eastern United States (Scudlark et al. 1988). Thus nitrogen inputs to southern temperate ecosystems may well be underestimated and ecologically important.

Little is known about the sources of organic nitrogen in the atmosphere or its relative contribution to rain or cloudwater deposition, however, recent data suggest that it can be a very important contribution to the nitrogen budget of ecosystems (Cornell et al. 1995). The deposition of organic nitrogen may be of particular significance to relatively unimpacted regions such as remote, southern Chile.

4. CONCLUSIONS and RECOMMENDATIONS

We have shown that cloudwater collected from remote sites in southern Chile was often at least 20-fold more concentrated in inorganic ions than rainwater. Therefore, ecosystems in this region that receive significant cloudwater deposition may receive high nutrient loading. Nitrogen is an important component of cloudwater, but the origins of both inorganic and organic N in cloudwater from southern Chile are unknown. Future efforts should be focused on determining whether the sources of nitrogen in cloudwater from remote sites are of anthropogenic, terrestrial or aquatic biogenic origin, which is important both from scientific and policy perspectives.

5. ACKNOWLEDGMENTS

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