Chemistry and isotopic composition of precipitation and surface waters in Khumbu valley (Nepal Himalaya): N dynamics of high elevation basins

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HIGHLIGHTS

• Ionic concentrations in rain are the regional background deposition concentrations.
• In non-monsoon seasons, the Himalayas are not a barrier for airborne pollution.
• The chemistry of stream water is dominated by the dissolution of calcite and gypsum.
• N deposition fluxes do not adequately predict N concentrations in stream waters.

Abstract

We monitored the chemical and isotopic compositions of wet depositions, at the Pyramid International Laboratory (5050 m a.s.l.), and surrounding surface waters, in the Khumbu basin, to understand precipitation chemistry and to obtain insights regarding ecosystem responses to atmospheric inputs. The major cations in the precipitation were NH4+ and Ca2+, whereas the main anion was HCO3−, which constituted approximately 69% of the anions, followed by NO3−, SO42− and Cl−. Data analysis suggested that Na+, Cl− and K+ were derived from the long-range transport of marine aerosols. Ca2+, Mg2+ and HCO3− were related to rock and soil dust contributions and the NO3− and SO42− concentrations were derived from anthropogenic sources. Furthermore, NH4+ was derived from gaseous NH3 scavenging. The isotopic composition of weekly precipitation ranged from −1.9 to −23.2‰ in δ18O, and from −0.8 to −174‰ in δ2H, with depleted values characterizing the central part of the monsoon period. The chemical composition of the stream water was dominated by calcite and/or gypsum dissolution. However, the isotopic composition of the stream water did not fully reflect the composition of the monsoon precipitation, which suggested that other water sources contributed to the stream flow.

Precipitation contents for all ions were the lowest ones among those measured in high elevation sites around the world. During the monsoon periods the depositions were not substantially influenced by anthropogenic inputs, while in pre- and post-monsoon seasons the Himalayas could not represent an effective barrier for airborne pollution. In the late monsoon phase, the increase of ionic contents in precipitation could also be due to a change in the moisture source. The calculated atmospheric N load (0.30 kg ha−1 y−1) was considerably lower than the levels that were measured in other high-altitude environments. Nevertheless, the NO3− concentrations in the surface waters (from 2 to 17 μeq L−1) were greater than expected based on the low N inputs from wet deposition.

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1. Introduction

Located between the Tibetan Plateau and Indian subcontinent, the high Himalayan region represents a unique ecosystem that hosts the highest peaks of the world and the sources of many large Asian rivers, including the Yangtze, Indus and Ganges. The region is one of the 34 world biodiversity hotspots, to which 50% of the world’s floristic diversity is restricted (Mittermeier et al., 2005). Glaciers in this area serve as “water towers” in the regional hydrological cycle and provide significant amounts of melt water (Immerzeel et al., 2010). In particular, the south slope of Mt. Everest is one of the most heavily glaciated regions in the Himalayas (Scherler et al., 2011) and contains the highest glaciers in the world (Salerno et al., 2012). Perceived as one of the most uncontaminated places of the Earth, the Himalayas host an extremely fragile ecosystem, with a low resistance and resilience. These features make this region sensitive to any environmental change.