Acidification processes in high alpine lakes

Second title omitted in final version: Impacts of atmospheric deposition and global change

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Abstract

Remote high alpine lakes are among the rare ecosystems that are almost undisturbed by direct human activities. Still, their water quality is affected by atmospheric acid deposition and pH decreases have been observed in many areas. Moreover, the biology and limnochemistry of these lakes are sensitive to climate change: even a small increase in air temperature results in higher biological activity, enhanced weathering rates and increased local dust deposition. In contrast, during cold periods a perennial ice cover is closing the lakes against atmospheric input and pH is controlled primarily by in-lake processes.

Here we present a palaeolimnological study of five high alpine lakes of different alkalinity (0-100µeq/l) spanning the last 200 to 500 years. In two of these lakes, air temperature is the main driving force for the acid base equilibrium, whereas in the three other lakes, acid deposition has been causing strong pH decrease since the turn of this century. Temperature effects on acidity are also confirmed by limnochemical investigations of 57 high alpine lakes. We discuss why both, climate change and acid rain, will have to be considered for predicting future changes in the quality of alpine headwaters.

Introduction

Lakes at very high altitudes (resp. latitudes) are sensitive indicators of environmental change. Their water quality is influenced strongly by temperature variations (Psenner and Schmidt 1992; Schmidt and Psenner 1992; Wright and Schindler 1995; Pienitz et al. 1995), atmospheric deposition (Mosello 1984; Marchetto et al. 1994) and UV radiation (Vincent and Pienitz 1996; Sommaruga and Psenner 1997), while the impact by local anthropogenic activities is comparatively small. Impacts on the biology and limnochemistry are recorded in the sediments of the lakes. Taking sediment cores and analysing variations in the assemblages of indicator species (e.g. diatoms) makes it possible to infer past environmental conditions. The combination of biological, physical and chemical information preserved in sediment profiles is used to estimate background conditions of aquatic ecosystems and to detect changes due to anthropogenic impacts. As sediment layers can be dated quite accurately, the chronology of environmental stress and also their causes (e.g. acidification) can be determined (Smol 1992; Dixit et al. 1992; Battarbee and Charles 1992; Renberg et al. 1993).

In this paper we present palaeolimnological investigations of five high alpine soft-water lakes. We address the following questions: a) what is the natural variability of the acid base balance related to temperature changes, b) how are these lakes modified by anthropogenic activities, especially by acid deposition, and c) are the reactions to temperature changes site-specific?

Material and Methods:

Five high alpine lakes located on crystalline bedrock were sampled for sediment analysis. The lakes are located in the Oetztaler Alps (Tyrol, Austria; and Southern Tyrol, Italy), at very high altitudes: Portless See (lake P) at 2892 m above sea level (a.s.l), Schwarzsee ob Sölden (lake S) at 2796 m a.s.l., Rassas See (lake R) at 2682 m a.s.l., Mutterberger See (lake M) at 2483, and Brechsee (lake B) at 2145 m a.s.l. Vegetation and soil formation are sparse in the catchment areas but the amount of rocks and scree is high. The maximum depth of the lakes varies form 6.1 m (lake B; 1.32 ha) to 17.5m (lake S; 3.05 ha). The maximum horizontal distance between the lakes is about 75 km. Thus the lakes are affected by comparable acid deposition patterns (mean rain pH 4.93, (Camarero et al. 1994)) depending on the amount of precipitation.

Sediment cores were taken using a modified kajak sampler and sectioned into 0.25 or 0.5 cm layers for high time resolution profiles. From every layer, diatom slides were prepared according to standard techniques (Battarbee 1986), and diatom valves were counted in a light microscope. Additionally the sediment was analysed for loss on ignition, carbon and nitrogen (CHN-Analyser Carlo Erba), and calcium, magnesium, potassium, sodium, silica, titanium, aluminium, lead, iron and manganese (ICP-Spectrometry and Atomic Absorption Spectrometry resp.). The sediment was dated by radioactive lead (^{210}Pb; constant rate of supply model) and Caesium (^{137}Cs). The age of layers older than 150 years was interpolated in relation to variations in loss on ignition and dry weight (detailed description of methods in Koinig et al. 1997a and b).

We reconstructed pH from changes in diatom composition using weighted averages calibration and regression: We used the pH optima estimated for the diatom taxa from 32 high alpine lakes (Marchetto and Schmidt 1993) to infer the pH for every layer.