Carbon and nitrogen dynamics in eutrophic mountain Lake Planina (NW Slovenia)

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Abstract: Stable C and N isotope analyses were used in combination with chemical analyses (i.e. alkalinity, nitrite, nitrate, ammonium and dissolved oxygen concentrations) to study C and N dynamics in the water column of Lake Planina. Substantial variations in all parameters were observed and are related to biogeochemical changes in this stratified eutrophic lake.

Key words: carbon, nitrogen, stable isotopes, particulate organic matter, water column, Lake Planina

Introduction

Despite the remoteness of alpine lakes, previous investigations showed that these environments are also exposed to enhanced environmental changes. Although eutrophication is a natural process in the ontogenetic development of lakes, human activities can greatly accelerate this process. The response to a disturbed natural equilibrium and higher input of nutrients from the surrounding watershed into the water is increased bioproduction and the process of eutrophication. Organic matter produced photosynthetically in the surface water is assumed to be the principal control of carbon and nitrogen cycling, but in eutrophic systems the development of anoxic conditions in the water column and sediments may create conditions favourable for expansion of microbially mediated C and N cycling processes, which can distinctly influence the water chemistry and the isotopic signatures of sinking or sedimented organic matter (Furrer and Wehrli, 1996, Hollander and Smith, 2001, Lehmann et al., 2002).

Postglacial Lake Planina is located in the area of the Triglav National Park in the northwestern part of Slovenia. The lake is situated 1430 m a.s.l. with a surface area of 0.018 km^2 and a maximum depth of 11 m. The lake is dimictic and the thermocline occurs at a depth of 1-3 m. The hypolimnion is dysoxic during the stratification period. The lake sediment is characterized as organic-rich carbonate silt. Since the area of the Triglav National Park is protected, direct pollution is expected to be limited, but the lake is easily accessible. Many human activities like woodcutting and Alpine dairying took place around the lake since the 14th century and nowadays tourism is very popular. As a consequence of human activities more nutrients

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and terrigenous organic matter were introduced into the lake. The response to human activities was an induced process of eutrophication.

In this study, we used stable carbon and nitrogen isotope analyses in combination with chemical analyses to study C and N dynamics in the water column of Lake Planina.

SAMPLING AND ANALYSES

Sampling of the water column was performed during 2002 and 2004 from the depest part of the lake using a van Dorn sampling device. Water samples were collected every 2.5 m and filtered through a 0.2 μm filter. Several chemical parameters were determined in the samples. Alkalinity was determined by the Gran titration method, while nitrite, nitrate and ammonium were determined with a 761 Compact IC ion chromatograph (APHA et al. 1998). Temperature and oxygen concentrations were measured in the field. Samples for the analysis of the isotopic composition of dissolved inorganic carbon ($\delta^{13}C_{DIC}$) were filtered through 0.45 μm membrane filters. Particulate organic matter (POM) samples for $\delta^{13}C$ and $\delta^{15}N$ analyses were collected on Whatman GF/C fiberglass filters by filtration of 200-1000 mL of water. The stable isotopic composition of carbon and nitrogen was determined on a continuous-flow Europa 20-20 isotope ratio mass spectrometer.

RESULTS AND DISCUSSION

Stratification of the water column is distinctive in summer and winter, while in the intervals mixing occurs. In the epilimnion temperatures were as high as 21 °C and dissolved oxygen concentrations varied from 6 to 11 mg/L. In the hypolimnion temperatures were up to 9 °C and dissolved oxygen concentrations varied from 0.2 to 6 mg/L. The alkalinity was high, since the lake is situated on limestone bedrock. In the surface waters, the alkalinity averaged 1.7 mmol/L but increased with depth. Thus, high alkalinity values were observed in the bottom waters, frequently exceeding 3.0 mmol/L and were caused by the shift of the carbonate equilibrium. Nitrite concentrations were below the limit of detection (0.05 mg/L) at all times. Nitrate concentrations varied remarkably during the year. In spring and early summer, nitrates mostly exceeded 1.0 mg/L and were rather uniform in the water column. However, during late summer/early autumn, when lake stratification was the most pronounced, nitrate concentrations decreased even below 0.1 mg/L, since nitrate is used by aquatic organisms. In contrast, ammonium concentrations were below the limit of detection (0.05 mg/L) in the surface waters. Ammonium increased in the deeper water layers and frequently exceeded 1.0 mg/L at the lake bottom.

Changes in isotopic composition of DIC and POM are related to changes in water chemistry and biogeochemical processes that predominately influence the carbon and nitrogen cycle in the lake. $\delta^{13}C_{DIC}$ decreased from –5.5 at the lake surface to –13.2 ‰ at the bottom of the lake. Simultaneously $\delta^{13}C_{POM}$ decreased from –34.3 to –50.6 ‰ and $\delta^{15}N_{POM}$ from +2.5 to –6.4 ‰, respectively. Variations in $\delta^{13}C_{DIC}$, $\delta^{13}C_{POM}$ and $\delta^{15}N_{POM}$ are related to stratification of the water column and indicate the influence of photosynthesis, respiration and decomposition of organic matter during sinking to the dysoxic lake bottom. The most positive isotope values were observed in the photic zone during spring and summer and are associated with uptake of light isotopes in synthesized biomass. With the development of dysoxic conditions in the hypolimnion $\delta^{13}C_{DIC}$, $\delta^{13}C_{POM}$ and $\delta^{15}N_{POM}$ values decreased considerably. Very negative isotope values indicate that with increasing depth aerobic/anaerobic bacteria utilizing methane and ammonium derived from decomposition of organic matter as carbon and nitrogen sources play an important role.

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