

Biogeochemistry of a large, meromictic tropical lake (Lake Kivu, East Africa): insights from a stable isotope study covering an annual cycle

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Lake Kivu (East Africa) is a large (2370 km²) and deep (maximum depth of 485 m) meromictic lake. Its vertical structure consists of an oxic and nutrient-poor mixed layer down to 70 m maximum, and a permanently anoxic monimolimnion rich in dissolved gases (methane and carbon dioxide) and nutrients. Seasonal variation of the vertical position of the oxic-anoxic interface is driven by contrasting air humidity and wind speed regimes between rainy (October-May) and dry (June-September) seasons. The latter is characterized by a deepening of the oxic zone, and an increased input of dissolved gases and inorganic nutrients. The mean annual photic depth is 18 m, but water transparency slightly decreases during the dry season. In this study, we present a comprehensive data set covering a full annual cycle at a fortnightly resolution, which combine hydrochemical data, $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ measurements of particulate organic carbon and nitrogen (POC, PN) and zooplankton, $\delta^{13}\text{C}$ of dissolved organic and inorganic carbon (DOC, DIC), nutrients and gases (CH₄) concentrations, phytoplankton biomass and composition. In the euphotic zone, phytoplankton biomass was constant during the rainy season, but doubled during the dry season. In contrast, $\delta^{13}\text{C}$ -DIC increased linearly with time during the rainy season, deviating from the values expected at isotopic equilibrium with the atmosphere, then suddenly decreased in the dry season due to the vertical mixing with ¹³C-depleted DIC. Results of mass-balance calculations indicate that the $\delta^{13}\text{C}$ -DIC increase reflects the net autotrophic status of the mixed layer. Irrespective of the season, the $\delta^{13}\text{C}$ -POC signatures were constant from the surface to the oxic-anoxic interface, then showed a local and abrupt excursion to values as low as -40 per mil, reflecting the incorporation of a ¹³C-depleted source in the POC. While the large pool of DIC is the main carbon source for POC in surface waters, CH₄ contributes significantly to C fixation at the oxic-anoxic interface all year round. The $\delta^{13}\text{C}$ signature of the DOC pool shows very little variation in the mixolimnion and thus appears to be uncoupled from the POC pool, suggesting that old and refractory compounds constitute the major part of the DOC pool. Also the more labile and freshly produced DOC that reflects the $\delta^{13}\text{C}$ signature of the POC, is rapidly mineralized. Finally, we noticed a shift toward higher values in the $\delta^{15}\text{N}$ -PN during the dry season (from 0.5 per mil to 4.0 per mil) and $\delta^{15}\text{N}$ -PN was significantly related to the proportion of cyanobacteria in the euphotic zone. Hence the variation of $\delta^{15}\text{N}$ -PN in surface waters could either reflect a change in the dominant phytoplankton taxa or in the biogeochemical processes controlling the upward nitrate and ammonium fluxes. Zooplankton $\delta^{15}\text{N}$ signatures mirrored the seasonal changes in $\delta^{15}\text{N}$ -PN and were significantly correlated to phytoplankton biomass, highlighting their dependence on autochthonous sources of organic matter in this large lake.