



Anaerobic methane oxidation in two tropical freshwater systems

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Lake Kivu is one of the East African Great Lakes. It is located at the border between Rwanda and the Democratic Republic of the Congo. It is a deep meromictic lake characterized by huge amounts of methane (CH_4) (60 km^3 at 0°C and 1 atm) dissolved in its deep waters. Two thirds of the CH_4 originates from anoxic bacterial reduction of dissolved carbon dioxide and one third from anaerobic degradation of settling organic material. CH_4 then diffuses slowly from the monimolimnion to surface waters where many is oxidised by methanotrophic microorganisms. In Lake Kivu, this biological oxidation of CH_4 could occur with different final electron acceptors: oxygen (aerobic oxidation) but also nitrate (NO_3^-), nitrite, sulfate (SO_4^{2-}), iron (Fe) or manganese (Mn) in anaerobic conditions. If the anaerobic oxidation of CH_4 (AOM) is generally coupled to SO_4^{2-} reduction in marine waters, electron acceptors of the AOM were rarely investigated in freshwater systems. Five field campaigns were conducted from 2011 to 2013 during periods with contrasted ventilations of the upper water column. The dry season is characterized by a deeper mixing of surface waters ended by a steep gradient of physico-chemical conditions at the redox interface, while during the rainy season the mixed layer is shallower and ended at its deeper part by a NO_3^- accumulation zone. Sampling was conducted in the main basin of Lake Kivu but also in a particular sub-basin located northeast of the lake, the Kabuno Bay. Both systems are meromictic but differ in terms of morphometry and geochemistry with a shallower permanent chemocline and higher concentrations of CH_4 , Fe and Mn in the anoxic waters in Kabuno Bay compared to the main lake. Samples were collected for the measurements of CH_4 concentrations and the various potential electron acceptors of the AOM. CH_4 oxidation rates were measured along vertical profiles at 5 m and 0.5 m depth intervals respectively in the main basin and Kabuno bay water columns. Results indicate high rates of AOM in both main basin (up to $7 \mu\text{mol L}^{-1} \text{d}^{-1}$) and Kabuno bay (up to $16 \mu\text{mol L}^{-1} \text{d}^{-1}$). In the main basin, we observed a co-occurrence of the AOM and the SO_4^{2-} reduction in the dry season. During the rainy season, higher oxidation rates occurred in the NO_3^- accumulation zone, which is in favour of a coupling between AOM and NO_3^- reduction. In Kabuno Bay, the higher AOM rates were observed at depths with highest particulate Fe concentrations. Our results suggest that AOM coupled with SO_4^{2-} reduction may occur during the dry season in the main basin, whereas this oxidation could be coupled with NO_3^- reduction during the rainy season. In Kabuno Bay, the co-occurrence of the Fe [III] peak with high AOM suggests a coupling between the AOM and Fe reduction.