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Oxygen control on nitrate reduction processes in lacustrine sediment: a reassessment of O_2 inhibition thresholds

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Lake sediments play a key role in the biological turnover of fixed nitrogen (N). Denitrification and anammox are efficient sinks for reactive N (i.e. NO_3-, NO_2-, NH4+) by conversion to N2. In contrast, dissimilatory nitrate reduction to ammonium (DNRA) retains a bioavailable form of nitrogen within the system, promoting internal eutrophication. Oxygen (O_2) is a key regulator governing the distribution, modes, and rates of N-transformation processes in sediments. Recent studies have investigated O_2 control on denitrification and anammox in bacterial cultures as well as incubation experiments with marine sediments and water samples. The exact O_2 inhibition thresholds on benthic N-transforming pathways, however, are still uncertain, particularly for lacustrine sediments. Moreover, information regarding the O_2 tolerance of DNRA in sediments is scarce. The holo-monomictic south basin of Lake Lugano is an ideal site to study the O_2-control on DNRA and other benthic N-transformations due to its distinct seasonal fluctuations in bottom-water oxygenation. Conducting laboratory slurry incubation experiments with 15N-labelled substrate additions under controlled O_2 conditions, we investigated the O_2-control on benthic NO_3–reduction pathways at concentrations ranging from 0, 1, 2, 3 … to 85 μM O_2, at two different locations in the lake. Denitrification and DNRA were the main N-transformation pathways. Anammox rates were negligible and thus not investigated any further. The relative contribution of denitrification versus DNRA was close to 50/50 in the anoxic control experiments. At 1 μM O_2, potential rates of denitrification and DNRA decreased by ~35% and ~55% respectively compared to the anoxic control experiments. Increasing O_2 concentrations seemed to further decrease 15N-N2 and 15NH4+ production, but both denitrification and DNRA remained active at 50 μM O_2. Oxygen concentration changes had a significant effect on the denitrification/DNRA ratio, as nitrate ammonifiers seem to display a greater O_2 tolerance than denitrifiers at higher O_2 concentrations. We conclude that both denitrification and DNRA persist under microaerobic conditions, and the differential susceptibility of denitrifiers versus DNRA bacteria towards O_2 has important implications for an O_2-ecosystem control on the benthic fixed N elimination versus resupply to the water column.