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

Adeline Cojean (1), Alan Gerster (1), Fabio Lepori (2), Jakob Zopfi (1), and Moritz F. Lehmann (1)
(1) University of Basel, Environmental sciences, Biogeochemistry, Basel, Switzerland (adeline.cojean@unibas.ch), (2) Institute of Earth Science, Scuola Universitaria Professionale della Svizzera Italiana (SUPSI), Trevano, CH-6952 Canobbio, Switzerland

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. $NO_3^-$, $NO_2^-$, NH$_4^+$) by conversion to N$_2$. 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 $\mu$M $O_2$, 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 $\mu$M $O_2$, potential rates of denitrification and DNRA decreased by $\sim$35% and $\sim$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 $\mu$M $O_2$. 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.