Universität Basel

Research Project

Controls of N2O production by nitrifier denitrification in marine and lacustrine environments - Isotopic constraints

Third-party funded project

Project title Controls of N2O production by nitrifier denitrification in marine and lacustrine environments - Isotopic constraints

Principal Investigator(s) Lehmann, Moritz ;

Organisation / Research unit

Departement Umweltwissenschaften / Aquatic and Isotope Biogeochemistry (Lehmann)

Department

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Status Completed

With this proposal, we seek funding for a 12-month extension of the postdoctoral project "Isotopic constraints on seasonal N2O dynamics in marine and lacustrine environments" (SNF 147106; April 2013 - March 2015). Large uncertainties exist with regards to the biogeochemical controls on microbial N2O production. The main objectives of SNF project 147106 were to better understand the environmental conditions that modulate N2O fluxes in aquatic environments. In this context, we proposed to study specific biogeochemical controls (e.g., pH, O2, ecosystem productivity) on the rates of different microbial N2O production pathways (specifically, nitrification/ammonia oxidation and nitrifier-denitrification) in two contrasting aquatic environments with strong seasonal N cycle dynamics: eutrophic Lake Lugano in southern Switzerland and the highly productive Namibian Upwelling region along the coast of southwestern Africa. Making use of incubation-based stable N isotope tracer methods and natural N isotope measurements in dissolved N2O, we focused on the following questions:

- How much do ammonia oxidation and nitrifier-denitrification, respectively, contribute to N2O formation in Lake Lugano and the Namibian Upwelling Zone?
- Which biogeochemical factors control nitrifier-denitrification rates, and are there systematic differences between the marine and freshwater environment?

  During the first 18 months of the project, we generated a comprehensive data set that provides compelling biogeochemical evidence that under insitu conditions, N2O production in Lake Lugano subsurface waters can be largely attributed to the decomposition of hydroxylamine (NH2OH) during ammonium oxidation. At low pH (pH = 6.5) conditions, however, N2O production by nitrifier denitrification is significantly enhanced, and the impact of lowering the pH appears to be amplified when O2 concentrations are also reduced. While we still lack a clear understanding of the mechanisms responsible for these observations, our data clearly demonstrate that relatively mild pH and redox condition changes can have a strong effect on the proportion of N2O produced by nitrifier denitrification versus NH2OH oxidation, and on the overall N2O production. The "biogeochemical switch" in N2O production observed in Lake Lugano, stands in contrast to observations in the Namibian upwelling system. Here, N2O production by either mechanism was not significant at the in situ pH (pH = 7.7) and fully aerobic conditions (20% headspace O2), yet under reduced pH conditions (pH = 7), N2O production by nitrifier denitrification was also enhanced, implying that periods of upwelling of CO2-rich/low-pH deep waters can stimulate N2O production by nitrifier denitrification.

  Although the preliminary data are highly promising, not all questions could be addressed unambiguously thus far

(due to analytical problems during the initial phase of the project). The robustness of our existing results should be
confirmed by additional/outstanding measurements of samples that have already been collected, and by additional
incubation experiments with samples from another Swiss Lake, Lake Cadagno, where preliminary N2O
concentration/isotope data reveal shallow-water N2O production by nitrifier-denitrification. Additional efforts also
include the assessment of ammonium oxidation rates based on existing 15N-label incubation data. Our goal is to
compare the ammonia oxidation rates under each set of experimental treatments to the production rates of N2O by
both NH2OH decomposition and nitrifier denitrification. We plan to combine the natural abundance N2O isotope
measurements and N2O production measurements in a 1-D geochemical model (for Lake Lugano), in an effort to
describe N2O production as a function of ammonia oxidation rate, nitrifier denitrification rate, and to gain
information on the N and O isotope effects that are associated with shallow N2O production processes. Similarly,
using the combined N2O and NOx isotope data from the Namibian upwelling region, we will attempt to assess the
relative importance of upwelling-stimulated N2O production to the total N2O emissions to the atmosphere (which
includes both "pre-formed" deep N2O which is upwelled to the surface, as well as "new" N2O production stimulated
by the upwelling itself). Finally, we propose some molecular biological work, applying next generation sequencing
techniques to the microbial community in our tracer incubations from Lugano and the Namibian upwelling, in order
to understand the phylogenetic context that may explain why there are differences in the relative rates of N2O
production by NH2OH decomposition and nitrifier denitrification in Lugano versus the Namibian Upwelling area.
The research proposed here will provide new information about the controls on aquatic N2O production, which are
needed to accurately model the global dynamics of this powerful greenhouse gas.

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Follow-up project of 1711916 Isotopic constraints on seasonal N2O dynamics in marine and lacustrine environments

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