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Progress in quantifying rates and product ratios of microbial denitrification using stable isotope approaches

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Although it is known since long that microbial denitrification plays a central role in N cycling in soils due to loss of nutrient N, emissions of N_2O and lowering of N leaching, few data at the field scale are available due to the difficulty in measurement. In recent years, stable isotope signatures of N_2O such as $\delta^{18}O$, average $\delta^{15}N$ ($\delta^{15}N^{bulk}$) and ^{15}N site preference (SP = difference in $\delta^{15}N$ between the central and peripheral N positions of the asymmetric N_2O molecule) have been used to constrain the atmospheric N_2O budget and to characterize N_2O turnover processes including N_2O production and reduction by microbial denitrification. However, the use of this approach to study N_2O dynamics in soils requires knowledge of isotope fractionation factors for the various partial processes involved, e.g. N_2O production by nitrification or fungal/bacterial denitrification, and N_2O reduction by bacterial denitrification.

Here we present recent progress on the principles of isotope fractionation modeling to estimate N_2O reduction and on the role of microbial groups and their specific impact on isotope values. Moreover, we report and discuss approaches to determine isotope values of produced N_2O prior to its reduction as well as enrichment factors of N_2O reduction. Finally, a variety of results from lab and field studies will be shown were N_2O reduction estimates by isotope fractionation modeling are validated by independent measurements using ^{15}N tracing or He/O_2 incubations. Methodical improvements to increase sensitivity of the ^{15}N tracing approach will be briefly addressed.

We conclude that up to now SP of soil-emitted N_2O proved to be suitable to constrain the product ratio of denitrification if N_2O fluxes are dominated by bacterial denitrification. Although this approach is not yet precise enough for robust quantification of N_2 fluxes, improved precision can be obtained in future, if further progress in understanding the control of fractionation factors of production and reduction and identifying N_2O formation by processes other than bacterial denitrification is achieved.

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