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Mechanisms of inorganic nitrous oxide production in soils during nitrification and their dependence on soil properties

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Nitrous oxide (N2O) is an important anthropogenic greenhouse gas and today's single most ozone depleting substance. Soils have been identified as the major source of N2O. Microbial nitrification and denitrification are considered the major N2O emission sources. However, N2O production in soils, especially during nitrification, is far from being completely understood. Several abiotic reactions involving the nitrification intermediate hydroxylamine (NH_2OH) have been identified leading to N2O emissions, but are being neglected in most current studies. However, it is known that NH_2OH can be oxidized by several soil constituents to form N2O. For better mitigation strategies it is mandatory to understand the underlying processes of N2O production during nitrification and their controlling factors. We studied N2O emissions from different soils in laboratory incubation experiments. Soils covered a wide range of land use types from arable to grassland and forest. Soil incubations were conducted with and without the addition of NH_2OH at conditions favorable for nitrification with non-sterile as well as with sterile samples. N2O and, additionally, CO_2 evolution were analyzed using gas chromatography. To get insight into the dynamics of N2O formation, N2O production from NH_2OH was quantified online using quantum cascade laser absorption spectroscopy. Furthermore, isotope ratio mass spectrometry was used to analyze the isotopic signature of the produced N2O (i.e. δ15N, δ18O, and 15N site preference). We observed large differences in N2O emissions between different soils upon the addition of NH_2OH. While a forest soil sample with $pH < 3$ showed hardly any reaction to the addition of NH_2OH, a very high and immediate formation of N2O was observed in a cropland soil sample at neutral pH. N2O production after NH_2OH addition was also observed in autoclaved samples, which confirmed an abiotic production mechanism. Further, isotopic signatures of N2O could be used to differentiate between production processes. We correlated the N2O emission rates after NH_2OH addition with soil chemical properties. We found three primarily controlling factors of the NH_2OH induced N2O production in the following order: soil pH, C/N ratio, and Mn content. The combination of these three soil properties could explain up to 90% of the variability of the N2O emissions caused by NH_2OH addition. Although it was shown in the past that NH_2OH can react with Fe(III) to form N2O, we could not find any correlation between Fe concentration in soils and N2O emission rates. Our results suggest a coupled biotic–abiotic production of N2O during nitrification. We hypothesize that N2O production is the result of a leakage of the nitrification intermediate NH_2OH. N2O emissions during nitrification could then be explained as a function of nitrification rate and a combination of soil properties. However, further research is necessary to consolidate this relationship.