Microbial consumption of mineral nitrogen promotes HONO emissions in agricultural soils

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A new study indicates that microbial nitrate reduction is an important nitrous acid (HONO) production pathway in aerobic soils. This suggests that the terrestrial ecosystems favoring it could be hotspots for HONO

emissions, thereby influencing atmospheric chemistry. The study was published in March in *Communications Earth and Environment*.

The study highlighted that soils supporting the activities of microbes consuming nitrate could be vital for the production, and thus release, of HONO from soil into the atmosphere. This finding has wide implications. For example, here in the boreal region, the gradually progressing spring thaw and the increasing air temperature as the summer months approach may increase nitrate reduction, and thus soil HONO emissions. The current HONO budget indicates that soil is a missing HONO source. Understanding the soil processes, and especially its microbial processes, will therefore help improve our understanding of the HONO budget, and thus its associated atmospheric reactions.

Globally, half of our habitable land is used for agriculture, and the HONO emissions from this could influence the chemical balance of the atmosphere. HONO is a non-greenhouse gas, unlike nitrous oxide (N_2O). However, both of these gases are produced in the soil nitrogen cycle. "As we know, agricultural soils globally receive a large amount of mineral nitrogen as a fertilizer, thus making agricultural soils a N_2O emission hotspot. However, studies reporting HONO emissions from agricultural soils are limited, with scarce information about HONO production pathways," Research Scientist Hem Raj Bhattarai from Natural Resources Institute Finland says.

Soils are strong HONO emitters, yet HONO production pathways in soils and their relative contributions are poorly constrained. This study assessed the role and quantified the contribution of soil microbes in HONO emissions by using stable isotopes of nitrogen (15N) as tracers.

The study is the first to show the relative contribution of microbial pathways in soil HONO emissions.

By using two distinct agricultural soils, mineral and organic, in Maaninka in Finland, the study showed that soil microbes consuming mineral nitrogen contributed to the formation, and thus, release of HONO—a nitrogen gas that produces hydroxyl radical (OH) in the atmosphere. "OH radical is a strong atmospheric oxidant that initiates several chemical reactions in the atmosphere, including cloud formation and the removal of a powerful greenhouse gas, methane," Bhattarai explains.

The study found that a soil microbial path that used nitrate (denitrification) contributed more to HONO production than a microbial path that used ammonium (nitrification) in arable agricultural soils. Denitrification is an anoxic process in which nitrate is reduced, whereas nitrification is an oxic process which ammonium is oxidized. The denitrification contribution exceeded nitrification in both studied soils. "These findings are vital, mainly for two reasons. First, this study is the first to have assessed and shown the relative contribution of microbial pathways in soil HONO emissions at a given space and time by using the ^{15}N tracer approach. Second, we clearly showed that denitrification contributed substantially to HONO emissions in arable, meaning oxic soil, conditions. Oxic conditions in soils are generally known to favor nitrification instead of denitrification."

Although the potential link between the soil and atmospheric HONO was first reported in late 1960, it was only in 2013 that atmospheric HONO was tightly linked to the soil nitrogen cycle. However, soil mineral nitrogen cycling processes that contribute to HONO formation in many ecosystems, including boreal agricultural ecosystems, have remained unexplored. "But with this study, we can now explicitly state that soil microbes using mineral nitrogen are the key in producing OH precursor, that is, HONO, in agricultural soils. Yet more soil HONO emission studies are needed to better constrain the role of soil in atmospheric chemistry via emitted HONO, thus producing OH," Bhattarai says.

More information: Hem Raj Bhattarai et al. Denitrification is the major nitrous acid production pathway in boreal agricultural soils, *Communications Earth & Environment* (2021). DOI: 10.1038/s43247-021-00125-7

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