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Nitrous oxide emissions and stable isotopic composition in urban sources and ambient air in Seoul, South Korea

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Nitrous oxide (N_2O), known for its ozone-depleting potential and characterized by a long residence time of 120 years in the atmosphere, is the third most significant anthropogenic greenhouse gas after CO_2 and CH_4. Primary sources of N_2O include nitrification and denitrification processes in soils and aquatic systems, as well as from direct anthropogenic sources such as fossil fuel combustion and wastewater treatment plants. The increase in N_2O emissions due to agricultural activities and urbanization is complex, given the high variability of these emissions. To characterize anthropogenic N_2O sources, we collected air samples from tunnels and wastewater treatment plants. Additionally, to establish the background levels for Seoul, a megacity in South Korea, we collected ambient air from three sites (Mt Gwanak, Mt Nam, and Olympic Park) monthly throughout the year 2023. These air samples were measured for greenhouse gas concentrations (CO_2, CH_4, and N_2O), and the stable isotopic compositions of N_2O ($\delta^{15}N^{bulk}$, $\delta^{18}O$, and SP values) were analyzed using IRMS. The stable isotopic ratios of N_2O emitted from the vehicles were determined as 6.0 ± 1.2 ‰ for $\delta^{15}N^{bulk}$, 34.4 ± 11.7 ‰ for $\delta^{18}O$, and 6.0 ± 4.2 ‰ for SP values. Furthermore, N_2O from wastewater treatment plant water tank air exhibited variations dependent on dissolved oxygen levels. Notably, the stable isotopic compositions of N_2O from anthropogenic sources were consistently depleted compared to the ambient air of Seoul ($\delta^{15}N^{bulk}$: 5.9± 0.2 ‰, $\delta^{18}O$: 43.8 ± 0.1 ‰, SP: 18.6 ± 0.3 ‰ (S.E.)). Intriguingly, while $\delta^{15}N^{bulk}$ and $\delta^{18}O$ values of ambient air were depleted relative to the global average, SP values exhibited a wide range and significant variability. This suggests the presence of pronounced spatial and temporal variabilities in N_2O emissions, underscoring the need for further research to understand the extent of anthropogenic impacts.