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Measurements of Real-World Cold Start Emissions and Secondary Organic Aerosol Formation in a Parking Garage

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Motor vehicles remain a significant contributor to urban air pollution, emitting compounds in both the gas and particulate phases. While emissions under hot driving conditions have decreased due to improvements in exhaust after-treatment systems, cold starts continue to contribute disproportionately to total vehicle emissions. Furthermore, gas-phase organic compounds emitted during cold starts can be oxidized in the atmosphere, leading to the formation of secondary organic aerosol (SOA).

To enhance our understanding of cold-start emissions and their potential to form SOA, measurements of approximately 21,000 cold starts were carried out inside an underground parking garage from November 29 to December 24, 2024. The garage consists of 250 parking spaces and is located beneath a shopping mall in Patras, Greece.

The particle phase was measured by a scanning mobility particle sizer (SMPS) and further characterized using a high-resolution aerosol mass spectrometer (HR-ToF-AMS) and a high-resolution proton-transfer-reaction time-of-flight mass spectrometer (PTR-ToF-MS) coupled to a CHARON inlet. Black carbon was quantified by an Aethalometer (AE33). Gas-phase composition was measured with the PTR-MS, while inorganic trace gases including NO, NO_2, CO, CO_2, O_3, and SO_2 were continuously monitored. Tenax tubes were also collected from the garage ambient air for offline GC-MS analysis. Additionally, the traffic flow was recorded at both the entrance and exit of the garage. The SOA formation from vehicle emissions was investigated using an oxidation flow reactor (OFR) under controlled OH exposures by varying combinations of the reactor's UV lamps.

The measurements of the traffic and the concentrations were combined to derive average emissions of gas and particulate phase pollutants. The estimated cold start emission factors were then compared to those reported in the Dutch Emission Inventory. Within the OFR, organic aerosol concentrations increased from four to eleven times depending on OH exposure, with the production of highly oxygenated organic compounds. Aromatic compounds were identified as the dominant precursors of SOA.