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Atmospheric nitrated phenols at a mountain site in North China: compositions, phase partitioning, and aqueous formation

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Nitrated phenols in the atmosphere are receiving increasing attentions due to their light absorption and biological toxicity. However, the partitioning characteristics of nitrated phenols among gas, particle, and aqueous phases and the dominant influencing factors remain unclear. In this work, particulate, gaseous, and cloud water samples were simultaneously collected at the summit of Mt. Tai in North China in spring, summer and winter. The contents of 11 nitrated phenols in these samples were determined with an ultra-high-performance liquid chromatograph in tandem with a mass spectrometer. The total concentrations of nitrated phenols in $PM_{2.5}$ were in the range of several to dozens of ng m^{-3}, a little lower than those measured in gas phase. The total concentrations of nitrated phenols in cloud water were in the level of hundreds of μg L^{-1}. Among the 11 nitrated phenols, 4-nitrophenol and nitrosalicylic acids were the most dominant compounds in $PM_{2.5}$, while 4-nitrophenol and 2,4-dinitrophenol were the most abundant in gas-phase and cloud water samples. During cloud events, most nitrated phenols were mainly distributed in particle phase, except dinitrophenols which were mainly distributed in gas phase. The observed concentration ratios of aqueous nitrated phenols to those in gas phase were one to two orders higher than the theoretical Henry's law coefficients in pure water. Moreover, the measured concentrations of particulate nitrated phenols were substantially greater than the theoretically predicted values. The above results indicate that nitrated phenols potentially formed via aqueous-phase reactions inside the cloud droplets or on the surface of particles. The much higher ratios of the sum of 4-nitrophenol and 5-nitrosalicylic acid to 2,4-dinitrophenol in cloud water than those in $PM_{2.5}$ further confirms the enhanced formation via aqueous processes. Overall, aqueous-phase reactions were important sources of atmospheric nitrated phenols during cloud events and had significant influences on the abundance and distributions of nitrated phenols in different phases.