Urban Aerosol Physicochemical Properties:Implications for Air Quality and Human Health

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Abstract

Urban aerosol physicochemical properties fundamentally determine air quality degradation and human health impacts through complex mechanisms that transcend conventional mass-based characterization approaches. Recent investigations establish a conceptual framework for comprehensive aerosol assessment, distinguishing between extensive properties (mass concentration, number concentration) that scale with particle quantity and intensive properties (size distribution, hygroscopicity, density, optical characteristics) that reflect intrinsic particle characteristics independent of concentration. This physicochemical property paradigm reveals critical limitations in traditional $PM_{2.5}$ and PM_{10} standards for health risk evaluation, particularly evident in ultrafine particles (UFPs, <100 nm) that contribute negligible mass while dominating number concentrations in urban environments through vehicle emissions and presenting elevated health risks via enhanced lung deposition and systemic translocation capabilities. Field campaigns such as NASA's ASIA-AQ and TW KPEx campaign study demonstrate the practical application of these multidimensional characterization approaches in real-world urban environments. Air quality implications manifest through visibility impairment mechanisms where particle light extinction, involving both scattering and absorption, depends on size-composition interactions and hygroscopic growth processes, demonstrating that environmental impacts cannot be adequately predicted from mass concentrations alone.

Human health implications are conceptualized through oxidative potential (OP) as a chemical toxicity indicator, representing aerosol capacity to generate reactive oxygen species and induce cellular damage independent of particle mass. Measurable through standardized assays such as DTT and ascorbic acid methods, OP provides a practical assessment of chemical reactivity. Atmospheric aging processes, driven by photochemical reactions including ozone and hydroxyl radical interactions, modify chemical composition and enhance toxicity through formation of more oxidized organics. These findings advocate for multidimensional air quality standards incorporating lung-deposited surface

area (LDSA) as a physical exposure metric and oxidative potential as a chemical toxicity metric, both relatively new approaches compared to traditional PM mass measurements. Such comprehensive characterization enables effective urban air quality management by addressing both physical and chemical dimensions of particulate matter impacts, providing a scientific foundation for progressive regulatory strategies that better protect human health and environmental quality in complex urban environments.