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Non-Exhaust Traffic Emissions as an Underrecognized Source of Elemental Carbon in Urban Aerosols

SHIZHEN ZHAO, LELE TIAN AND **GAN ZHANG**

Guangzhou Institute of Geochemistry, Chinese Academy of Sciences

Elemental carbon (EC), commonly used as a quantitative surrogate for black carbon, is a major light-absorbing component of atmospheric aerosols that contributes to radiative forcing while adversely affecting air quality and human health. Urban EC has traditionally been attributed primarily to combustion sources; however, fossil carbon associated with non-exhaust traffic processes remains poorly constrained and is rarely represented in emission inventories or isotope-based source apportionment frameworks.

Here, we investigated EC characteristics in representative non-exhaust traffic materials and environmental matrices, including tire tread particles, carbon black, asphalt, and road dust, and quantified their contribution to urban aerosol EC using positive matrix factorization (PMF). Non-exhaust materials exhibited substantial EC contents, with the highest levels observed in carbon black and tire particles, followed by fresh asphalt, whereas environmental asphalt and road dust showed lower concentrations due to mineral dilution and environmental aging. Source materials were dominated by soot-EC, while road dust was enriched in char-EC, indicating strong environmental mixing and transformation. Literature comparisons further suggest that tire–road friction processes can enhance EC production and shift composition toward char-EC, consistent with thermally induced carbonization during high-temperature friction.

PMF analysis across nine cities in the Pearl River Delta of China revealed that non-exhaust traffic emissions account for 29 ± 13% of EC in urban $PM_{2.5}$. This factor was characterized by elevated Ca^{2+} and Mg^{2+} together with the tire-wear marker 6PPD-quinone, indicating contributions from road dust resuspension, tire wear, asphalt abrasion, and friction-induced thermal processes. Unlike combustion-derived EC, non-exhaust EC represents radiocarbon-depleted fossil carbon, which may bias ^{14}C-based source apportionment by inflating estimated fossil contributions and distorting fossil versus non-fossil carbon partitioning in atmospheric aerosols.

These findings demonstrate that non-exhaust traffic processes constitute a previously underrecognized source of a climate-relevant light-absorbing aerosol component. As exhaust emissions decline under electrification and stricter regulations, incorporating non-exhaust EC into emission inventories and carbon source apportionment frameworks will be essential for accurate assessment of aerosol radiative forcing and for developing co-beneficial climate and air-quality mitigation strategies.