Characteristics of Brake-Wear Particles and Chemical Speciation Profiles and Potential Health Effects of the Particles in California

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Brake-wear emissions have become the dominant source of directly emitted particles from motor vehicles, as tailpipe emissions have been substantially reduced in response to stringent tailpipe emissions standards in California. Understanding the characteristics of brake-wear particles, including particle number, size distributions, and mass, as well as their chemical speciation profiles, is a crucial step in understanding their potential adverse health effects. The presence of heavy metals in the particles is a concern for public health, particularly in communities near major urban arterials and highways.

The California Air Resources Board (CARB) has undertaken investigations to measure airborne brake-wear particles under brake-dynamometer testing conditions, characterize their chemical speciation profiles, and assess their potential health effects locally and regionally. Airborne brake-wear particles are generated during vehicle braking when shear forces increase between the friction material and the disk. CARB analysis revealed that the major inorganic contents of brake-wear particles from California light-duty and heavy-duty vehicles include iron (Fe), barium (Ba), copper (Cu), zinc (Zn), and titanium (Ti), while approximately half of the particles consisted of non-metallic components. The oxidative potentials of the particles collected near roadways were significantly greater than those collected in urban background areas, indicating that brake-wear particles may have a greater adverse health effect in near-road communities and populated urban areas.

Session 10: Nanoparticle toxicity and health effects, Talk

Systematic review and meta-analysis on the health effects of long-term exposure to ultrafine particles

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BACKGROUND: Ultrafine particles (UFP; ≤100 nm diameter) may have a higher toxicity than larger particles but are still not regulated nor part of routine air pollution monitoring. So far, health effects of long-term exposure to ambient UFP are not well understood, due to a lack of exposure data and epidemiological studies.

METHOD: We conducted a systematic review and meta-analysis on the health effects of long-term exposure to UFP, including studies published until December 2024. Meta-analysis was conducted for outcomes with at least four available effect estimates. Confidence in the body of evidence was evaluated using the Office of Health Assessment and Translation (OHAT) method.

We identified 85 studies investigating various mortality, morbidity, and subclinical outcomes. In meta-analyses of single-pollutant models, we found positive associations with natural mortality (hazard ratio: 1.06 [95% confidence interval [CI]: 1.04; 1.08]) and C-reactive protein (10.14% increase [95% CI: -0.51; 21.99]), per 10,000 pt/cm^3 increase in long-term exposure to UFP, with low and inadequate levels of evidence, respectively. The remaining studies revealed overall limited evidence for adverse effects on a wide range of outcomes. Less than half of the studies adjusted for co-pollutants.

CONCLUSION: The evidence base on long-term health effects of UFP has increased substantially in the last decade, while the overall evidence for independent effects of long-term UFP exposure remains inadequate to low. More studies are needed to draw firm conclusions about the independent adverse effects of long-term UFP on various health endpoints, with a special focus on the influence of co-pollutant adjustment.

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Non-Tailpipe Traffic Emissions and Airway Dysfunction: Evidence from a Real-World Crossover Study (IONA)

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Background: Non-exhaust traffic emissions from brake, tyre, and road wear are now major contributors to urban particulate matter (PM), yet remain unregulated and insufficiently characterised in terms of health effects. These mechanically generated particles are enriched in metals and contain fine and ultrafine fractions. We investigated whether source-resolved non-tailpipe particles induce airway dysfunction and immune activation in adults with asthma.

Methods:
In a randomised crossover study, 38 adults with mild-to-moderate asthma were exposed during intermittent exercise to three real-world London environments: a stop–go traffic site enriched in brake wear, a high-speed traffic site enriched in tyre/road wear, and an urban background control site. High-time-resolution aerosol chemical speciation (ACSM), X-ray fluorescence (Xact), and positive matrix factorisation were used to quantify $PM_{2.5}$ and PM_{10} mass and resolve source contributions, including brake wear, tyre/road wear, train wear, re-suspended dust, and long-range transport. Respiratory outcomes (FEV_1, FVC and Oscillometry indices), fractional exhaled nitric oxide (FeNO), and nasal lavage cytokines (IL-6 primary inflammatory endpoint) were measured pre-exposure, immediately post-exposure, and the day after the exposure. Nasal metals were quantified using ICP-MS as biomarkers of airway particle deposition.

Results:
Non-tailpipe–dominated exposures produced delayed impairments in lung function. Compared with the background site, FEV_1 declined by 140–220 mL at the day after the exposure ($p<0.05$), with parallel reductions in FVC. Tyre/road wear fractions were associated with next-day reductions in FEV_1 and FVC, while brake wear was associated with increased small airway resistance (R5–R20). PM_{10} and tyre/road wear were significantly associated with increased nasal IL-6.

Conclusions:
Short-term exposure to non-exhaust traffic particles leads to delayed airway dysfunction in adults with asthma. These findings highlight the emerging health relevance of nanoparticle-rich non-tailpipe emissions and the urgent need for regulatory frameworks addressing evolving urban PM sources.