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Advancing Tire and Road Wear Particles (TRWP) Measurements: Balancing Laboratory Conditions and Real-World Relevance

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Airborne non-exhaust emissions (NEE) from road traffic originate from multiple sources, including brakes, dry clutches, tires, and roads. A significant proportion of these pollutants is believed to consist of airborne tire and road wear particles (TRWP). Studies on airborne TRWP typically involve particle collection in field conditions or controlled laboratory setups. Literature reviews report that airborne TRWP may contribute 5–30% of total road transport PM_{10} emissions, depending on a wide range of conditions [1]. The need for reliable TWP measurement methods has been highlighted in the literature to improve overall understanding [2]. This knowledge is crucial to assess whether airborne TRWP in urban environments pose a public health concern. The contact between the tire and road can be divided into a rolling and a sliding (tire slip) part. Most primary TRWP are generated from the sliding interaction between road surfaces and tires. Existing experimental approaches sometimes overestimate slip speed, resulting in excessively high contact temperatures. Consequently, the airborne TRWP generated and analysed under such conditions may not accurately represent those from real-world road use, especially nanosized particles. Furthermore, some experimental methods fail to include both contact surfaces (tire and road), which is essential to simulate the actual tribological mechanisms occurring during real driving.

This study identifies representative load and slip conditions using a scaled experimental approach. The method allows testing under different nominal contact pressures and slip speeds. Load and slip speed conditions are iteratively adjusted based on visual comparisons of tire wear scars to those observed on real, used car tires. A pin-on-disc tribometer, designed specifically for NEE studies, was employed to investigate friction, wear, and airborne TRWP. Test specimens were prepared from a used commercial tire (pin) and an asphalt road disc (SMA11 with pen. Bitumen 70/100). The tribometer was enclosed within a sealed box. During testing, compressed particle-free air (35 L/min) was directed at the contact zone to maintain clean air within the box and simulate airflow equivalent to 100 km/h, cheering wear particles to become airborne. A TSI CPC and a Grimm MiniWRAS were used to measure particle number concentrations inside the box. Nominal contact pressure was varied between 0.64 and 2.56 bar, with sliding speeds ranging from 0.08 to 0.16 m/s (28.8 to 56.7 km/h car speed assuming a tire slip of 1%). Test durations ranged from 30 to 120 minutes, corresponding to a total sliding distance of 576 meters (57.6 km of driving assuming a tire slip of 1%).

The results indicate that sliding speed and normal load strongly influence friction and wear behaviour, and resulting TRWP generation. Under moderate contact conditions, almost no concentration (< 2 cm^{-3} for both instruments) of airborne TRWP were measured inside the box. These conditions produced smooth surfaces, a stable coefficient of friction, and reasonable coefficient of wear. Airborne TRWP were observed under severe or catastrophic contact conditions, where friction and wear mechanisms (and contact temperatures) drastically changed, resulting in significant detachment of tire material. However, such worn contact surfaces are not representative of those found on road-used car tires. This study therefore suggests prioritizing representative test conditions in future experimental studies, as they better replicate real-world driving conditions.

1. Giechaskiel B, et al. *Contribution of Road Vehicle Tyre Wear to Microplastics and Ambient Air Pollution*. Sustainability, 16, 2024

2. Mennekes D, Nowack B, *Tire wear particle emissions: Measurement data where are you?* Sci. Total Environ., 830, 2022