

## CHARACTERIZING ULTRAFINE PARTICLE NUMBER REDUCTIONS INSIDE VEHICLES

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**Background and Aims:** Time spent in vehicles is an important contributor to ultrafine particle (UFP) exposure, but exposures are difficult to characterize due to the complicated interplay between varying on-road UFP concentrations, particle losses to the ventilation system and cabin interior surfaces, and particle replenishment rates, as reflected by air exchange rate (AER). No study to date has systematically characterized all of these factors under a full range of real-world conditions.

**Methods:** In this study, six vehicles were chosen to be representative of vehicles up to 10 years old across a full range of driving speeds. Each vehicle was tested at seven AER conditions. UFP losses were determined as a function of particle size at different driving speeds, fan settings, cabin filter loadings, and ventilation conditions (outside air [OA] or recirculation [RC]) for each vehicle. AER was also measured.

**Results :** AER was determined as the dominant factor affecting inside-to-outside (I/O) UFP concentration ratios. Lower AERs occurred under RC conditions, e.g., <30 air changes per hour ( $\text{hr}^{-1}$ ). Under these conditions, I/O ratios ranged from <0.05 at AER <  $2\text{hr}^{-1}$  up to 0.40 at AER =  $20\text{hr}^{-1}$  and were highly negatively correlated to AER ( $r^2=0.83$ ). At OA ventilation setting, AERs were an order of magnitude higher, e.g., 20 to  $145\text{hr}^{-1}$ , and I/O ratios were higher, ranging from 0.4 to 0.6. Vehicle cabin filter condition was never a major factor and filtration appeared to play a very small role in UFP removal. Particle losses were lowest in the range of 100 to 200 nm and were roughly constant over the range where on-road UFP size distributions vary the most, i.e., < 50 nm.

**Conclusions :** UFP concentration reductions inside vehicles are driven primarily by AER, with I/O ratios ranging from nearly zero to above 0.6. Therefore, ventilation setting and AER are necessary to accurately estimate in-vehicle UFP exposure.