Steady-state mass-mobility measurements of cigarette smoke using a CPMA

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Tobacco smoke is a dynamic formation of gaseous and particulate material. The density of particulate phase can change due to evaporation - condensation and alter its mass and mobility. Therefore these aerosol characteristics are important for modelling lung deposition or smoke particle transport in air. The mass and mobility of cigarette smoke particles was measured using a Centrifugal Particle Mass Analyzer (CPMA) and Differential Mobility Analyzer (DMA).

The experimental setup, shown in Figure 1, placed a DMA and Condensation Particle Counter (CPC) upstream of a CPMA. The DMA selected the particles based on electrical mobility, while the upstream CPC accounted for the particle concentration decreasing in the bag over time. The CPMA then further classified the particles by mass-to-charge ratio. By stepping the CPMA through the particle mass range and counting the number of classified particles with the downstream CPC the mass-classified concentration peak was determined for the set DMA mobility size.

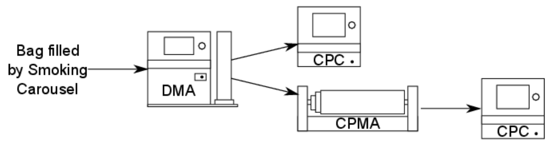

Figure 1. Experimental setup of DMA-CPMA-CPC system.

Due to the scanning nature of the DMA-CPMA-CPC set-up, only steady-state measurements could be completed. Since smoking is not a steady-state process, smoke was produced using an ISO smoking routine on a smoking carousel and collected in a Tedlar bag. The effective density measured using this experimental setup is shown in Figure 2.

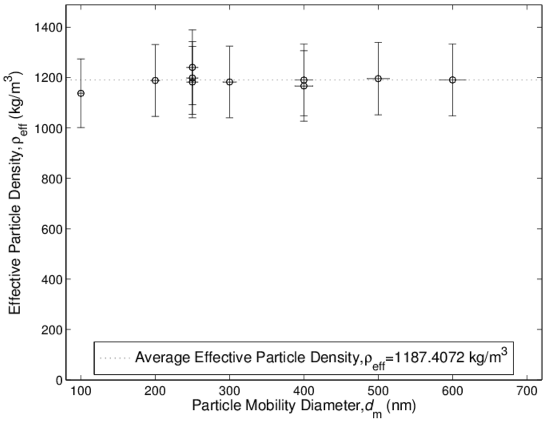

Figure 2. Effective density of cigarette smoke measured using a DMA-CPMA-CPC system.

The effective density is constant over the measured mobility size range and has a mean value of 1190±140 kg/m^3. Using a Millikan cell Lipowicz (1988) measured the effective density of smoke particles in the 1.1 to 1.5 µm diameter range to be 1100±20 kg/m^3.

The effects of the initial particle concentration and smoke aging time on the effective particle density are shown in Figure 3.

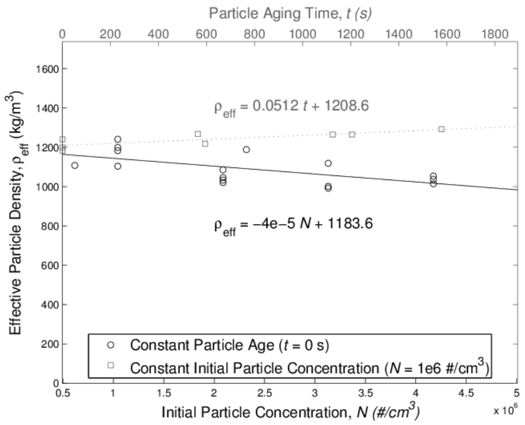

Figure 3. Effects of initial particle concentration and aging time on effective density of 250 nm particles.

Aging the particles caused the effective density to increase slightly, with every 1000 seconds of aging increasing the effective density on average by 4.3% compared to fresh smoke. This increase could be due to the volatility of the smoke causing lighter components of the particle to evaporate over time. Conversely, increasing the initial particle concentration in the bag caused the effective density of fresh smoke to decrease. A 10^6 particle per cm^3 increase in initial particle concentration caused a 3.3% decrease in the effective density. During the bag filling process, the evaporation of volatile material is sensitive to the initial particle concentration. Therefore, as the initial particle concentration increased or more volatile material evaporated during the filling process, the vapour pressure in the bag increased, slowing the evaporation rate of the volatile components. However the effects of aging and initial particle concentration are relatively small and within the uncertainty of the instruments.

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Lipowicz, P. J. (1988). Determination of cigarette smoke particle density from mass and mobility measurements in a Millikan cell, *Journal of Aerosol Science*, **19**, 587–589.