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INTERCOMPARISON OF SMPS, ELPI AND APS 3320 DURING SAMPLING OF PARTICLES EMITTED FROM A DOMESTIC WOOD PELLET BURNER

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INTRODUCTION

During biomass combustion in residential boilers and in small district heating plants (e.g grate fired boilers) large amounts of fine particles (PM₁) are being formed. Under some circumstances a significant mass fraction may be found in the coarse fraction (PM₁₋₁₀). Therefore it may be desirable to study the particle size distribution up to 10 µm in near real-time. Scanning Mobility Particle Sizers (SMPS) offers excellent size-resolution in the range 3-1000 nm (depending on model). The time-resolution is limited to about 120 s for a full size-scan. The Electrical Low Pressure Impactor (ELPI) offers high time resolution (about 1 s.) throughout a large size spectrum (30 nm – 10 µm). However the size resolution is limited to 12 size ranges. The Aerodynamic Particle Sizer (APS) offers high time- (about 1 s.) and size-resolution in the size range larger than about 1 µm. The SMPS determines mobility diameters, while the ELPI and the APS determines aerodynamic diameters. Using process dependent effective densities Moisio (1999) demonstrated a satisfying agreement between the SMPS and the ELPI. Virtanen et al (2001) studied the magnitude of submicrometer particle losses in the ELPI/DLPI impactor. They found that the particle losses varied between 0.1-6% in the range 10-400 nm particles. These losses may cause a significant contribution to the signal in the upper ELPI-stages as the number concentration in the coarse mode is several orders of magnitude lower than in the ultrafine range. These effects become mostly evident when estimating the mass size distribution from the ELPI-data. Armendariz and Leith (2002) found several limitations in the APS 3320. Potential errors include: artificial counts due to recirculation of particles in the sensor, erroneous particle concentration in the correlated mode and relatively low counting efficiency. The aim of this work was to compare the SMPS, ELPI and APS 3320 during sampling of particulate mater from a domestic wood pellet burner, where the mass is dominated by the fine mode. To our knowledge there are no published comparisons between the ELPI and the APS.

METHODS

Particulate matter (PM) was sampled from a 15 kW Pellet burner during 80% load. PM was sampled isokinetically from a flue-gas temperature of 130 °C, using a cascade of either two or three ejector diluters (Dekati Ltd. and Palas GmbH). The filtered and dried pressurised dilution air to the first dilution stage was heated to 180 °C. Concentrations of O₂, CO and THC (total hydrocarbons) were monitored on-line. Two SMPS-systems (3934 and 3936, TSI Inc.) were used . Both systems used a CPC 3010 to detect the particles. An ELPI (Dekati Ltd.) was used to measure the

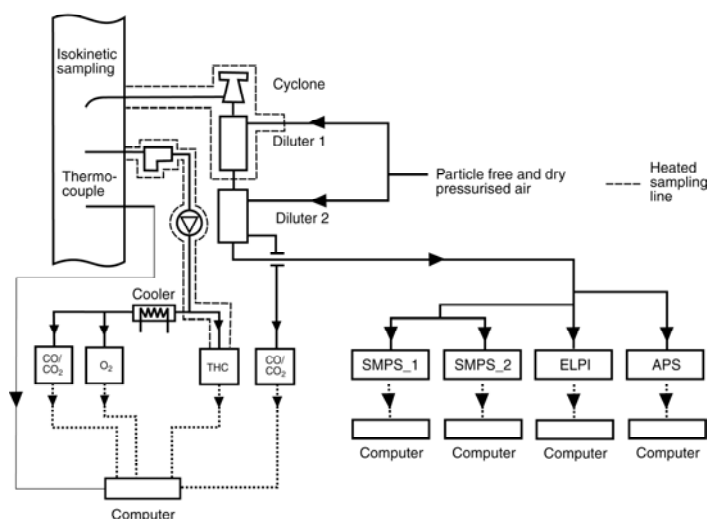


Figure 1. Schematic view of the set-up

aerodynamic diameter of particles. The APS was used in the summing mode. The flow to the APS 3320 (1 dm³/min) was sampled isokinetically. The mass size distribution was determined using a low-pressure impactor, DLPI (Dekati Ltd.) and a microbalance.

RESULTS AND DISCUSSION

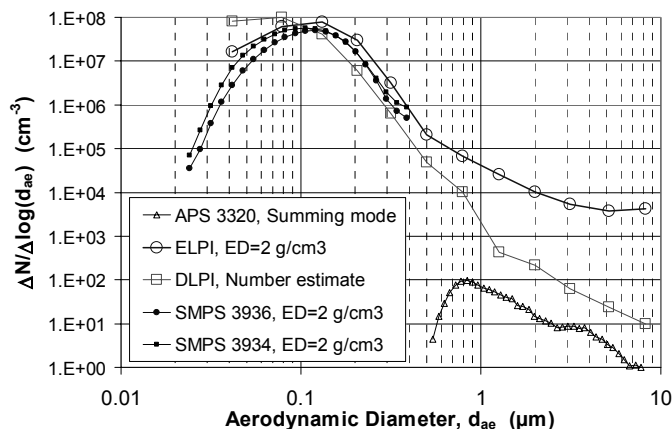


Figure 2. Mean number size distributions.

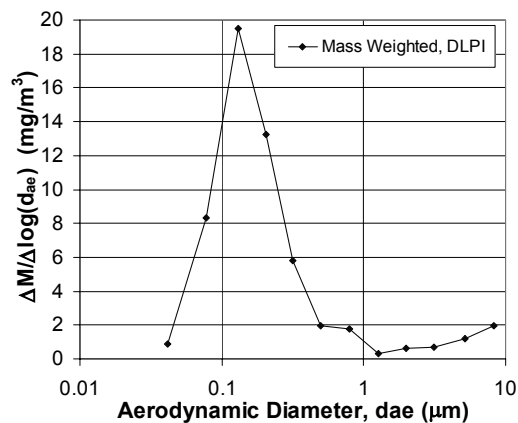


Figure 3. Mass weighted size distribution

The mean O₂ concentration was 10.2% while the CO and THC concentrations were 110 and 3 mg/m³ respectively. In figure 2, preliminary mean size distribution data for simultaneous measurements are shown. An effective particle density of 2 g/cm³ was assumed to convert the mobility diameters measured by the SMPS to aerodynamic diameters. There is reasonably good agreement between the two SMPS-systems and the ELPI. In the coarse region there is a striking lack of agreement between the APS and the ELPI. As seen in figure 3, the mass weighted size distribution using the DLPI is totally dominated by the fine fraction. An estimate of the number size distribution has been calculated from the DLPI data (figure 2). For the aerosol in this particular case the difference in number concentration of the 60 nm particles at the peak (mobility diameter) and the super micrometer particles is 5-7 orders of magnitude, according to the estimate from the DLPI. Thus the ELPI signal from several of the coarse particle stages may be dominated by diffusion losses of the small particles.

CONCLUSIONS

During sampling of a biomass combustion aerosol dominated by fine particles, reasonably good agreement was found between the ELPI and two different SMPS models. However, in the coarse region the agreement between the ELPI and the APS 3320 was poor. One likely contributing factor is diffusion losses of small particles on the upper impaction plates of the ELPI. Another contributing factor to the poor agreement may be the low counting efficiency of the APS 3320. It is likely that the ELPI overestimates the number of particles in the range 1 – 10 μm, while the APS 3320 underestimates the particle concentration.

ACKNOWLEDGEMENTS

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