Using polydisperse SMPS samples for fast determination of respiratory deposition in humans – influence of small size-shifts between the inhaled and exhaled sample

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INTRODUCTION

Techniques comparing dried samples of inhaled and exhaled air taken with Scanning Mobility Particle Sizers (SMPS) offer a fast way to determine size dependent respiratory deposition fractions in the range 20-500 nm (Pagels et al., 2002 and Rosati et al., 2002). With the set-up described by Pagels et al. (2002) good agreement was found with present respiratory deposition models (ICRP 66) for a hydrophobic (Di-ethyl-hexyl Sebacate) and a hygroscopic (NaCl) aerosol with relatively wide size-distributions ($\sigma_g \approx 2.2$).

One potential artefact of the methods when applied to complex “real-world” aerosols is that the determined respiratory deposition is sensitive to small size-shifts between the particles in the inhaled and exhaled aerosol. A potential mechanism for such shifts is a reduction of the mobility diameter of agglomerates when exposed to the high relative humidity (RH) in the respiratory tract (99.5%). Freshly produced combustion particles “shrinks” 1 to 10% in mobility diameter at a high RH (Weingartner et al. 1997 and Rissler et al. 2003). It is believed that the particles collapse to a more compact shape upon exposure to high RH. It needs to be investigated whether there is a corresponding size-shift for “ambient” particles.

The aim of this work is to discuss the influence of small size-shifts in the size-distribution on the determined respiratory deposition and to present data of a model experiment utilizing a Hygroscopic-Tandem Differential Mobility Analyser (H-TDMA).

METHODS

The influence of a small shift in the size-distribution on the determined respiratory deposition fraction was investigated. A data-set collected on roof-level near a busy road (Hornsgatan in Stockholm) was used (figure 1). The exhaled concentration (idealised experiment) was calculated by using respiratory deposition fractions from the ICRP 66 model. The exhaled size-distribution was shifted 15% (corresponding to 1 channel in the size-spectra) and 1% respectively towards smaller particle sizes.

A model-experiment has been performed in order to investigate whether the particles are brought back to the same mobility diameter after the humidification in the lungs and subsequent redrying. A H-TDMA system was used. Two cases were considered representing the sampling from inhaled and exhaled air, respectively. Dry-Dry-Dry where the RH after the aerosol humidifier was set to 20% and Dry-Wet-Dry with RH after the Aerosol Humidifier set to 90%. The system was modified by adding a 24” Nafion-drier in the aerosol line after the aerosol humidifier. The RH in DMA2 was 22-25% in both cases. Particles of 6 dry sizes between 30 and 400 nm were extracted with the first DMA at an RH of 4%. In addition conventional H-TDMA measurements at RH=90% were performed.

RESULTS AND DISCUSSION

The influence of a small size-shift on the determined respiratory deposition is given in figure 2. It can be seen that the recovered respiratory deposition fractions are totally obscured when the size shift is 15% in diameter. However when the shift is only 1%, the error is almost negligible in the range below 200 nm. It can also be noted that the regions where the gradient in the original size-distribution data is highest gives the largest errors.
The result of the model experiment with the modified H-TDMA is given in figure 3. Each point is the ratio of a single dry-wet-dry experiment divided by the mean value of the diameter from the dry-dry-dry experiments. During the measurement day, the size-shift was within 1% on average for all sizes. These results are in contrast to the experiments performed on fresh combustion particles where considerable particle shrinking occurred. One likely explanation is that the particles studied by Weingartner et al. (1997) and Rissler et al. (2003), where diluted using artificial heated dilution and did not experience the transient supersaturation after the stack or the tail-pipe.

In the conventional hygroscopic growth measurements it was found that the 30 nm particles were dominated by less hygroscopic particles. Particles of 60, 100 and 200 nm had a bimodal hygroscopic growth spectra.

REFERENCES


