Respiratory tract deposition of fine particles in candle smoke

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Candles are common sources of both ultrafine and fine particles in indoor environments (Zai et al., 2006). Pagels et al. (2007) have shown that ultrafine candle smoke particles grow by absorption of water in a humid environment. As the relative humidity (RH) in the respiratory tract is high, this would alter the deposition from that of the models, which often only include insoluble particles (Löndahl et al. 2007). There are few or none published measurements of respiratory tract deposition of any indoor particle source apart from tobacco smoke. This work presents preliminary results from measurements of respiratory tract deposition fraction (DF) of particles emitted from tea light candles. Three tea light candles were lit in a 0.5 m$^3$ box. In order to establish an increased and “controlled” generation of soot, the candle flames were cooled by a plate of stainless steel. A fan was used to mix and dilute the aerosol. Number concentrations ranged from 6000-30000 cm$^{-3}$ and the size-distribution basically had two modes; the first with a geometric mean diameter (GMD) around 50 nm and the second with a GMD around 300 nm. An instrument, incorporating a scanning mobility particle sizer (SMPS), has previously been developed to measure the respiratory tract deposition of polydisperse aerosols (RESPI, Löndahl et al. 2006). In this experiment it was used to determine the size-resolved DF in the range 20-400 nm on 2 healthy, non-smoking male subjects breathing spontaneously. The size shift of the particles at an RH > 90% was measured with a tandem differential mobility setup.

DF for the subjects is shown in Figure 1. The tidal volume and breathing frequency was 0.8 L respectively 10 min$^{-1}$ for subject 1 and 0.4 L respectively 25 min$^{-1}$ for subject 2. Figure 1 also show DF calculated for the subjects with the ICRP model (1995) for insoluble particles. The particles shrank about 1% during inhalation, which indicate limited agglomeration. However, the shift was taken into account in the deposition measurement.

The ultrafine particles below 80 nm had a lower DF than calculated with the ICRP model. This indicates growth by water uptake in the respiratory tract and is in agreement with the hygroscopic growth measurements by Pagels et al. (2007). The larger particles (GMD around 300 nm) presumably consist to a large extent of soot, which also is discussed by Pagels et al. (2007). These are most likely water insoluble with little or no growth at high RH. The measured DF for these is similar to the calculated DF for hydrophobic particles, which confirm the assumption of low solubility.

As a first test, the measurements demonstrate the deposition behaviour of candle smoke particles. Further, the importance of including hygroscopicity in respiratory tract deposition estimates is clearly stressed. Ultrafine combustion particles could contain a substantial amount of salt, which lead to a decreased DF.

In the near future respiratory tract deposition of diesel exhaust aerosols will be measured for a larger group of subjects. The performed measurements are partly made as a pre-study to identify experimental difficulties and improve the technique.

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