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Pagels, Joakim; Swietlicki, Erik; Gudmundsson, Anders; Bohgard, Mats

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A SET-UP FOR FIELD MEASUREMENTS OF FINE AND ULTRAFINE PARTICLE RESPIRATORY TRACT DEPOSITION IN HUMANS

J. PAGELS[1], E. SWIETLICKI[2], A. GUDMUNDSSON[1] and M. BOHGARD[1]

[1]Division of Ergonomics and Aerosol Technology (EAT), Lund University, SE-221 00, PO Box 118, Lund, Sweden

[2]Division of Nuclear Physics, Lund University, Lund, Sweden

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INTRODUCTION

The aim of this work is to develop a method for fast (~5-10 min) measurements of size fractionated respiratory tract deposition of environmental particles in humans.

Epidemiology tells us that elevated outdoor particle concentration, e.g. $PM_{2.5}$ or number of ultrafine particles is associated with increased prevalence of respiratory and cardio-vascular disease in susceptible sub-population (e.g. asthmatics and children). Detailed knowledge of the deposited fraction of inhaled aerosol is needed when determining the dose to the respiratory tract e.g. for different environmental aerosols, when comparing susceptible sub-groups or during controlled exposure studies. Respiratory deposition varies strongly with particle diameter in $PM_{2.5}$. For hydrophobic particles in the size range 100 – 1000 nm, as little as 10-20% of the inhaled particles deposits in the respiratory tract (ICRP 66) while 80-90% is exhaled. In this region the majority of the mass in rural and urban $PM_{2.5}$ is found. However for 20 nm particles the deposited fraction is as high as 70-80 % with the major part depositing in the lower respiratory tract. The equilibrium RH in the alveolar region is ~99.5% (Anselm et al. 1990) which causes the majority of environmental particles to grow to different extent, thereby changing the deposition probability. Ammonium sulphate (an important constituent of the ambient aerosol) has a diametric growth factor (G_F) of 3-5 at RH=99.5%.

METHODS

The system (fig. 1) utilises near-realtime aerosol spectrometers, alternatively sampling in inhaled and exhaled air samples. The basis of the method is the conservation of the particle diameter in dehydrated samples of inhaled and exhaled air. Environmental aerosol is inhaled, a three-way valve is used to separate inhaled and exhaled air. 10 to 20 breaths of exhaled aerosol is collected in a rebreathing bag. The breath pattern is monitored using pneumotachographs. Both the inhaled and the exhaled aerosols are *dried* to a well defined state (RH<15%), using a Nafion drier (Perma Pure inc.). A reservoir with residence time~10 s is used to ensure recrystalisation before the samples enter a SMPS 3934 (15 - 800 nm) and an APS 3320 (0.5 –2.5 μm). The inhaled sample is analysed during the breathing manouvre, followed by the exhaled sample. From the two measurements the deposited fraction as a function of diameter is deduced. The system has been initially tested using stable di-(2-ethylhexyl) sebacate (DEHS) and hygroscopic NaCl polydisperse aerosols generated to a 18 m^3 stainless steel chamber from which the aerosols were inhaled.

RESULTS AND DISCUSSION

In figure 2 the effect of hygroscopic particle growth on respiratory tract deposition is clearly evident, suggesting a growth factor of 5. The deposited fractions presented here for a single test-subject agrees within ±0.1 with previous experimental data based on monodisperse particles (e.g. Tu and Knutson 1984). The measured losses in the drier are between 1 and 10% for sub-micrometer particles and agree with diffusion theory. This effect however is minimized as both the inhaled and the exhaled sample is taken through the same drier. The breathing valves opens up with minimal obstruction, therefore the impaction losses are believed to be small.

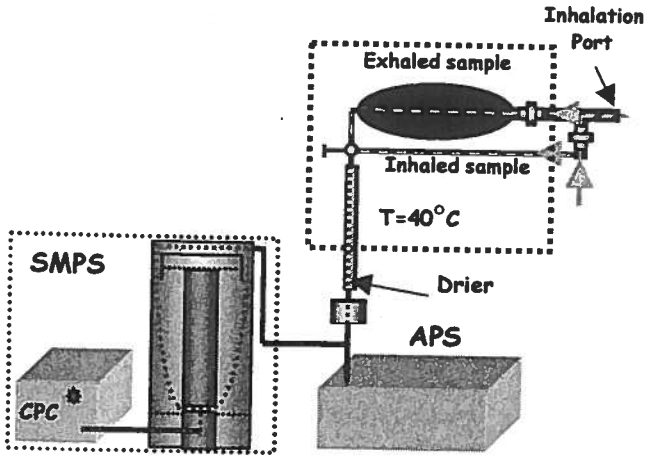

Figure 1, Schematic view of the deposition set-up.

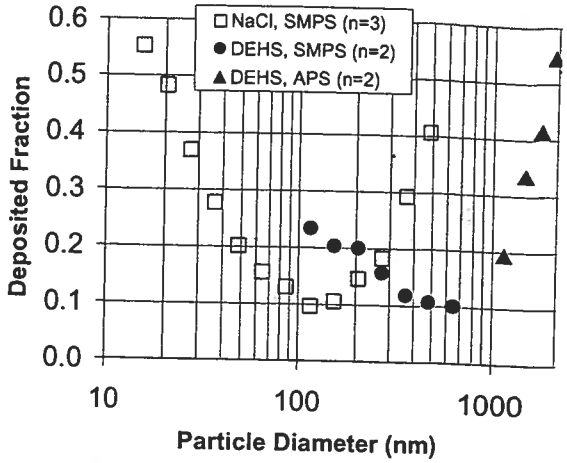

Figure 2. NaCl and DEHS, 1 test subject, male 28 years, fp=15 min^{-1}, Vt=700 cm^3, breathing through the nose.

At high concentrations coagulation might distort the measured deposition of the smallest particles. In a "bad case" of two modes at 15 and 150 nm respectively, the artefact in the deposited fraction is around ±0.05 for the smallest particles for a concentration of 100.000 cm^{-3}. If the detection limit is defined as 0.05 uncertainty in deposited fraction for a given size, then with the present operating parameters a concentration (dN/dlog[dp]) of ~3.000 cm^{-3} is needed at 150 nm and ~15.000 cm^{-3} is needed in the outer SMPS channels (15 and 650 nm). In the APS-region a concentration ~5 cm^{-3} is needed in each size channel. Solid ultrafine particles may consist of *agglomerates* that collapses and shrinks when exposed to a high relative humidity, however the presence of liquid/semi-volatile components may inhibit this behaviour (Weingartner et al. 1997). Further the *semi-volatile components* may evaporate in the human lung or in the equipment. These effects, which we believe are small for most common aerosols, we will try to quantify in future experiments

CONCLUSIONS

A set-up for field studies of size fractionated respiratory tract deposition of environmental particles has been constructed and initially tested. Results for one hygroscopic and one hydrophobic aerosol show that the method produces fast (~5-10 min) and reliable data in the size range 15 nm - 2.5 µm.. The method is suitable for field measurements in various indoor and workplace environments as well as in controlled exposure studies. By concurrent measurements of the particle hygroscopic properties using a H-TDMA at a high RH (e.g. RH=95%) and knowledge of the breathing pattern and the dimensions of the respiratory tract, the respiratory deposition models used today may be verified and if needed, optimised.

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