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Respiratory tract deposition measurements of aerosol particles with on-line techniques; review of sources of error and estimation of their impact

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A common method to measure the respiratory tract deposition fraction (DF) of aerosol particles is to compare the particle concentration in the inhaled and exhaled air. Tyndall made the first study with this approach 1870. Since then the technique has been improved and a variety of sources of errors have been identified and discussed to improve the technique.

In this work experimental difficulties and systematic errors in respiratory tract deposition measurements are reviewed, both to improve the quality of future measurements and to facilitate comparison between experiments and models. The review is essentially based on 33 publications, whereof most are summarized by Löndahl (2006).

Some difficulties are general. Others are specific for monodisperse experiment, where one size is measured at a time and others for polydisperse experiments, where the complete size distribution is studied at once.

General difficulties

A. Losses (e.g. electrostatic) in the measurement equipment may be interpreted as an increased deposition. This is especially complicated for bag-systems since the losses depend on the volume in the bags.

B. Pressure variations caused by the breathing may give errors in the particle counting.

C. Temperature and relative humidity could be higher in exhaled than inhaled air leading to particle loss or diameter change by evaporation or condensation.

D. The air trapped in the dead space in the mouthpiece after exhalation is inhaled again. Thereby the inhaled concentration is lower than measured.

E. The finite response time of particle counters delay and smear the signal, thereby decreasing the difference between measured inhaled and exhaled concentration.

F. Only one of the studies present a lowest acceptable concentration limit due to counting statistics or an upper concentration limit, e.g. due to particle coagulation. Some studies may use too high concentration.

G. If inhaling dry or room temperature aerosol, the volume of the exhaled air is larger than the inhaled because of the temperature and humidity change. This dilutes the exhaled air and decreases concentration, thereby seeming to increase DF.

I. An error may arise if the concentration of the inhaled particles is varying. This is in particular impor-

tant for polydisperse measurements because the size distribution could change too much between the scans. Scan times must be short, measurement time long or the concentration stable.

J. Hygroscopicity may alter deposition.

Specific difficulties

a. If monodisperse particles are separated in an electric field (e.g. with a DMA) they will have similar electrical mobility but different mechanical mobility because of multiple charges. It is the mechanical mobility that determines the deposition.

b. The polydisperse techniques are sensitive to small size shifts of the dried diameter between the inhaled and exhaled sample. If not taken into account, this could render substantial errors.

c. Polydisperse techniques are also sensitive to smearing of the output signal in the SMPS mainly caused by the finite CPC response time. This distorts the size-classification and is of significance if the scan time is too short and no correction is made.

Discussion and conclusion

Table 1 Estimated impact of errors

Error	Deviation from true DF*
A.	+ 1 – 20%
B.	- 0 – -3%
C.	+ 0 – 10%
D.	- -1 – -5%
E.	- 0 – -5%
F.	- 0 – -5%
G.	- 0 – -10%
I.	-/+ -0.1 – 0.1 in DF
b.	-/+ -0.2 – 0.2 in DF

* Note that some errors are relative and therefore given in percentage while others are absolute and given as deviation from true DF.

Table 1 shows estimates of the impact of the errors, if not taken into account, on the measured DF. Especially error D and G are well known but often not mentioned in publications, which make it probable that some experiments systematically underestimate DF. Errors may mask the real variability of DF and make comparisons of experimental results difficult.

Löndahl (2006), *Licentiate Dissertation*, Div. of Nuclear Physics, Lund University