Influence of sampling tubes on the measurement with unipolar diffusion chargers

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Unipolar diffusion chargers are used in a variety of aerosol instruments to e.g. measure the lung deposited surface area (LDSA) concentration. These monitors include the Partector (naneos particle solutions GmbH, Windisch, Switzerland), DiSCmini (Testo AG, Titisee-Neustadt, Germany), and Nanoparticle Surface Area Monitor (NSAM; TSI Inc, Shoreview, MN, USA). All three monitors use unipolar diffusion charging to electrically charge the particles and eventually measure the particle induced current, which is proportional to the LDSA concentration. Except for the NSAM, all monitors are portable and suitable for personal exposure monitoring, however, only the Partector is small enough to be mounted directly in the breathing zone (defined as a 30 cm hemisphere around mouth and nose), whereas the other two monitors can still be easily carried by a person, but need to sample from the breathing zone through flexible tubes. Different tube materials exist that can be used for this purpose. Generally, electrically conductive tubing is preferred to transport aerosols in order to minimize electrostatic particle losses. Carbon impregnated silicone tubes are therefore typically considered the best choice and are widely used in aerosol research.

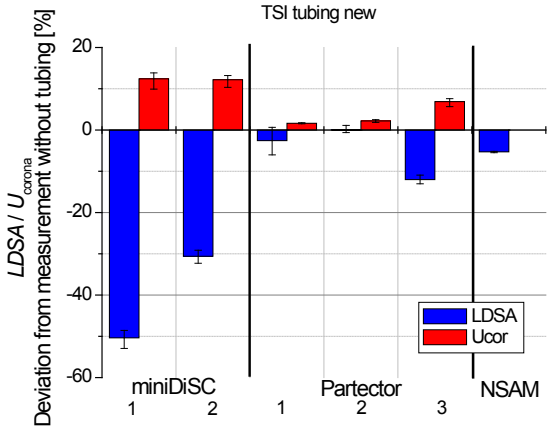

Fig. 1: Deviation of LDSA concentrations measured with and without silicone tubing with miniDiSC (left), Partector (center) and NSAM(right)

However, we observed that in some cases monitors based on unipolar diffusion charging, when connected to 75 cm long conductive silicone tubing significantly underreported the actual particle concentrations. In extreme cases, the deviations reached a factor of up to three, which drastically exceeds the expected particle losses inside the tubes. When the tubes were disconnected from the monitors, their results agreed fairly well.

We also observed that the corona voltage increased steeply when the tube was attached to the monitor and decreased when it was detached. The corona voltage is controlled by the instruments to maintain a constant ion current in the unipolar charger. The coincidence of these two observations gives rise to the assumption that it is not particle losses that cause the discrepancies but an effect on the particle charging.

It is known that among others siloxane can degas from silicone tubing and it has been observed that this causes a change in the chemical particle composition. Furthermore it has been observed that over time a silicon oxide layer will form on the corona electrode from the siloxane, resulting in a more rapid aging of the corona wire and a steady increase of the corona voltage. This increase is, however, much slower and - unlike in the present case- does not reverse when the tube is disconnected. We assume that the siloxane affects the mean mass and mobility of ions, generated in the corona and therefore lowers the charging efficiency. To test this hypothesis, we measured the response of DiSCmini, Partector and NSAM when sampling a defined test aerosol through different 75 cm long flexible sampling tubes. The results qualitatively confirm the findings from field measurements, i.e. DiSCmini reports significantly too low concentrations, when sampling through conductive silicone tubing (see example in Fig. 1). The effect was strongest, when new tubing was used and almost vanished in case of aged tubes. The Partector showed in principle the same effect, however, to a much lower extent. NSAM was unaffected by the choice of tubing. NSAM uses a different charger design that allows for a filtering of the air passing the corona electrode with an activated carbon filter. In addition, several other tube materials were tested, but their influence on the measurement results was found to be much smaller and in most cases negligible. Strangely, the effect on both concentration and corona voltage was reversed with some of these tube materials.

Results from both the field and the lab study will be presented and discussed in view of recommendations for the use of tubing when measuring with unipolar diffusion charges.