Atmos. Meas. Tech. Discuss., 8, C5348–C5352, 2016
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Atmospheric Measurement Techniques
Discussions
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AMTD
8, C5348–C5352, 2016

Interactive Comment

Interactive comment on "Aerosol effective density measurement using scanning mobility particle sizer and quartz crystal microbalance with the estimation of involved uncertainty" *by* B. Sarangi et al.

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Received and published: 7 February 2016

Anonymous Referee #1 These all comments/suggestions we have incorporated in the manuscript which is published in AMTD. Following are point-to-point replies.

In the section of the Experimental setup, an assumption was made that the salt particles were spherical and thus the electrical mobility diameter is the same as the aerodynamic diameter. Do you think it is a fair assumption? If the density of a sphere is greater than 1 g/cm3, the aerodynamic diameter becomes larger than the electrical mobility diameter due to the heavier mass compared to the droplet of the same size. Similarly, the aerodynamic diameter becomes smaller than the electrical mobility if the particle density is smaller than 1 g/cm3. Would the assumption contribute to the uncertainty of the determination of the effective density?

Response: Yes, this assumption will contribute to the uncertainty of the determination of effective density, and has been accounted for in section 3.2.2 (page no. 12903, line no. 13) and Table 3.

Assumption was made that the particles are spherical and thus the electrical mobility diameter is the same as the aerodynamic diameter. This assumption is valid because mobility equivalent diameter is related to aerodynamic diameter through dynamic shape factor (χ). If $\chi \neq 1$, then electrical mobility diameter will not be equal to aerodynamic diameter. If this is the case, then we will have some uncertainty contribution because of this assumption in effective density measurement, especially for salt particles. Therefore, we have estimated the uncertainty contribution due to shape factor (refer to section 3.2.2). The estimated uncertainty contribution is small, i.e. about 0.7 – 0.9% to the total combined relative uncertainty of density measurement, Table 3.

Following the comment, we have clarified it in page no. 12894, line no. 10.

Some major uncertainties to the SMPSâĂŘQCM system have been uncovered. It would be greatly appreciated to provide some suggestions or solutions to reduce the uncertainties. For example, as discussed in 3.2.3, one of major uncertainties is that the volume of particles derived from the CPC and the QCM data would not be equal, which is opposite to the assumption made in the study. It would be appreciated to provide the details about how the volume was derived from the QCM. If the QCMâĂŘ derived volume was based on the mass data and the literature density, then the error may directly come from the mass sensed by the QCM. In contrast, if the volume was based on the size distribution in aerodynamic diameter, then the particles bounced from collecting stage to lower stage may shift the size distribution to smaller side and result in

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the underestimation of the QCMâĂŘ derived volume. Moreover, dose the assumption that the electrical mobility diameter is the same as the aerodynamic diameter contribute to the discrepancy?

Response: Yes, the QCM-derived volume was based on the mass data and the material literature density. Following the comment, this has been clarified in the revised (AMTD) version in page no. 12911, line nos. 12-19.

The uncertainty because of the assumption of equivalency of CPC derived volume (based on CMD of the distributions) and corresponding particle volume derived from QCM (based on mass obtained from QCM and material density) is calculated based on the standard deviations in both the measurements. Because QCM mass is directly sensed (not calculated based on size measurement), therefore here we have not considered the uncertainty due to assumption that the electrical mobility diameter is the same as the aerodynamic diameter (section 3.2.3).

As mentioned in the text (page no. 12917 and line nos. 9-11), among individual uncertainty components, repeatability of particle mass obtained by QCM, QCM crystal frequency, CPC counting accuracy, and equivalence of CPC- and QCM- derived volume are the major contributors to the expanded uncertainty (at k=2) in comparison to other components. This suggests that minimizing the calibration uncertainties of QCM (i.e., in particle mass sensing) and CPC (i.e., in particle counting) can result in reducing the uncertainty of particle density measurement. Following the comment, in revised paper we have incorporated this suggestion (page no. 12917 and line nos. 11-13).

The standard deviation in figure 4 is large that the difference between the data in each day become insignificantly. In the study, the daily average data of the CMD, number concentration and effective density of the atmospheric particles taken over 10:00 to 13:00 were used to correlate to various meteorological data. The SMPSâĂŘQCM determines the effective density realâĂŘtimely, while the meteorological data were taken hourly. Would the use of the hourly particle information reduce the standard deviations

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and refine clearer trends in the correlation analysis?

Response: The prime focus of this paper is to demonstrate a method using SMPS-QCM for density measurement and discussed the involved uncertainty. We appreciate the valuable suggestion of the reviewer. We have all real-time data for 10:00 to 13:00 h except QCM data. Due to technical reasons, for some segments, the hourly data of QCM measurement for some days were missing. Therefore 3 hours average data of CMD, number concentration and effective density and meteorological data within the period (10:00 to 13:00 h) were considered in this paper.

As discussed in section 3.3 at page 27, the daily mean particle number concentration is strongly correlated to CO and NOx, of which is related to traffic related emission. However, both the CO and NOx dropped significantly on Dec 16 with unclear reason. Is there any information or data about the traffic in related regions? For example, the field sampling was done 7 days in a row. Daily and hourly traffic flow as well as traffic types in ordinary days and holidays may be different and thus could be directly related to the drop. It would be appreciated to have more information to support the inference of the traffic exhaust.

Response: Yes, the strong correlation between CO and NOx in the sampling days indicating for a common source which is possibly from traffic related emissions. As reviewer pointed out, both CO and NOx dropped significantly on November 16, which was Sunday. Recently Gour et al. (2015) published a detailed report based on five years observation that in New Delhi CO and NOx concentration is become lower in weekends and public holidays than those during working days. This is further suggested that both of the species are related with traffic source.

Following the comments, we have incorporated a paragraph in the revised version (AMTD) (page no. 12916 and line nos. 5-8) with the reference (page no. 12917 and line nos. 15-17) in which detailed traffic information of Delhi region is given.

Other points:

In section 3.2.2.3 at page 17, an unit of cm3 should be noted for the value shown in the sentence of “The uncertainty estimated from DMA calibration using PSL-60 nm by Eq. (20) is 55.62$\pm$1.53 (with coverage factor k =2).”

Response: Following the suggestion, the corrections have been incorporated in (AMTD), page no. 12905 and line no. 19.

It would be appreciate to notify the Monday to Sunday for the sampling day in the article for more complete information for readers. Response: We have mentioned the days with the date as suggested by the reviewer, page no. 12913 and line no. 9

Interactive comment on Atmos. Meas. Tech. Discuss., 8, 12887, 2015.