Real-time Instrument for Aerosol Mass Distribution Measurement

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Keywords: real-time, QCM, cascade impactor, aerosol mass distribution
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A novel instrument has been developed for real-time aerosol mass distribution measurements. The instrument includes two major components: a relative humidity (RH) conditioner and a 6-stage quartz crystal microbalance (QCM) micro-orifice impactor. The RH conditioner ensures that the incoming aerosol is conditioned to the range of 40 % to 65 % RH. The impactor operates at 10 L/min inlet flow rate and measures the mass of the collected particles in six aerodynamic diameter channels covering the range of 45 nm to 2.5 µm. The nozzles of the impactor stages are clustered so that the particles are collected at the center of the QCM, where the mass sensitivity is close to unity (Cumpson and Seah 1990). Laboratory tests conducted with monodisperse aerosol particles (Figure 1) showed that the RH conditioning ensures excellent agreement between the mass calculated from direct condensation particle counter (CPC) readings and the mass calculated for the QCM using the Sauerbrey equation (Sauerbrey 1959). Good agreement was found for mass loadings of up to about 130 µg for solid particles and up to about 2 µg for liquid particles. The experimental results indicate that the RH conditioning also eliminated solid particle bounce.

The QCM impactor was calibrated with monodisperse liquid particles using conventional calibration techniques. The collection efficiency as a function of aerodynamic diameter of each impactor stage was measured. The experimental cutpoints (Table 1) were in good agreement with numerical predictions from classical impactor theory (Rader and Marple 1985).

Table 1. QCM impactor calibration results.

Stage	Cutpoint (nm)	$(St_{50})^{1/2}$	σ_g
Inlet	2440	0.475	1.12
1	960	0.458	1.10
2	510	0.474	1.15
3	305	0.514	1.18
4	156	0.467	1.18
5	74	0.493	1.18
6	45	0.469	1.24

The QCM cascade impactor was also tested in an outdoor environment. The measured ambient aerosol distribution was compared with an independent co-located measurement using a wide-range particle spectrometer, WPS (Liu et al. 2010). The results are shown in Figure 2. The WPS mobility data were converted to the mass distribution data by assuming the particles were spherical and of 1 g/cm^3 density. In reality, the particles are likely to be non-spheres with a shape factor larger than 1 and with a density larger than 1 g/cm^3. The use of realistic values for these two parameters is likely to further improve the agreement between the two measurement techniques.

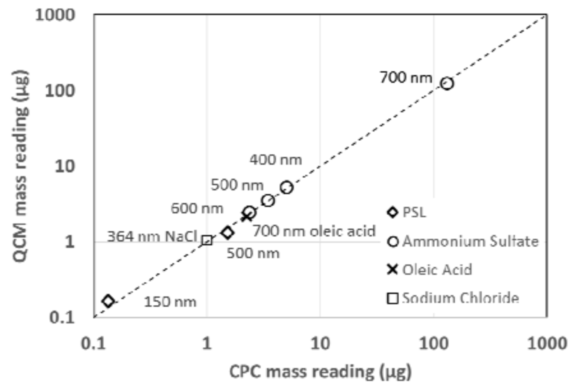

Figure 1. Comparison of the mass measured by QCM and by CPC methods. The mass readings are the amount of mass collected at the end of each test.

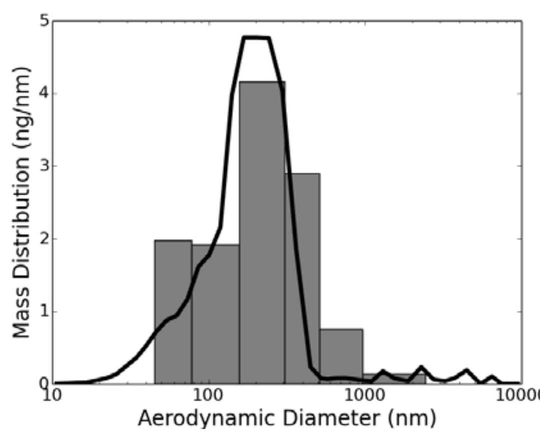

Figure 2. Comparison of the mass distribution measured by the QCM impactor (bars) and theWPS (line).

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