AMBIENT PM2.5 MONITORING WITH TSI'S MODEL 140 QCM-MOUDI

APPLICATION NOTE QCM-MOUDI-002 (US)
(11/7/2018) REV A

Contents

Why use the QCM-MOUDI for monitoring ambient air?

The Model 140 QCM-MOUDI is a valuable tool for monitoring ambient air quality because it provides measurements of mass concentration of particles below 2.5µm in real time. PM2.5 fraction is measured in six channels, and mass measurements are made using a first-principles technique (Quartz Crystal Microbalance) that does not require a calibration or zeroing. Data is stored on the instrument itself and can quickly be exported to a USB drive or remotely accessed via Ethernet. Maintenance steps for the QCM MOUDI are easy and relatively quick.

With the ability to observe rapid changes in conditions that affect particle pollution (such as meteorology or traffic) and the potential to provide real-time insight into the particle mass distribution, the QCM-MOUDI is a highly valuable complementary tool to standard reference filter-based, or equivalent measurements.

Figure 1: QCM MOUDI

How does the QCM-MOUDI compare to other techniques?

QCM-MOUDI co-located with TEOM and FRM

To investigate how the performance of the QCM-MOUDI compares with two well-established PM2.5 monitoring techniques, a co-located field campaign was conducted in June 2018. The Queens College II site in Flushing, NY is part of the New York State Ambient Air Monitoring Program, as well as the New York City Community Air Survey.

At this site, the QCM-MOUDI was co-located with a filter sampler compliant with the Federal Reference Method (FRM) and with a 1405-DF TEOM instrument (Tapered Element Oscillating Microbalance, Thermo Fisher), which is a Federal Equivalent Method (FEM) for PM2.5. Sampling was conducted for approximately 30 days, where FRM filter samples were collected daily for PM2.5 determination via gravimetric analysis, and the DF TEOM measured total PM2.5 mass concentration in 1-hr intervals.

The total PM2.5 measurement made by the DF TEOM includes both nonvolatile and volatile fractions (Kulkarni et al., 2011). The loss of the volatile fraction is often a negative artifact in traditional filter-based sampling, and the DF TEOM measures this artifact. This is done by adding two measurements:

- the mass collected on the TEOM filter during the Base measurement at 30 °C,
- the absolute value of the mass lost by the TEOM filter through volatilization during the Reference measurement (when the sample flow is pre-filtered at 4 °C before measurement).

During the Reference measurement, volatile mass is lost from the previously collected PM2.5; this loss is presumed to be equivalent to the loss (i.e. sampling artifact) that occurs during the Base measurement.

Total PM2.5 concentrations

Both the DF TEOM and the FRM measure total PM2.5 in μg/m^3, and do not provide data on how that PM2.5 mass is distributed among particles of varying sizes. As such, we can only compare the total PM2.5 mass concentration as measured by the QCM MOUDI to the PM2.5 measured by either of the two other instruments. This comparison can be done using daily averages (24-hr integrated values) to examine the agreement among the different techniques.

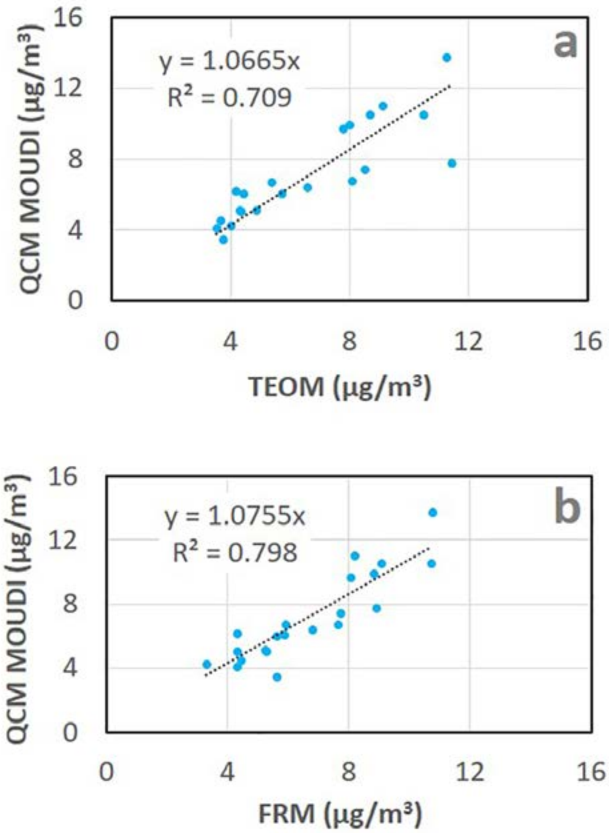

Figure 2: Correlations in total PM2.5 mass concentration measured over the course of the sampling campaign by QCM MOUDI and (a) TEOM, and (b) FRM.

Figure 2 shows the agreement between the QCM MOUDI and (a) the TEOM, and (b) the FRM over the course of approximately 30 days (June 2018). The QCM correlates well with these instruments, showing slopes of 1.067 and 1.076, respectively.

In both cases, the QCM MOUDI measured slightly larger PM2.5 mass concentrations than the other two instruments. This is explained by the higher relative humidity (i.e. 65% RH) used to condition the aerosol in the QCM MOUDI as compared with the RH used to weigh the filters (i.e. 30-40%), and the RH of the conditioned TEOM aerosol (i.e. 20-30%).

Mass Size Distributions

In addition to measuring real-time PM2.5 mass, the QCM provides data on how that mass is distributed among six size classes (i.e. 45 nm to 2.5 μm). This is possible because the QCM MOUDI's design segregates the incoming aerosol by size, using state-of-the-art cascade impactor technology based on inertial impaction (Chen et al, 2016). This unique feature allows researchers to examine how the mass size distribution changes over the course of sampling.

Figure 3 shows a time trace (showing data from 8 to 11 June) of total PM2.5 as measured by QCM MOUDI and TEOM (bottom plot). Strong agreement is shown between the two methods. TEOM data has hourly resolution while QCM data has half-hour resolution for these measurements. Notice that when PM2.5 concentrations are below 5 μg/m^3, the QCM MOUDI has better mass sensitivity.

The two insets in Figure 3 show the mass-based size distributions measured by the QCM at the two indicated time points. Although the total PM2.5 mass concentration is very comparable in magnitude, the mass distribution shape is quite different. This size information is relevant for both source apportionment and public health assessments, helping researchers to connect ambient mass concentration measurements to their causes (i.e. sources) and their consequences or potential effects.

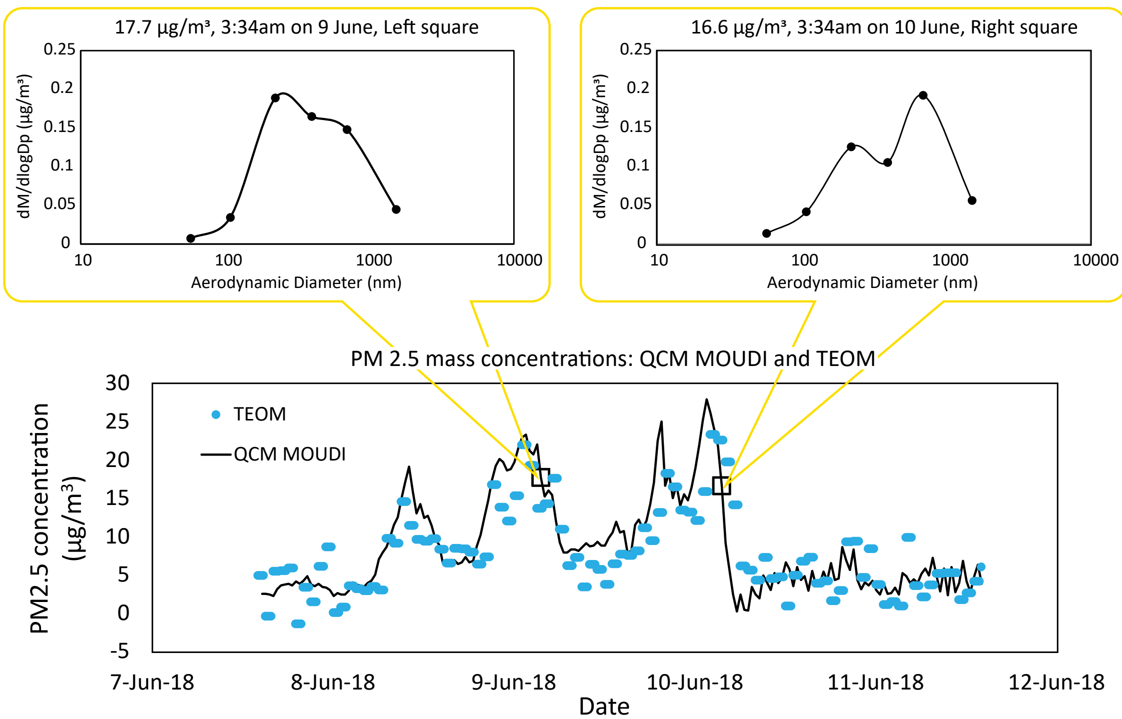

Figure 3: QCM data from 7-11 June. Bottom: time trace of total PM2.5 as measured by the QCM MOUDI and DF TEOM. Insets above show QCM MOUDI size distributions at two selected points (squares) within the QCM MOUDI total PM2.5 time series.

QCM-MOUDI: two co-located units

To investigate the consistency between two QCM MOUDI instruments, co-located ambient sampling was conducted at TSI's global headquarters in Shoreview, MN, US in May 2018. Two QCM MOUDI instruments sampled ambient air through a common sampling inlet in the building's roof; the sample flow was split between the instruments using tubing of identical length and inner diameter.

Figure 4 shows the results from the two QCM MOUDI instruments when sampling this common ambient aerosol. In (a), time series of total PM2.5 concentration from both instruments show a very strong agreement between the two. To look at that agreement quantitatively, (b) plots the PM2.5 concentrations from the two instruments against one another. The resulting linear fit has a slope of 0.934 and an R^2 value of 0.92, demonstrating excellent agreement between the two QCM MOUDI instruments.

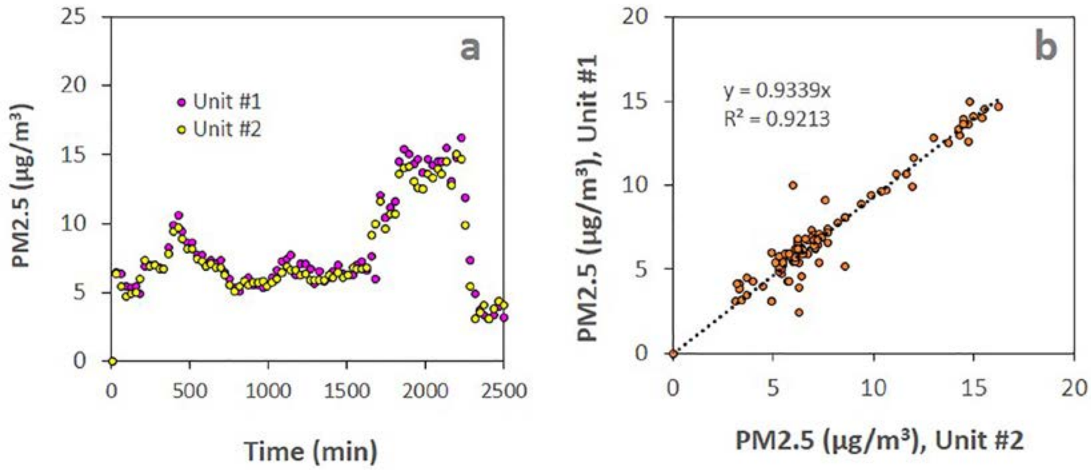

Figure 4: Ambient air measurements with two co-located QCM MOUDI instruments. (a) Time traces of both instruments; (b) plotting total PM2.5 results from the two instruments against each other reveals excellent agreement.

What steps do I have to take to ensure data accuracy in my environment?

As illustrated above, the QCM MOUDI is a powerful and accurate tool for making ambient size-segregated PM2.5 measurements in real time. Since ambient environments can vary widely in terms of PM2.5 concentration, temperature, and humidity, these parameters must be carefully considered while planning a measurement campaign. Proper selection of accessories, settings, and the maintenance needs of the instrument is vital to ensuring optimum data accuracy.

To learn more about what accessories and settings are needed to provide the best data quality in your environment, please refer to TSI Application Note # QCM-001, "Making Accurate Measurements with TSI's Model 140 QCM-MOUDI: Best Practices."

References

1. New York State Department of Environmental Conservation, 2018 Annual Monitoring Network Plan, New York State Ambient Air Monitoring Program, 19 June 2015, p 81-82.
2. Chen, M.; Romay, F. J.; Li, L.; Naqwi, A.; Marple, V.A. "A novel quartz crystal cascade impactor for real-time aerosol mass distribution measurement." Aerosol Science and Technology 50:9, 971-983.
3. TSI Application Note QCM-MOUDI 001, "Making Accurate Measurements with TSI's Model 140 QCM-MOUDI: Best Practices.", 2018.
4. Kulkarni, P., Baron, A.P., Willeke, K., Aerosol Measurement: Principles, Techniques, and Applications, Third Edition, John Wiley & Sons, p 260, 2011.

USA	**Tel:** +1 800 874 2811	**India**	**Tel:** +91 80 67877200
UK	**Tel:** +44 149 4 459200	**China**	**Tel:** +86 10 8219 7688
France	**Tel:** +33 1 41 19 21 99	**Singapore**	**Tel:** +65 6595 6388
Germany	**Tel:** +49 241 523030		

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Kenelec Scientific Pty Ltd
1300 73 22 33
sales@kenelec.com.au
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