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Experimental set-up for sensors evaluation in a controlled environment

Alexandre Bescond[1], François Gaie-Levrel[1], Lola Bregonzio-Rozier[1], Tatiana Macé[1]
[1] Laboratoire National de Métrologie et des Essais 1 Rue Gaston Boissier, 75724 Paris Cedex 15, FRANCE
alexandre.bescond@lne.fr

Summary:
Sensors appear to be a very promising technology for monitoring air pollution in the world. Main advantages are the improvement of the spatial and temporal resolution. However, accuracy and reliability of these technologies must be assessed. In this work, we will describe an experimental set-up in a controlled environment in terms of temperature and relative humidity. Sensors have been tested with different ranges of aerosol concentrations and their performance has been evaluated.

Keywords: Sensors, environment, monitoring, aerosol, mass concentration, air pollution

Introduction

Regular monitoring of particulate mass concentrations is carried out by regional Air Quality Survey Networks (AQSNs). Many member states rely on instruments having determined their equivalence to the gravimetric reference method (CEN/TS 16450:2013). Filtration-based methods, like oscillating element microbalances (TEOM) and radiometric gauges are commonly used. But many optical instruments can also be implemented such as photometers [1], particle counters [2], [3] and optical spectrometers [4], [5]. The evaluation of mass concentration measurement devices is therefore essential in order to ensure their metrological performance. Concerning sensors, several issues are raised in terms of controlled variability for operating points combining temperature, relative humidity, particle concentration and aerosol chemical composition. In this work, we will present an experimental set-up in a controlled environment dedicated to sensors performance evaluation.

Experimental set-up

Exposure chamber consists of a stainless steel enclosure and is equipped with injection modules for the introduction of aerosols and gases and sampling in order to connect the reference instrumentation. A calibrated thermo-hygrometer is used to measure the temperature and relative humidity in the exposure chamber. (See Fig. 1).

Particle size distribution of the generated aerosols within the exposure chamber was measured using a Scanning Mobility Particles Sizer (SMPS) and an Aerosol Particles Sizer (APS). The SMPS allows to measure a number size distribution in a range of electric mobility diameters between 10 nm and 1 µm, while APS allows to determine the particle concentration in number as a function of the aerodynamic diameter for a size range from 0.6 to 20 µm.

Particulate mass concentrations are measured using a TEOM 50°C microbalance coupled to a PM_{10} / $PM_{2.5}$ sampling head with a time resolution of 30s.

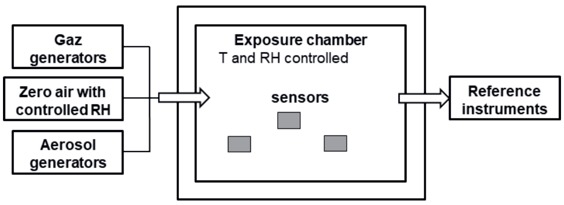

Fig. 1. Schematic diagram of the instrumental set-up for the metrological evaluation of cost sensors performance.

Results

Different types of Arizona dust have been used to achieve target particulate mass concentrations successively generated in the exposure chamber in order to evaluate sensors in PM2.5 and PM10 (See Tab. 1). All results presented below have been done at 20°C and 50% RH.

Thus, four reference concentrations were generated for PM2.5 and PM10, i.e. 0.9 ± 2.3 µg/m^3 ; 61.7 ± 3.8 µg/m^3 ;116.8 ± 4.8 µg/m^3 ;244.3 ± 4.4 µg/m^3 and 0.9 ± 2.3 µg/m^3 ;55.1 ± 3.8 µg/m^3 ; 87.7 ± 3.5 µg/m^3 ; 217.0 ± 4.2 µg/m^3 respectively.

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Tab. 1: PM10 and PM2.5 average mass concentrations measured within exposition chamber with reference instrument (TEOM 50°C)

$PM_{2,5}$ ($\mu g/m^3$)		**PM_{10} ($\mu g/m^3$)**	
Average	Standard Deviation	Average	Standard Deviation
0.9	2.3	0.9	2.3
61.7	3.8	55.1	3.8
116.8	4.8	87.7	3.5
244.3	4.4	217.0	4.2

Determination of accuracy and linearity of three sensors (C1, C2, C3) in PM2.5 and PM10, average values and standard deviations of quarter hourly measurements were calculated after stabilization of each mass concentration. Linearity results are shown in Fig. 2 for 3 sensors in comparison with reference method for PM2.5. The tests performed show similar behaviour between the sensors with slopes between 0.172 and 0.194 for PM2.5, and R^2 regression coefficients between 0.991 and 0.994. For PM10, the slopes obtained are between 0.277 and 0.328 with regression coefficients R^2 between 0.970 and 0.988.

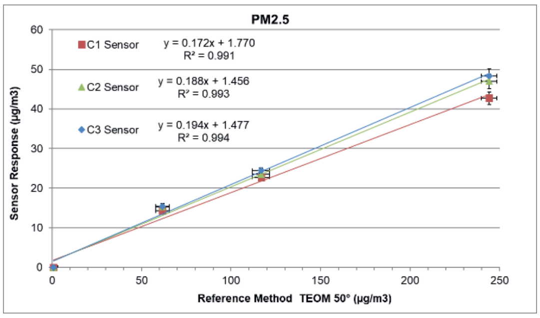

Fig. 2. Graphical representation of the results of the linearity and accuracy tests for PM2.5

Conclusion

This study allowed the development and optimization of sensors evaluation protocol by the implementation of dedicated instrumentation associated with the generation of aerosols and reference measurements around an exposure chamber. The environmental conditions associated with this protocol in terms of temperature and relative humidity were 20.0 °C ± 0.5 °C and 50% ± 2% respectively. In terms of prospects, this evaluation protocol will be optimized by associating controlled temperature and relative humidity conditions in order to test the effect of these parameters on the performance of the sensors.

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