Nephelometer sensitivities for the determination of $PM_{2.5}$ mass concentration in ambient and indoor air

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METHODS

Gravimetric determination of $PM_{2.5}$ concentrations

The aerosol was collected on preconditioned, at 500°C for 6 h, quartz fiber filters (8 inches × 10 inches, Whatman International Ltd., Middlesex, UK) of a high volume $PM_{2.5}$ sampler (TE-6001-2.5-I, Tisch Environmental Inc., Village of Cleves, OH, USA). The flow rate of 1.13 m^3 min^{-1} was controlled by a Sierra 620 Mass Flow Meter (Sierra Instruments Inc., CA, U.S.A) equipped with a totalizer. The average daily mass concentrations of $PM_{2.5}$ were determined by gravimetric analysis, according the European standard EN 14907:2005. The mass of particles was determined by the difference in filter weight before and after sampling using High Precision Digital Scale (Scaltec SBC 22, Denver Instruments, Denver, USA; precision ±10 μg; accuracy determined according to 90/384/EEC directive and its accuracy is class I according to EC Directive 2014/31/EU). The concentration of the suspended particulate matter in the designated size range was calculated by dividing the weight gain of the filter by the total volume of the air sampled.

Determination of $PM_{2.5}$ by light scattering coefficient of the nephelometer

Particle light scattering coefficient B_{sp} was measured with an integrating nephelometer (Radiance Research Model 903, wavelength at 530 nm; Radiance Research; Seattle, USA). The $PM_{2.5}$ cut-off diameter was effected by an inlet tubing of length and diameter calculated by a literature algorithm (von der Weiden et al., 2009). Specifically, a 2 m length, 3/8" outside and ¼ " inside diameter tubing (a Bev-A-Line® , Cole-Parmer, Germany tubing, which has a HYTREL® polyester liner, ideal for the PM sampling because they do not adhere to the liner). This was connected to the Nafion™ dryer of the same internal diameter, so that the overall length of the sampling train was 2.5 m. The flow of 2.0 L min^{-1} was controlled by a Sierra mass flow controller model 810C (Sierra Instruments Inc., Monterey, CA, U.S.A) at the exit of the nephelometer. The RH and temperature measurements were carried out by two Vaisala HMP45C Temperature and Relative Humidity Probes (Vaisala

HUMICAP® , Helsinki, Finland). The PVDF coated diaphragm of the sampling pump (Air Cadet® Pump, model no. 07530-50, Cole-Parmer Instrument Co., USA) returned the flow of dry air to the counter flow of the Nafion™ dryer and then to exhaust (see Fig. S1).

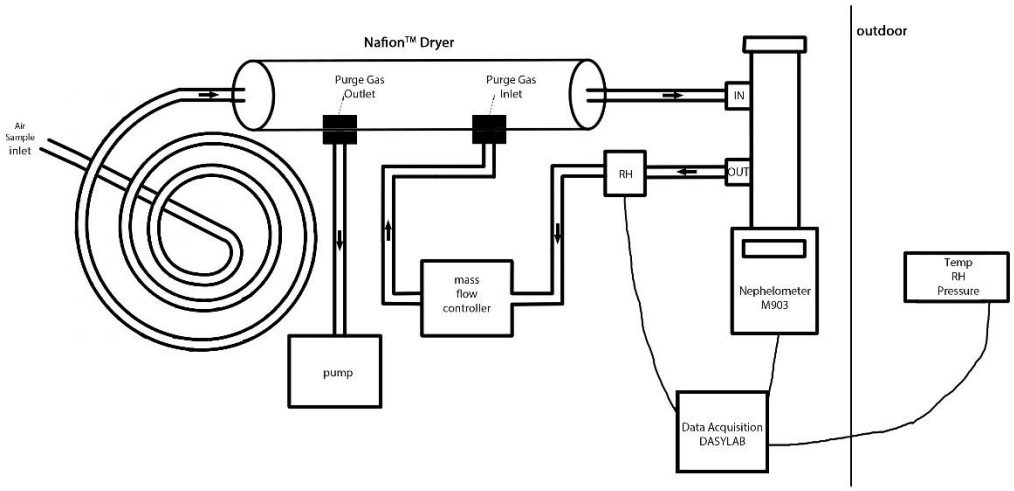

Fig. S1. RRN-903 set up with the Nafion™ drier in place.

For the first sampling campaign 2013-2014, all data were recorded by a CR10X data logger (Campbell Scientific, Inc., Logan, UT, USA) using the manufacturer's Loggernet software. $PM_{2.5}$ mass concentrations that were measured gravimetrically, as discussed above, were used to convert nephelometer readings into mass concentrations. The Nafion™ dryer was not in place.

For the 2019 sampling periods, indoors and outdoors, data from all sensors were directly recorded in the DASYLab program of Measurement Computing Corporation (MCC, Norton, MA, USA) via an Adam Module-Analog to Digital converter (ADAM 4017+ and 4520I, AdvanTech, Inc, Milpitas, CA, USA). The high volume sampler was used outdoors or indoors at will. To effect the drying of the aerosol laden stream a Nafion™ drier of 3/8"

outside diameter tubing, of 1/4" internal diameter and 0.5 meter length was used at the nephelometer inlet.

The uncertainty in the nephelometer readings is +3% (similar to TSI, Tnc. model 3563), plus 1-2% due to its larger forward truncation angle (Müller et al. 2009). A possible 10% uncertainty in the scattering coefficient has been avoided due to operating at low RH (Nafion™ dryer).

Indoor $PM_{2.5}$ densities

In order to calculate indoor $PM_{2.5}$ density, an aerosol light scattering spectrometer was employed. The particle number concentration range of the Palas PROMO 2000 particle sizer was 1 particle cm^{-3} to 10^6 particles cm^{-3}. The particle sizer was operating at 5 L min^{-1} and the particle volumes were obtained at 40 size bins between 200-2500 nm (Palas GmbH, Greschbachstraße 3 b, 76229 Karlsruhe, Germany). It was not necessary to dry the airstream entering the PROMO for the indoor measurements since the laboratory RH was controlled at 40% by a humidifier (Hygromatik MS05-B, Hygromatik GmbH, Germany) and an air conditioning installation (24,000 BTU Daikin Hellas – Athens, Greece).

REFERENCES

- EC Directive (1990). 90 /384 /Eec Council Directive of 20 June 1990 on the Harmonization of the Laws of the Member States Relating to Non-Automatic Weighing Instruments.
-EC Directive 2014/31/EU on the harmonisation of the laws of the Member States relating to the making available on the market of non-automatic weighing instruments.
-EN 14907:2005—AmbientAir Quality—Reference Gravimetric Method for the Determination of the PM2.5 Mass Fraction of Suspended Particulate Matter.
-Müller, T., Nowak, A., Wiedensohler, A., Sheridan, P., Laborde, M., Covert, D.S., Marinoni, A., Imre, K., Henzing, B. and Roger, J.-C. (2009). Angular illumination and truncation of three different integrating nephelometers: Implications for empirical, size-based corrections. Aerosol Sci. Technol. 43: 581-586.
-von der Weiden, S.L., Drewnick, F. and Borrmann, S. (2009). Particle Loss Calculator – a New Software Tool for the Assessment of the Performance of Aerosol Inlet Systems. *Atmos. Meas. Tech.* 2: 479-494.