The error in PM measurements caused by water vapour adsorption of the filter material

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According to the regulations of the European Commission operative at present the daily average of PM10 concentration should not exceed 50 μg m^{-3}, while the upper limit for the yearly average is 40 μg m^{-3}. The number of transgressions of the daily limit should not exceed 35 days/year. Furthermore, in case of reaching the alert threshold (100 μg m^{-3}) there is need for restrictions, which affect the way of life of the population as well as the economy. Hence knowledge on the reliability and environmental sensitivity of the method used for the measurement of the PM10 mass concentration is of great importance.

The online measurement of PM mass concentration is carried out worldwide with instruments using the β-ray attenuation method. The biggest uncertainty in the measurement of the PM mass concentration is caused by the fact that atmospheric water may significantly influence the mass and size of the aerosol particles as well as it can be adsorbed on and desorbed from the filter material used in PM monitors.

One of the objectives of this research was the quantification of the error in the determination of PM mass concentration caused by the uptake of water vapour of the filter material. Another objective was to construct an instrumental setup capable of minimizing this error in PM measurements.

Results

PM measurements were performed with a Thermo FH62C14 type particulate monitor working on the principle of beta attenuation. The PM10 inlet was changed for a HEPA filter in order to remove all particles from the gas stream sampled. Thus, only particle-free air was monitored by the instrument. Consequently, any change in mass was caused by gas phase components adsorbed or desorbed on the glass fibre filter (Whatman GF10) of the monitor. In terms of adsorbable mass water vapour is the dominant gas phase component in the atmosphere. Therefore this setup was suitable for the investigation of the effect of water vapour on PM measurements. The water uptake of the filter was examined both with heated (40 °C) and unheated inlet.

In Figure 1 the temporal variation in the mass of the filter (detected as PM concentration by the monitor) is shown for a summer period. Although considerable fluctuation of the hourly average values was experienced, periodicity of the signal is undoubtful. In the evening and night hours positive while during daytime negative bias was observed. The magnitude of the deviation in apparent hourly average PM concentration ranged from -21 to 23 μg m^{-3} and even the 6-hour moving average concentration values varied between -6 and 7 μg m^{-3}. During this experiment the PM10 concentration was measured with another PM monitor and the hourly average values ranged from 10 to 30 μg m^{-3}. These findings clearly show that the results of PM measurements are considerably distorted by the adsorption and desorption of atmospheric water vapour. This error is even more significant when PM2.5 or PM1 concentration is to be determined.

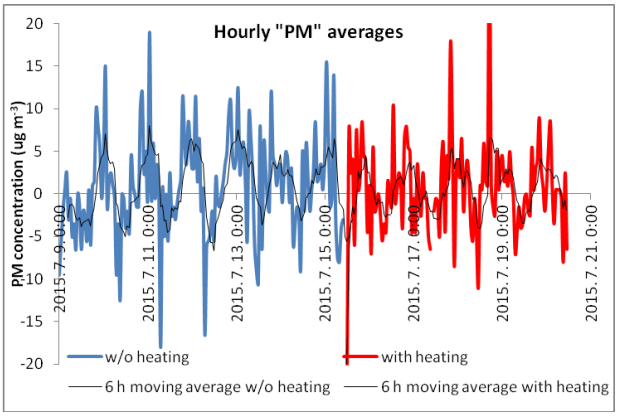

Figure 1. Temporal variation in the apparent PM concentration obtained with heated (red) and unheated (blue) inlet.

It is also visible in Figure 1 that the error in PM measurement caused by adsorbed and desorbed water can be decreased to some extent with heated inlet but it cannot be eliminated completely. Furthermore, the daily average concentrations were found to be >0 indicating that even 24 h average concentrations are influenced by the uptake and release of water vapour. In order to achieve more reliable PM measurements an instrumental setup was designed and tested under various meteorological conditions. With the help of this arrangement the water adsorption of the glass fibre filter as well as that of the particles was decreased. The setup and results will be shown in the presentation.

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