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The implications of tapered element oscillating microbalance (TEOM) software configuration on particulate matter measurements in the UK and Europe

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Abstract

The tapered element oscillating microbalance (TEOM) is used to measure ambient particulate matter concentrations worldwide. The instrument is configured with a correction factor required by the US Environmental Protection Agency (EPA) to account for the difference between the TEOM and the gravimetric method. However, numerous studies have shown that this factor does not fully account for these differences, consequently, the European Commission (EC) insists on an independent assessment of the differences. The US EPA correction was found to contribute between 3 and 5 $\mu g\,m^{-3}$ to the daily mean PM_{10} and $PM_{2.5}$ concentrations at Marylebone Road, London, between 1 January 2001 and 31 December 2004. The TEOM is also configured to express measurements to a standard temperature (25 °C) and a standard pressure (1 atm). This differs from the US EPA requirement of ambient reporting conditions for both PM_{10} and $PM_{2.5}$. It also differs from the European position, which also requires reporting at ambient conditions. When compared to ambient reporting conditions, the TEOM standard temperature and pressure correction was found to contribute between −1 and 7 $\mu g\,m^{-3}$ to the daily mean PM_{10} and $PM_{2.5}$ concentrations, and 2 $\mu g\,m^{-3}$ to the annual mean concentrations. The standard temperature and pressure correction was also demonstrated to vary the annual mean concentration measured using the TEOM by 2–8% between European capital cities, with higher values in colder northern cities. The standard temperature and pressure correction to individual daily mean concentrations was shown to be up to 20%. It is recommended that the US EPA correction factor is removed from TEOM measurements and that all measurements are reported at ambient temperature and pressure.

Keywords: TEOM; Gravimetric; PM_{10}; $PM_{2.5}$; Temperature; Pressure

1. Introduction

PM_{10} is measured routinely throughout the UK by central and local Government to comply with their statutory obligations (European Commission (EC), 1999; Department for the Environment, Transport and the Regions (DETR), 2000a, b). A recent review of particulate matter in the UK (Air Quality Expert Group (AQEG), 2005) analysed measurements of particulate matter made at 240 monitoring sites in the UK, most of these used the tapered element oscillating microbalance (TEOM)

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that is manufactured by Ruppecht and Patashnick (R&P). The TEOM is also used widely within the Europe and in other areas of the world. It was developed in the US as an automatic PM_{10} monitor. Able to measure particulate matter in real time, it offers advantages over the more labour-intensive manual gravimetric methods in terms of measurement time resolution and operating costs. However, there were two areas of the default software configuration that differ from the reporting requirements of the EC:

1.1 US Environmental Protection Agency (EPA) correction for the loss of volatile material.
1.2 Standard temperature and pressure (STP) correction.

1.1. US EPA correction for the loss of volatile material

The mass of volatile material in particulate matter is not, or is only partially, measured by the TEOM. This volatile material, such as ammonium nitrate and organic aerosols, is evaporated due to the elevated sample temperature (50 °C) which the TEOM employs to reduce the influence of particle bound water (Allen et al., 1997; Smith et al., 1997; Salter and Parsons, 1999; Soutar et al., 1999; Green et al., 2001; Josef et al., 2001; Charron et al., 2003). Concerns relating to the equivalence of the TEOM measurements to the established US EPA reference method, which is a gravimetric method, were addressed by comparing the two methods during a number of co-location exercises (Patashnick and Ruppecht, 1991). This information was used to calculate the US EPA correction factor:

$$\text{US EPA reference method equivalent mass} = (1.03 \times \text{TEOM}) + 3.$$

The TEOM received US EPA designation as a PM_{10} equivalent method in 1990 (EPA, 1990) by applying this correction factor to its measurements. This factor is programmed into the TEOM software as a default for all instruments sold in the US and abroad and is retained in the instruments used in the UK (AEA, 2005; AQEG, 2005). This correction factor has been identified and removed from ambient measurements in some previous studies (Charron et al., 2003; Harrison and Jones, 2005).

1.2. STP correction

In the US, reporting particulate matter concentrations to standard temperature and pressure (STP) conditions (25 °C, 298 °K and 1 atm) was originally adopted to provide a standard basis for comparing all pollutants measured in terms of mass per unit volume. The practice was dropped in favour of reporting to ambient temperature and pressure (ATP) conditions in the United States in 1997 as gaseous measurement units changed to a pollutant volume/air volume basis, which is not applicable to particle pollution (EPA, 1997a, b). The temperature and pressure reporting conditions for European Union (EU) legislation are not as well defined. The First Air Quality Daughter Directive (EC, 1999) required PM_{10} to be measured using the reference method but does not define reporting conditions, this was clarified in European Commission Decision in 2001 (EC, 2001), which specified ATP conditions. The ATP requirement is in the process of being transferred to EU legislation for PM_{10} and $PM_{2.5}$ (EC, 2005). To complicate matters further, TEOM instruments are configured to report measurements for comparison to the US EPA air quality criteria pre-1997 (Rupprecht & Patashnick Co., 1996) and consequently measurements are reported at 25 °C and 1 atm unless the software settings are changed. These STP settings have been retained in the TEOM instruments used in the UK (AEA, 2005).

1.3. The TEOM to gravimetric adjustment factor used in the UK

The gravimetric method is the basis of the European and US EPA reference methods for PM_{10} and $PM_{2.5}$ (EPA, 1997a, b; CEN, 1998; CEN, 2003), and is used to measure particulate matter concentrations worldwide. This method uses a sampler to collect particulate matter onto a pre-weighed filter. The filter is then re-weighed under standardised conditions to determine the mass of particulate collected on the filter. Using measurements of sample volume, a mass concentration of particulate matter in the air can be calculated. Measurements from these instruments are reported at ATP in the UK and elsewhere in the EU.

The UK Government is required to meet the EU air quality Stage 1 limit values by January 2005 as set out in the First Air Quality Daughter Directive. These are 50 $\mu g\,m^{-3}$, measured as a 24 h mean, not to be exceeded more than 35 times a year and an