

Studies of the effect of humidity and other factors on some different filter materials used for gravimetric measurements of ambient particulate matter

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Received 24 January 2006; received in revised form 18 April 2006; accepted 20 April 2006

Abstract

The results from studies of the effects of several factors on the accurate measurement of particulate matter (PM) mass collected on ambient air monitoring filters are described. The main investigation quantifies the effect of humidity on the mass of blank filters of some commonly used materials in Europe, namely quartz fibre, glass fibre and PTFE-bonded glass fibre. Supplementary work investigates the effect of humidity on the mass of sampled PM, and effects of storage and transport are also reported.

A number of fundamental problems associated with the weighing of filters are quantified and, for the materials and factors studied, we conclude that quartz filters are less well suited to high accuracy determinations of PM mass than glass fibre filters, while PTFE-bonded glass fibre filters are better than both. Though other factors also have an important role in the choice of filter material, we believe that the results form a useful addition to the limited amount of information available in this area.

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Keywords: Particulate matter; Gravimetry; Filters; Air monitoring; Health

1. Introduction

Airborne particulate matter (PM) is strongly associated with adverse human health effects (World Health Organisation Europe, 2003, 2004), and ambient concentrations are the subject of legislation within the European Union and in many other countries. This legislation effectively defines the measured quantity by specifying a standard method for its determination, based on the sampling

and weighing of the PM on filters (Council of the European Union, 1999). Current examples are the CEN (European Committee for Standardisation) European Standards EN 12341 (1999) for PM₁₀ (particles with aerodynamic diameter below 10 µm), and EN 14907 (2005) for PM_{2.5} (particles with aerodynamic diameter below 2.5 µm).

In the period since such methods were first developed, mitigation measures in a number of countries, for example the UK, have meant that PM concentrations have in general fallen dramatically. Also, emphasis on health effects has moved to smaller sized particles, so that future legislation is likely to cover PM_{2.5} rather than PM₁₀. These

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developments mean that the mass of PM available for measurement on the filter is becoming smaller. Issues connected with the accuracy of weighing the filters that were previously considered negligible have therefore become much more significant.

An additional factor that has been important historically is the production of mass artefacts on filters through the reaction of gaseous pollutants such as sulphur dioxide with the filter material (Appel et al., 1984), or the adsorption of organic compounds (Kirchstetter et al., 2001). However, as with PM, the concentrations of most gaseous pollutants in developed countries have decreased dramatically over recent decades and are currently very low by historical standards. This work does not attempt to study or quantify the effects of the absorption of SO₂ or other gases on the accurate weighing of filter media, even though these may still be significant factors in some circumstances.

Sampled PM is often analysed after collection for its chemical composition. This has led to an emphasis on standard methods for mass measurement that are compatible with subsequent analytical techniques, some of which involve the digestion of the filter together with the PM, making the chemical composition of the filter an important factor. The view taken in this work is that a standard method for the determination of the concentration of PM must focus primarily on making the measurement of the particle mass as reproducible and accurate as possible. The sources of measurement uncertainty in the standard method need to be reduced to a level where valid, definitive comparisons can be made with other methods, or with concentrations featuring in legislation. This may cause methods commonly used, with purposes that go beyond simple mass concentration, to fall outside the parameters of the standard method. Considerations of the wider purposes of monitoring campaigns and networks should not prevent the standard method for mass concentration being adequately defined.

There is a wide range of filter media available for particulate monitoring. These were well covered in a Critical Review (Chow, 1995). The European Standard for PM₁₀ (EN 12341, 1999) specifies that quartz filters must be used, whereas the European Standard for PM_{2.5} (EN 14907, 2005) allows the use of filters made from glass fibre, quartz, PTFE or PTFE-bonded glass fibre. In this study, the more common types of filter used for this application in Europe were investigated, namely quartz, glass fibre

(with and without binder) and PTFE-bonded glass fibre, and it was not the intention to include all filter types in widespread use around the world, such as PTFE in the USA.

The typical masses of 47 mm diameter filters of these materials are around 100 mg, ranging from approximately 85 mg (glass fibre) to 135 mg (quartz). When sampling an ambient mass concentration of 25 µg m⁻³ (the proposed annual EU ‘cap’ value for PM_{2.5}) for 24 h at the lowest commonly used flow rate of 1 m³ h⁻¹, the mass of particulates sampled is 600 µg. Errors in the mass of the collected particulate of 20 µg will therefore lead to errors of around 3% at the ‘cap’ value—a value which we consider to be fit for purpose. This ‘target’ uncertainty of 20 µg is equivalent to approximately 0.02% of the filter mass. For the EU standard low volume flow rate of 2.3 m³ h⁻¹, a 3% error at the ‘cap’ value would result from an weighing error of 46 µg (or approximately 0.04% of the filter mass).

The measurement of the small change in the filter mass is made more challenging by the necessity to obtain the masses of the blank and loaded filters many days apart. The filters may therefore be exposed to a wide range of, sometimes harsh, climatic conditions between these weighings. Systematic effects such as the mass dependence on humidity, or balance drift, need to be assessed and controlled, or significant errors in the mass difference will be introduced.

Two of the most important factors to consider when selecting a filter medium for mass concentration measurement are variation of weight with temperature and relative humidity (RH), and structural integrity (including resilience to transport). Other effects that may be important for specific applications are flow resistance (the tendency for the filter to become blocked with sampled material), chemical effects (e.g. adsorption of gases, nitrate retention, etc.), particle sampling efficiency, static charge effects, blank levels (for chemical analysis), thermal stability (when sampling hot exhausts), cost and availability.

This paper presents work studying primarily the first two factors in the above list. The main body of the work investigates the effects of different filter materials on the weighing process. Supplementary work considers the determination of the PM mass, studying effects such as humidity, and loss of material during storage and transport, on the measured mass of PM.

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