Title: Metrology for light absorption by atmospheric aerosols

Abstract

Combustion aerosols of anthropogenic emission sources (more commonly termed ‘soot particles’) are a key target for climate change. As a consequence a variety of optical methods have been used since the early 20th century to try and measure black carbon (BC) mass as an indicator of soot emissions. However, the quantitative measurement of the light absorption by atmospheric aerosols remains a significant challenge, as the aerosol properties are affected by the presence of filters. Traceable and reliable methods, as well as soot standard reference materials, are needed to address the metrological issues for light absorption by atmospheric aerosols.

Keywords

air pollution; climate change, black carbon mass, soot, light absorption, fine particles, optical methods, soot reference material, atmospheric aerosols

Background to the Metrological Challenges

Atmospheric light-absorbing particles are significant contributors to global warming. BC has been identified as the second most important climate agent behind CO_2 with soot particles contributing to almost as much as 30 % of the radiative force as current atmospheric CO_2 concentrations. BC has a much shorter atmospheric life than CO_2, and therefore strategies to reduce BC could slow down the rate of climate change more rapidly, by up to 40 % within 20 years. However, the lack of a metrological framework for particulate BC absorption measurements has been sited on a number of occasions, such as in 2013 by the European Environment Agency (EEA) and in 2015 by the BIPM-Working Group on Gas Analysis (GAWG) Particulate Workshop.

Measuring air pollution by assessing the darkness of particulate pollution sampled onto a filter began in the 1920s and the techniques have progressed in terms of the methods used to quantify optical absorption, and the assumptions made when converting the measured absorption into a pollutant mass concentration (typically in $\mu g/m^3$). However, the composition and optical properties of soot-like pollution changes markedly across combustion sources (e.g. coal burning to vehicle exhaust emissions) and atmospheric aging processes (such as the acquisition of light-scattering coatings) and thus have a significant influence on the relation between light absorption and mass concentration.

Current measurements for BC mass concentrations can vary by as much as a 4 times the amount, and are typically made with filter-based absorption photometers which are integrated into the aerosol network stations across Europe (e.g. the ACTRIS project). Therefore, it is important to define a metric for black carbon mass concentrations from optical absorption measurements in order to make these measurements from different aerosol network stations comparable to each other.

The use of the optical absorption coefficient together with a mass absorption coefficient to convert the light absorption into a mass concentration is already widespread in the scientific community. The parameter is known as equivalent Black Carbon i.e. the mass concentration of airborne material with the specified mass absorption coefficient that has exactly the same absorption coefficient as the sample. However, aerosol light absorption measurements of particles collected on filters typically show much larger and more poorly understood uncertainties than absorptions derived from scattering measurements of airborne particles. Several problems have also been identified for filter-based techniques, such as multiple scattering enhanced by the filter material and the shadowing effect caused by the aerosol material. Further to this, studies have highlighted that these techniques require significant corrections to provide the true aerosol absorption coefficient and although these are under development, for example within the ACTRIS network, traceability to the SI is an outstanding issue. As is, the lack of a soot standard reference material (SRM), which can be used for the calibration of filter based techniques and to optimise the lower detection limit of BC mass concentration.

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The JRP shall focus on the traceable measurement and characterisation of light absorption by atmospheric aerosols.

The specific objectives are

1. To establish a set of suitable parameters and mass absorption coefficients, which together can be used to reliably quantify a coefficient or conversion factor for light absorption by atmospheric aerosols.
2. To develop and characterise a soot standard reference material (SRM), that has a high content of elemental carbon as a near-black carbon source and is highly relevant for atmospheric aerosols.
3. To develop a traceable, primary method for determining aerosol absorption coefficients, using particulate black carbon (BC), at specific wavelengths. The method should have defined uncertainties and be quantified down to its lowest limit.
4. To develop a validated transfer standard for the traceable in-field calibration of established absorption photometers such as multi angle absorption photometers, aethalometers and particle soot/absorption photometers. The transfer standard should make use of the soot SRM (developed in objective 2) and associated portable instrumentation characterised by the primary method (from objective 3).
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by standards developing organisations (CEN, ISO) and end users (e.g. Environmental Protection Agency (EPA), European Environment Agency (EEA), World Meteorological Organization-Global Atmosphere Watch (WMO-GAW), the ACTRIS (Aerosols, Clouds, and Trace gases Research InfraStructure Network) Project).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research, the involvement of the appropriate user community such as industry, standardisation and regulatory bodies is strongly recommended, both prior to and during methodology development.

Proposers should establish the current state of the art, and explain how their proposed research goes beyond this.

EURAMET has defined an upper limit of 1.8 M€ for the EU Contribution to this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 35 % of the total EU Contribution to the project.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the “end user” community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the environmental sector, including those involved in climate change and air quality.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects (JRPs)”

You should also detail how your approach to realising the objectives will further the aim of EMPIR to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.