EMPIR Call 2019 – Energy, Environment, Normative and Research Potential

Selected Research Topic number: **SRT-v15**
Version: 1.0

Title: Metrology for light absorption by atmospheric aerosols II

Abstract

Black carbon particles are a type of light-absorbing atmospheric aerosol. As an air pollutant they pose serious risks to human health and they also have a direct role in climate change. The EMPIR JRP 16ENV02 Black Carbon project brought a clearer metrological focus to measurements of aerosol absorption, measured in Mm^{-1}, at one wavelength, giving the metric known as equivalent black carbon mass. However, metrological research is urgently needed to extend this to actual black carbon mass in $\mu g/m^3$, to multiple-wavelength instruments, to emissions inventories and to improve calibration procedures. These advances will greatly enhance the monitoring of the environmental impact of black carbon.

Keywords

Air pollution, black carbon, brown carbon, climate variable, fine particles, health effects, light–absorbing carbon, monitoring networks, reference material, soot

Background to the Metrological Challenges

Light-absorbing atmospheric aerosols, including black carbon particles, are of high importance because of their direct role in climate change. If black carbon mitigation strategies were adopted it is predicted that climate change could be slowed by up to 40 % within 20 years. In addition, ambient aerosols also pose a serious risk to human health with 430,000 premature deaths in the EU being attributed to fine particulate matter in 2011. Therefore, in addition to monitoring light absorption by black carbon in Mm^{-1} for climate change purposes, it is also important to monitor actual black carbon mass concentrations in $\mu g/m^3$ for air quality purposes, thus enabling a straightforward comparison with total particle mass concentration and emissions inventories. The relationship between these two quantities is given by a conversion factor (mass absorption coefficient, or cross-section), with typical units m^2/g. However, some instruments measure light attenuation rather than absorption, in which case a mass attenuation coefficient (also in m^2/g) is required.

The lack of a metrological framework for black carbon absorption measurements led to the development of the BIPM-Working Group on Gas Analysis (GAWG) roadmap. At present, filter-based absorption photometers are used for air quality monitoring purposes and these are integrated into many aerosol network stations in Europe (e.g. ACTRIS (Aerosols, Clouds, and Trace gases Research InfraStructure Project), GUAN (Global Climate Observing System Upper-Air Network), UK Black Carbon network). These rely on the use of the optical absorption (or attenuation) coefficient measurement, together with a mass absorption (or attenuation) coefficient, which are needed to convert light absorption into a mass concentration.

A methodology needs to be developed to convert optical absorption measurements in Mm^{-1} to actual black carbon mass concentrations in $\mu g/m^3$ in order to ensure that measurements from different air quality monitoring stations are comparable. However, this is challenging because aerosol light absorption measurements of particles collected on filters typically show larger uncertainties than light absorption derived from light extinction and scattering measurements of airborne particles. In addition, there are other linked issues associated with filter-based techniques, which 16ENV02 has made progress in addressing. Filter-free methods have also been developed, e.g. photoacoustic and extinction minus scattering, and one of these methods will soon be established as a reference for the measurement of light absorption. Therefore, further work is needed on this and the capabilities to identify and control sources of pollution need to be improved to allow measurements to be reported as the actual black carbon mass concentration.

The spatiotemporal variability of the mass absorption (or attenuation) coefficient needs to be better quantified. At present, this leads to considerable uncertainty in state-of-the-art black carbon measurements. However, by determining the wavelength-dependence of the absorption coefficient it will allow different black carbon sources, which change markedly with different combustion sources e.g. wood combustion versus diesel traffic, to be identified. Therefore, multiple-wavelength instruments need to be used to accurately and

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traceably measure aerosol absorption in order to give the actual black carbon mass concentration. The calibration procedures also need to be improved as these are expected to change at different wavelengths. Full traceability is expected to lead to improved analysis of the wavelength-dependence of the aerosol particles' properties, greatly improving diagnosis.

The accurate measurement of the mass absorption (or attenuation) coefficient needs to be solved. However, at present, gravimetric methods can only determine the total aerosol mass, which includes non-carbonaceous material, and they cannot discriminate between black and brown carbon. Thermo-optical methods can distinguish between black and brown carbon, but the uncertainties are ~30 %. In addition, other techniques like Laser-Induced Incandescence have shown potential for the quantification of the particles' black carbon mass, but this approach lacks standardisation and the measurement uncertainties are not properly understood because the results depend on the calibration material. Therefore, metrological support urgently needs to be supplied to those who will use this technique for the measurement of black carbon.

The stable and reproducible apparatus, which was developed in 16ENV02 for the generation of a series of well-defined and well-controlled model soot aerosols that are used as reference materials in the calibration of black carbon monitors, needs to be made portable so that it can be used as an accurate and validated transfer standard in regular in-field applications. Therefore, further work is needed to miniaturise the dimensions of the apparatus, to simplify its operation and accuracy, to lower its price, and to improve the calibration procedures.

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 accurately and traceably measure the mass concentration and optical absorption properties of the different types of absorbing particles that are found in ambient air. This should improve capabilities to identify and control sources of pollution and to allow measurements to be reported as the actual black carbon mass concentration in $\mu g/m^3$ with realistic conversion from aerosol absorption in Mm^{-1}.
2. To accurately and traceably measure aerosol absorption using multiple-wavelength instruments to give the actual black carbon mass concentration in $\mu g/m^3$. The calibration procedures should be improved as these are expected to differ at different wavelengths. In addition, full traceability should lead to improved analysis of the wavelength-dependence of the aerosol particles' properties, greatly improving their benefits for diagnosis, such as distinguishing between black carbon and brown carbon emission sources.
3. To provide metrological support to the users of techniques like Laser-Induced Incandescence, which are used to measure black carbon emissions from engines and black carbon concentrations in ambient air.
4. To refine the apparatus for the generation of the model soot aerosols that are used in the calibration of black carbon monitors. The apparatus should be portable (miniaturised and simplified), less expensive to purchase, and the calibration procedures should be improved so that the apparatus can be used as an accurate and validated transfer standard in field applications.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (accredited laboratories, instrumentation manufacturers), standards developing organisations (CEN, ISO) and end users (e.g. Environmental Protection Agency (EPA), European Environment Agency (EEA), World Meteorological Organisation-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 project goes beyond this. In particular, proposers should outline the achievements of the EMPIR project 16ENV02 Black Carbon and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 2.0 M€, and has defined an upper limit of 2.3 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 35 % of the total EU Contribution across all selected projects in this TP.

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.