Publishable Summary for 19ENV08 AEROMET II
Advanced aerosol metrology for atmospheric science and air quality

Overview

Air pollution is an environmental and social issue; air pollutants come from both anthropogenic and natural sources and give rise to health and climate change concerns. Accurate aerosol metrology i.e. dimensional quantification and chemical analysis, is a prerequisite for enforcing regulations, protecting human health, and supporting research on climate change and atmospheric processes. However, air pollution is a complex metrology challenge that currently lacks traceable measurement and characterisation of aerosols in the environment. To address this, the project will provide methodological improvements, including calibration guides reference materials, for the calibration of particle size spectrometers, pollen monitoring instruments and the chemical characterisation of ambient aerosols. The project will validate its developments using field campaigns and will support this with the development of portable instruments and software applicable for the measurement of ambient aerosol particle concentrations under variable environmental conditions. Finally, the project also responds to current challenges regarding aerosol instruments used by non-experts.

Need

In order for regulatory bodies, air quality networks and atmospheric instrument manufacturers to perform to the best of their abilities, accurate and reliable data for air quality monitoring is required. However, there is currently lack of traceable calibration standards and harmonised calibration procedures for measuring both anthropogenic and natural aerosols.

Improvement of the equivalency between gravimetrically derived particle mass concentration with those from Optical Particle Size Spectrometer (OPSS) and Aerodynamic Particle Size Spectrometer (APSS) is needed, particularly in cases with significant fraction of coarse mode particles (EU Air Quality Directive 2008/50/EC, Annex VI and CEN EN 12341). Understanding the deviation of non-radioactive bipolar charge conditioners to radioactive charge conditioners is important, especially for the application of charge conditioners in long-term traceable measurements of particle number size distributions using Mobility Particle Size Spectrometers (MPSS), such as used in the European research infrastructure Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS).

The quantification of element mass concentrations in aerosols is part of existing EU Regulations and is necessary for understanding the origins, behaviour, environmental fate and impacts of ambient particulate air pollution. However, current methods lack flexibility in terms of sensitivity and both time and spatial resolution. In terms of the generally decreasing air pollution levels in Europe, this may challenge the practice of monitoring the required and regulated air pollutants. Therefore, air quality monitoring networks need strengthening with additional options, such as offering high detection sensitivity and flexibility for monitoring the temporal and spatial variability of air pollution sources.

Currently, pollen monitoring relies on manual methods, which suffer from poor time resolution, while they are time consuming and hence incur high labour costs. As a result, meteorological institutes across Europe are now planning to equip their monitoring stations with automatic pollen monitors. However, to date, very little is known about the specifications of these automatic monitors. Thus, there is an urgent need for a rigorous investigation of their performance in the laboratory and in the field in order to establish a metrological framework for this newly emerged field.

Objectives

The overall goal of this project is to focus on the traceable measurement and characterisation of aerosols in the environment. The specific objectives are to:

1. Use test aerosol particles in test chambers, to develop traceable methods for the calibration of optical and aerodynamic particle size spectrometers to determine mass and number concentration, as well as size distribution. In addition to characterise aerosol bipolar charge conditioners in mobility particle size spectrometers and based on this the pre-normative definition of their performance criteria.
2. Develop new calibration procedures for automatic pollen monitoring instruments based on fluorescent polystyrene latex and real pollen particles (at concentrations < 1 /cm³, and particle sizes of 0.5 µm up to > 20 µm, with target uncertainties of < 10 %). In addition, comparisons to reference instruments in the field will be used to characterise instrument responses to pollen.
3. Develop certified reference substrates and traceable measurement techniques for the quantification of regulated and unregulated substances in ambient air with cascade impactor sampling and X-Ray Fluorescence analysis (XRF).
4. Develop portable instruments and software applicable for the measurement of ambient aerosol particle concentrations under variable environmental conditions. Knowledge gained will be applied to other appropriate classes of portable instruments by producing suitably adapted procedures.
5. Facilitate the take up of the technology and measurement infrastructure developed in the project by: the measurement supply chain (accredited laboratories), standards developing organisations (ISO and CEN) and end users (e.g. the Network of European Air Quality Reference Laboratories (AQUILA) , the European Monitoring and Evaluation Programme (EMEP), the European Research Infrastructure (Aerosol, Clouds and Trace Gases Infrastructure) and its future European Research Infrastructure Consortium (ERIC).

Progress beyond the state of the art and results

Currently the calibration of OPSS for particle mass concentration and number size distribution measurement is based on field-based empirical comparisons of aerosol gravimetry with the OPSS to be tested. This approach is both cost and time consuming and lacks the desired level of accuracy, versatility and comparability. This project will go beyond the current state-of-the art by developing a, traceable and lab-based approach to calibrate OPSS and APSS. Knowing the aerosol charging state as created by charge conditioners in MPSS is crucial for the accuracy of aerosol size spectroscopy. The long-term performance of new non-radioactive bipolar charge conditioners is not presently known and therefore needs to be investigated. This project will address this issue and develop, for the first time, robust procedures for determining the aerosol charging state.

At present, there is no standardisation or available calibration procedures for automatic pollen monitors. This is despite the fact that these instruments are about to be installed at meteorological stations across Europe. This project will go beyond the state of the art by developing, for the first time, traceable calibration procedures for automatic pollen monitors in the laboratory. The project will also produce a standardised pollen aerosolisation method and a transfer standard for instrument validation in the field.

Total Reflection X-ray Fluorescence (TXRF) spectrometers are currently calibrated using reference standards, either produced by the TXRF manufacturers or provided by NIST or BAM for respective analytes. The reference standard should be representative for the specimen investigated in terms of concentration and spatial resolution. However, significant deviations from the ‘real sample’ are often seen in the current situation and this results in significant levels of uncertainty for the quantitative result. In addition, the current methods do not work satisfactorily when the TXRF method is applied to cascade impactor samples. There are also no harmonised and standardised procedures available for cascade impactor samples. This project will develop the use of traceable reference samples as secondary quantitative standards for single or multiple use. This is an innovative solution and, as a result, should improve the uncertainty as well as the comparability in the quantification of regulated elements in ambient air by TXRF. Full traceability to primary standards, such as a synchrotron based GIXRF setup, will also be investigated by the project.

Portable, commercially available instruments for the measurement of ambient aerosol particle concentrations are popular because of their potential easy handling and rather low acquisition costs. However, they are associated with less defined uncertainties as well as signal instabilities compared to more sophisticated laboratory-based instrumentation. The project will undertake a comparison of the portable, commercially available instruments to calibrated reference instruments under laboratory conditions. This will be the first step in quantifying the effects of a variety of environmental conditions, e.g. high humidity, on the accuracy of the portable, commercially available instruments. The project will also go beyond the current state of the art by developing robust procedures for the use of the portable, commercially available instruments, that consider the effects of the environmental conditions and apply relevant measurement principles.

Real-time online measurements of black carbon (BC) with portable optical instruments are also facing similar measurement quality issues related to inappropriate guidelines and the lack of traceable calibration methods. These BC instruments are currently not a mandatory component of air quality monitoring stations, therefore periodic calibration does not happen on a regular basis. This project will again go beyond the current state of the art by improving the current limited knowledge about reliability and accuracy in BC measurements in different environmental scenarios by researching and developing compensation algorithms that can cancel out measurement artefacts and enhance the instrument's reproducibility.

Impact

Impact on industrial and other user communities

This project will develop new robust and improved calibration procedures for instrumentation such as OPSS and APSS. OPSS and APSS instrument manufacturers will directly benefit from these new capabilities. In addition, aerosol instrument manufactures will benefit from the project's improved knowledge of the performance of radioactive and non-radioactive bipolar charge conditioners including their long-term stability. To support the impact on manufacturers, the project intends to include instrument manufacturers and their devices in the project's tests and comparisons. Manufacturers will also be included in the project's stakeholder committee, so that feedback from them can be included in the project. Targeted feedback from manufacturers will also be gathered for necessary improvements for related evaluation software. This will support improved measurement uncertainties for commercial MPSS with non-radioactive bipolar charge conditioners.

The project's work on pollen monitoring will develop new metrological tools for manufacturers to (i) characterise the performance of such monitors, (ii) detect malfunctions and (iii) improve the measurement efficiency of their instruments. This will support the availability of new improved pollen monitoring products in the European market, particularly as three of the major players in this field are based in Europe.

The calibration of TXRF spectrometers based on cascade impactor reference samples is by its principle applicable to other impactor and TXRF instrumentation. Therefore, the project's results should motivate manufacturers to develop alternative systems, which can be calibrated in a similar harmonised way. This is an important step for the harmonised and traceable calibration of TXRF spectrometers and will enable reference samples to become available to end users as commercial products, as well as providing much needed flexibility in the combination of elements in reference samples so that they can meet individual end user requirement, e.g. for the measurement of specific industrial air pollutants or background aerosols.

The use, by non-experts, of portable, commercial instruments such as monitors for BC and particle number concentration for ambient aerosol measurements, has meant that manufacturers of such instruments urgently need to develop robust and easy to follow technical user guidance. This project will support the development of such guidance with the interpretation of data from non-expert users. The analysis will then be used to provide end users and manufacturers with a comprehensive description of application limits such as environmental conditions and margins of uncertainty.

Impact on the metrology and scientific communities

The project's new and improved calibration procedures for OPSS and APSS: with (i) an extended traceable size range, (ii) knowledge of the performance of non-radioactive bipolar charge conditioners and (iii) their long-term stability for MPSS measurements will be disseminated to the European Research Infrastructure ACTRIS.

Thus, the project's results will be promoted to ACTRIS' stakeholders and will support ACTRIS and its central facility (i.e. Topical Centre for Aerosol In-Situ Measurements) within the European Research Infrastructure Consortium (ERIC).

The project's development of calibration procedures for automatic pollen monitors will enable meteorological stations to automate their monitoring stations and will in turn improve data comparability in Europe. This will result in accurate, real-time data becoming readily available while at the same time reducing operational costs (compared to the current time-consuming, manual methods for monitoring pollen). Moreover, the methods developed for pollen monitors could be used in future applications for the detection of other bioaerosols, such as bacterial and fungal spores, many of which are human and plant pathogens.

In atmospheric research and air quality networks the project will support the availability of traceable reference samples. This will support traceable and validated measurements and add value to the use of cascade impactor sampling and TXRF spectroscopy for element mass concentration measurements in ambient air.

In the scientific aerosol community, portable instruments are widely used as an important supplement to laboratory-based reference equipment. The project's qualification of portable instruments for measurements of the particle number concentration and BC will, therefore, be of great importance for researchers in the air quality network community.

Impact on relevant standards

The consortium will promote the results of this project within the relevant standardisation community such as DIN NA062-08-16AA (and ISO TC201 SC10), ISO/TC 146 SC6, EURAMET TC-MC SC Gas, BIPM CCQM WG Gas Analysis and WG Surface Analysis. The work on the calibration of OPSS and APSS will impact standardisation activities within ISO/TC 24 SC4 WG12 Electrical mobility and number concentration analysis for aerosol particles, ISO/TC 24 SC4 WG9 Single particle light interaction methods and CEN/TC 264 WG32 Ambient air - Particle number concentration. The performance characteristics of non-radioactive charge conditioners will be disseminated for inclusion into the next revision of ISO 15900 on MPSS and should help to drive forward the work on the Preliminary Work Item (PWI) ISO 19996 on charge conditioners and respective test procedures. The project's work on automatic pollen monitoring will initiate the development of a new ISO standard (within ISO/TC 24 SC4 WG9) and will also feed into the CEN EN 16868:2019 "Ambient air – Sampling and analysis of airborne pollen grains and fungal spores for networks related to allergy – Volumetric Hirst method (joined)". The project's harmonised calibration guides for TXRF spectrometers may also lead to a new work item proposal within ISO/TC 24 SC4 Particle characterisation, ISO/TC 201 Surface chemical analysis. Furthermore, the work on portable aerosol particle instrumentation will support a future CEN Technical Specification (TS) on the performance evaluation of sensors for the determination of concentrations of particulate matter (PM) in ambient air (CEN/TC 264 WG 42).

Longer-term economic, social and environmental impacts

This project will make significant improvements to air quality data by reducing the measurement uncertainties for key particulate air pollutants, such as ultrafine particles (UFP), BC, and metals, and allergens such as pollen. This will be achieved by developing new calibration procedures for (bio)aerosol monitoring systems, reference materials as well as portable devices that can serve as transfer standards for instrument calibration in the field.

Improving the monitoring of airborne particles is indispensable for developing effective public health measures and reducing the exposure of the population to the most harmful components of ambient PM. The outputs from this project will enable a more targeted policy on health-relevant components/properties and promote the revision of air quality legislation by extending the current legal framework to include metrics beyond PM mass concentration. Considering the enormous costs arising from hospitalisation and premature deaths due to particulate air pollution, the protection of public health should also lead to considerable financial benefits.

List of publications

(not yet available)

This list will also be available here: https://www.euramet.org/repository/research-publications-repository-link/

Project start date and duration:	01 September 2020, 36 months
Coordinator: Burkhard Beckhoff, PTB Tel: +49 30 34817170 E-mail: Burkhard.Beckhoff@PTB.de Project website address: www.AEROMETproject.com (link for AEROMET II to be implemented at this website)	

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