

Title: Standardisation of aerosol surface area metrics for assessing health impacts of air quality

Abstract

Toxicological studies have shown that particle surface area (PSA) is the most relevant dose metric for nanoparticle toxicity in the lung. Currently, there is no guidelines developed on the quality assurance required for PSA / Lung Deposited Surface Area (LDSA) measurements and is not subject to regulation. Moreover, traceability for these measurements is incomplete and uncertainties are poorly understood. Therefore, this project will address these gaps by developing one new standard on PSA within CEN/TC264/WG32 dedicated to traceable measurements of LDSA and mobility-based surface area through comparison with the traceable Fuchs surface area method as well as providing quality assurance procedures for these surface area parameters.

Keywords

Aerosol, Particle Surface Area (PSA), Lung Deposited Surface Area (LDSA), ultrafine particles, nano-objects their aggregates and agglomerates (NOAA), calibration, reference methods, standardisation

Background to the Metrological Challenges

Correlations between respiratory disease incidence and number concentrations of airborne particles are well documented and have shown such health effects correlate better with particle surface area (PSA) dose than with particle number or particle mass dose. PSA is a strong candidate to be implemented in future air quality regulations, as current regulations are based on PM₁₀ and PM_{2.5} mass concentration (EN 12341, 2014)(EN 16450, 2017) and measurements of some chemical components of particulate matter (e.g. metals, organic carbon and elemental carbon). PSA studies have been performed to characterize nanoparticle exposure and health effects. Since lung fluid–particle interactions occur on the surface of particles, robust measurement of the surface area of deposited particles which is accessible to the lung fluid are required. However, estimation of the accessible surface area of non-spherical particles remains an open issue. For non-porous spherical particles, the surface area is equal to the geometric surface area (GSA) and can be used as the biologically most relevant dose metric. However, the assumption that these particles is spherical can lead to miscalculation of the “true” surface area of airborne particles.

The epiphaniometer (EPI) is the first device designed specifically to monitor aerosol (FSA) Fuchs” or “Active” surface area by measuring the alpha-activity of the radioactive atoms attached onto particles by alpha-spectroscopy. However, this makes the EPI inappropriate for routine field use. FSA and GSA have different parameters: at small mobility diameters ($d < 100$ nm), FSA is proportional to d^2 (assuming spherical particles), but for larger particles is proportional to d . This EPI method for FSA measurements has the advantage of being very sensitive, as it is based on counting single alpha-decay events. By contrast, diffusion chargers (DC) use electrical ions as the labelling material and are widely used in field measurements. DC aerosol monitors (DCAM) use a lung deposition curve such as the ICRP lung deposition curve to measure lung-deposited surface area (LDSA) concentrations. Instruments based on this measurement principle can be designed very compact with a low power consumption. This makes them ideally suited for personal exposure measurements (Geiss et al., 2016) and adapted to serve as stationary instruments in air quality monitoring stations.

The methods are limited by only measuring the surface area of total airborne particulates and does not allow measurements of particle size fraction. An existing instrument to measure the size-fractionated surface area is the Electrical Low Pressure Impactor (ELPI) which is based on the principle of combining cascade impactor with DC. The widely-used Scanning Mobility Particle Sizer (SMPS) also offers quasi-real-time size-resolved particle size distribution with time resolution of the order of minutes. Mobility-based surface area can be therefore calculated based on the integrated distribution of particles across the size fractions. There are some

developments of a weighted-sum method for application to SMPS data to determine GSA concentrations in real time. In addition, a six-stage cascade epiphaniometer (CEPI) to measure the real-time FSA size distribution by using a radioactive source as the labelling material has been also developed. CEPI offers the advantage of direct measurement of FSA size distribution based on fundamental principles, especially for low aerosol concentrations. For spherical or near-spherical particles, CEPI measurements typically agree well with the fundamental definition of FSA (based on the mobility diameter), with a mean relative measurement error across studies of around 12 %. As CEPI measures the FSA without relying on morphology assumptions, quantitative FSA size distribution measurements can be performed over a wide size range with adequate time resolution. However, there is a need to examine the CEPI response in the case of non-spherical particles with low fractal dimension, such as chain-like aggregates.

Moreover, by establishing a measurement framework for aerosol surface area/LDSA the traceability, consistency and comparability to these measurements performed across Europe will be ensured. However, no guidelines currently exist on the quality assurance on surface area/LDSA measurements. In 2022 CEN/TC264, WG32 has drafted a Technical Specification for specifying the design for LDSA measuring diffusion charging aerosol monitors as well as performance criteria and associated test procedures, this draft is still under development and only dedicated to DCAM. Therefore, there is a need for developing a new standard within WG32 dedicated to traceable measurements of LDSA and mobility-based surface area by comparison to the traceable Fuchs surface area method. This measurement framework for aerosol will significantly benefit both human health within Europe (air quality is responsible for 300,000 premature deaths per year in the EU (E. E. A. European Environment Agency, 2022)) and to global environmental sustainability.

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 aerosol in particular particle surface area (PSA).

The specific objectives are

1. To develop a procedure for SI traceable measurements of aerosol Fuchs surface area using a cascade epiphaniometer (CEPI) and robustly determine the uncertainty of the measurement. Target measurement uncertainties are $\leq 15\%$ (95 % confidence level). This includes providing clear guidelines to end-users about the limitations and application range of the method.
2. To develop a procedure for the method-dependent conversion of traceably-measured aerosol particle size distributions to Lung Deposited Surface Area (LDSA) measured by electrical aerosol monitors based on diffusion charging (DCAM) by optimising calibration processing using spherical and non-spherical reference aerosols. In addition, to define a full uncertainty budget for the measurement.
3. To perform interlaboratory comparisons using the reference aerosols defined in objective 2 to characterise real-time LDSA measurements by DCAM (ELPI, Diskmini, Partector) and SMPS mobility-based surface area against the CEPI traceable method defined in objective 1. In addition, calibration procedures using particle number size distributions will be standardised to achieve full traceability to the SI.
4. To lead the development and contribute to a new CEN standard within CEN/TC264/WG32, dedicated to traceable measurements of LDSA (Objective 2) and mobility-based surface area (Objective 3) through comparison with the traceable Fuchs surface area method (Objective 1).
5. To address stakeholder needs related to the measurement of particle surface area metrics and establish strong collaboration with the EMN POLMO (European Metrology Network on Pollution Monitoring). To facilitate the uptake of the technology and measurement infrastructure developed in the project by the measurement supply chain (European national air quality monitoring networks (e.g. ACTRIS, AQUILA, EMEP, GUAN, NABEL, Atmo-France), instrument manufacturers, and also by the International Society For Environmental Epidemiology), standards developing organisations (CEN/TC264/WG32) and end users.

The proposed research shall be justified by clear reference to the measurement needs within strategic documents published by the relevant Regulatory body or Standards Developing Organisation or by a letter signed by the convenor of the respective TC/WG. EURAMET encourages proposals that include

representatives from industry, regulators and standardisation bodies actively participating in the projects. The proposal must name a “Chief Stakeholder”, not a member of the consortium, but a representative of the user community that will benefit from the proposed work. The “Chief Stakeholder” should write a letter of support explaining how their organisation will make use of the outcomes from the research, be consulted regularly by the consortium during the project to ensure that the planned outcomes are still relevant, and be prepared to report to EURAMET on the benefits they have gained from the project.

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

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.0 M€ and has defined an upper limit of 1.3 M€ for this project.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 30 % of the total EU Contribution across all selected projects in this TP.

Any industrial beneficiaries that will receive significant benefit from the results of the proposed project are expected to be beneficiaries without receiving funding or associated 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,
- Facilitate improved industrial capability or improved quality of life for European citizens in terms of personal health, protection of the environment and the climate, or energy security,
- Transfer knowledge to the environment sector.

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 the Partnership 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.