

Title: Standardisation of bioaerosol monitoring for air quality and climate modelling

Abstract

Biological aerosol is abundant in the atmosphere and influence the hydrological cycle and climate, and some of them are known human and plant pathogens and/or allergens. Newly developed systems based on automatic bioaerosol monitors and machine learning have revolutionised the field by providing real-time information on the number concentration and taxa/species of airborne biological particles. However, traceability is incomplete and measurement uncertainties are not yet fully understood. Therefore, this project will contribute to the development a new standard on automatic pollen and fungal spore monitoring within the CEN/TC 264/WG 39 and develop, for the first time, quality assurance procedures for this new class of bioaerosol monitors.

Keywords

Bioaerosol, biological particles, pollen, fungal spores, machine learning, artificial intelligence, counting efficiency, number concentration, automatic monitoring, (near) real time

Background to the Metrological Challenges

Biological aerosols are abundant in the atmosphere such as pollen and fungal spores, but also bacteria, viruses and plant debris are released into the air by plants, fungi, and other living organisms, although their concentration and composition can vary significantly in time and by location. Bioaerosols act as cloud condensation nuclei as well as ice nuclei, influencing the hydrological cycle and climate. Therefore, information on bioaerosols is crucial for agriculture and forestry, where real-time data about the presence of pathogens, mostly fungi, is required for protecting agricultural production and developing knowledge-based technologies.

Aside the environmental impact, many bioaerosols, especially pollen and some fungal spores, has an allergenic or pathogenic effect on humans. Pollen allergy and asthma are the most common chronic diseases, affecting between 15 %-40 % of the European population, with estimated direct and indirect health costs exceeding €50 billion per year.

Recent technological developments and machine learning (ML) have made possible to automate bioaerosol monitoring, revolutionising the information that can be made available to end-users. Currently, more than 40 high-end automated bio-aerosol monitors is operational across Europe, and it is expected to exceed 400-500 (high-end and mid-cost) instruments in the coming years. ML algorithms are trained to identify a large number of common pollen and fungal spore taxa as well as other particles. The instruments run continuously and is suitable for unattended operation. However, since the ML technologies are new, a metrology framework with appropriate quality assurance has not been established yet and thus the need for the measurement uncertainties to be quantified and the framework for the ML algorithm validation defined.

ML algorithms are currently trained with particles supplied to the devices under generic laboratory conditions or outdoors (e.g. rooftops of meteorological institutes), with no strict control over the environmental conditions. There is a need to perform ML training in well-controlled environmental chambers, where temperature, pressure and relative humidity can be tuned/scanned according to the experimental needs. Furthermore, the data output of the automated bioaerosol instruments is not standardised; some of them report coarse particle number concentration, others only particle counts. Similarly, some instruments report counts in size bins, while other do not assign particles to size classes.

Calibrating automatic bioaerosols monitors has been made in EMPIR project 19ENV08 Aeromet II. The calibration procedures relied on the use of certified polymer spheres with a geometric diameter in the range 0.5 μm – 20 μm as reference materials. Although this method covers the fungal spore size range (typically

1 µm -10 µm), pollen particles tend to be larger (typically 15 µm – 50 µm). Moreover, some pollen grains and fungal spores has a complex morphology (is not spherical) and their outer membrane can have adhesive properties (as opposed to polymer spheres which is elastic). Calibration procedures needs to be extended to larger particle sizes and use real bioparticles as calibration materials. New calibration methods based on particle flow visualisation are promising for bioparticle counting but these need to be validated and standardised.

Moreover, no standards exist on the quality assurance of automatic bioaerosol monitors and, as a result, monitoring stations develop procedures at a regional level. Currently, there exists only one standard and one technical specification (TS) for bioaerosols in ambient air (CEN/TC 264/WG 39 and CEN/TC 264/WG 28). In addition, CEN/TC 264/WG 39 started in 2021 to draft a new document on "Near real-time measurement methods for monitoring airborne pollen and fungal spore concentrations" however, the draft is still at a very early stage and input is needed on the calibration of automatic bioaerosol monitors, training of the ML algorithms and curation of the databanks.

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 development of traceable measurement and calibration methods to contribute to a new standard on automatic pollen and fungal spore monitoring within the CEN/TC 264/WG 39.

The specific objectives are

1. To develop traceable methods (e.g. light scattering and particle flow visualisation) for the calibration of automatic bioaerosol monitors with respect to particle size and number concentration (target expanded uncertainty $\leq 15\%$). This includes providing clear guidelines to end users about the specifications, limitations and application range of each primary method.
2. To develop methods for training and validating machine learning (ML) and conventional algorithms, which identify airborne pollen taxa and fungal spore species in real-time, based on the collection of bioaerosol particles from natural sources, appropriate conditioning/treatment in the laboratory and controlled re-dispersion in air. In addition, to develop methods for quantifying the accuracy of the algorithms and for deriving a combined uncertainty arising from uncertainties in both particle counting and particle identification (target expanded uncertainty $\leq 30\%$).
3. To standardise the data output, interface and metadata of the automatic bioaerosol monitors. This includes developing guidelines on data storage, handling and distribution, ensuring data availability and accessibility compliant with EU Environmental regulations, in particular with the Inspire Directive.
4. To contribute to the development of a new standard on automatic pollen and fungal spore monitoring within the CEN/TC 264/WG 39 – Sampling and Analysis of Airborne Pollen Grains and Fungal Spores, this includes contribution to the revision of existing standards published by CEN/TC 264/WG 28 – Measurement of Airborne Microorganisms in Ambient Air.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (BIPM/CCQM workshop on particle metrology, EUMETNET AutoPollen), standards developing organisations (CEN/TC 264/WG 39, CEN/TC 264/WG 28) and end users (SYLVA project).

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. In particular, proposers should outline the achievements of the EMPIR project 19ENV08 Aeromet II project and how their proposal will build on those.

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 and health 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.