Title: Metrology to underpin air quality measurements using low cost sensor systems

Abstract

Environmental pollution causes adverse effects on human health; therefore, air quality needs to be monitored using measurement networks. At present, these networks do not provide sufficient coverage. New low-cost sensor systems have the potential to revolutionise ambient air quality monitoring with the prospect of delivering spatially dense pollution data rapidly in real time through the implementation of new large networks, which complement the established reference measurement methods defined in EU Air Quality Directives. Further work is needed to address the metrology issues required to facilitate the uptake and application of this new technology. These advances will deliver cheaper and robust compliance with air quality legislation with the goal of reducing ambient air pollution and the risks it poses to human health.

Keywords

Air quality monitoring networks, big data, calibration, European technical specification, field collocation studies, gas sensing, laboratory testing, low cost sensor systems, particulate material sensing, pollutant source apportionment, PM (particulate material)

Background to the Metrological Challenges

Air pollution poses a serious risk to human health as it contributes to conditions such as chronic obstructive pulmonary disease, asthma and heart disease. In the EU there are 391 000 premature deaths per annum associated with $PM_{2.5}$ and 69 000 for NO_2, leading to an economic impact of 24 billion €. Local and national authorities are required to manage and reduce air pollution to meet EU Air Quality Directives (e.g. 2008/50/EC).

Air quality measurement networks currently depend on high quality, but low time resolution, reference measurement data generated from a small number of discretely positioned expensive continuous reference monitors that measure trace gases and particulate matter. Such high-quality measurements with low uncertainties comply with EU Directives, but the low numbers of instruments used means that they provide limited data for local pollutant source apportionment, on the local pollution climate, on atmospheric chemistry processes, or on individual exposure, and the usefulness of this information decays with the distance from the monitoring point. In addition, the siting of the reference instruments may miss newly polluted sites. To increase coverage, supplementary indicative spot monitoring of average concentrations is often performed using low cost diffusive samplers, with a much higher uncertainty, but this does not provide real-time data and the data suffers from well-known biases. There is also a reliance on atmospheric computer models to predict the regional distribution of pollution, but these models may lack validation.

CEN TC264 (Air Quality) WG42 is developing a European technical specification for air- and particulate material-based sensor systems to cover regulatory reporting and non-compliance targeted measurements, through a new work item. The draft technical specification proposes several cost effective optional routes in the type-testing programme based on a balance of field and laboratory tests. However, field collocation studies and laboratory tests, using low cost sensor systems, need to be performed to demonstrate whether the draft technical specification is fit-for-purpose. This will lead to a harmonised European technical specification being completed and validated through CEN TC264 WG42. Without this, there will still be a barrier to the technology being exploited more widely and this will prevent substantial industrial growth.

Low cost sensor systems, which can measure key chemical trace species and particulate material, are beginning to be used for ambient air quality monitoring and they are being marketed as “fit and forget” solutions, with claims that the data quality is either comparable or better than other commercial methods. At present, the air quality measurements obtained from such systems are poorly characterised and there is no standard method of verifying that the data meets the performance requirements for regulatory reporting. Therefore, state-of-the-art pan-European field and laboratory facilities are needed to traceably demonstrate the ability of these low-cost sensor systems to meet the new specialised type-testing requirements stated in the Air Quality Directives. In addition, the capability of the low-cost sensor systems, which can identify sensor malfunctioning and/or drift problems, needs to be validated in order to deliver robust and improved pollutant measurements. Portable calibration technology, for use as independent transfer standards, is also needed and the effects of site relocation, and long-term deployment, on sensor performance and data quality needs to be investigated too.

Low-cost air quality sensor systems will generate large amounts of data in real time that will be accessible through apps, exploiting the global positioning system (GPS) for time and location and general packet radio service (GPRS) for data transmission. In order to develop such a system, novel cost-effective cloud-based calibration and QA/QC (Quality Assurance / Quality Control) procedures need to be developed. These need to be based on the intelligent assessment of pollutant and tracer measurements either from the whole network, or a region of the network, and the use of collocated reference instrument data and/or the deployment of more frequently calibrated low-cost sensor systems as transfer standards needs to be investigated. In addition, a range of mathematical models will need to be developed to maximise the usefulness of the information generated from these large combined datasets. This will need to be merged with new sensor network approaches and this approach will need to be replicated in new networks. Therefore, cost effective cloud-based QA/QC and calibration are urgently needed.

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 air quality using low cost sensor systems.

The specific objectives are

1. To complete and validate a harmonised European technical specification for air- and Particulate Material (PM)-based sensor systems through CEN TC264 WG42. Field collocation studies and laboratory tests, using low cost sensor systems, should be used to deliver the required future type-testing infrastructure for the EU, including the assessment of the measurement uncertainty budgets.
2. To develop state-of-the-art pan-European field and laboratory facilities to traceably demonstrate the ability of low cost sensor systems to meet the new specialised type-testing requirements stated in the Air Quality Directives, for both particulate material ($PM_{2.5}$, PM_{10}) and for molecules such as NO_2, O_3, NO, CO, SO_2, and CO_2.
3. To validate the capability of low cost sensor systems, which can identify sensor malfunctioning and/or drift problems, to deliver robust and improved pollutant measurements. Portable calibration technology, for use as independent transfer standards, should also be developed. In addition, to investigate the effects of site relocation, and long-term deployment, on sensor performance and data quality.
4. To develop and implement cost effective cloud-based QA/QC (Quality Assurance / Quality Control) and calibration. Maximum use should be made of multiple species pollutant data from (i) networks of sensor systems, (ii) collocated static reference measurements, (iii) the use of transfer standards, and (iv) mobile measurements. In addition, to develop a range of mathematical models to maximise the usefulness of the information generated from these large combined datasets, to merge this with new sensor network approaches and to replicate this approach in new networks.
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. air quality networks).

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.

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 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.