PAS 4023:2023

Selection, deployment and quality control of low-cost air quality sensor systems in outdoor ambient air – Code of practice

Department for Environment Food & Rural Affairs

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Foreword

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It has been assumed in the preparation of this PAS that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The provisions of this document are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

The word "should" is used to express recommendations of this PAS. The word "may" is used in the text to express permissibility, e.g. as an alternative to the primary recommendation of the clause. The word "can" is used to express possibility, e.g. a consequence of an action or an event.

Notes and commentaries are provided throughout the text of this document. Notes give references and additional information that are important but do not form part of the recommendations. Commentaries give background information.

Where words have alternative spellings, the preferred spelling of the Shorter Oxford English Dictionary is used (e.g. "organization" rather than "organisation").

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Introduction

Recent developments in air quality monitoring have resulted in new sensor systems that potentially provide an informative low-cost addition to reference methods. Such sensor systems are expected to allow air pollution monitoring to be performed at a lower cost and with a higher spatial density than is possible with the current reference methods. They also allow for new source apportionment and calibration methodologies, when coupled with spatial information, to provide a much better understanding of an individual's or group's exposure to air pollutants.

The potential advantages of low-cost air quality sensor systems include the following:

- small footprint making them easily deployable in the urban environment;
- larger area coverage than fixed point measurements if a network approach is implemented and improved spatial and temporal resolution; and
- potential of continuous calibration through co-location with reference style analysers and a network calibration.

For these advantages to be exploited, it is important that robust quality assurance is performed on the data produced.

This PAS has been developed to provide recommendations and guidance to users to:

- select sensor systems appropriate for their monitoring needs;
- deploy sensors in a way that promotes representative sample collection; and
- undertake the quality assurance (QA) processes to generate good quality data from these systems.

Additional information is also provided in four annexes as follows:

- Possible monitoring scenarios (Annex A);
- Examples of network calibrations (Annex B);
- Case studies on improving the comparability of sensor systems (Annex C); and
- Sensor technologies and performance issues (Annex D).

The sensor systems are based upon several principles of operation, including:

- electrochemical for NO_2, NO, SO_2, CO and O_3;
- light scattering optical particle counter for PM_{10}, $PM_{2.5}$ and PM_1; and
- non-dispersive infrared (NDIR) for CO_2.

The sensor systems can also continuously monitor air pollution, with fast response times ranging between a few tens of seconds to a few minutes, but presently with a reduced measurement accuracy (higher uncertainty) and lower precision.

NOTE 1 *The term "low cost" refers to the initial purchase price of a single air quality sensor system and is not an indicator of measurement accuracy. The cost is dependent on the number of pollutant sensors employed and users implementing a large network of systems. The cost of necessary co-location deployments, quality checking and adjustment can be substantial. Examples of these costs are sensor replacement, installation, removal, consent issues/legal, power access, co-location charges and data processing. Most importantly, the purchase price might not account for additional ongoing charges for access to the measurement data. Whilst the UK has performance standards for reference quality instruments, and guidance for monitoring under Local Air Quality Management (LAQM) application, there is no formal code of practice for the evaluation, deployment and use of low cost sensors and networks composed of these sensors.*

NOTE 2 *Although "low-cost" air quality sensor systems have advanced significantly, there are currently no validated published documentary standards against which to judge their performance and therefore cannot be used for official compliance reporting against limit values. PD CEN/TS 17660-1, however, provides information on how to test the performance of these types of sensor systems for gaseous species.*

1 Scope

This PAS provides recommendations for the selection, deployment, maintenance and quality assurance of low-cost air quality sensor systems as standalone units or as part of a network, for the measurement of outdoor ambient air as suited to their application and desired purpose. This includes systems that are static in position and semi-permanent in placement.

This PAS covers air quality sensor systems which measure one or more of the following gaseous or particulate pollutants:

- nitrogen dioxide (NO_2);
- oxides of nitrogen (NO_x);
- nitric oxide (NO);
- ozone (O_3);
- sulfur dioxide (SO_2);
- carbon monoxide (CO);
- carbon dioxide (CO_2); and
- particulate matter (PM_{10}, $PM_{2.5}$ and PM_1) in outdoor ambient air.

This PAS is intended for use by those aiming to monitor and report on air quality through the implementation of low-cost air quality sensor systems, including policy makers, local authorities, environmental health officers, citizen scientists, industrial users, sensor system manufacturers and suppliers, academics, researchers, and those with an interest in air quality quantification and improvement.

NOTE 1 *The PAS would be beneficial to those involved in delivering Local Air Quality Management (LAQM). Technical guidance on measurements for LAQM purposes is given in TG22 [1].*

This PAS does not cover:

- statutory legal reporting of data against national air quality objectives;
- passive diffusive tubes, e.g. Palmes diffusion tubes;
- pumped sorption tubes;
- total volatile organic compound (VOC) low-cost sensors;
- single hydrocarbon/VOC low-cost sensors;
- sensors providing an indoor air quality index (IAQ);

  NOTE 2 *This PAS acknowledges the use of sensors for measuring indoor air quality but provides no formal guidance or recommendations for making occupational health measurements or other indoor air measurements.*

- portable hand-held or wearable sensor systems;
- sensor systems used in mobile applications, both ambient and indoor air;
- the provision of intellectual property for the air quality sensor system specific technologies or specific products;
- the collection format and storage of data obtained from the sensor system, including any human interventions, such as for the analysis and interpretation of results;
- access to the data and the data format;
- making reliable measurements in confined spaces, including subways, tunnels or underground railways; and
- the use of air quality sensor systems for compliance monitoring and reporting, including demonstrating adherence to pollutant limit values or targets enshrined in legislation.

  NOTE 3 *Examples of such legislation include the Air Quality Standards Regulations 2010 [2], the Air Quality Standards (Scotland) Regulations 2010 [3], the Air Quality Standards (Wales) Regulations 2010 [4], the Air Quality Standards (Northern Ireland) Regulations 2010 [5] and the Environmental Targets (Fine Particulate Matter) (England) Regulations 2023 [6].*