NPL
National Physical Laboratory

AQ standards: an update on standardization for low-cost sensors

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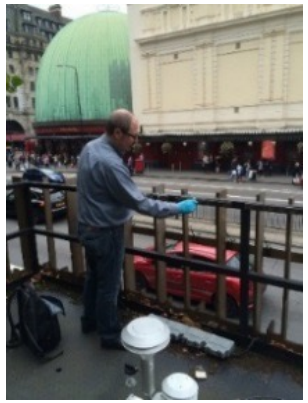
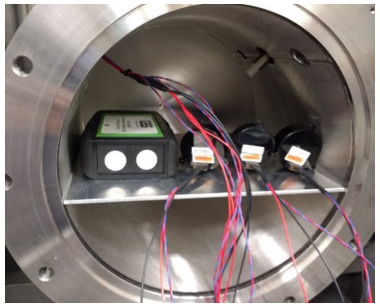
Introduction

- Current AQ monitoring
- Low cost powered sensor (LCS) systems
- European Standardization activities
- NPL's testing facilities
- Update on Publicly Available Specification (PAS)
- Summary





Current AQ monitoring

Well-characterised measuring system [Uncertainty, calibration, traceability, no reference to other sensor systems]

Reference measurements: Automatic Urban Rural Network (AURN)

- 171 sites of which 16 are part of the **Automatic London Network (ALN)**
- Measure: NO, NO_2, O_3, CO, SO_2, PM_{10} & $PM_{2.5}$

Reference network: data disseminated to the public on an hourly basis
https://uk-air.defra.gov.uk/data/

Indicative measurements: carried out using diffusion tubes (cheap, deploy over wide areas)

- LAs use as part of Local Air Quality Management (LAQM)
- Defra's UK Urban NO_2 Network (UUNN)
- After 28/35 day exposure, post chemical analysis, delivers average concentration

Low cost powered sensor systems

- Potential to transform AQ monitoring
- Many systems measure several pollutants: NO_2, NO, O_3 (electrochemical sensors), $PM_{2.5}$, PM_{10} (light scattering optical particle counter), CO_2 (non-dispersive infrared), T, RH, and P
- Rapid measurements (1 min vs 1 month) over wide geographical area
- Ambitious new networks are being implemented, personalised exposure (journey planning), citizen science (schools, infrastructure buildings)
- Large scale data, new ways to calibrate may need to be developed
- Over promising on performance?
- Standardization required (distinguish good from bad products)

European Standardization activities

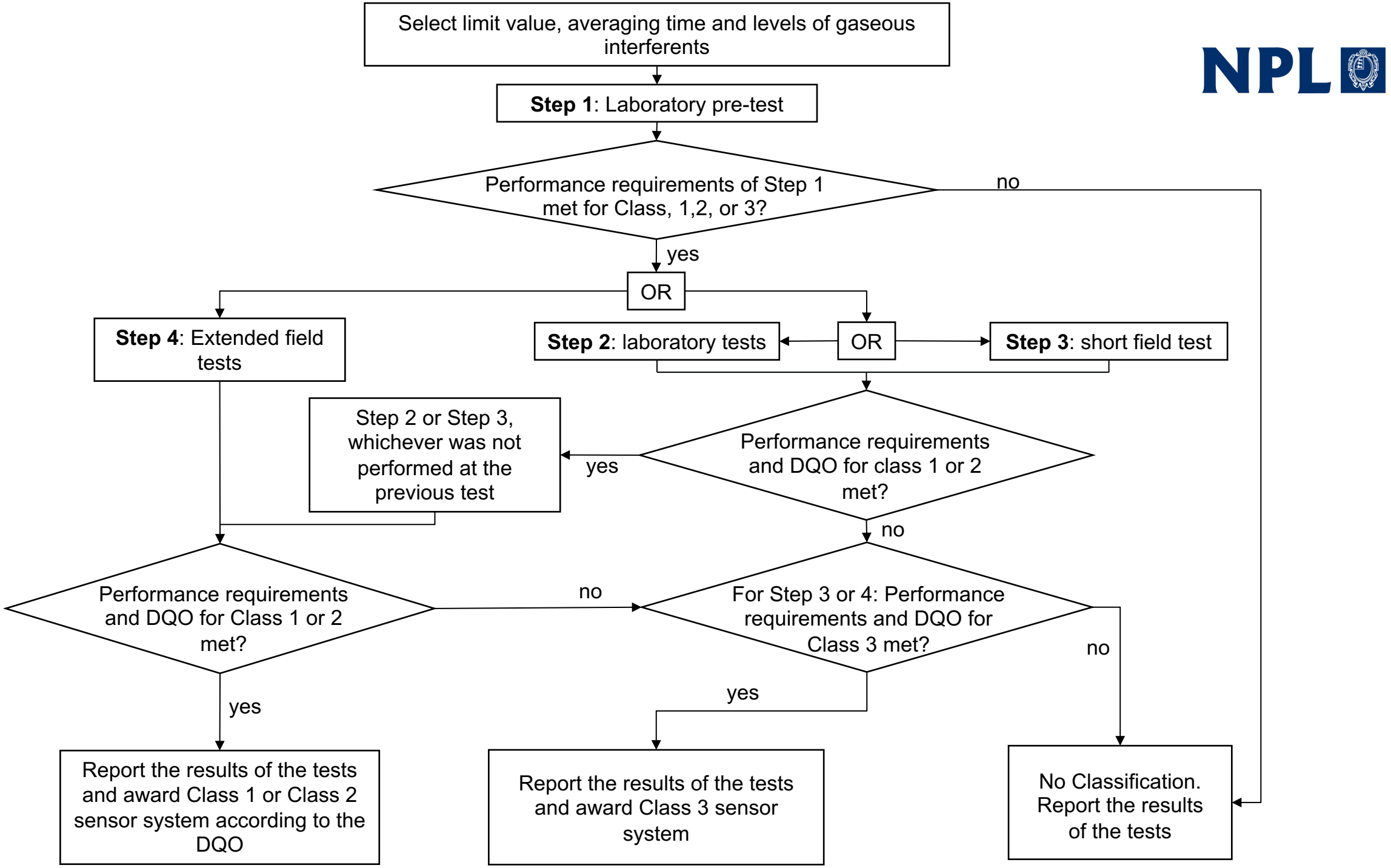
- European Committee for Standardization (CEN) (founded in 1961 with 34 national members) supports the consensus development of documentary European Standards (ENs) and Technical Specifications (TS)
- CEN TC264 WG42 has been developing a TS for low-cost sensors
- **CEN/TS 17760-1: 2021, Air quality-Performance evaluation of air quality sensor systems-Part 1 Gaseous pollutants in ambient air**
- TS is one stage down from a standard. Not yet validated
- UK will convert TS into an MCERTS document
- Part 2: Particulate matter in ambient air for PM_{10} and $PM_{2.5}$ (still in development)
- Final stages require agreement, translation of English version into French and German, and sending out for CEN enquiry before publication (2024?)
- Documents specify the general principles, including testing procedures and requirements, for the classification of performance of low-cost sensor systems

EU DQO (2008/50/EC)

Pollutant	Required uncertainty for reference method /%LV	DQO of Class 1 sensor system (indicative methods) / %LV	DQO of Class 2 sensor system (objective estimations) / %LV	DQO of Class 3 sensor system / %LV
SO_2, NO_2, NO, CO	15	**25**	75	200
O_3	15	**30**	75	200
benzene	25	**30**	100	200
PM_{10} and $PM_{2.5}$	25	**50**	100	200
Averaging periods (1, 8, 24 h, 1 year)				

Class 1 (indicative) and **Class 2** (objective estimations) for regulatory measurements. Uncertainty requirements defined in Directive 2008/50/EC

Class 3 sensor systems for non-regulatory purposes that have relaxed uncertainty requirements (specific research topics, educational purposes, citizen science


Select limit value, averaging time and levels of gaseous interferents
Step 1: Laboratory pre-test
Performance requirements of Step 1 met for Class, 1,2, or 3?
no
yes
OR
Step 4: Extended field tests
Step 2: laboratory tests
OR
Step 3: short field test
Step 2 or Step 3, whichever was not performed at the previous test
yes
Performance requirements and DQO for class 1 or 2 met?
no
Performance requirements and DQO for Class 1 or 2 met?
no
For Step 3 or 4: Performance requirements and DQO for Class 3 met?
yes
no
yes
Report the results of the tests and award Class 1 or Class 2 sensor system according to the DQO
Report the results of the tests and award Class 3 sensor system
No Classification. Report the results of the tests

NPL's testing facilities

- **Multiple Atmosphere Controlled Environment (MACE) facility**
- **Step 1 tests:** Response time, lack of fit, repeatability, limit of detection
- **Step 2 tests:** Long term drift, cross sensitivities by gaseous interfering compounds, temperature effect, humidity effect, memory effect, power supply effect, wind velocity, pressure effect, electromagnetic fields effect
- **Steps 3 and 4:** Short or extended field tests with collocated reference instruments

Field Tests (2 seasons (May-Sept and Nov-Mar) of 40 days duration)

Pollutant	Area types		Site types		Short field test (Step 3)	Extended field test (Step 4)
	urban/suburban	rural	traffic	background	total sites	total sites
NO_2	x	-	x	x	2	4
NO	x	-	x	x	2	4
O_3	x	x	-	x	2	4
CO	x	-	x	x	2	4
SO_2	x	-	-	x	1	2
Benzene	x	-	x	-	1	2

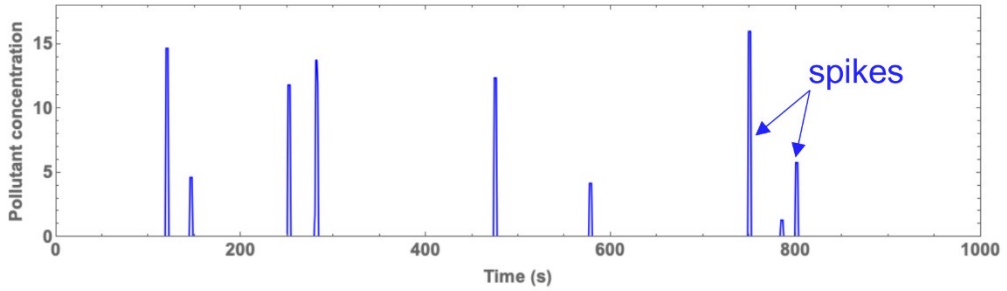
Additional laboratory tests for PM
Humidity test to identify problems with over reading
Coarse PM test to identify systems not measuring PM_{10}

Update on Publicly Available Specification (PAS)

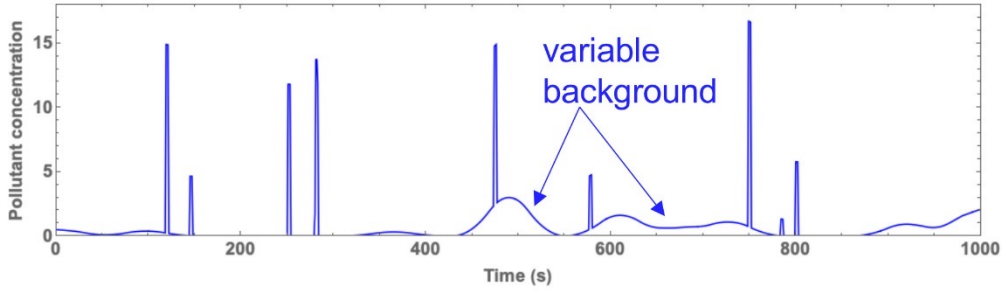
- Defra sponsored BSI to commission NPL to develop UK PAS on Air quality monitors – Selection, deployment, and quality control of mountable, static air quality monitors in ambient air – Code of Practice
- How to use LCS
- Not for compliance monitoring (Defra)
- Document identifies particular monitoring categories: single short-, long-term in one location, long term monitoring with a network
- Deployment and maintenance, calibration regimes and quality control, appendices: senor technologies in use, performance issues, performance evaluation, facilities for carrying out tests, cloud-based calibration, data quality bands, case studies (inter-device precision, collocation calibrations, location transfer)

Low cost sensors: cloud based calibration

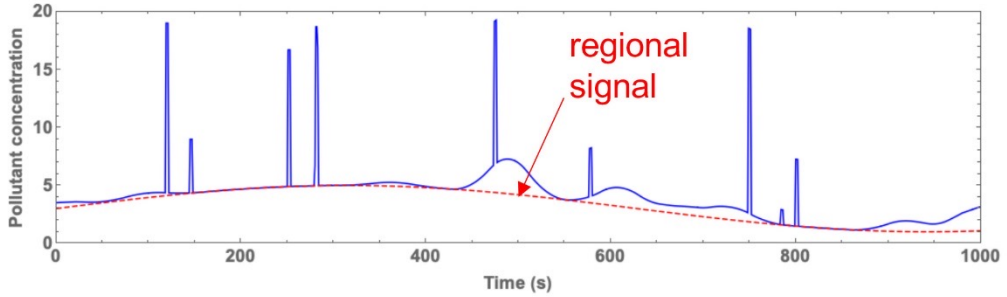
- Combined response is composed of different source signatures



Sources (e.g. vehicles)
local to sensor
- ‘spikes’



Dispersed sources
~local to sensor
- ‘variable background’



Regional signal

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Summary

- Emphasised the role for standardization in use of LCS for AQ monitoring (CEN + BSI)
- LCS role additional to, and not replacing reference instruments
- New ways to operate networks
- PAS consultation now open
- https://standardsdevelopment.bsigroup.com/projects/2022-00710#/section to view the draft
- https://standardsdevelopment.bsigroup.com/Home/Help.
- The closing date for the public consultation is **5 July 2023**
- **Please send in case studies**

Thank-you for listening