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The road to developing performance standards in Europe for low cost sensors-Part 1: Example of implementation of an existing reference instrument standardisation method

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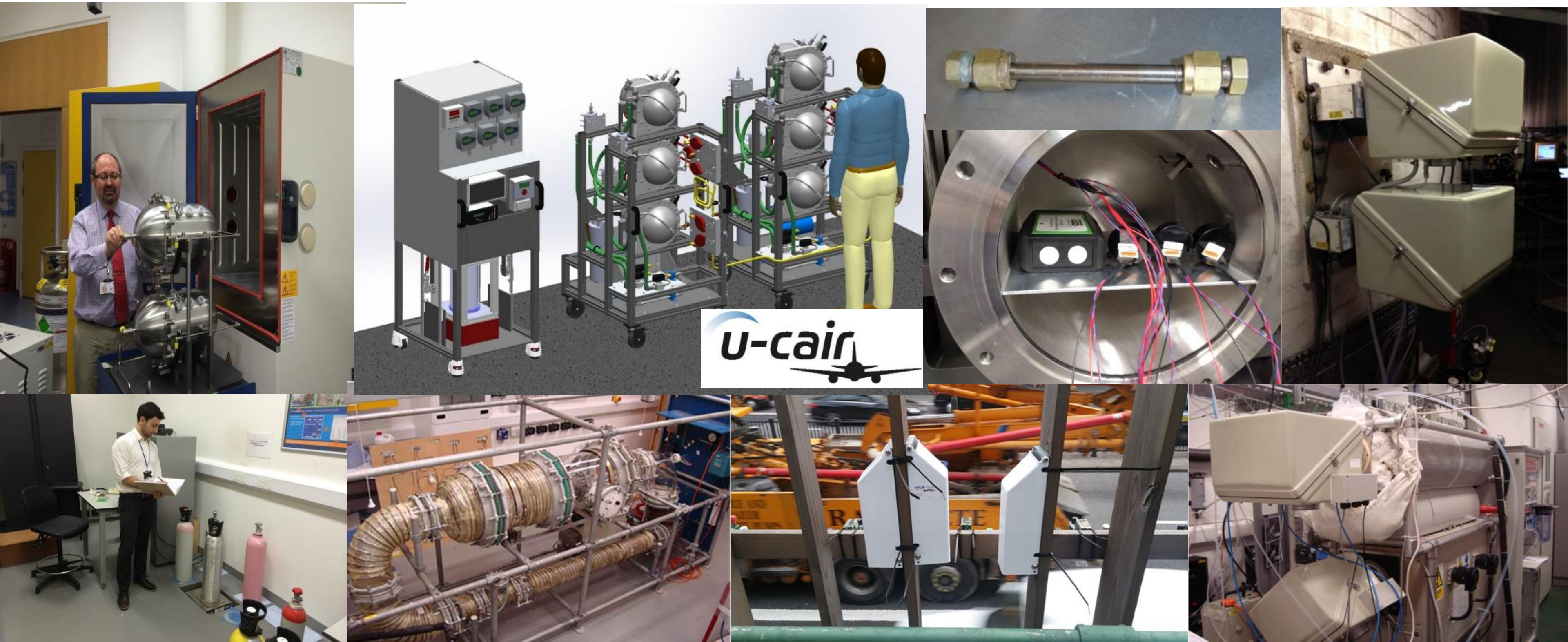
EPA AIR SENSORS 2018
25th June 2018

Introduction

- What is NPL and what does it do?
- European Standardisation Activities and NPL's role
- How are instruments type-tested at NPL and certified?
- Why do we need a different approach for low cost sensors?
- Conclusions



What is NPL and what does it do?

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- Founded in 1900, UK's NMI, respected centre of excellence in research and development, including applications in environmental monitoring
- NPL sits at the heart of an important infrastructure designed to ensure accuracy and consistency with traceability in all physical measurements, in support of business and society
- Government owned, government operated ("GOGO") with ~1000 personnel (scientists, students, and maintenance)
- International role in standardisation, developing laboratory and field test facilities, traceable Primary Standard gas Mixtures (PSMs), runs AQ networks (and QA/QC)

European Standardisation Activities

- Goal of European Commission is harmonised implementation of AQ legislation in EU through responsible bodies and by use of reference measurement methods
- European Committee for Standardization, Comité Européen de Normalisation (CEN)
- NPL is well represented on TC264 which is the standardisation committee responsible for all European documentary standards on emissions to air and ambient air measurements
- "Translating" technical requirements of EU Directives into European Standards carried out by the various WGs including WG42 on AQ Sensors, WG11(diffusive samplers), WG12 (benzene)

How are instruments certified?

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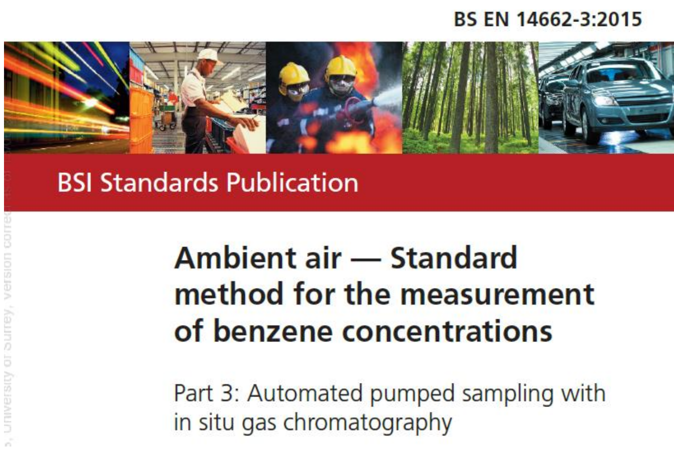
- Continuous ambient monitors (CAMs) generate measurements with the lowest uncertainties to comply with EU AQ Directives (2008/50/EC and its daughters) [REFERENCE METHODS defined]
- Comprehensive, pollutant-specific, and rigorous type-testing procedures carried out before the method is allowed to be used in AQ Networks that report monitoring data to the European Commission
- Tests in accordance with UK certification scheme called MCERTS and the harmonised European Standard EN14662-3 (for benzene), by accredited laboratories (e.g., ISO17025)


BS EN 14662-3:2015

BSI Standards Publication

Ambient air — Standard method for the measurement of benzene concentrations

Part 3: Automated pumped sampling with in situ gas chromatography

How are instruments certified?

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- Procedures include laboratory tests covering extremes of conditions and field tests lasting three months
- 2 instruments tested at key benzene concentrations: 1/10xLV, LV, Span

Performance characteristic	Performance criterion	Performance characteristic	Performance criterion
Repeatability standard deviation at 10% of AL	≤ 0.20 µg/m³	Interference of H_2O at 19 mmol/mol (80% RH) for AL	≤0.015 µg/m³/mmol/mol
Repeatability standard deviation at AL	≤ 0.25 µg/m³	Interference of organic compound mixture for AL	≤ 0.50 µg/m³
Lack of fit	≤ 5% of measured value	Carry over (memory effect)	≤1.0 µg/m³
Sensitivity coefficient of sample gas pressure	≤ 0.40 µg/m³/kPa	Short term drift at span level	≤ 2.0 µg/m³ over 12 h
Sensitivity coefficient of surrounding temperature	≤ 0.08 µg/m³/K	Difference sample/calibration port	≤ 1%
Sensitivity coefficient of electrical voltage	≤ 0.08 µg/m³/V		

How are instruments certified?

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Performance characteristic	Performance criterion
Reproducibility standard deviation under field conditions (correlation between 2 identical instruments)	≤0.25µg/m^3
Long term drift at span level	≤10% of maximum of certification range
Period of unattended operation (maintenance interval between manufacturer's intervention	>14 days or less if manufacturer indicates a shorter period
Availability of the analyser (% useful data retrieved during trial)	>90%

How are instruments certified?

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- Test results for the performance criteria are used to calculate individual standard uncertainty components (µg /m³), including the calibration gas
- Combined uncertainty, u_c , calculated by summing in quadrature:

$$u_c = \sqrt{\sum_{i=1}^{N} u_i^2}$$

- Then divide by Annual Limit for benzene (5 µg/m³)
- Expanded uncertainty at 95% confidence level, U= 2 x u_c
- Must be less than ± 25% as required by EU Directives for benzene reference measurements
- PASS (Report -> Certification Body CSA awards MCERTS)

Why we need a different approach for low cost sensors

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- New sensor developments focussed on spatially dense networks generating large scale data with high time resolution to complement reference measurements
- Used for atmospheric modelling and predicting air pollution in real time, air management for “intelligent buildings” to reduce energy consumption, adaptive air control systems on aircraft, neighbourhood “citizen science” projects
- Limited data already available suggests that many systems perform less well than has been claimed by their manufacturers, peer review process bypassed, IP retained
- WG42 (since 2015) TS “Performance evaluation of sensors for the determination of concentrations of gaseous pollutants and particulate matter in ambient air.“

Why do we need a different approach for low cost sensors?

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Pollutant	Required uncertainty of reference methods	Expanded uncertainty of indicative methods (Class 1 sensor system)	Expanded uncertainty of objective estimations (Class 2 sensor system)	Expanded uncertainty of Class 3 sensor system
SO_2, NO_2/NO_x, CO	15%	25%	75%	N/A
Benzene	25%	30%	100%	N/A
$PM_{10}/PM_{2.5}$	25%	50%	100%	N/A
O_3	15%	30%	100%	N/A
Thresholds†	>UAT	UAT<[ ]<LAT	<LAT	N/A

†UAT = Upper Assessment Threshold, LAT = Lower Assessment Threshold, [ ] = concentration. **EU DQO (2008/50/EC)**

- Current methodology focusses on the measurement of a pollutant, using a well-characterised measuring system
- A network of sensor systems is more than just the sum of its individual nodes
- Information at one node of the network can be exchanged with other nodes, and used to make inferences at nearby nodes

Conclusions

- Current robust approach to the certification of reference instruments needs to be adapted to meet the new requirements of networks of low cost sensors
- Standardisation will overcome market barriers by defining performance requirements to demonstrate that they are fit for purpose for a range of applications (so results are accepted by stakeholders)
- Promote research into new technologies (not just fine tuning of existing methods) because developers will see a potential market to pay for their investment
- To maximise the potential benefits new thinking is required to take into account linkages between sensor systems