NPL
National Physical Laboratory

Air Quality & Aerosol Metrology at NPL

30th September 2025

Jordan Tompkins

National Physical Laboratory

- UK's National Measurement Institute founded in 1900
- Public Corporation owned by Dept for Business, Energy & Industrial Strategy
- 1000+ scientists, 200+ visiting researchers
- Independent and impartial advice
- World-leading breadth and depth of metrology expertise

Air Quality and Aerosol Metrology Group

- Develops traceable methods for measurements of air pollutants, and particles in gases
- Ensures international comparability of measurements
- 20 staff + 3 PhD students + 2 sandwich students

Department for Business, Energy & Industrial Strategy

Air Quality and Aerosol Metrology Group

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Measurements for industry

- Accredited calibration of instruments for:
  - Air quality monitoring
  - Engine emissions
- Bespoke sensor / instrument testing and characterisation; proficiency testing
- Analysis of samples particles in air for metals, EC/OC, etc
- On-side measurements of particulate emissions from industrial processes / health practices

Air quality Networks, policy and regulation

- Delivery of three ambient air quality monitoring networks for EA / Defra: assesses compliance to air quality targets
- Member of Defra Air Quality Expert Group
- Provide ad hoc advice to Defra, DfT, EA, etc.

Traceable measurement of physical properties of aerosols

Traceable measurement of the composition of particles in air

AQAM

Primary traceability for measurements of ozone in ambient air

Sensor / instrument testing and conformity assessment

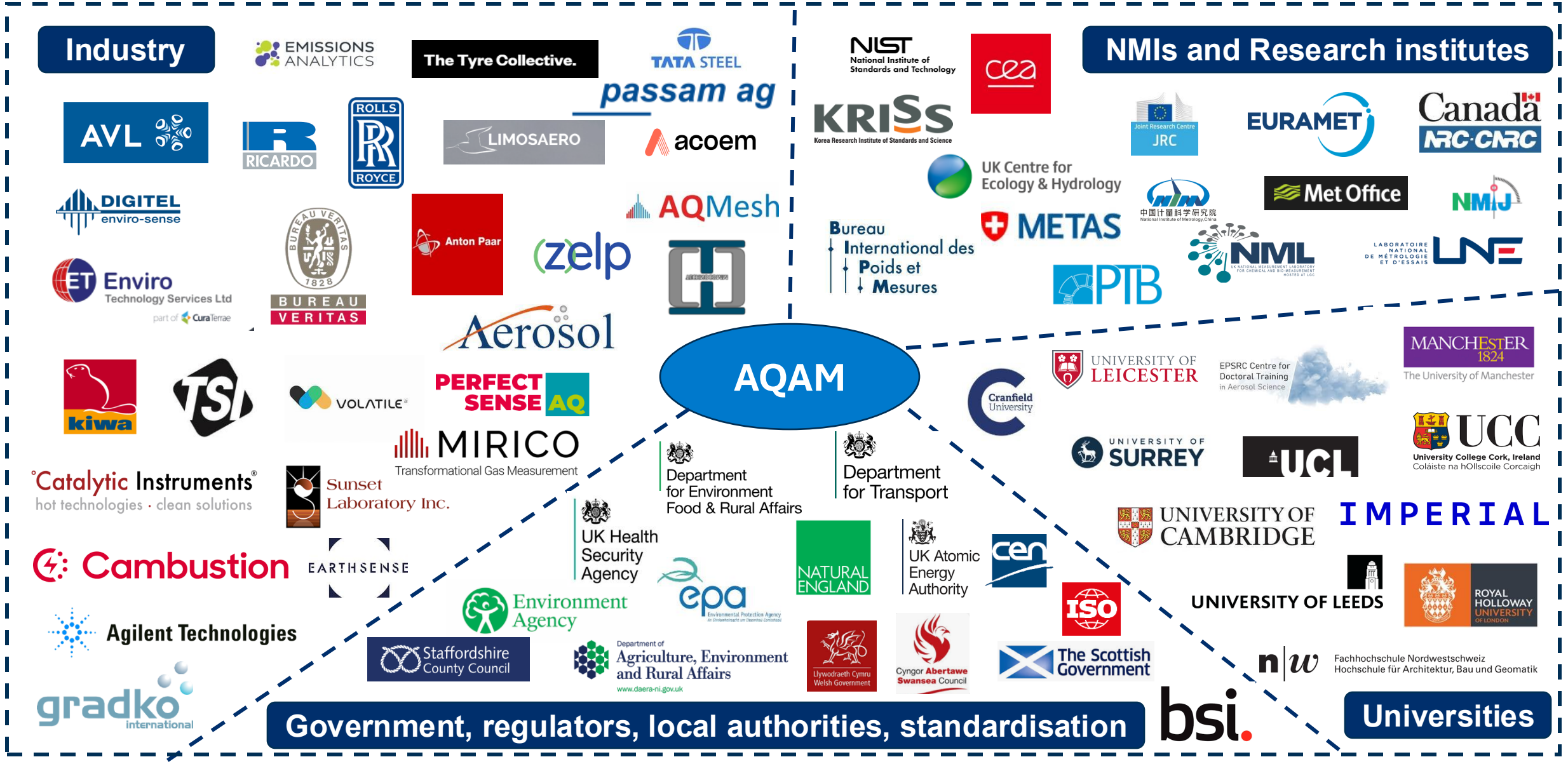
Knowledge leadership

- Chair / Convenorship of BSI & CEN ambient air committees
- Expert input into in numerous CEN & ISO WGs
- Established International Aerosol Metrology Task Group
- Member of numerous project advisory boards

Research & Development

- Novel, characterised reference particle sources
- Measurements of non-exhaust emissions
- Traceable calibrations of optical particle counters
- Characterised silver particles for improved CPC calibrations
- Traceability for measurements of black carbon
- Novel sensor validation and testing facilities
- Data algorithms for AQ sensor networks
- Assessing biodiversity through eDNA in airborne particulate matter
- Measuring lung deposited surface area concentration

Air Quality and Aerosol Metrology Group stakeholder map



Partnership with universities

- Strategic partnership with Universities of Surrey and Strathclyde since 2015 (Vice-Chancellors of the two universities sit on the NPL Board).

- Developing a presence for NPL across the UK through regional hubs, bringing expertise and services closer to user communities:

  - ✓ East of England with University of Cambridge (data science, quantum technology, life sciences)
  - ✓ North of England with University of Huddersfield (digital manufacturing, graphene & 2D materials)
  - ✓ South of England with University of Surrey (telecommunications, space)
  - ✓ Scotland with University of Strathclyde (smart grids, medical physics)

- Postgraduate Institute which trains up to 300 PhD students and provides a pipeline of skilled researchers.

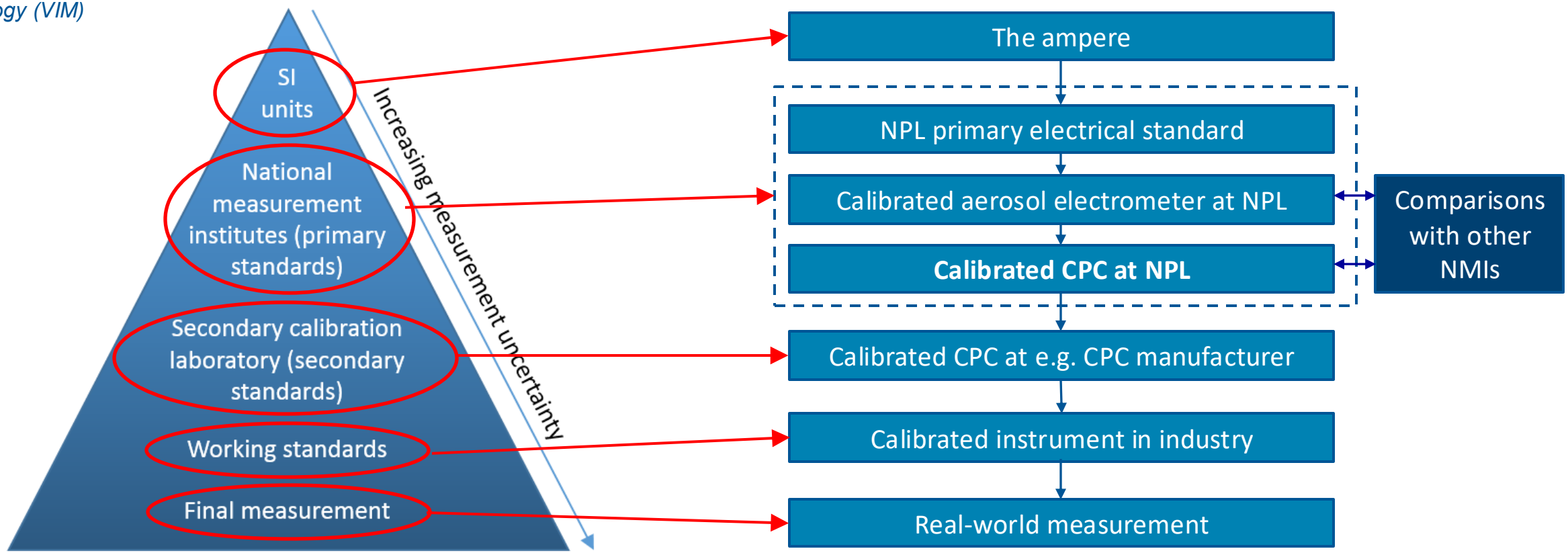
Traceability

metrological traceability

property of a **measurement result** whereby the result can be related to a reference through a documented unbroken chain of **calibrations**, each contributing to the **measurement uncertainty**

International Vocabulary of Metrology (VIM)

Example: Calibration condensation particle counters (CPC) to measure particle number concentration



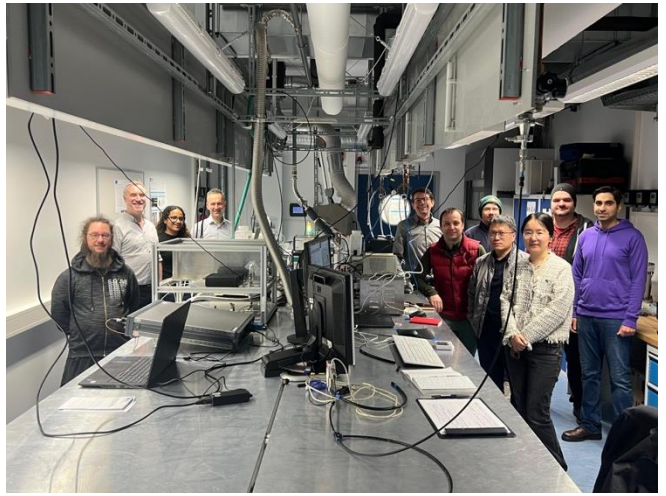
CCQM-K187/P235

Part	Particle type (and size)	Particle number concentrations / cm^{-3}	Particle charge concentrations / $fC\ cm^{-3}$
A-CPC (monodisperse)	Monodisperse soot (30 nm and 50 nm)	1 000, 4 000, 10 000, 20 000, 50 000 and 100 000	-
A-AE	Monodisperse soot (30 nm and 50 nm)	-	0.16, 0.64, 1.6, 3.2, 8.0 and 16.0
B-CPC (polydisperse)	Polydisperse soot (80 nm)	50 000, 100 000, 250 000 and 500 000	-

Measurement campaign held at PTB, November 2024

CCQM-P237:
NIM, NPL, PTB, TROPOS, and UBA

CCQM-K185:
KRISS, METAS, NIM, NMIJ/ AIST, NMC/A*STAR, NPL, PTB



PTB aerosol generation and testing facility

UK ambient air quality networks operated by NPL

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Heavy metals network

- Metals content of PM_{10} measured at 23 sites (urban/industrial and rural): As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Se, V, Zn
- Metals in deposition measured at five rural sites
- Measurements of metals in PM_{10} are carried out at NPL using inductively coupled plasma mass spectrometry (ICP-MS)

Particle numbers and concentrations network

- Network comprises four sites (two rural sites and two sites in London)
- Measurements:
  - Particle number concentration (larger than 7 nm): three sites
  - Particle size distribution: three sites
  - Organic carbon / elemental carbon in $PM_{2.5}$: four sites
  - Anions, cations and organic mass concentration: three sites
  - Elemental analysis: two sites

Black carbon network

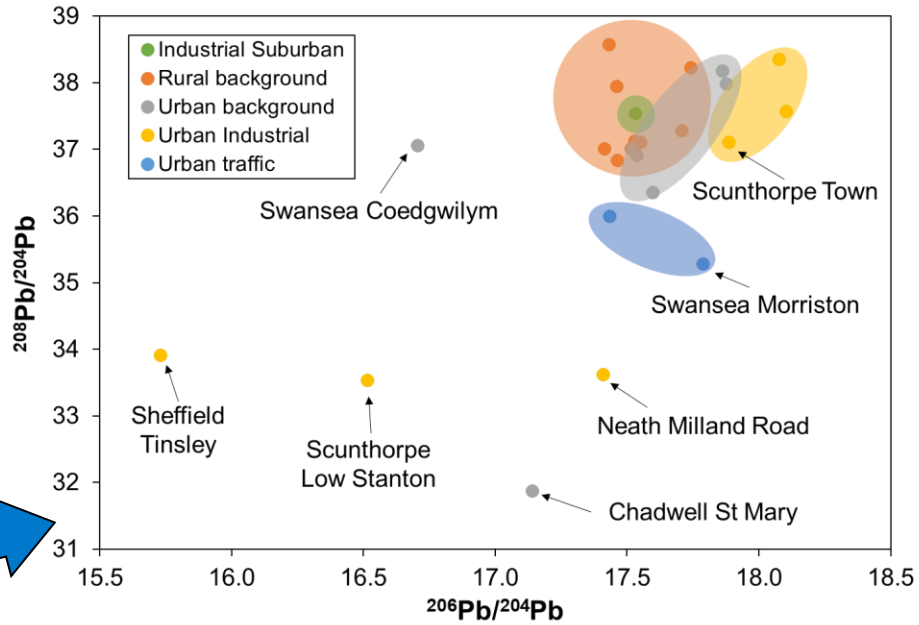
- Measurement of black carbon concentrations at 14 sites using 7-channel (AE33 model) aethalometers
- Sites are focussed in areas of high solid fuel burning
- IR channel indicates the concentration of black carbon; UV channel indicates the presence of aromatic organic compounds

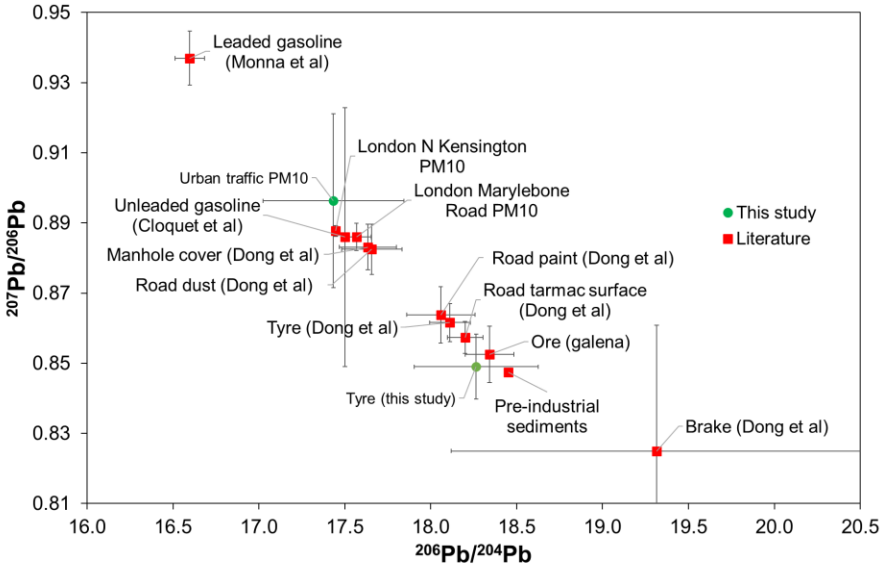
Royal Society of Chemistry Technical Excellence Prize

For the outstanding application of knowledge and teamwork to produce 20 years of robust, high-quality air pollutant data for three of the UK's air quality networks, advancing science, informing policy makers, and protecting the health of the public.

Source apportionment of Pb by isotope ratios

- Network sites in close proximity to steel or metal processing plants have the highest lead concentrations
- ICP-MS/MS method developed to measure ^{204}Pb, ^{206}Pb, ^{207}Pb & ^{208}Pb. Method validated against NIST SRM 891 (lead wire) for isotope ratios
- Samples from all network sites analysed for Pb isotope ratios
- Sites generally form clusters based on the site type, with some exceptions
- Measured isotope ratios for urban traffic sites are in agreement with studies in the literature

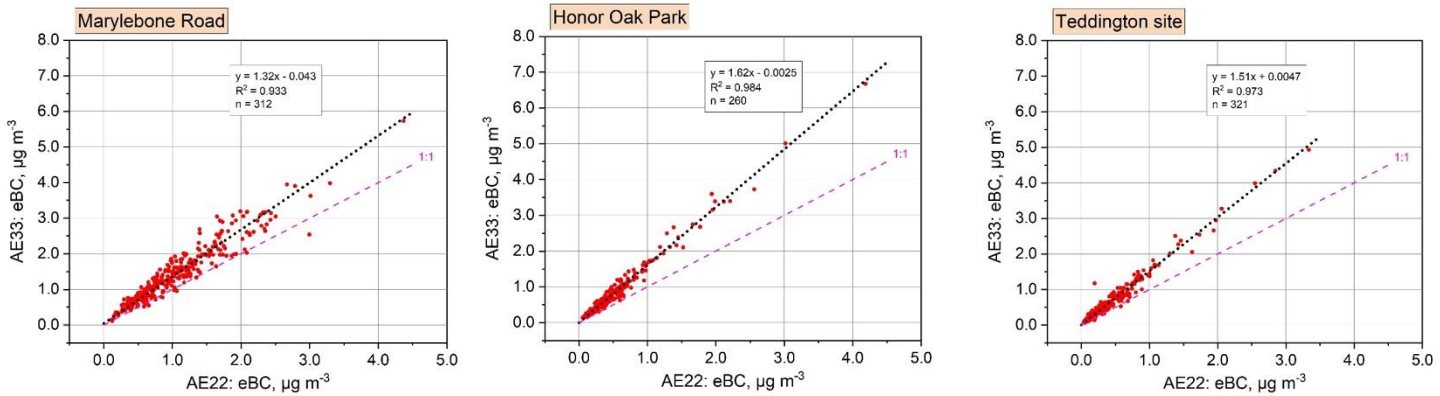




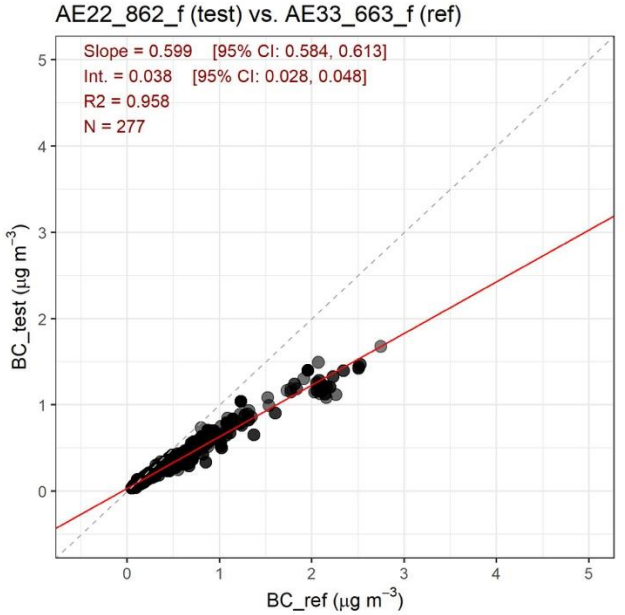
E. Braysher *et al*, DOI: 10.3390/atmos16030283

Comparison of aethalometer models

- Aethalometers used for measuring black carbon mass concs (as ‘equivalent black carbon’ (eBC)) in UK air quality network
- AE22 models swapped for AE33 models in November 2019
- Comparison at three sites showed a model-dependent constant difference between AE22 & AE33s



PARAMETER	AE22	AE33
No. of wavelengths	2	7
Filter material	Quartz	Teflon
Loading effect compensation	No	Yes
Inlet flow	4 lpm	5 lpm



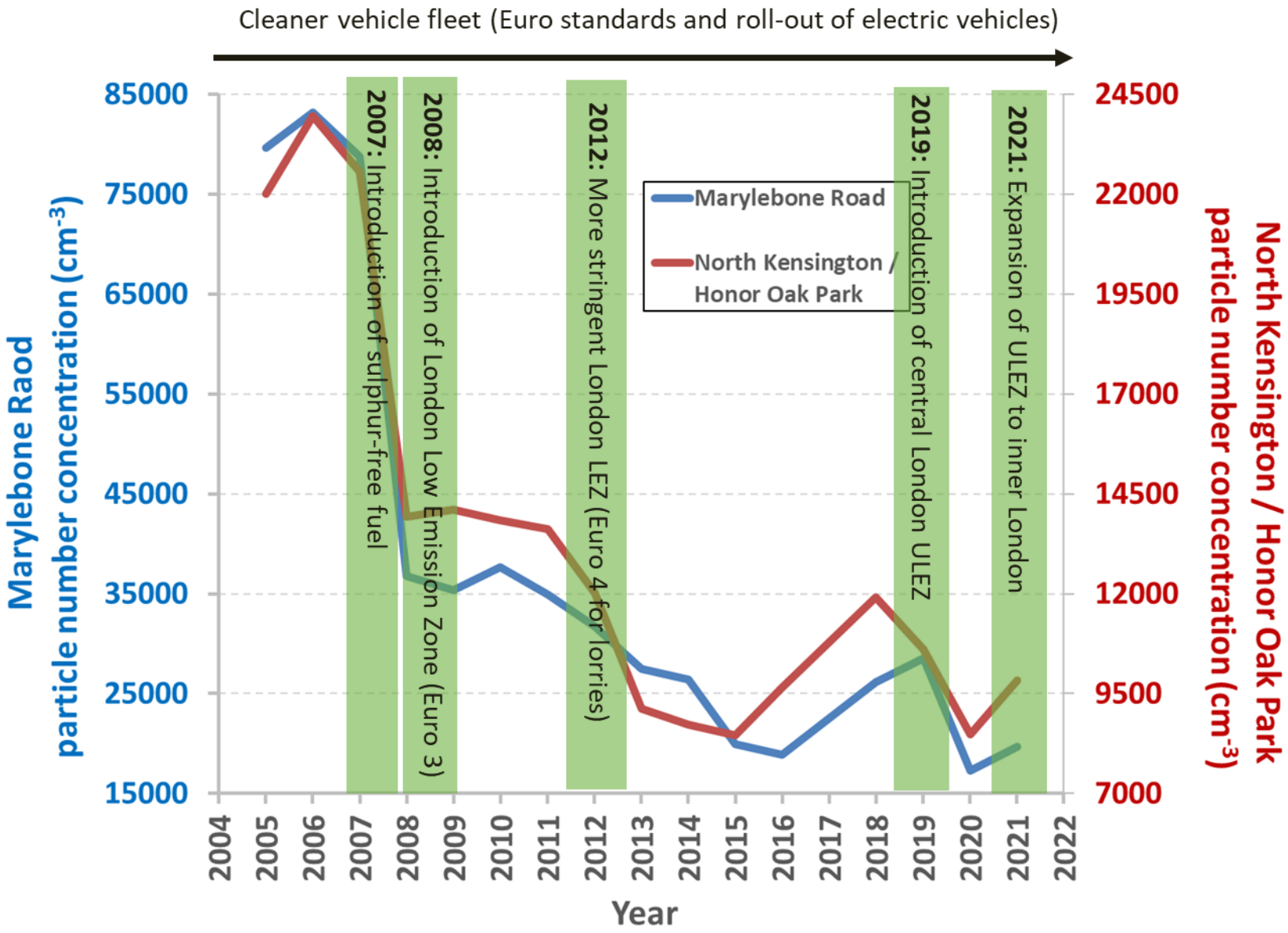
- More extensive follow-up study found that all AE22 instruments were comparable within 10% (after servicing)
- The agreement between models can be improved by appropriate application of parameters (e.g. multiple-scattering factor (C), mass absorption cross-section (MAC) and other AE22 and AE33 model-specific parameters. This is not standardised. Default values were used during this study

Particle number concentrations in London

Marylebone Road
[Urban traffic]

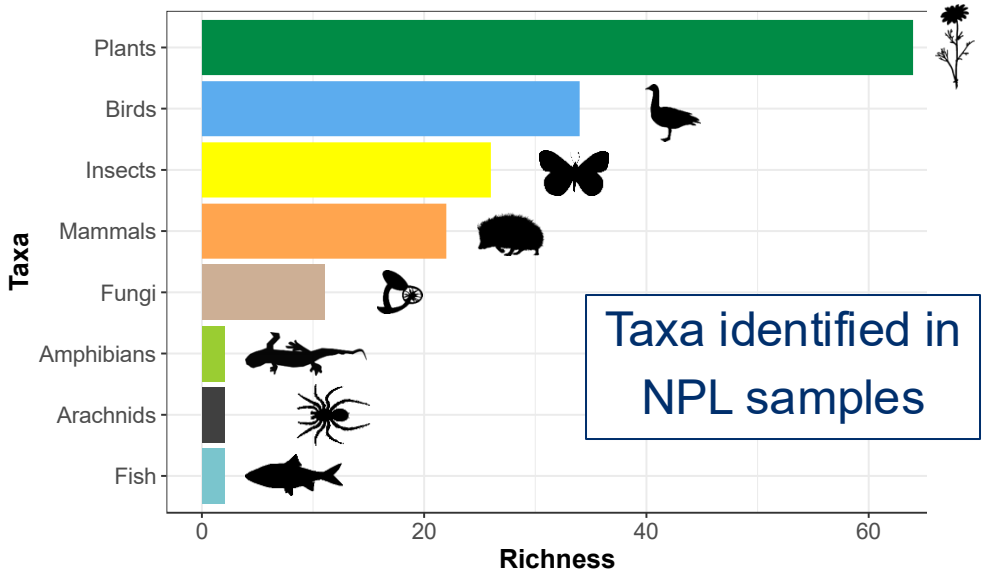
Honor Oak Park (North Kensington before 2019)
[Urban background]

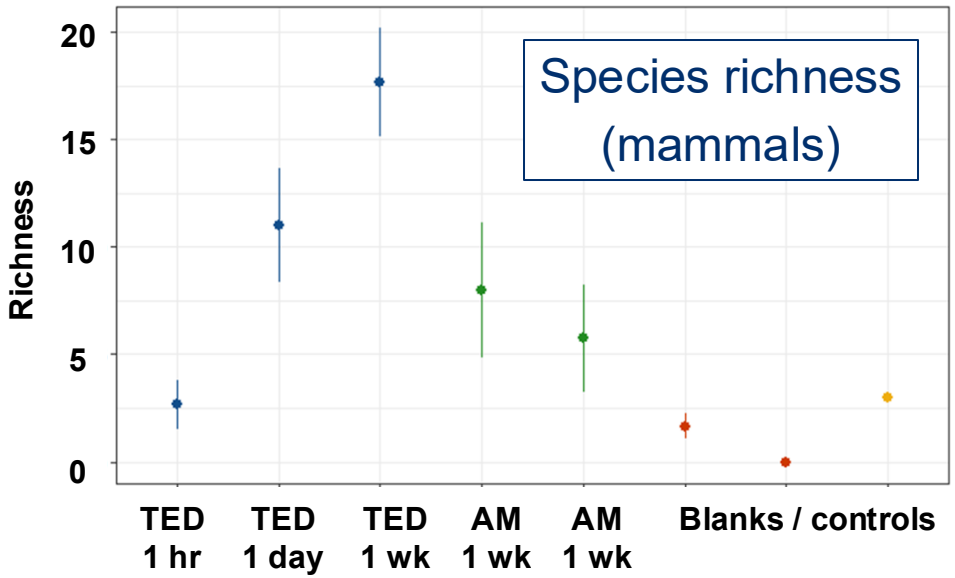
- Clear effect on particle number concentrations of early policy interventions
- Effect of more recent central and inner London ULEZ less clear



eDNA analysis of particulate matter to monitor biodiversity

- Pilot study to assess whether environmental DNA (eDNA) could be identified from sub-samples from the metals network
  - Auchencorth Moss (rural): PM_{10} samples, four week period
  - Teddington (urban background), TSP samples, 1 hour, 1 day and 1 week periods





J. Litttlefair *et al.* (2023) DOI: 10.1016/j.cub.2023.04.036

Condensation Particle Counter Calibrations with Silver Particles

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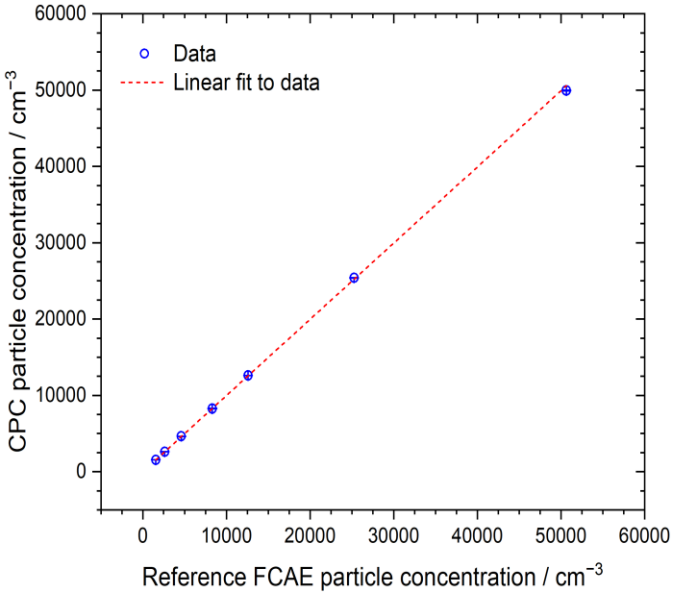
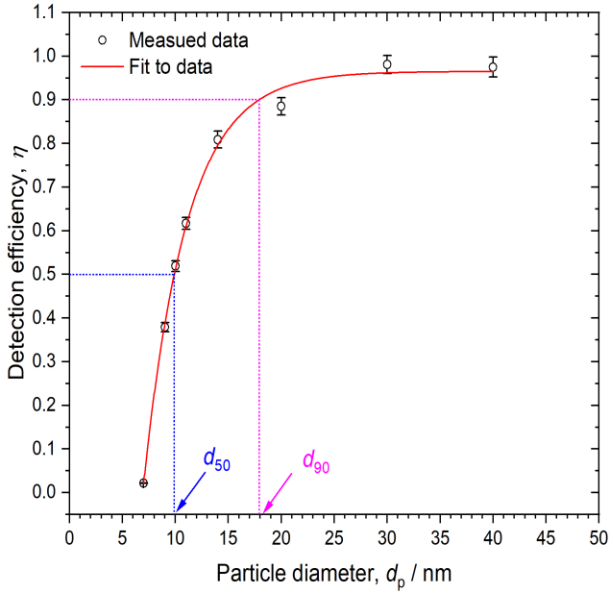
Latest EN 16976 standard drives use of silver particles:

- Defines method for using CPCs for measuring particles in ambient air.
- Specifically requires use of **spherical silver particles** for linearity and detection efficiency assessments.
- Sphericity achieved by using a sintering stage.

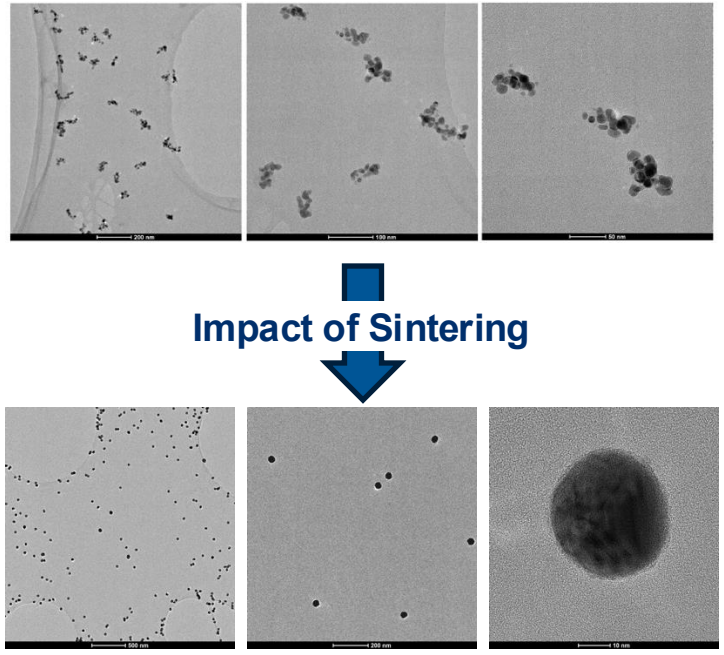
CPC Assessment Type	Particle Sizes Needed / nm	Particle Number Concentration Needed / cm^{-3}
Linearity Calibration	40	1 000 – 50 000
Detection Efficiency Assessment	7, 9, 10, 11, 14, 20, 30 and 40	1 000 – 3 000

Table 1: Additional requirements of Silver Particle Generator to perform compliant EN 16979 calibrations.





Linearity and detection efficiency assessments for a UK Air Quality site CPC using silver particles.



TEM images courtesy of NPL Biometrology group (above) and the University of Cambridge (below).

Delivered both linearity and detection efficiency assessments:

- UK Air Quality site CPCs calibrated using silver particles.
- CPCs now operating offsite following new outline of EN 16976 standard.

Non-exhaust emissions: tyre wear

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Environmental Science Processes & Impacts

ROYAL SOCIETY OF CHEMISTRY

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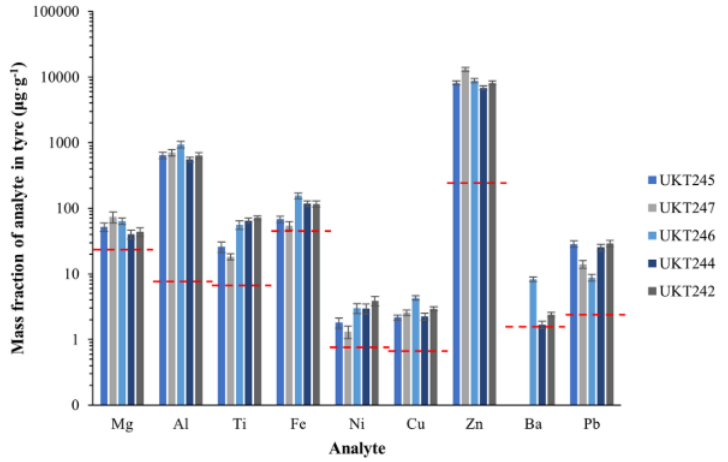
Cite this: *Environ. Sci.: Processes Impacts*, 2024, **26**, 298

Traceable determination of metal composition of tyres using tandem ICP-MS and benchmarking of emissions inventories†

Emma C. Braysher, *[a] Andrew S. Brown, [a] Richard J. C. Brown [a] and Nick Molden [b]



	Mg	Al	Ti	Fe	Ni	Cu	Zn	Ba	Pb
PM_{10} tyre emission rate (ng km^{-1})	273	3477	236	511	12.9	14.1	45 141	13.6	106
PM_{10} tyre emission in 2020 (kg)*	87	1104	74.8	162	4.10	4.50	14 337	4.33	33.7
PM_{10} tyre emission in 2020 (kg)#	148	1890	128	278	7.03	7.70	24 540	7.40	57.6

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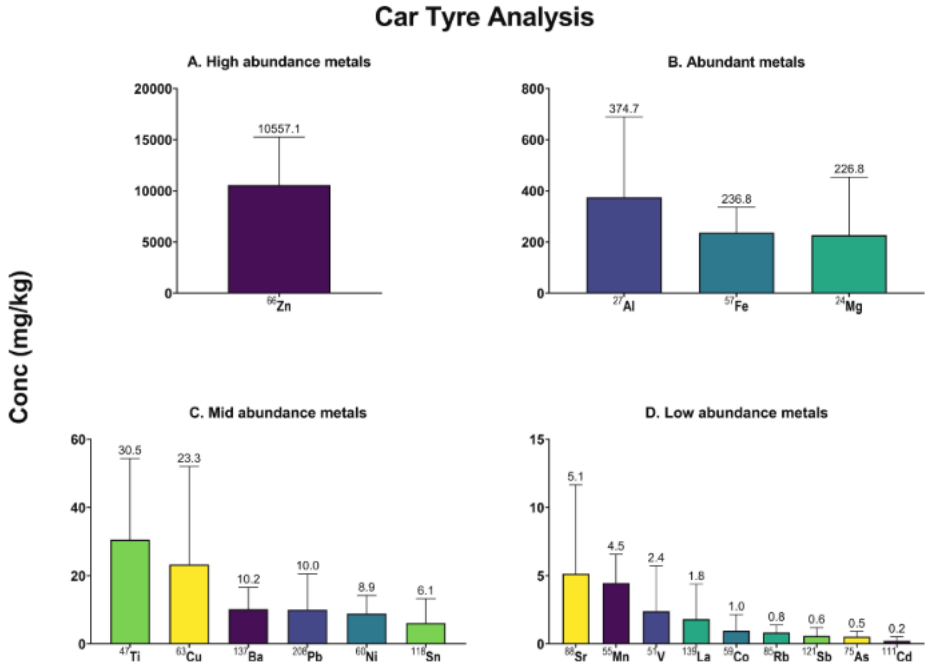
ELSEVIER

Full length article

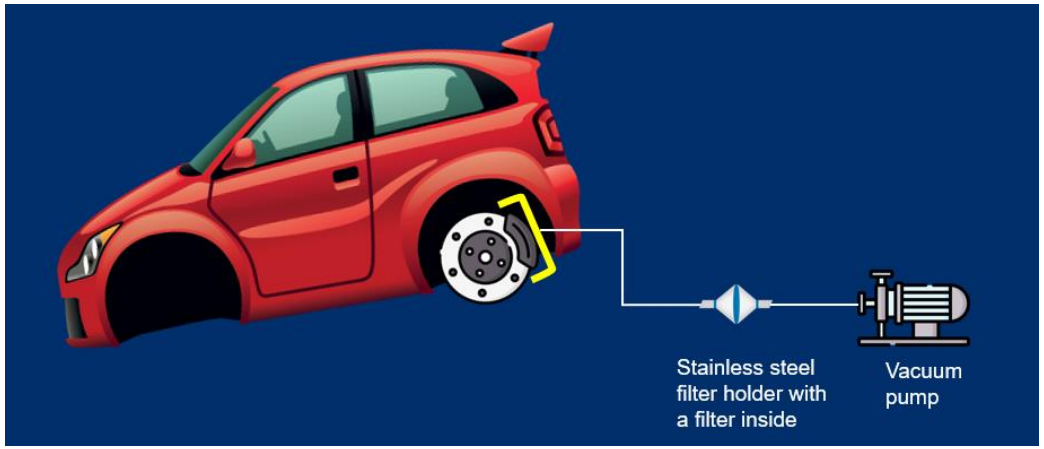
Multi-element analysis of tyre rubber for metal tracers

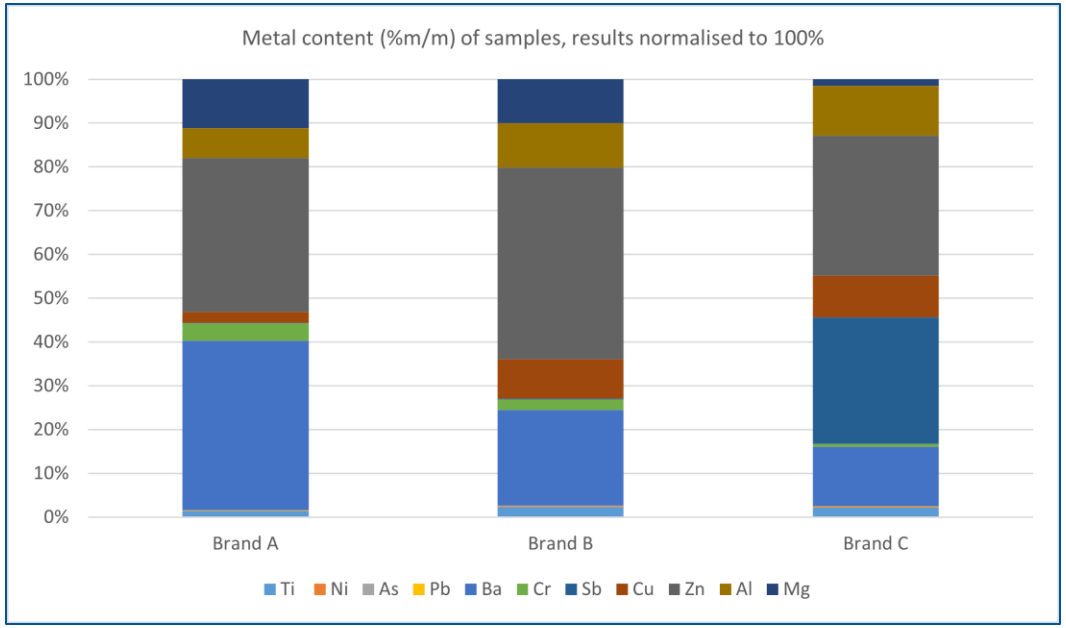
David P. O'Loughlin [a,b], Molly J. Haugen [b], Jason Day [c], Andrew S. Brown [d], Emma C. Braysher [d], Nick Molden [e], Anne E. Willis [b], Marion MacFarlane [b,*], Adam M. Boies [a,*]



Non-exhaust emissions – brake wear

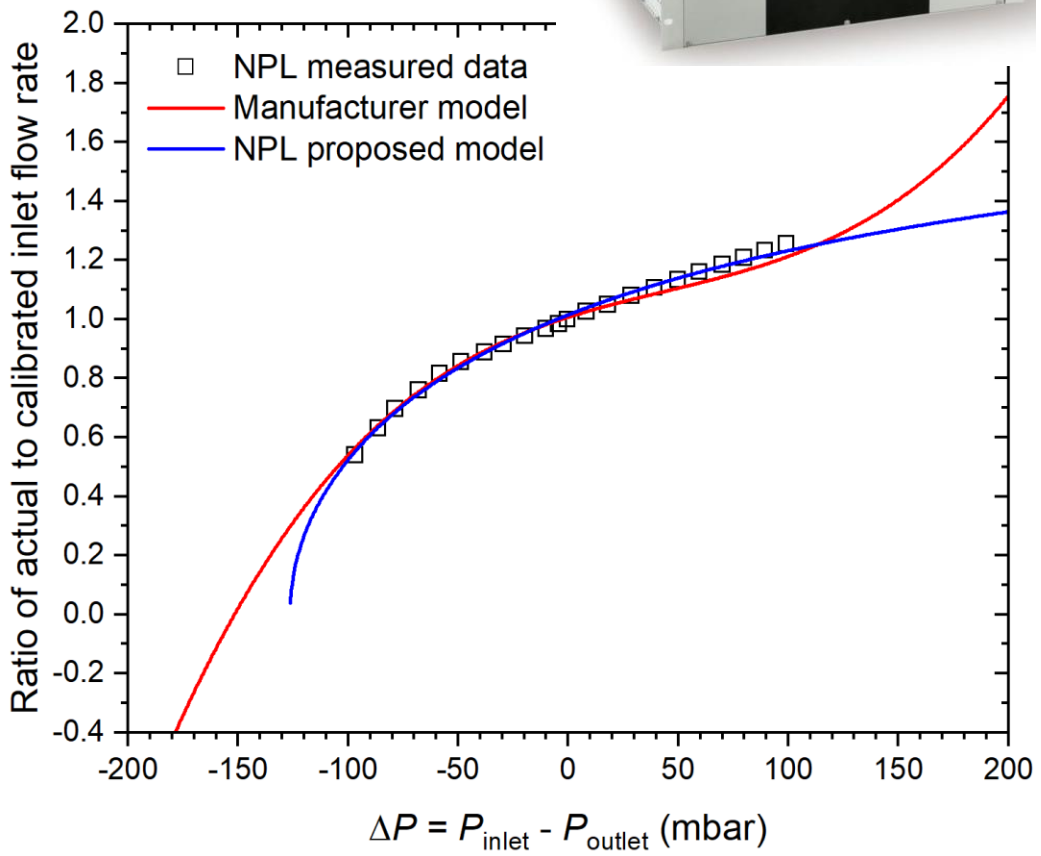
- Develop a novel measurement technique to characterise metal compositions in brake wear using ICP-MS/MS
- Overcome sample preparation challenges by employing cellulose ester membrane filters into our custom sampling equipment
- The method has been validated using a vehicle exhaust particulate CRM and through an interlaboratory comparison exercise with academia and industries





Testing volatile particle remover devices for the aviation industry

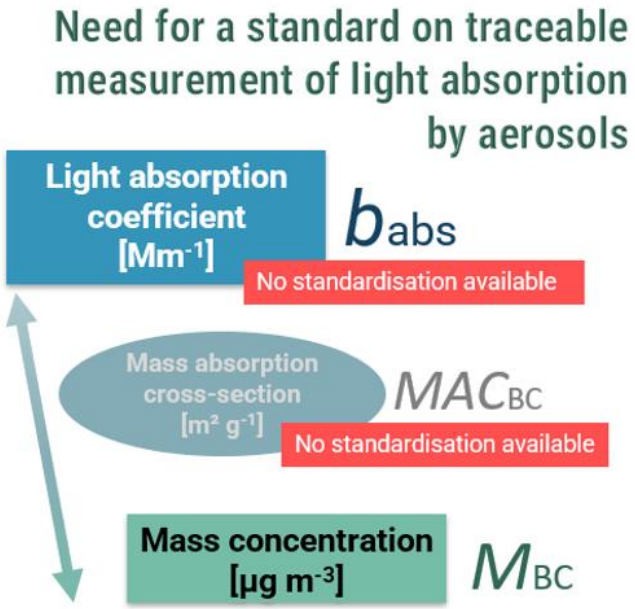
- A leading aero-engine manufacturer asked NPL to determine the parameters relating pressure, flow rate, and dilution factor of their VPR used in engine testing.
- NPL provided a physical model between VPR flow rate and pressure that was superior to the model used by the manufacturer.
- The NPL proposed model was able to predict the VPR flow rate and dilution factor correctly over a wide range of pressures.
- An ongoing investigation campaign to study the stability of VPRs and warm-up effects on their dilution factor.

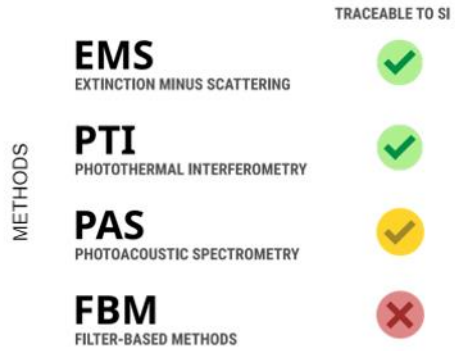


Standardisation of measurements of black carbon by light absorption

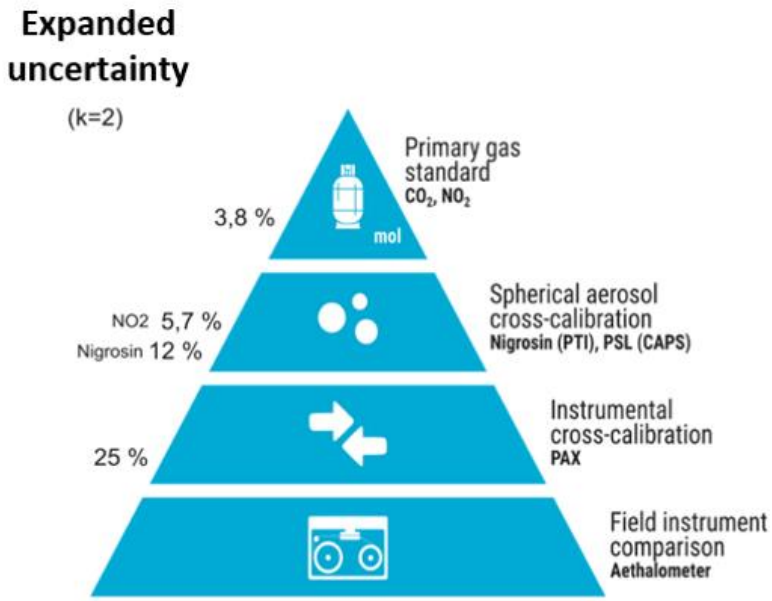
NPL

stanBC





- Absorption by a known gas standard is used to calibrate the primary methods: EMS (extinction) and PTI (absorption).
- This calibration can be used to determine aerosol extinction/absorption of spherical particles like polystyrene latex beads (PSL) or nigrosin.
- Cross-Comparison/calibration can be conducted between field instruments and transfer standards.



Equivalence Testing of Particulate Analysers to CEN Standards

- One of the 2 UK sites for the demonstration of on-going equivalence of automatic analysers
- Test site for MCERTS equivalence testing for particulate sensor systems.

Characterising low-cost air quality sensors

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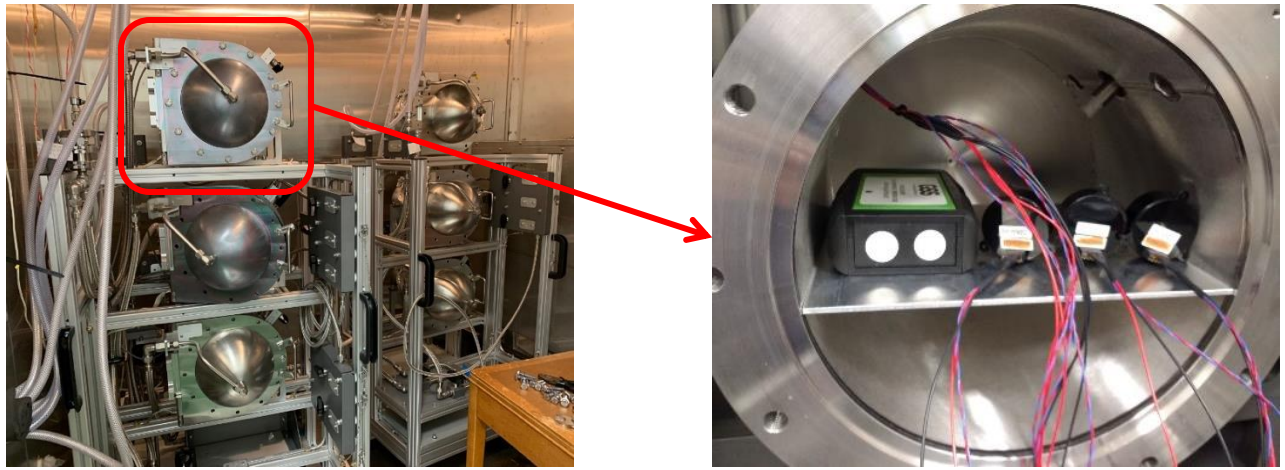
- Unlike reference instruments, no infrastructure exists for standardization of small low-cost sensors.
- Gas sensors are generally quite well developed and established (with limitations), whereas PM sensors are not.
- Low-cost PM sensors suffer from poor performance under variable T & RH as well as pollution levels. → Low-quality data
- Current capability at NPL: environmental chambers for gas sensors
- Proposed capability at NPL: reference aerosol chamber with varying T & RH for testing/calibration of PM sensors.



Co-location with reference instruments

Measurement Services

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- Calibration of condensation particle counters (CPCs) using soot particles to a primary current calibration of a Faraday cup aerosol electrometer – *ISO 17025 accredited*
- Calibration of condensation particle counters (CPCs) using silver particles and determination of D_{50} cut-off size in accordance with EN 16976
- Calibration of Faraday cup aerosol electrometers (FCAEs) for use in CPC calibrations - *ISO 17025 accredited*
- Calibration of differential mobility analyzer (DMAs) found in scanning mobility particle sizer (SMPSs) used to characterise the size distribution of aerosols - *ISO 17025 accreditation applied for*
- Testing of Volatile Particle Remover (VPR) devices for the aerospace industry
- Analysis of trace elements in particulate matter using inductively-coupled plasma mass spectrometry (ICP-MS) - *ISO 17025 accredited*
- Analysis of organic carbon and elemental carbon in ambient air and from emissions sources using thermal optical analysis - *ISO 17025 accredited*
- Gravimetric measurement of the PM_{10} or $PM_{2.5}$ mass concentration of particulate matter in ambient air - *ISO 17025 accredited*
- Calibration of ozone photometer to the UK Standard Reference Photometer - *ISO 17025 accredited*

Our team

- 18 permanent scientists
- 3 PhD students
- 2 sandwich course students
- Supported by an air quality network manager and laboratory / quality manager

Photo taken in December 2024

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