BIPM CCQM Workshop on Particle Metrology, 26 October 2022

Topic 1: Particles suspended in air or other gases

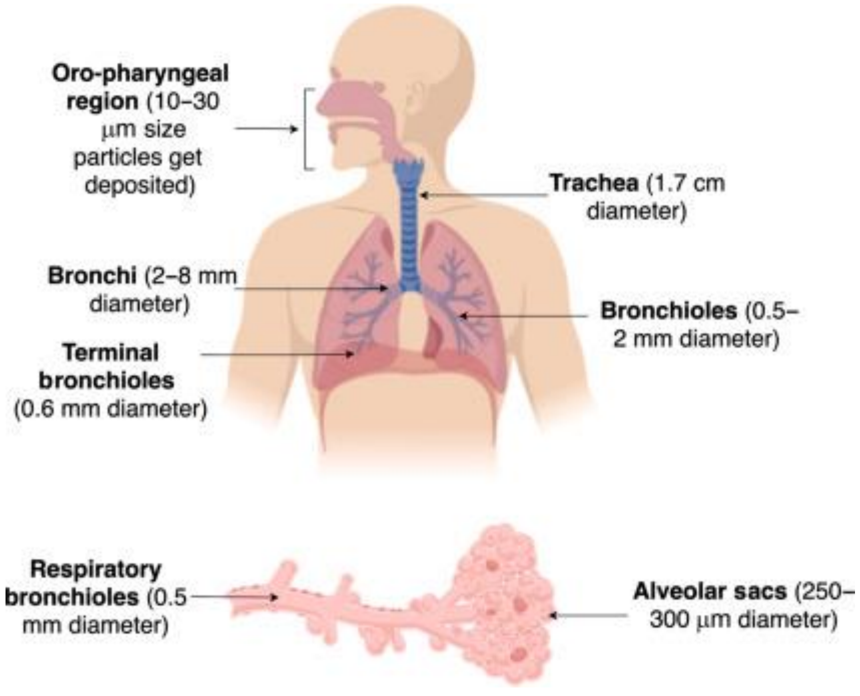
Overview of NMI/DI Measurement Capabilities and Activities

Konstantina Vasilatou, Greg Smallwood, François Gaie-Levrel, Shankar Aggarwal,
Andrew Brown, Paola Fisicaro, Kenjiro Iida, Thomas Y. Wu, Junjie Liu

virus | soot | organic matter | inorganic matter | bacteria | mineral dust | pollen

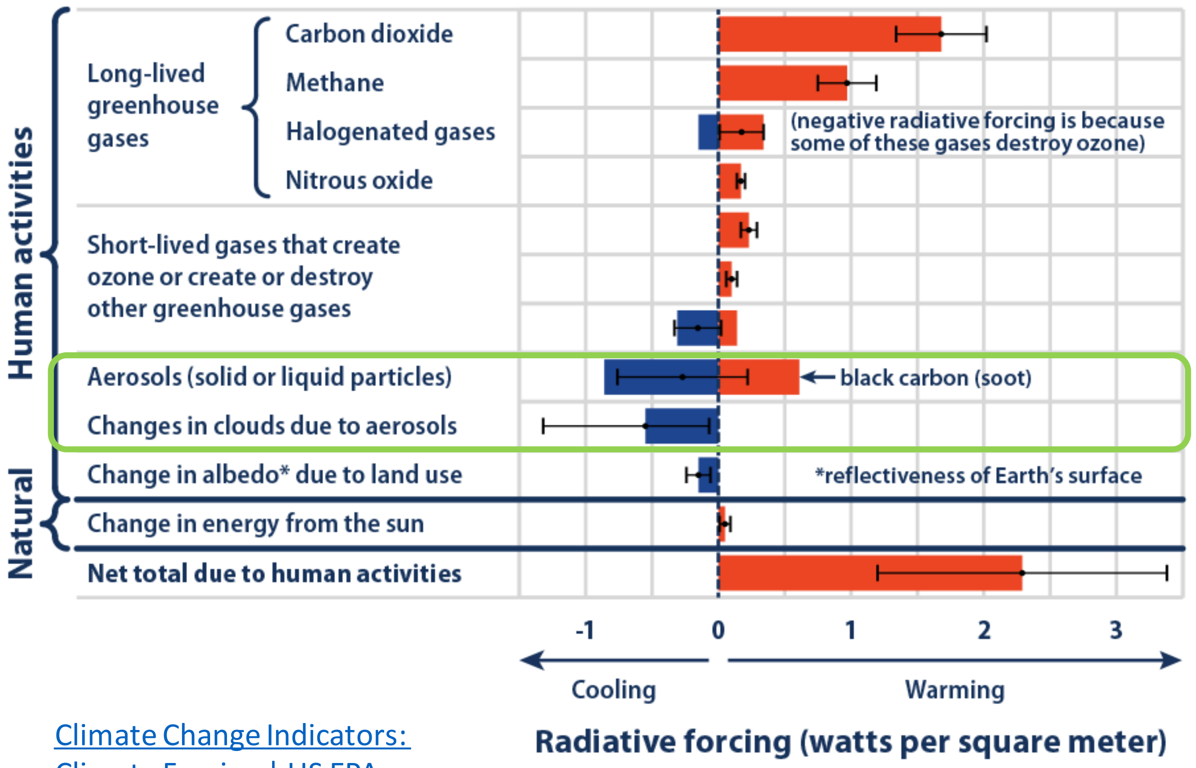
Airborne particles affect human health and contribute to climate change

Particle deposition in the respiratory system



K. Thakur at al. in [Targeting Chronic Inflammatory Lung Diseases Using Advanced Drug Delivery Systems](), 2020

Radiative Forcing Caused by Human Activities Since 1750



[Climate Change Indicators: Climate Forcing | US EPA]()

Particle monitoring is also essential for many industrial processes and medical applications (e.g. biotechnology, pharmaceutical production, semiconductor manufacturing, operating theaters in hospitals) which require a clean room.

Number concentration of sub-micrometre particles

Condensation Particle Counters (and other counters)

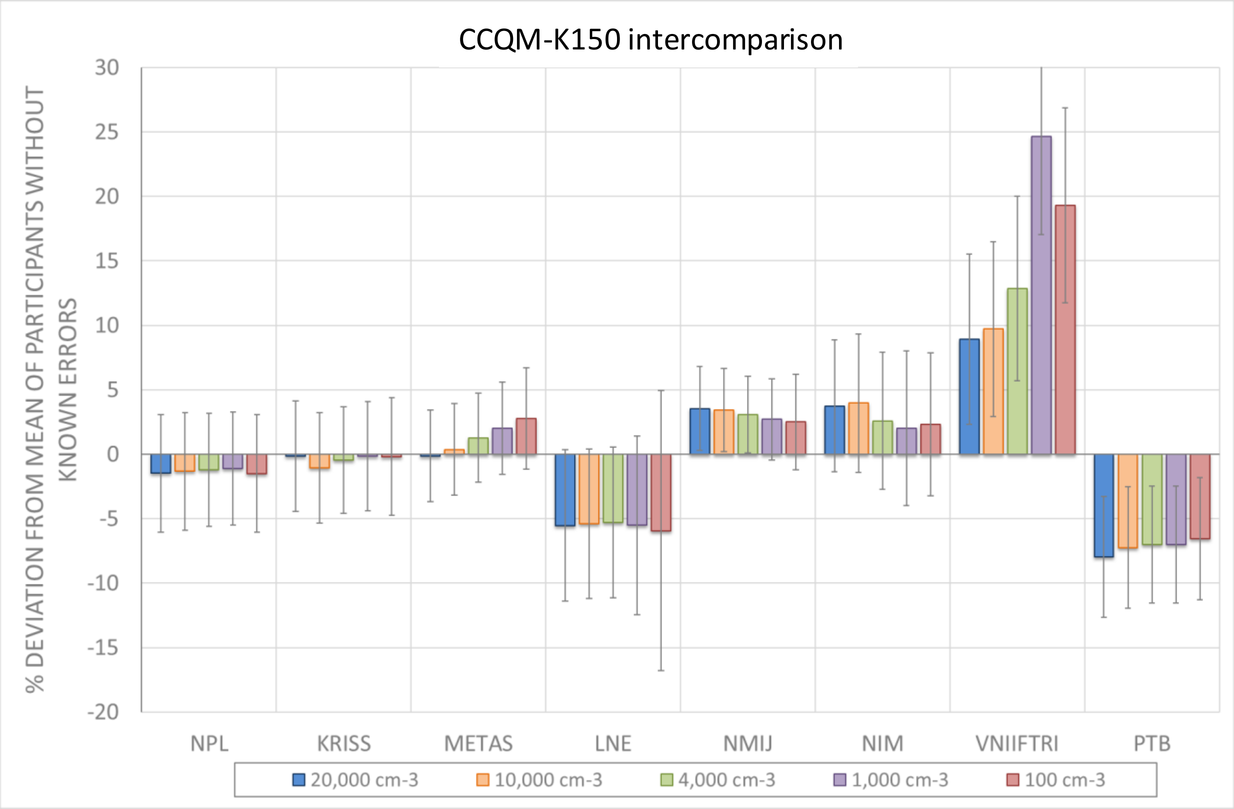
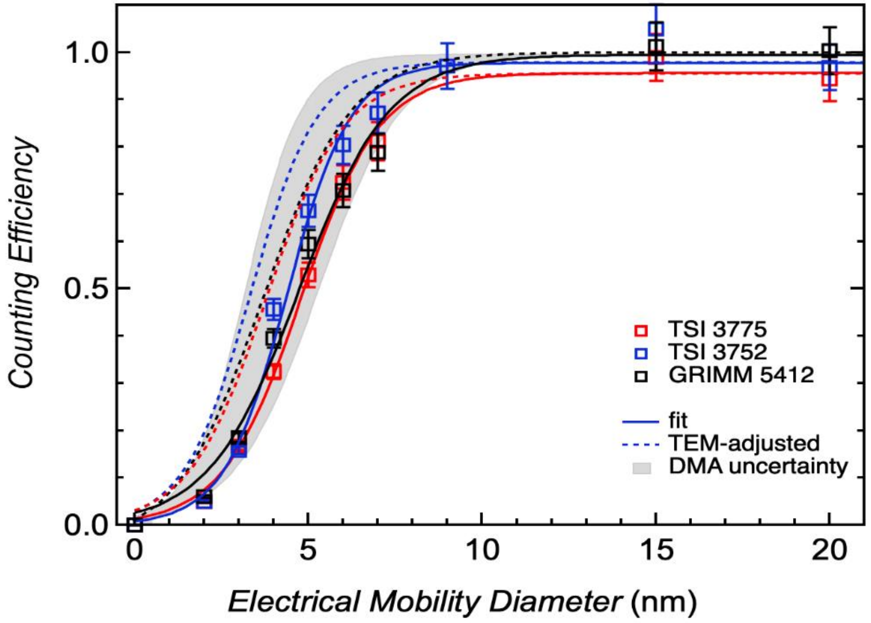


Figure: Condensation Particle Counter (CPC) comparison results for 40 nm aerosol particles. Prior to the comparison, the CPCs had been calibrated against an electrometer according to ISO 27891.



Example of CPC calibration: counting efficiency as a function of the particle mobility diameter.

State of the art

Traceable measurement of number concentration in the range 100 cm^{-3} - 20'000 cm^{-3}

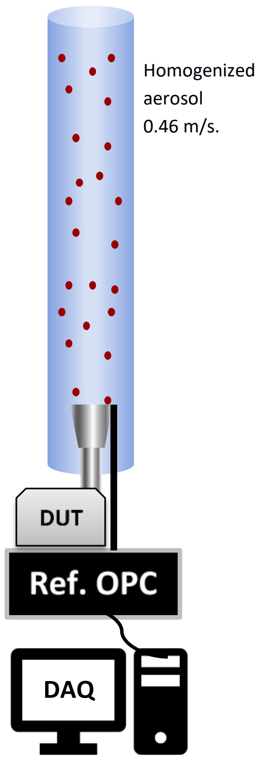
Relative expanded uncertainties (95 % confidence level) down to 3%, CMCs available

Particle mobility diameter: 23 nm – 500 nm

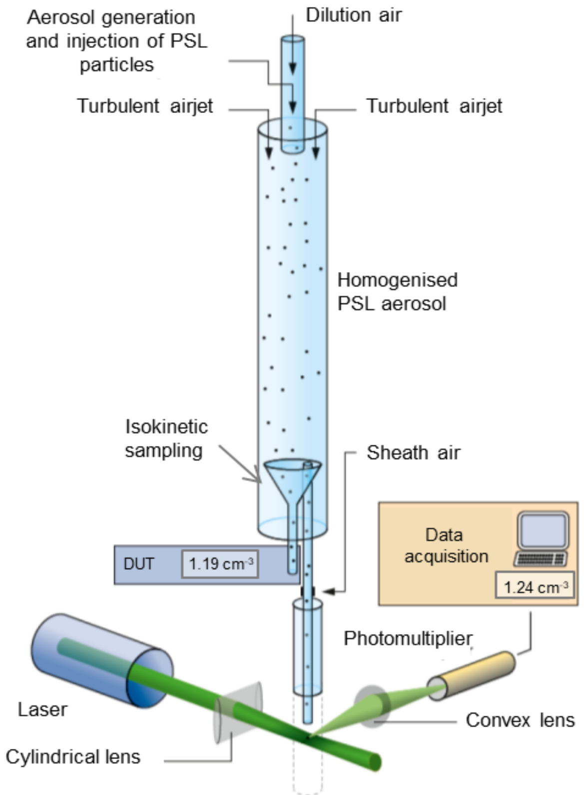
CMC= internationally recognised Calibration and Measurement Capabilities

Particle size distribution of micrometre-sized particles

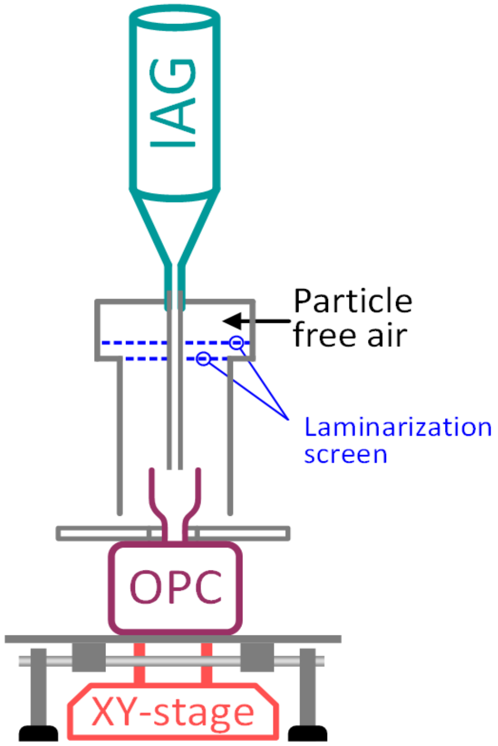
DFM



METAS



NMIJ



NIM has also an IAG

Optical & Aerodynamic Particle Sizers, Bioaerosol monitors

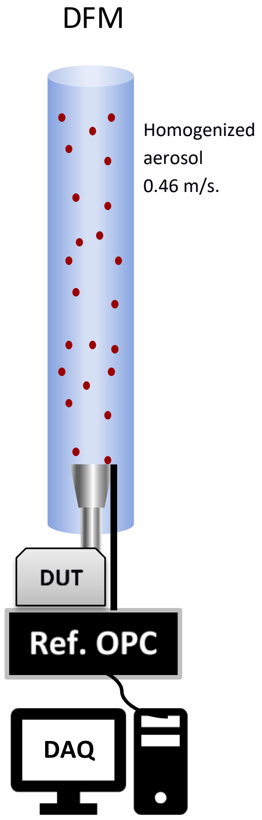
Iida et al., AIP Conference Proceedings **1527**, 453 (2013)
Iida and Sakurai, *Aerosol Science & Technology*, **52**:10, 1156 (2018)
Horender et al. Review of Scientific Instruments **90**, 075111 (2019)
Vasilatou et al., *Metrologia* **57,** 025005 (2020)
Vasilatou et al., *Journal of Aerosol Science* **157**, 105818 (2021)
Lieberherr et al., *Atmos. Meas. Tech*. **14**, 7693–7706 (2021)
Wu et al, *Measurement* **189**, 110446 (2022)
Vasilatou et al., *Aerosol Science & Technology*, accepted (2022)

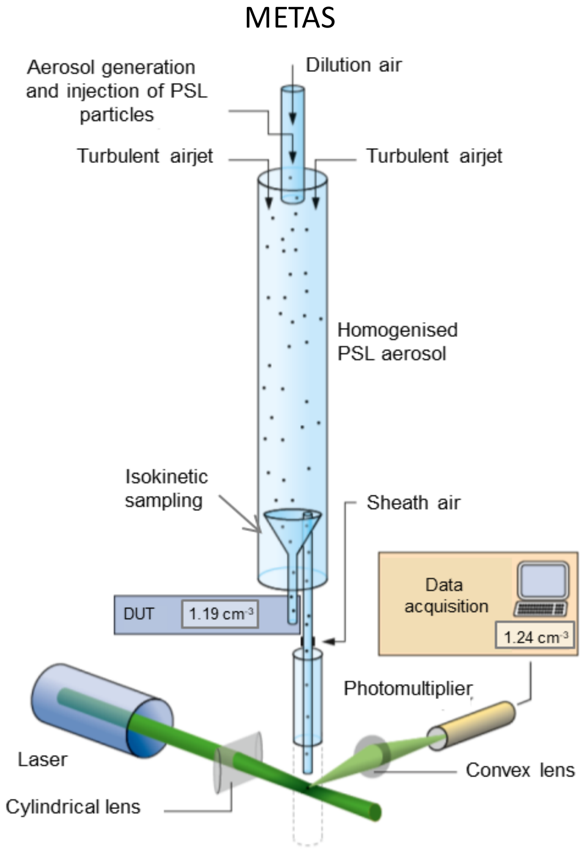
Primary standard for PNC
Custom-made optical particle counter or
Inkjet Aerosol Generator

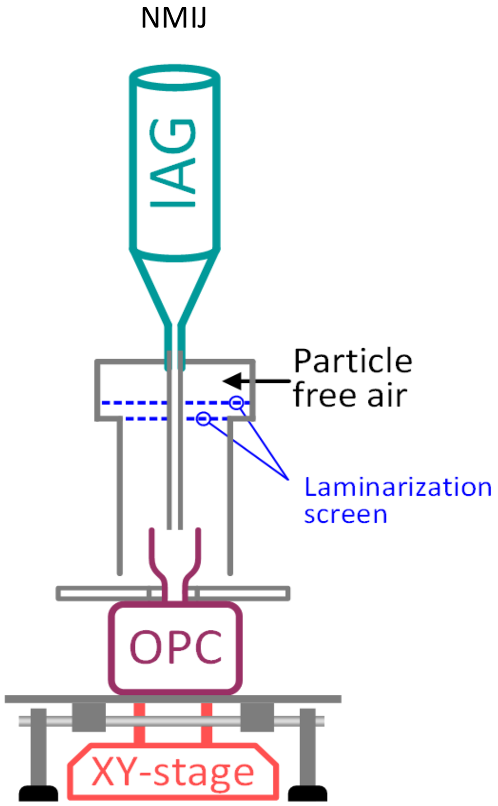
Primary standard for particle diameter
Atomic Force or Electron Microscopy

State of the art
Traceable measurement of number concentration in the range 0.01 cm^{-3} – 800 cm^{-3}
Relative expanded uncertainties (95 % confidence level) of 2-9 %, CMCs available
Particle diameter range: 100 nm – 15 µm

Particle size distribution of micrometre-sized particles







NIM has also an IAG

Optical & Aerodynamic Particle Sizers, Bioaerosol monitors

Iida et al., AIP Conference Proceedings **1527**, 453 (2013)
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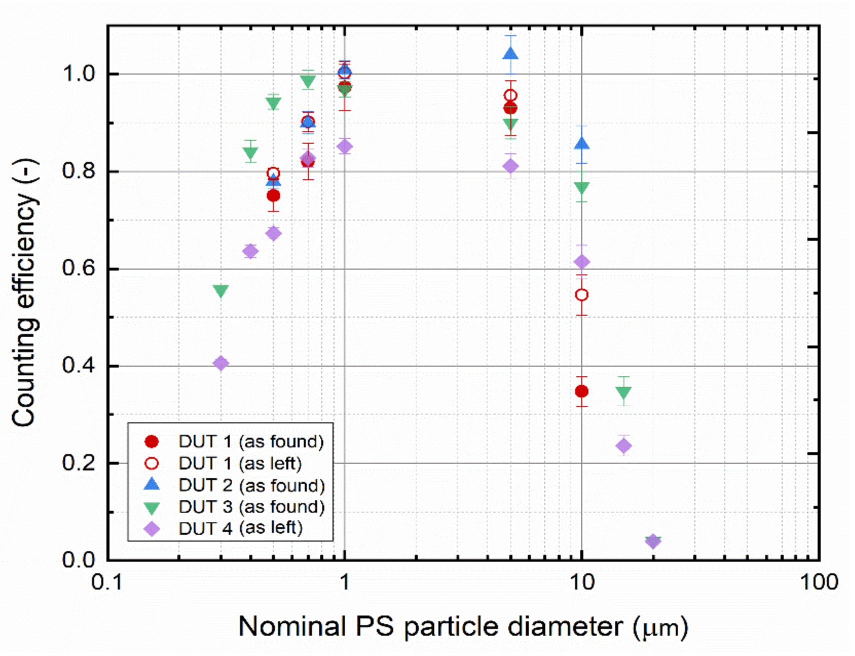


Calibration of four aerodynamic particle sizers

<u>State of the art</u>

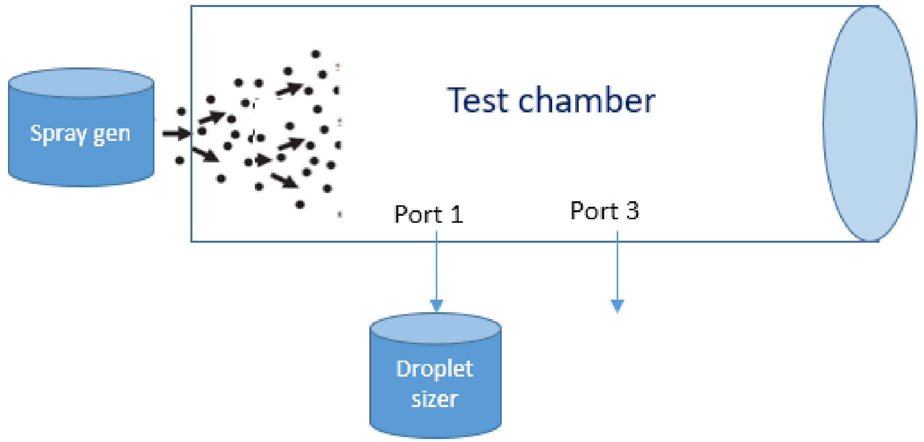
Traceable measurement of number concentration in the range 0.01 cm^{-3} – 800 cm^{-3}

Relative expanded uncertainties (95 % confidence level) of 2-9 %, CMCs available

Particle diameter range: 100 nm – 15 µm

APMP's Response to COVID19 Project: Saliva and saline droplet size measurement

(NMC, CMS, NIM, KRISS, HSA)



T. Wu et al, Investigation of the saliva and saline droplet size measurement for COVID-19 infection control, APMP Webinar on APMP's Responses to COVID-19, (to be held on 3 Nov 2022)

- Speech droplet size measurement is critical for COVID-19 infection control
- Droplet size measured by aerosol spectrometer in NMC and aerodynamic particle sizer in CMS, NIM & KRISS via a inter-NMI comparison
- Artificial saliva droplets' Volume Equivalent Diameter (VED) size show large deviations (up to 22.7%) from the mean VED value (~ 4 µm)
- New droplet size reference standard (1-20 µm) are needed to establish traceability for saliva and saline droplet size measurement

Aerosol mass concentration- (reference gravimetric method)

NPL

Conditioning and automatic weighing facility to weigh filters to the requirements of EN 12341: (47 ± 2.5) % RH, (20 ± 1) °C for $PM_{2.5}$ and PM_{10}

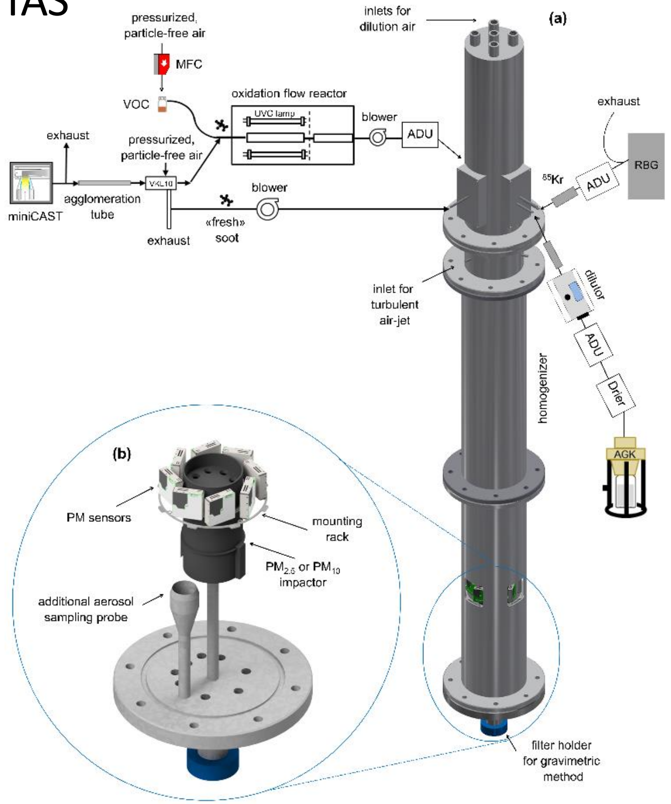
State of the art

Weighing uncertainty: 14 µg (95% confidence level)

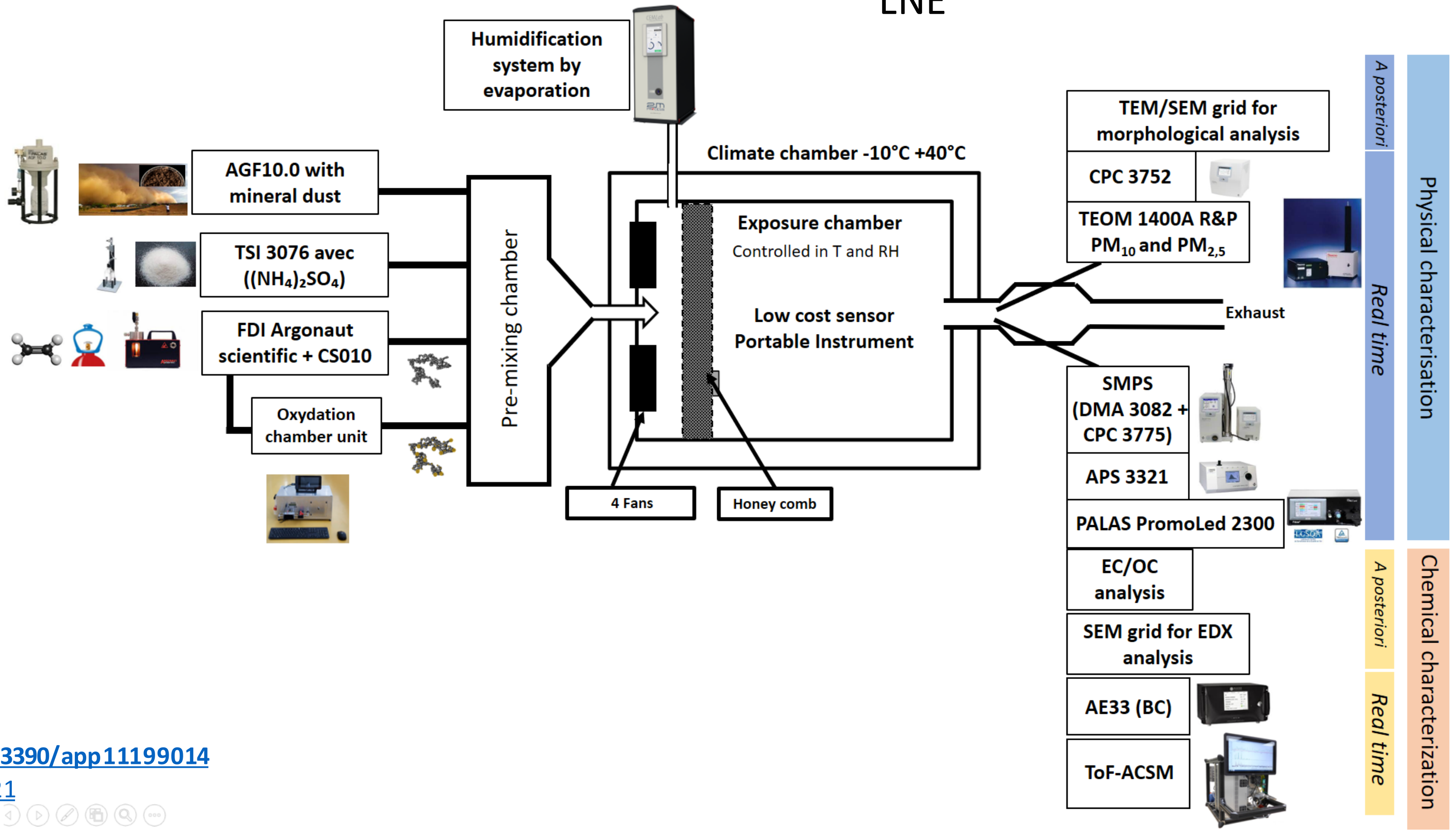
Aerosol mass concentration

$PM_{2.5}$ & PM_{10} monitors and low-cost sensors

METAS



LNE



Horender et al. (2021) Atmospheric Measurement Techniques, **10.3390/app11199014**
Horender et al. (2021) Applied Sciences, 10.5194/amt-14-1225-2021

State of the art

Traceable calibration of multiple sensors in parallel against the reference gravimetric method (METAS) or the TEOM (LNE)

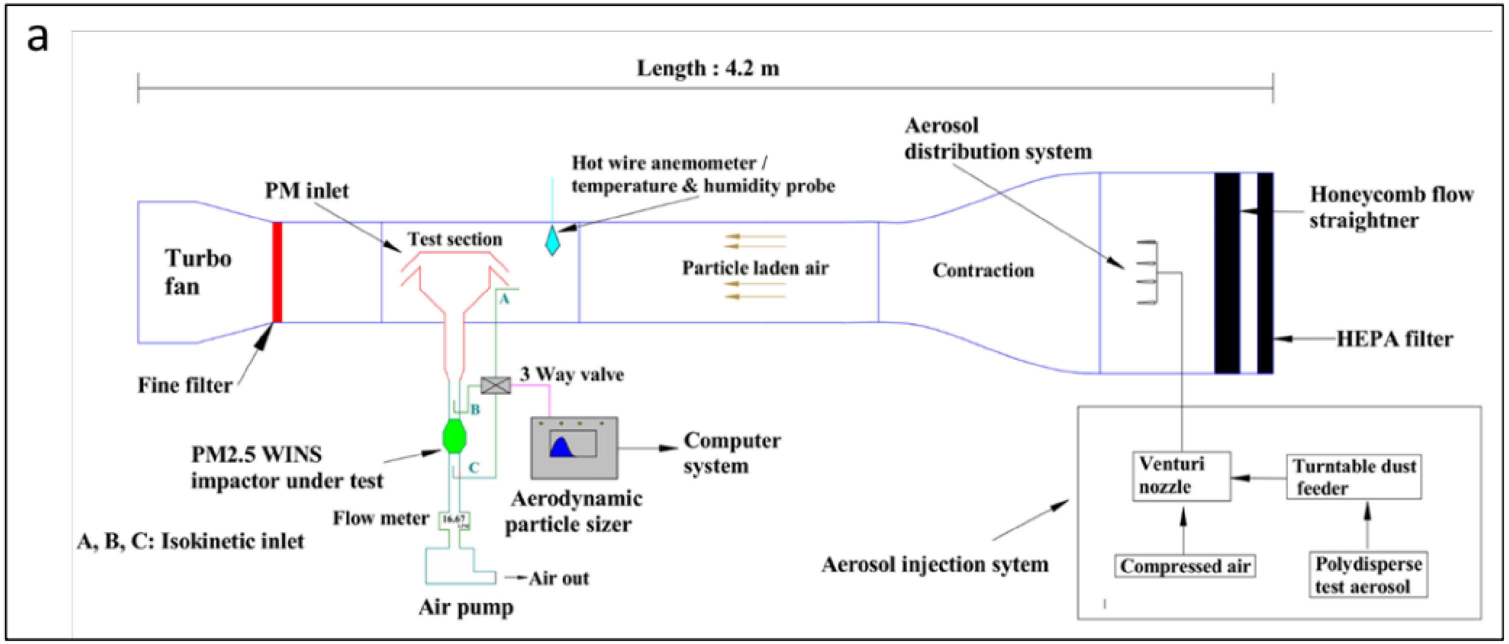
Well-defined aerosols: mixtures of fresh soot, aged soot, ammonium sulfate and mineral dust

Measurements can be performed at different environmental conditions (temparature & pressure)

Expanded measurement uncertainty: typically 5-8 %

Aerosol mass concentration

NPL India



Calibration of PM monitors with dust particles in a wind tunnel

P. Patel, S. G. Aggarwal , Aerosol and Air Quality Research, 21(7), 210006 (2021)

State of the art

Aerosol mass concentration range 10-200 µg/m^3

Expanded uncertainties = 5% (95% confidence level)

No direct CMC for cutoff size;

CMCs are available for all measuring parameters: mass, size, flow, temperature and pressure

PM impactors

NPL India

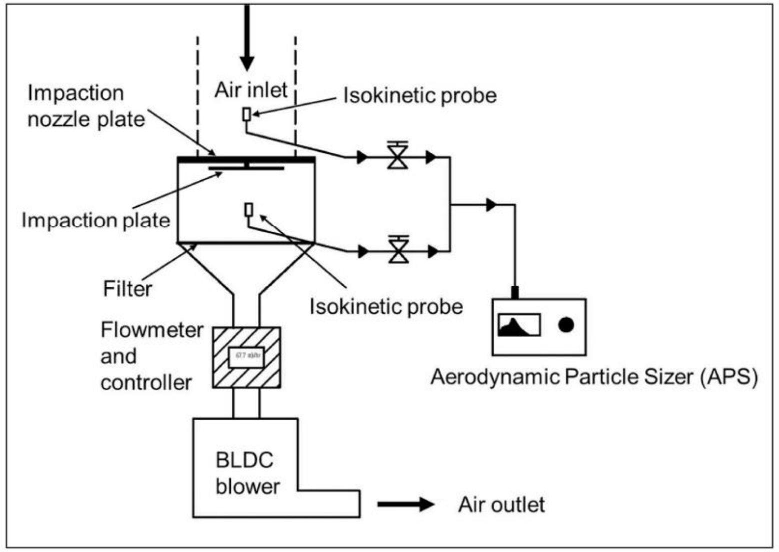


Fig. 4. Schematic of the laboratory experimental test setup of $PM_{2.5}$ HVI (not to scale).

Development of a high-volume PM2.5 impactor inlet

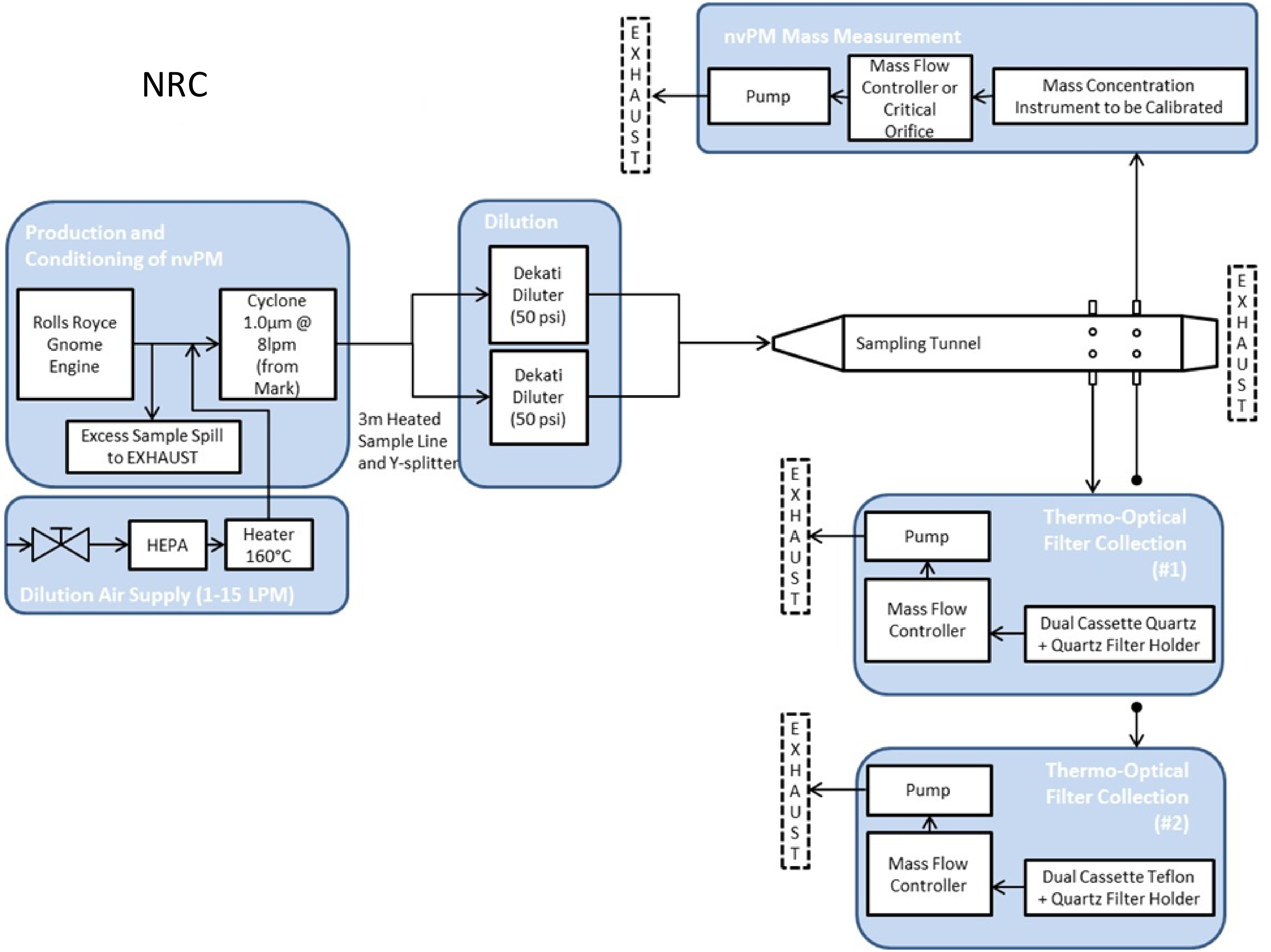
P. Patel, S. G. Aggarwal, C-J Tsai, T. Okuda, Atmospheric Environement 244, 117811 (2021)

A CCQM pilot has been suggested by NPL-India on PM impactor aerodynamic size cut-off and mass

Aerosol nvPM mass concentration

Real-time BC mass concentration instruments

NRC



- Nonvolatile particulate matter (nvPM) mass calibrated using elemental carbon (EC) as determined by thermal optical analysis (TOA) as the reference
- Accepted as a certification standard for aircraft engine emissions by ICAO and adopted by governments worldwide

Conventional approach

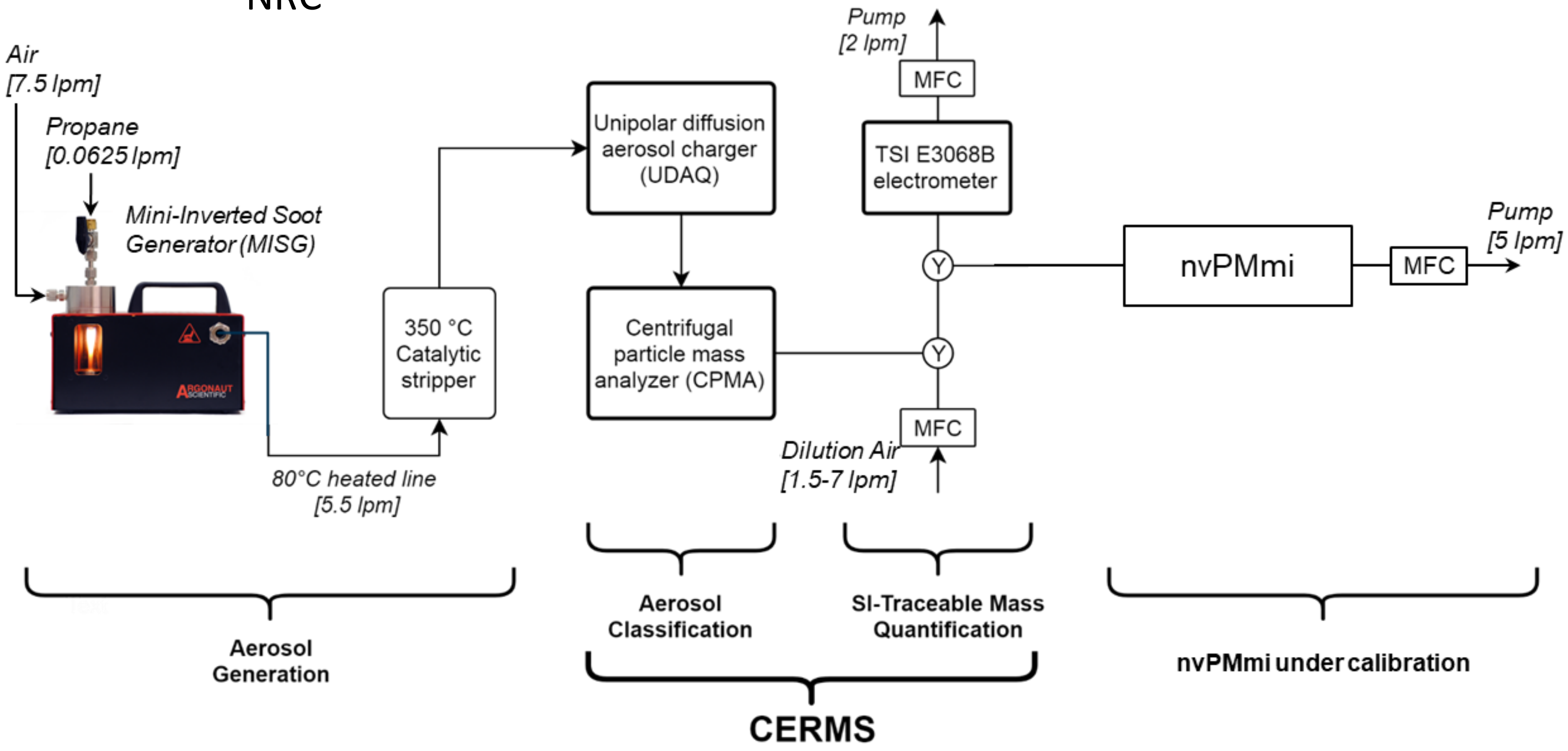
- Measurement of mass concentration 50 – 500 µg/m^3
- Relative expanded uncertainties (95 % confidence level) of 15-20 %
- Particle diameter range: 10 nm – 1 µm mobility diameter
- Standardized as SAE ARP6320A (2021)

- no CMCs

Aerosol mass concentration

Real-time mass concentration instruments

NRC



CPMA-Electrometer Reference Mass Standard (CERMS)

- Demonstrated for black carbon (BC) mass concentration instruments
    - Artium LII 300, DMT PAX, AVL MSS
- An ILC is planned for March 2023 with NRC, University of Alberta, and Missouri University of Science and Technology
- Plan to test forthcoming NMIJ mass calibrated sphere reference material

1. J. C. Corbin, T. J. Johnson, F. Liu, T. A. Sipkens, M. P. Johnson, P. Lobo, & G. J. Smallwood (2022) Carbon, 192, 438–451. doi:10.1016/j.carbon.2022.02.037

2. J. Corbin, A. Moallemi, F. Liu, S. Gagné, J. Olfert, G. Smallwood, and P. Lobo (2020) Aerosol Science and Technology, 54, 1293-1309. doi:10.1080/02786826.2020.1788710

3. J. Titosky, A. Momenimovahed, J. Corbin, K. Thomson, G. Smallwood, and J. S. Olfert (2019) Aerosol Science and Technology, 53, 701-711. doi:10.1080/02786826.2019.1592103

4. J. C. Corbin, A. Moallemi, J. Olfert, F. Liu, K. Thomson, G. J. Smallwood, and P. Lobo (2018) 10th International Aerosol Conference, Poster 13CB.5, St. Louis, MO, USA.

5. M. Dickau, T. J. Johnson, K. Thomson, G. Smallwood and J. S. Olfert (2015) Aerosol Science and Technology, 49, 152-158, doi:10.1080/02786826.2015.1010033

<u>State of the art</u>

Traceable measurement of mass concentration in the range 0.1 – 500 µg/m^3

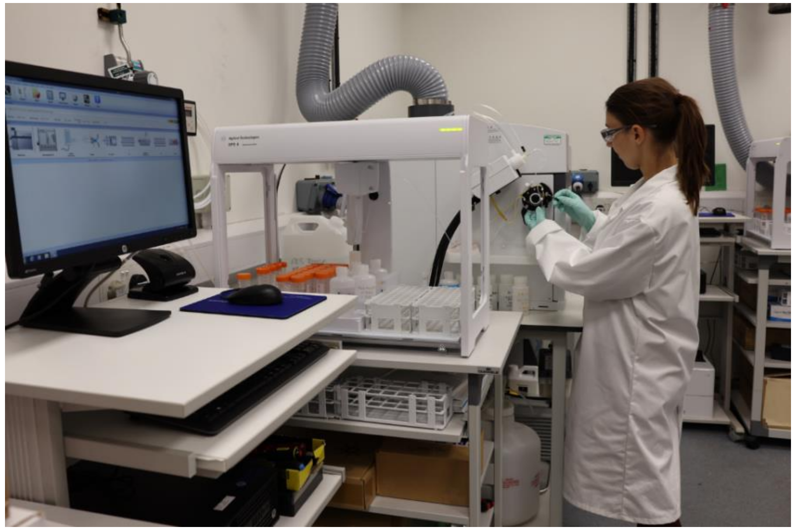
Relative expanded uncertainties (95 % confidence level) of 3-5 %

Particle diameter range: 10 nm – 1 µm mobility diameter

- no CMCs, no standards (yet)

Chemical compostion of airborne particles – Reference solutions and test filters

NPL



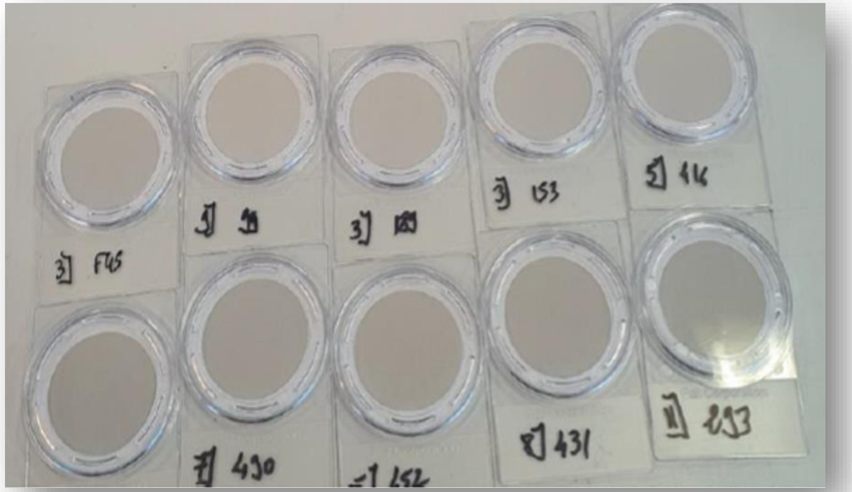
Analysis of metals by ICP-MS

- Measurements of metals for ambient air and emissions monitoring applications
- Analysis of non-exhaust emissions
- Isotope ratio measurements for source apportionment

Goddard *et al*. 2019 10.1007/s10661-019-7774-8

State of the art (for metals in ambient air)
Typical expanded measurement uncertainty: 9 – 25 %
Conc. range (in air): approx 10^{-3} – 10^{3} ng m^{-3}

LNE



Analysis of metals by ICP-HR-MS

- Provision of test filters and reference solutions
- Development of quartz fiber filters RM loaded with PM2.5 produced by aerosol generation

A. Bescond *et Al*. 2021 10.3390/atmos12010067 ; C. Oster *et Al*. 2015 10.1007/s00216-014-8194-9

State of the art (for metals in ambient air)
CMCs for the 4 regulated metals (Ar, Ni, Cd, Pb)
concentration range between 10 and 3000 mg/kg
with an expanded measurement uncertainty of ≤13%

Thank you for your attention!

For more information, contact:

KRISS:	National Metrology Institute of Korea	jsjung@kriss.re.kr
LNE:	National Metrology Institute of France	Francois.GAIE-LEVREL@lne.fr; Paola.Fisicaro@lne.fr
METAS:	Federal Institute of Metrology, Switzerland	konstantina.vasilatou@metas.ch
NIM:	National Institute of Metrology, China	liujj@nim.ac.cn
NMC:	National Metrology Center, Singapore	thomas_wu@nmc.a-star.edu.sg
NMIJ:	National Metrology Institute of Japan	kenjiro.iida@aist.go.jp
NPL:	National Physical Laboratory, UK	andrew.brown@npl.co.uk
NPLI:	National Physical Laboratory – India	aggarwalsg@nplindia.org
NRC:	National Research Council Canada	greg.smallwood@nrc-cnrc.gc.ca
PTB:	National Metrology Institute of Germany	jorge.saturno@ptb.de