Powerful approach for characterising vehicle interior air quality

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Agenda

- How bad is pollution entry into the vehicle cabin?

- Does it matter from a health and safety perspective?

- New standardised test method

- Results from comparative filter testing

- Future applications

In collaboration with:

Professor Heejung Jung
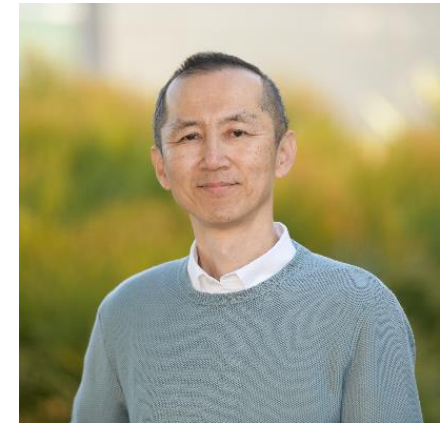
The issue

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Pollution in the cabin

- Very limited regulation – mainly health and safety at work in Europe

- Issue is particle ingress through heating, ventilation and air conditioning (HVAC) system via filter

- Ambient particle concentrations measured around roadways
  - 22,901 #/cm^3 in Los Angeles
  - 43,312 #/cm^3 near Oxford, UK
  - and 3.1 μg/m^3

- Ambient PM within WHO guidelines of <5 µg/m^3

- No limits for PN; typical rural background of 2,610 #/cm^3

- Using recirculation mode to stop ingress leads to carbon dioxide build-up

Potential health and safety impacts

- Particles >10 μm are stopped in the nose; <2.5 μm can penetration deep in lungs

- Retention half-life of 250 nm particles 170 days; 20 nm ultrafines are 500 days

- Ultrafine particles can cause stronger and more persistent inflammation

- Potential diseases caused by particle inhalation: respiratory, cardiovascular, central nervous system, diabetes and cancer

- Precise role of particles in these illnesses is still largely unknown, although the body of evidence is growing – apply precautionary principle?

- Double-blind cognitive tests suggests 50% lower scores in the presence of high CO_2

- Worst performance on decision-making, focus and crisis response

- Potential driving safety risk, especially with multiple passengers

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Standardised method

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Methodology overview

- HVAC systems are complex and non-linear
- No existing standard method for real-world particle ingress testing
- Novel concept proposed in SAE International paper in 2019
- Standardisation pursued through CEN Workshop 103, with ~50 participants
- CWA17934 published in September 2022

➢ Key concept: ratio of average inside to outside particle concentration converges to repeatable value for given vehicle set-up, with wide boundary conditions

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Equipment set-up

- Stainless steel, forward-facing exterior sample inlet

- Head-height sample point between vehicle headrests

- 1" diameter satisfies isokinetic sampling up to 2μm at 80km/h

- Matched pair of detectors

CWA17934 – essentials

- Urban driving 30-50 km/h; max speed 80 km/h

- Test duration 30-120 minutes

- No rain, fog or snow

- New filters aged 100 km

- Mean external PN concentration 5-100k #/cm^3

- Ambient temperature 5-25 degrees Celsius
- Correlation slope 0.8-1.2, r2$\geq$0.98

CEN/WS 103 Real drive test method for collecting vehicle interior air quality data

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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1   FOR INFORMATION

2   SUBJECT

Draft CWA Real drive test method for collecting vehicle interior air quality data – Final version for publication

$$CAQI_i = \frac{\int_0^t C_{i,\text{cabin}} \, dt}{\int_0^t C_{i,\text{outside}} \, dt}$$

$y = 1.1053x + 1530.5$
$R^2 = 0.981$

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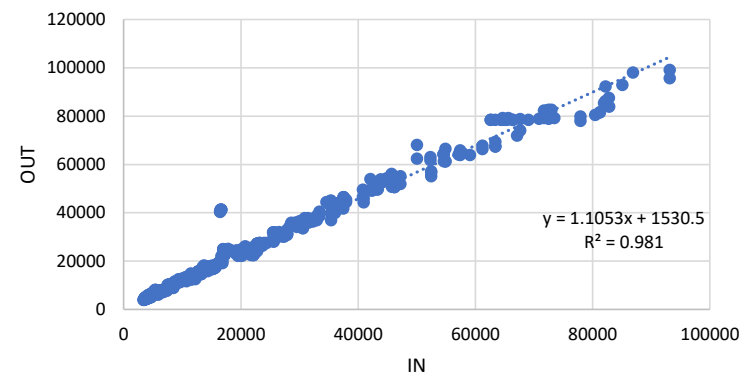
Boundary conditions

- CAQI is independent of...
    - Mean outside concentrations
    - Peak outside concentrations
    - Ambient temperature
- ...within boundaries similar to RDE

- Variability has Normal distribution consistent with random error

PN CAQI

$y = -7E{-}06x + 0.5501$
$R^2 = 0.1594$
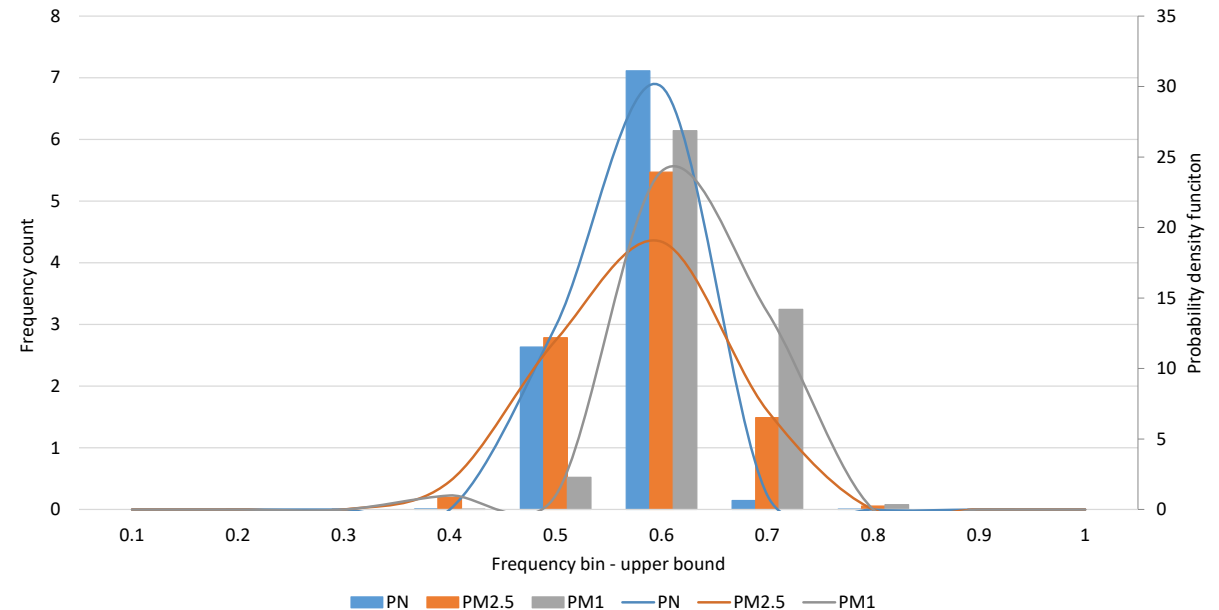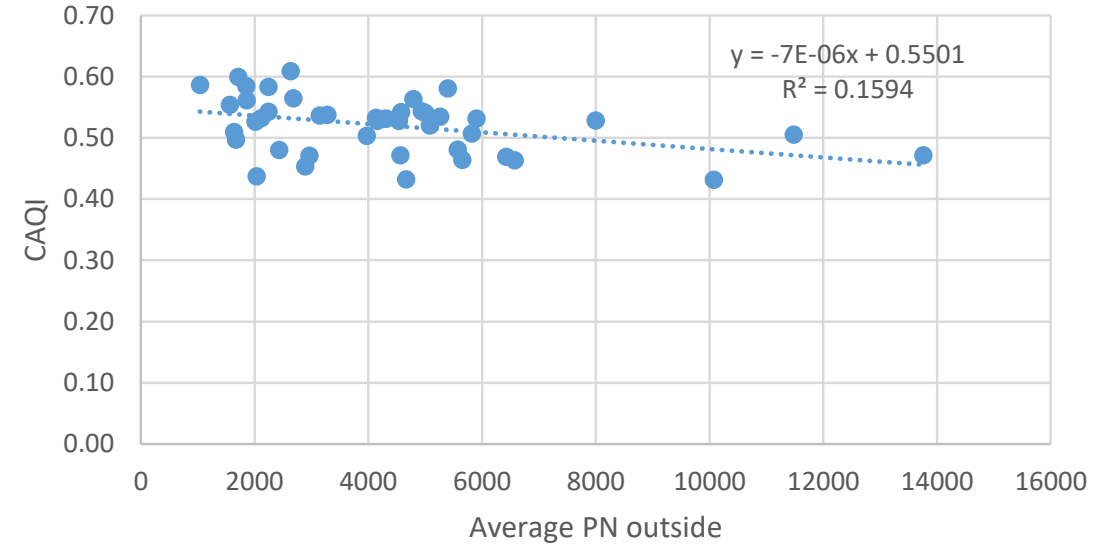
Repeatability

- Volkswagen Golf
- GRIMM miniWRAS
- 6 different locations
- Germany, Sweden, Belgium
- 4 different testers
- 3 vehicle OEMs

PN
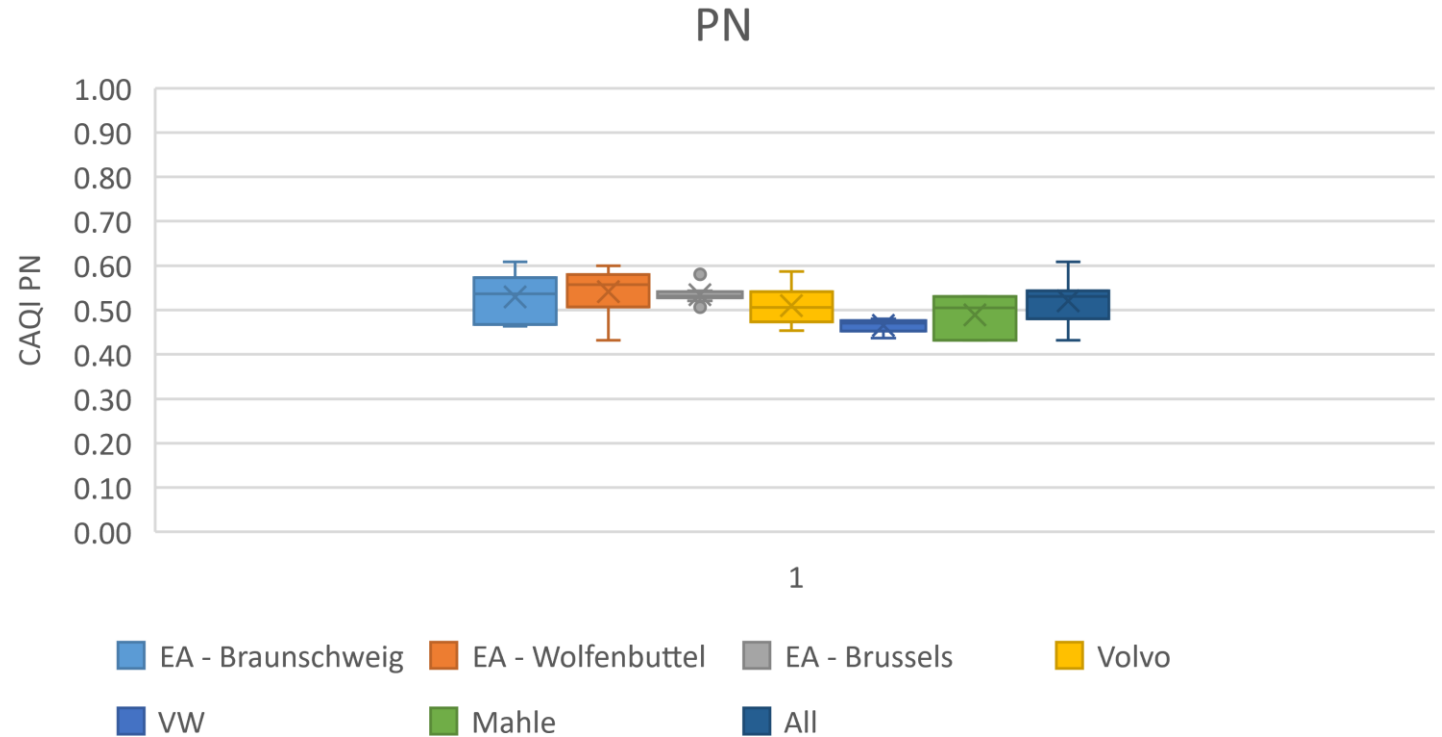
	FRESH				
	Repeats	Test duration	Max PN outside	Avg PN outside	PN CAQI
EA - Braunschweig	9	1800 +/- 0	106000	3774 +/- 1665	0.53 +/- 0.05
EA - Wolfenbuttel	8	1800 +/- 0	225600	2409 +/- 1088	0.54 +/- 0.05
EA - Brussels	13	1776 +/- 58	95110	5162 +/- 1029	0.53 +/- 0.02
Volvo	7	1800 +/- 0	46770	2247 +/- 962	0.51 +/- 0.04
VW	5	1476 +/- 329	77240	6149 +/- 4620	0.47 +/- 0.02
Mahle	3	1800 +/- 0	93160	8603 +/- 3830	0.49 +/- 0.05

Filter test results

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Test programme

- Nissan Qashqai Euro 6 diesel

- Testing near Oxford, UK

- According to CWA17934

- December 2022

- Original, aged filter

- Brand new OEM filter

- 5 different aftermarket filters
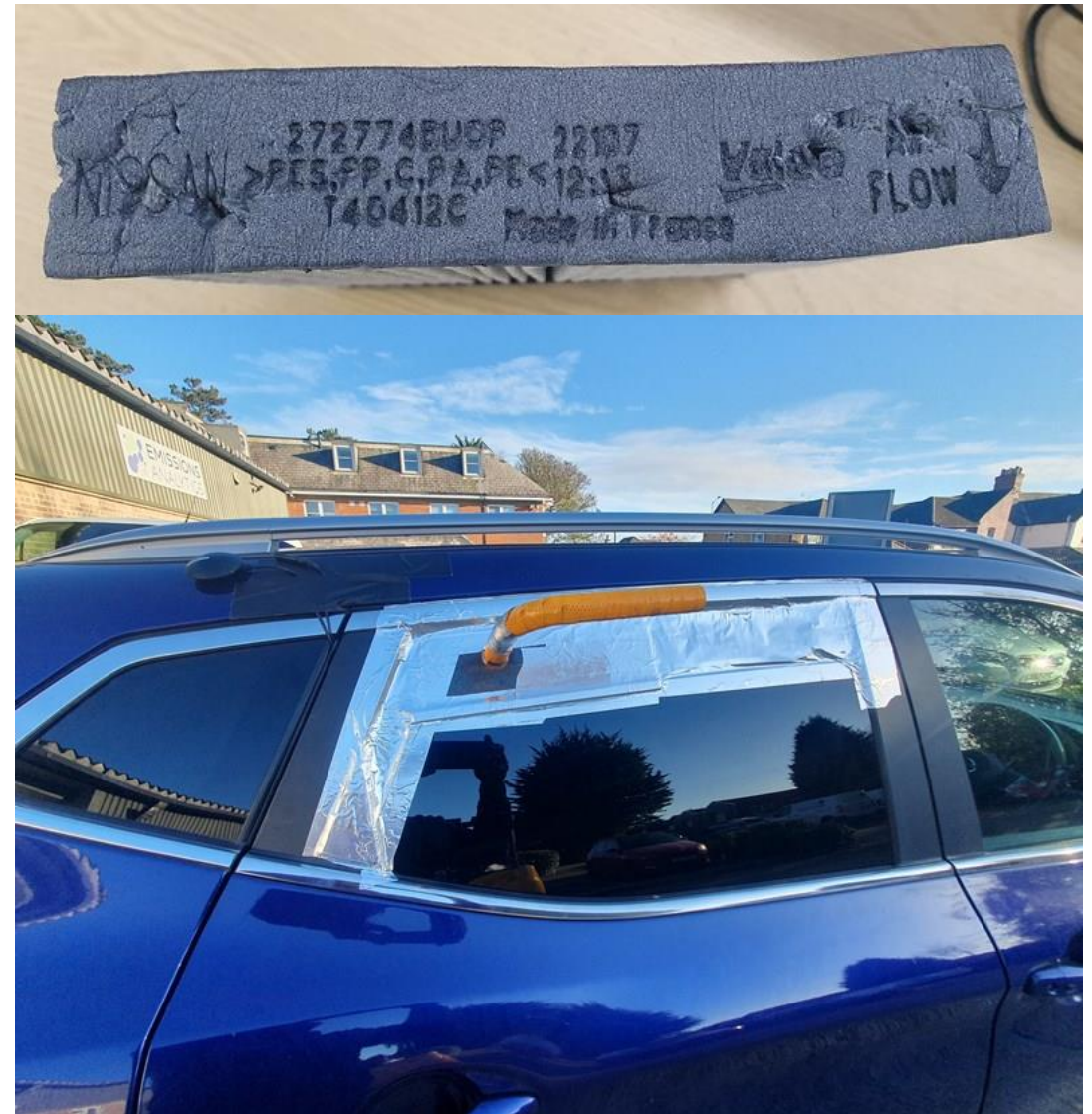
Comparative results

- Aged filter (>2 years) worst performer

- Best filter almost three times better at stopping PN ingress than worst

- Price range from $13 to $44

- Impressive repeatability, given the wide boundaries

➤ Relative quick, easy and cheap intervention to reduce human exposures

Filter	Mean PN CAQI	Standard deviation
Old filter	0.93	0.04
OEM new filter	0.52	0.05
Alternative #1	0.69	0.05
Alternative #2	0.52	0.05
Alternative #3	0.18	0.02
Alternative #4	0.44	0.08
Alternative #5	0.70	0.04
Mean	0.57	0.05

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Summary

- New standardised method makes characterising HVAC performance tractable

- Relatively short, practical test

- In real-world conditions, with wide boundaries

- To allow comparison of filters, HVAC systems and vehicles

- Repeatability shown for PN ingress

- Larger variability on PM, but concentrations generally low

- Firm methodological platform for inclusion of additional pollutants

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Future directions

- Testing vehicles comparatively for consumer information

- Subscription database for benchmarking and R&D

- Widening boundary conditions

- Measuring ingress of NO_x and VOCs

- Build-up of VOCs from off-gassing from interior materials

Thank you.

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Assured
Emissions testing in real-world conditions brings challenges that experience anticipates and expertise overcomes. We deliver.

Independent
Objectivity and candour are the driving forces in all our work, so you know the facts.

Responsive
We're fast on our feet so we can conduct emissions testing when and where we're needed.

Our Belief

When it comes to the pursuit for improved air quality, we believe in the power of clarity, transparency and integrity. With real-world data we can meet emissions challenges – instilling trust and confidence in our industry partners and public.

It's with our commitment and independence we are able to make a significant contribution toward positive change and to achieve enduring results.