ENHANCING THE TESTING METHODOLOGY FOR MEASURING TYRE PARTICLE EMISSIONS

ETH Nanoparticles Conference (NPC 2025)

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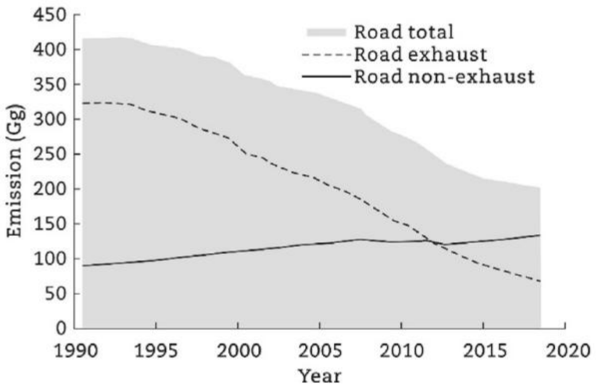
Agenda

- Introduction Tyre and Road Wear Particles (TRWP)
- Non-exhaust emissions measurements at DLR
  - Project ZEDU-1
  - Methodology for tyre emissions in a dynamometer
- Selected results
- Next steps

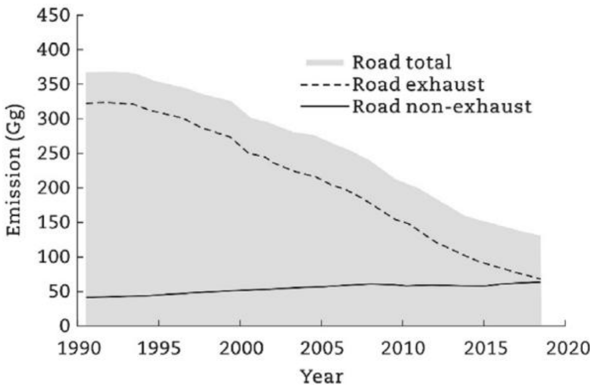
Let´s go!

Introduction

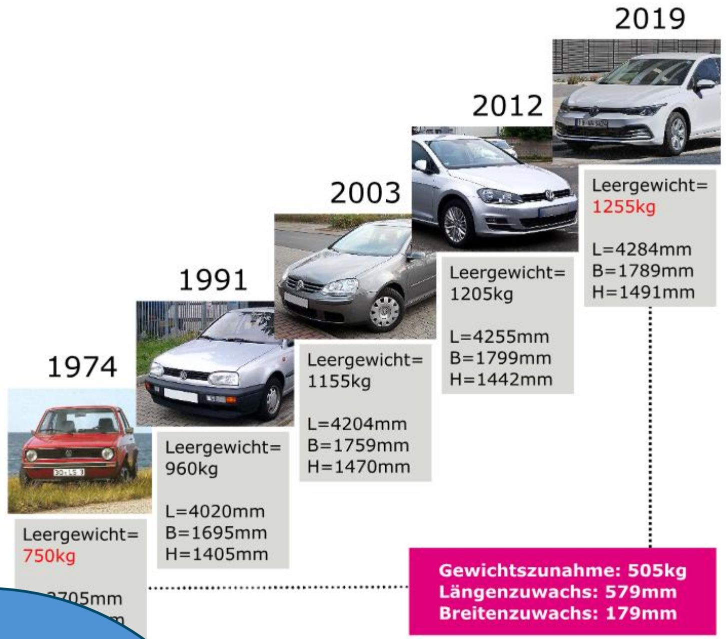
PM$_{10}$



PM$_{2.5}$



Source: He, C et al.: A review of non-exhaust emissions on pavement area: Sources, compositions, evaluation and mitigation, J. Traffic Transp. Eng., 11, 6, 1243-1258 / CC BY-NC-ND 4.0



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- Tailpipe emissions have been significantly reduced, non-exhaust emissions are becoming increasingly important
- With the electrification of vehicles, the relative contribution of TRWP to total particulate matter is expected to rise

Euro 7 → Tyre abrasion limits

Do you understand what you would like to regulate?

TRWP: Tyre and Road Wear Particles

Introduction

- Scarce studies
- Discrepancies in the literature
- A lot of factors influence the result
  - Dynamometer or field?
  - T? RH?
  - Tyre pressure?
  - Tyre composition?
  - Vehicle load?
  - Road composition?
  - Speed?
  - Tyre mileage?
  - Tyre age?
  - Collection efficiency?
  - Measurement techniques?

*"In summary, the identified primary studies reported **35 TWP PM_{10} emission factors ranging from 0.00093 to 11.0 mg/vkm** (mean of 2.7 mg/vkm, median of 1.1 mg/vkm) including estimates for mixed fleets and resuspended TWP"*

Saladin et al., 2024 Airbone tyre wear particles: a critical reanalysis of the literature reveals emission factors lower than expected Environ. Sci. Technol. Lett., 11 (2024), pp. 1296-1307

Standardization is urgently needed!

TWP: Tyre Wear Particles

NON-EXHAUST EMISSION MEASUREMENTS AT DLR

Zero Emission Drive Unit Generation 1 (ZEDU-1)

Objective: Demonstration and evaluation of novel technologies for zero-emission driving

Duration: 03/2020 – 03/2023

Sponsor: Baden-Württemberg Ministry of Economics, Labour and Tourism

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Environmental Science and Pollution Research (2024) 31:53521–53531
https://doi.org/10.1007/s11356-024-34543-9

RESEARCH ARTICLE

Check for updates

Investigations of airborne tire and brake wear particles using a novel vehicle design

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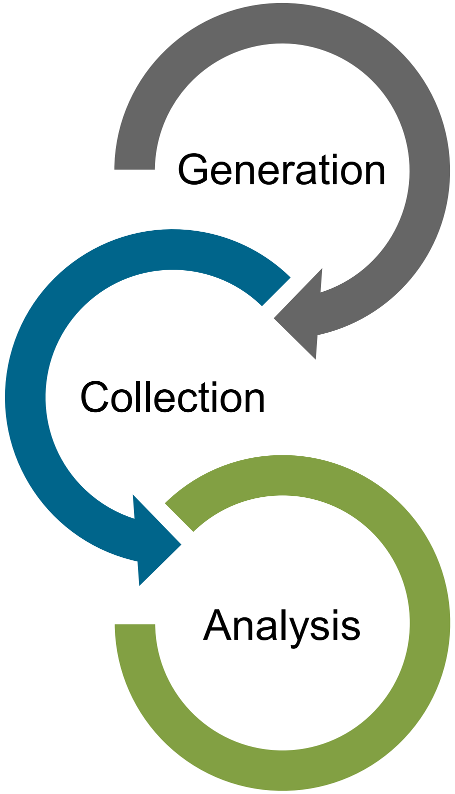
ZEDU-1 Demonstrator

- **Reduction of airborne tyre emissions:** Housing with particle extraction and filter system

Development of tyre measurement methods: The 3 step approach



- Same vehicle / rear tyres
- Tyre temperature monitoring / Same start temperature
- 4 roller chassis dyno
- WLTC 3b, driving error limited
- Constant ambient temperature and RH

- Clean room conditions
- Monitoring of background concentration

- Identical instrumentation
- PM – gravimetric – cyclone (offline)
- PN – condensation – CPC (online)
- PSD – optical – OPS (online)

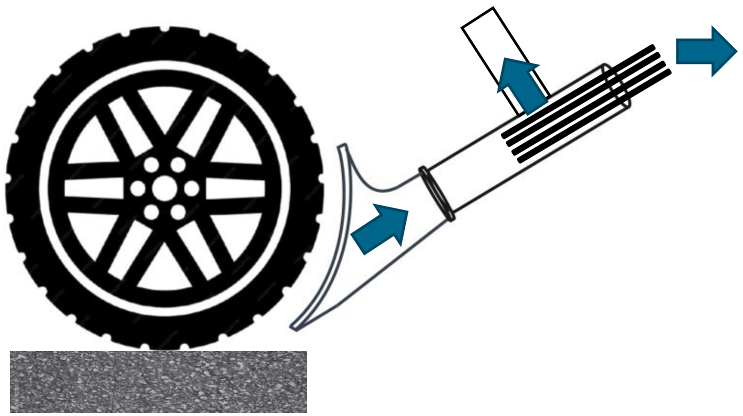
Adapted from Seren Celenlioglu et.al., *Influence of Collection System on the Tyre Wear Emission Measurements* in Tyre Emission Research Conference, Munich, 04 Dec 2024

Methodology – Collection systems

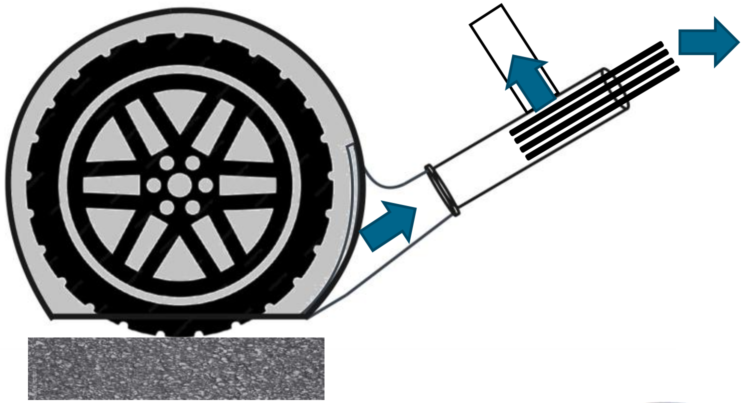
- Chassis dynamometer test bench
- Realistic driving resistance
- Electric vehicle BMW i3
- WLTC class 3b
- Brake encapsulation
- Tyre surface < 30 °C
- T: 23 °C, RH: 50 %
- Nozzle adaptation for isokinetic sampling
- Constant dilution rate
- Background particles control
- Characterization of particle losses

WLTC: Worldwide Harmonised Light vehicles Test Cycle

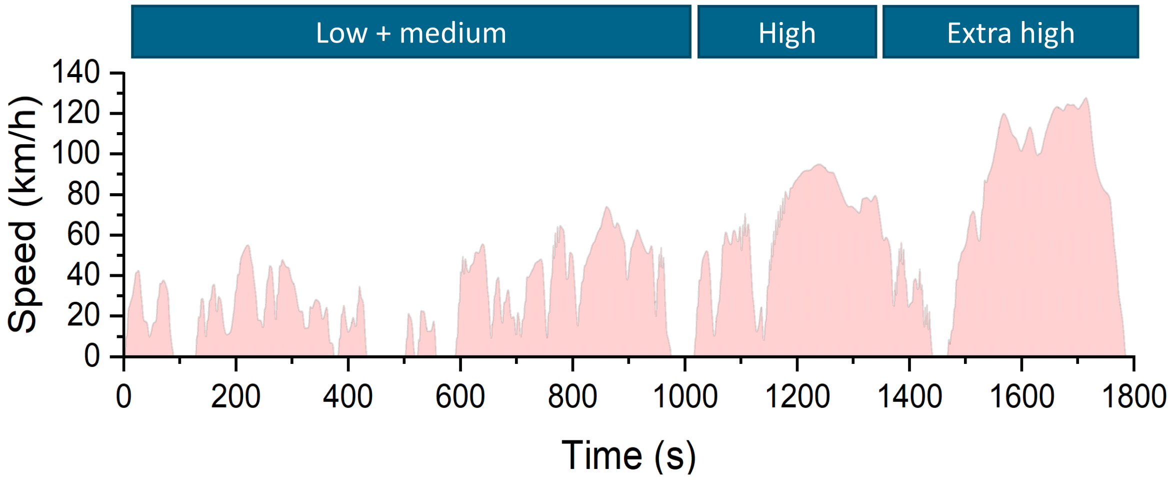
Open Collection System (DLR^{TM})

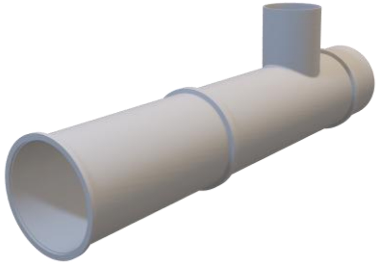


Housing Collection System (DLR^{TM})

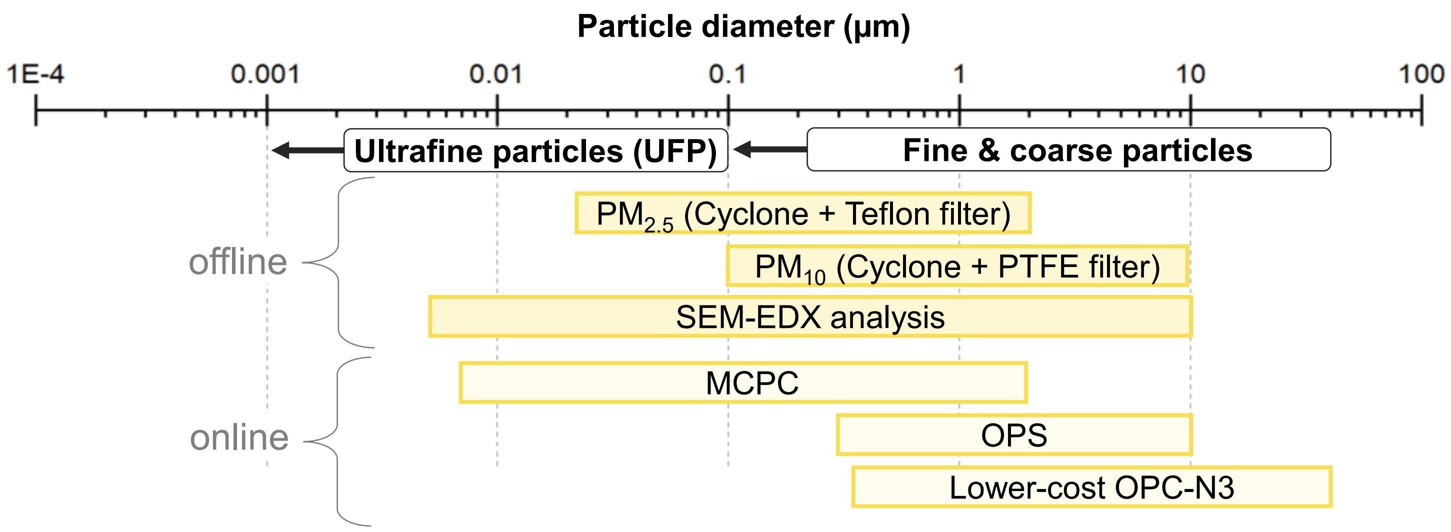


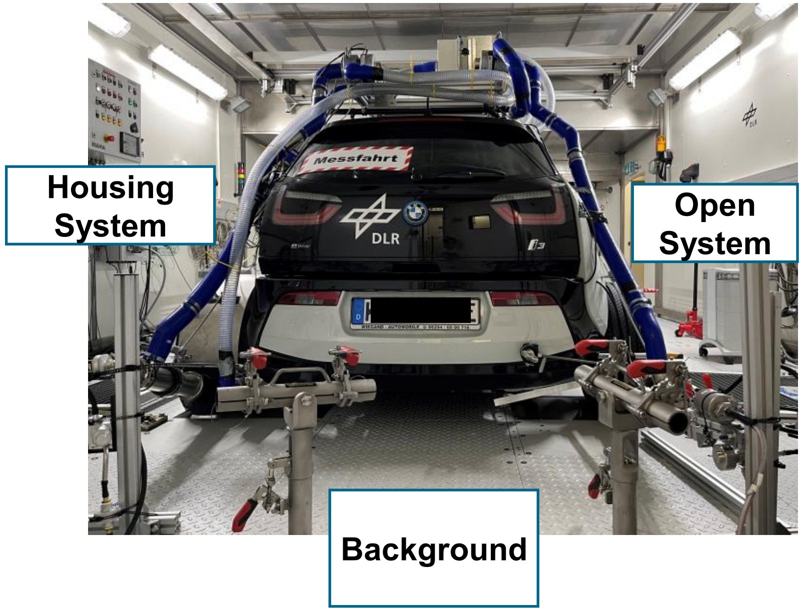
WLTC class 3b





Methodology – Particle measurement techniques





Models and Data for Future Mobility

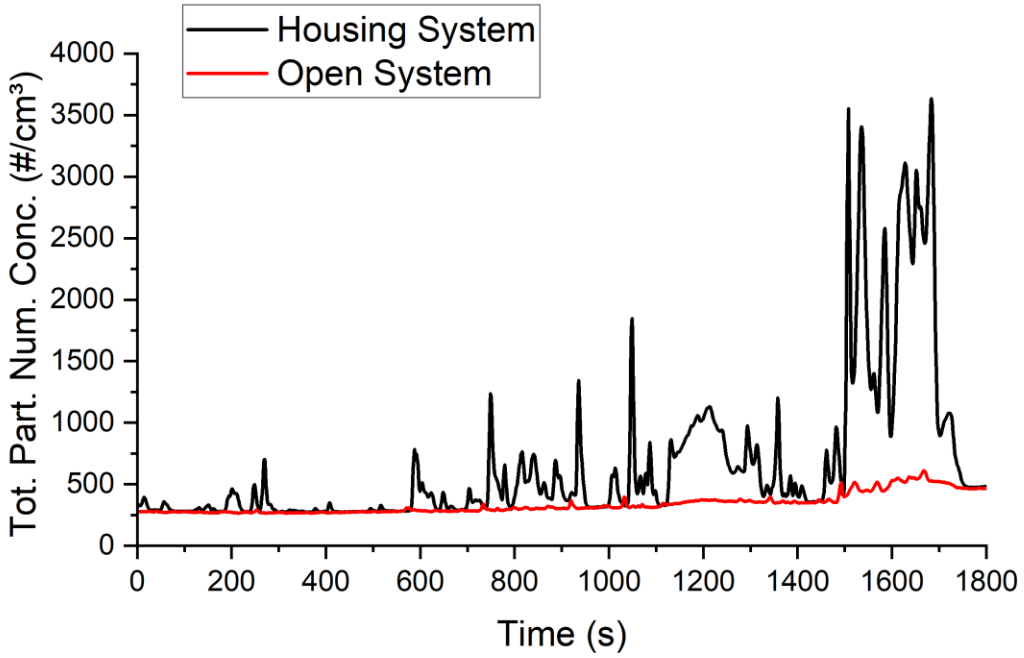
Air Quality Live

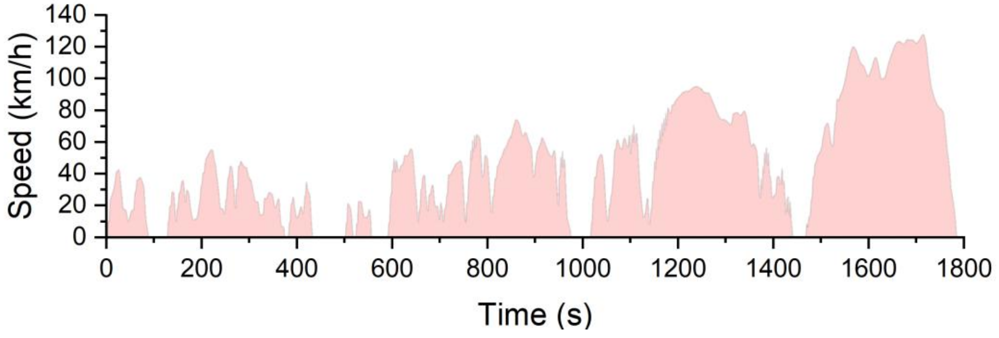
- Optical Sensors for Non-Exhaust Emissions in RDE tests
- Mobile sensor network
- Stationary sensor network (PM + Gases)

MCPC: Mixing condensation particle counter
OPS: Optical particle sizer
OPC: Optical particle counter
SEM-EDX: Scanning electron microscopy-energy dispersive X-ray spectroscopy
RDE: real driving emission

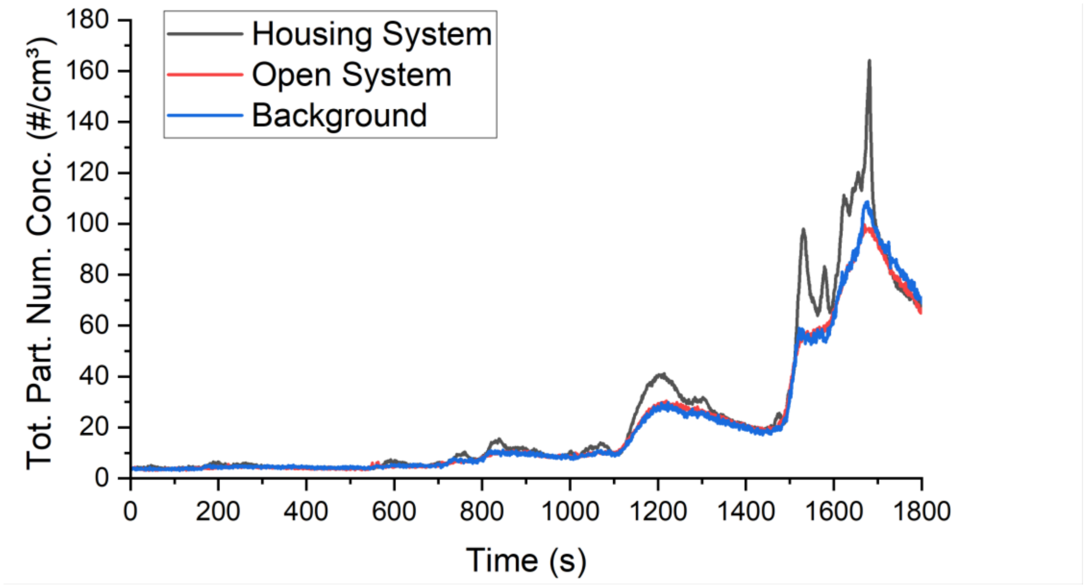
Results – Housing vs open system (average 8 WLTCs)

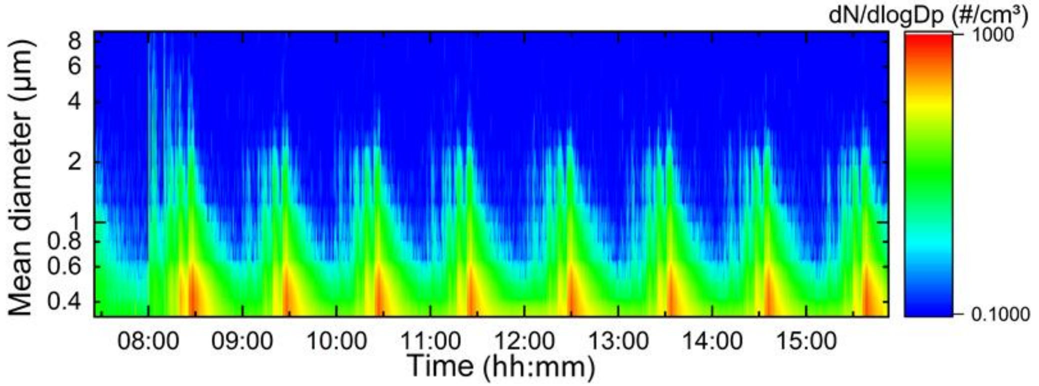
7 nm to 2 µm





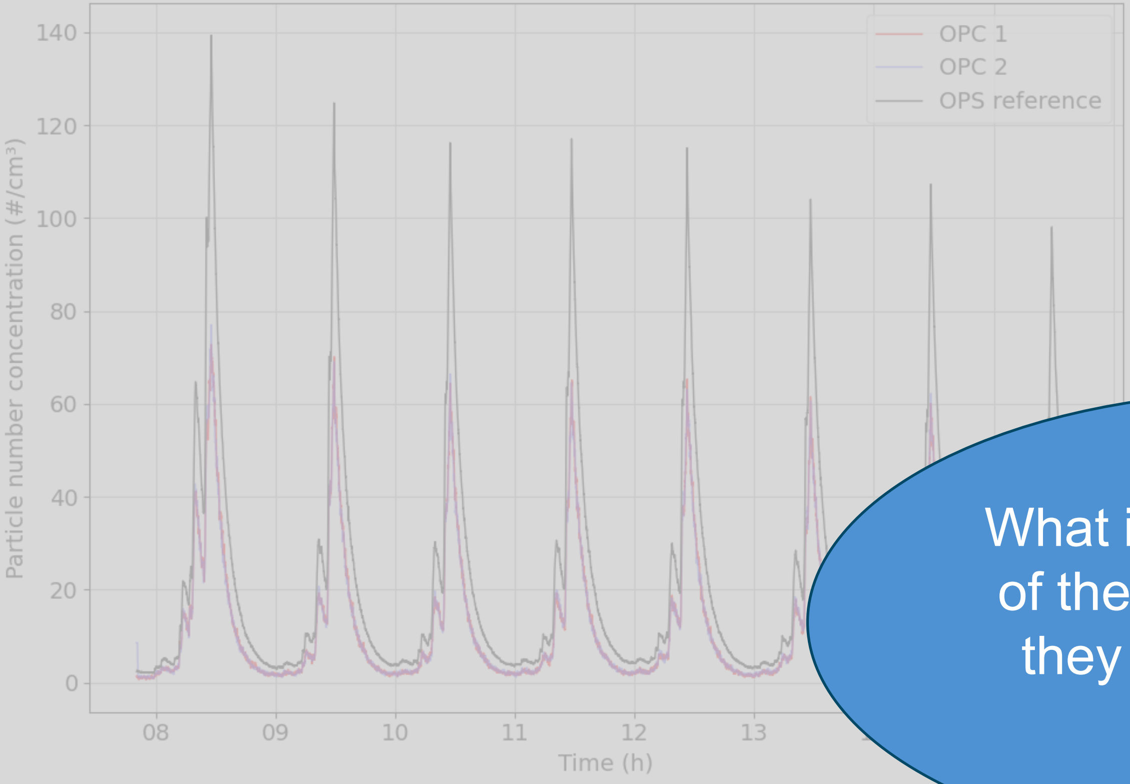
0.3 to 10 µm

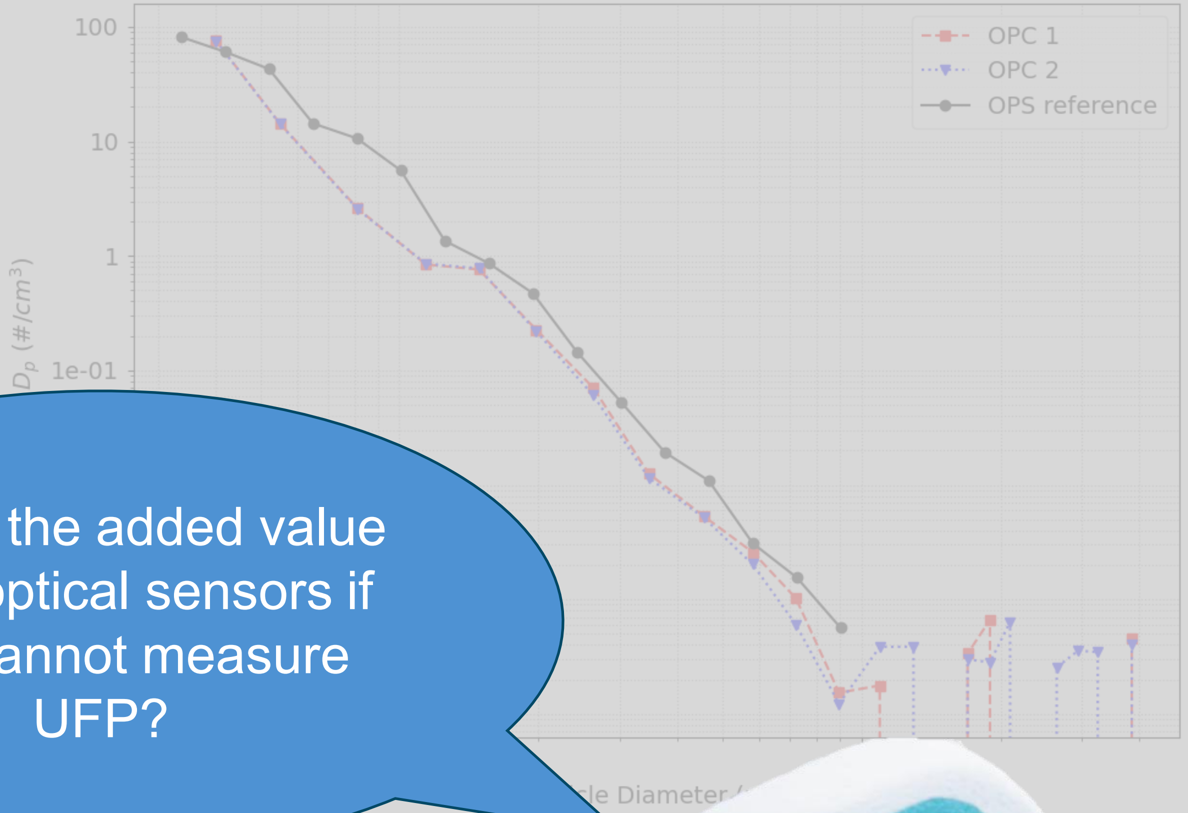




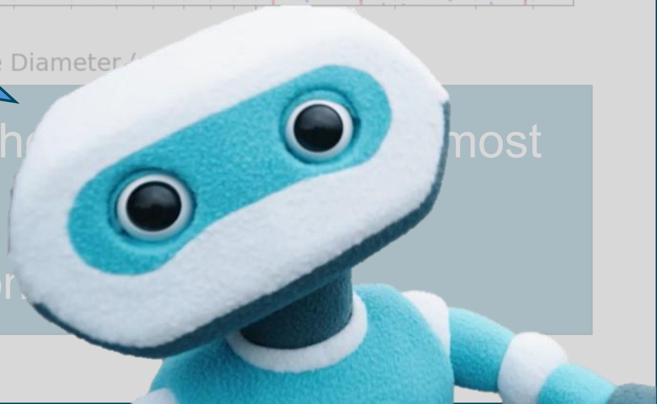
WLTC: Worldwide Harmonised Light vehicles Test Cycle

Results – Background OPS and OPC-N3 sensors 8 WLTC





What is the added value of the optical sensors if they cannot measure UFP?



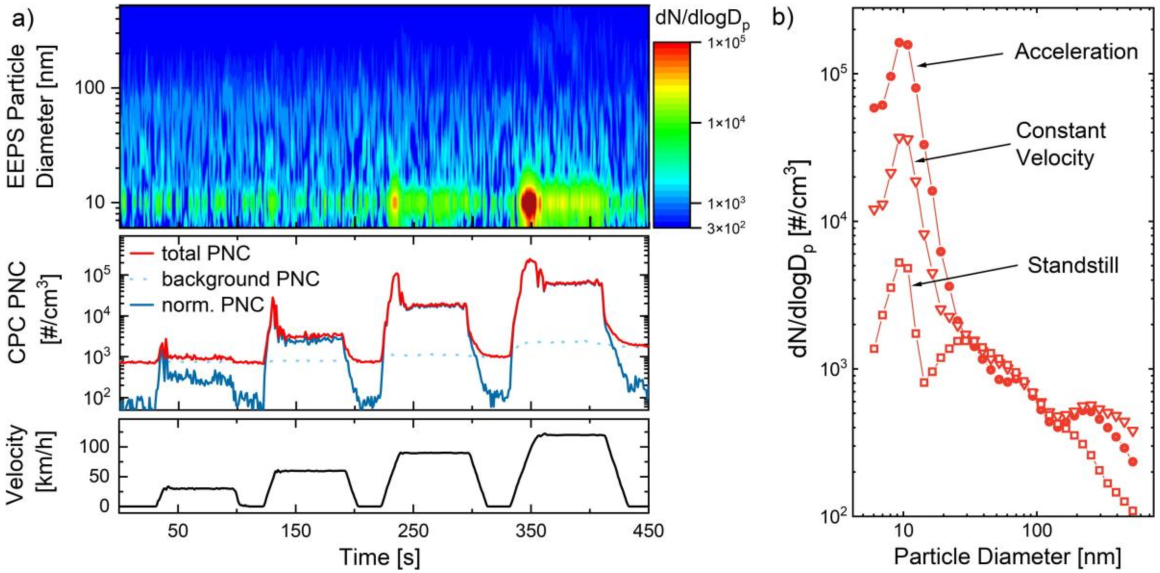
- Background measurements with real driving resistance at different speeds
- Very good results for a being 30 times cheaper

- Underestimation of th… most of the channels
- Additional informatio…

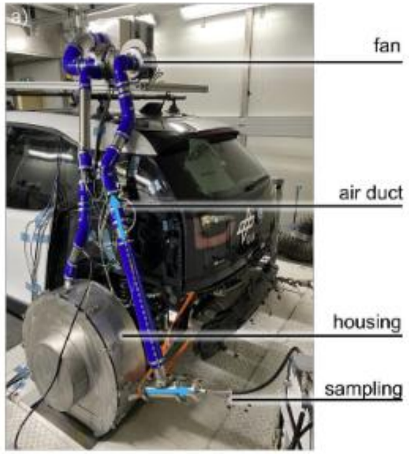
Characterization of airborne tire particle emissions under realistic conditions on the chassis dynamometer, on the test track, and on the road

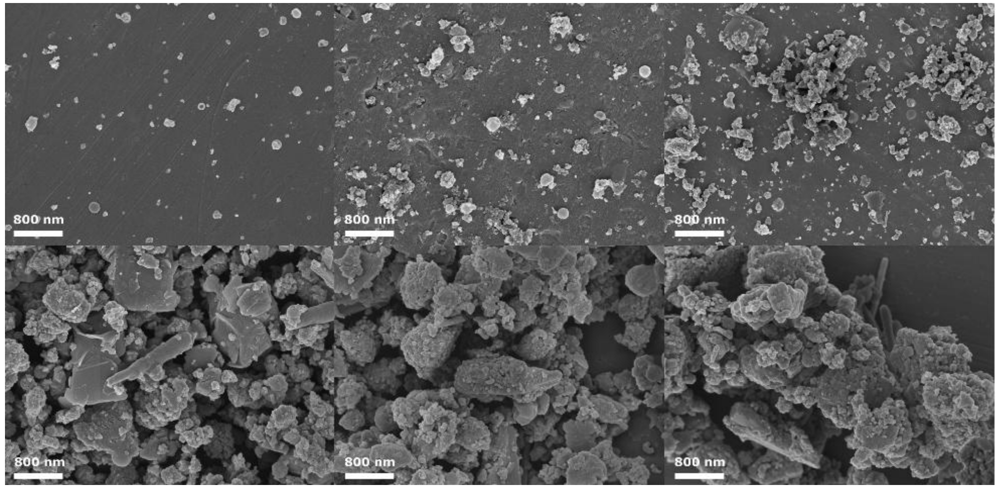
Linda Bondorf, Manuel Löber, Tobias Grein, Lennart Köhler, Fabius Epple, Tobias Schripp, ...show all

- Normalization by substraction of the background concentration (CPC)
- A dominating **ultrafine particle mode at 10 nm** and a second esmission mode at **270 nm**



- SEM analysis: A variety of particle types, indicating different particle formation processes
- Chemical composition (EDX) is dominated by C, O and Fe, with the latter presumably originating from the drum surface





Characterization of airborne tire particle emissions under realistic conditions on the chassis dynamometer, on the test track, and on the road

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Driving cycles and Emission Factors (EF)

- Four different driving cycles investigated on the chassis dynamometer
- Emission factors (EF) calculated using background correction and the volume flow
- Large variance of the EF from 1.15×10^9 #/km for the LA4 to 2.75×10^9 #/km for the US06
- A representative driving cycle and real-world driving emissions measurements are crucial

Driving Cycle	Avg. Velocity (km/h)	Avg. Force (N)	UF[illegible] left rear	$EF/EF_{WLTC\ Class\ 3b}$
WLTC Class 3b	46.5	277.7	[illegible]	1.0
Großglockner	40	505.1	[illegible]	0[illegible]
ZEDU RDE	47.2	316.6	[illegible]	[illegible]
LA4	31.5	235.9	[illegible]	[illegible]
US06	77.9	487.1	[illegible]	[illegible]

*particles between 4 nm and 3 µm

Next steps

- Additional sensors will be added for better understanding on the tyre surface temperature (thermography) and its influence in the UFP emissions
- Optimize Housing Collection System for measurements on the roads
- Integrate low-cost sensors for RDE testing

RDE: real driving emission

Impressum

Thanks for your attention :)

Topic:	Enhancing the testing methodology for measuring tyre particle emissions
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I have a lot questions!!!