nPETS
nanoParticle Emissions
from the Transport Sector

Nanopartiklar från tranportsektorn – en översikt över nPETS-projektet

Ulf Olofsson & Ellen Bergseth, KTH

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This project has received funding from the European Union's Horizon 2020 Research and Innovation programme, under grant agreement № 954377.

Outline

- **Introduction to nPETS**
- **Measurements**
  - Lab
  - Field (near-source)
- **Particle analysis**
  - The ALI-system
- **Communication & dissemination**

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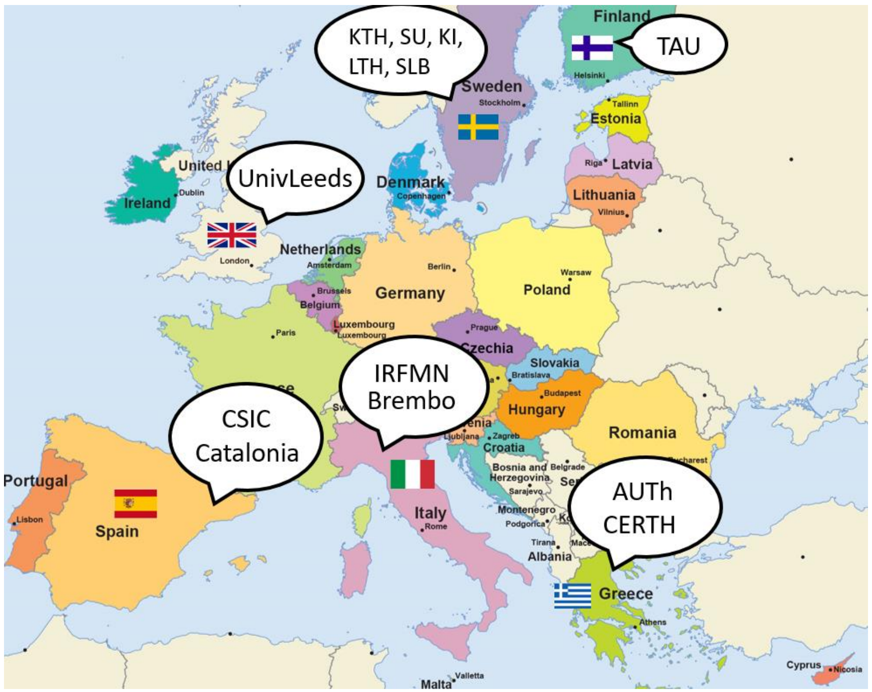
7 universities, 3 research institutes, 2 cities and 1 company (>50 people)



UNIVERSITY OF LEEDS
Tampere University
KTH VETENSKAP OCH KONST
brembo
IMN
Stockholm University
KAROLINSKA INSTITUTET ANNO 1810
CSIC
Generalitat de Catalunya
LUND UNIVERSITY
ARISTOTLE UNIVERSITY OF THESSALONIKI
CERTH CENTRE FOR RESEARCH & TECHNOLOGY HELLAS
Stockholms stad

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nPETS user group

1. European Conference of Transport Research Institutes (ECTRI), Belgium
2. Aena S.M.E., S.A., Airport Josep Tarradellas Barcelona-El Prat, Spain
3. Port de Barcelona Harbour, Spain
4. Stockholm city, Environmental and Health Administration, Sweden
5. Polis – cities and regions for transport innovation, Belgium
6. NGVA Europe, for sustainable mobility, Belgium
7. Comune di Milano, Italy
8. Ferrocarrils de la Generalitat Valenciana (FGV), Valencian public railway, Spain
9. Trafikverket (the Swedish Transport Administration), Sweden
10. The Swedish Environmental Protection Agency, Sweden

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Emissions from the transport sector both exhaust and non-exhaust

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Transport nanoparticles (call text)

Assessing and understanding the biological processes leading to negative effects on human beings and animals (including sex and gender differences, when relevant) in particular impacts of nanoparticles below 100 nm on carcinogenesis in multiple organs including both inflammation effects and the "Trojan Horse" effect of the different chemicals constituting or absorbed on the particles, as well as combined effects of the various components of exhaust gases. Work should consider both aged and fresh aerosols, include primary and secondary volatile and not volatile particles, in particular considering the significant emerging component of extremely fine nanoparticles (below 23 and even 10 nm) constituting a large share of exhausts from certain types of engines like gasoline and natural gas ones.

Assessing if and what variability of these effects exists with size, chemical composition and morphology, linking as far as possible the impacts with specific emission sources and leading to an understanding and quantification of the risks posed by different types and sources of particles. This research should cover all types of transport-related particles sources (both exhaust and non-exhaust, from road, rail, aviation and shipping) taking into account results from previously funded research projects in the same areas.

Evaluating the possible future impact of new policies in this area on public health and well-being of citizens and acceptance of the negative economic impacts that could derive from them.

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nPETS story

The story that nPETS aims to communicate is the life of the sub 100 nm emissions from its creation to its potential path to human beings and animals.

The nPETS consortium aims to improve the knowledge of transport generated exhaust and non-exhaust nanoparticle emissions and their impacts on health and new public policies.

It aims to monitor and sample with state-of-the-art particle instruments the sub 100 nm transport generated emissions from shipping, road, rail, and aviation both in field and controlled laboratory environments.

Both aged and fresh aerosols will be considered, including primary and secondary volatile and non-volatile particles.

Characterising the emissions will be done from shipping, road, rail, and aviation by linking their sizes, chemical compositions, and morphologies to its specific emission sources such as engines, brakes, clutches, and tyres to increase the understanding of the mechanisms behind adverse risks posed by different types and sources of the identified sub 100 nm particles.

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An overview of the nPETS concept

Emission quantification

Sampling of primary particles in laboratories
- Exhaust (gasoline, natural gas)
- Non-exhaust (tyres, brakes, clutches)

In field sampling of particles in core cities
- Road
- Aviation
- Shipping
- Railway

Particle characterization

- Particle size distribution
- Morphology
- Chemical composition

Toxicology

- Laboratory cell exposure studies
- Real-world cell exposure studies
- Review of nanoparticles toxicology and epidemiology studies

Health risks and policies

- Review of policies and their economic impacts
- Health impact assessment of future policies

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nPETS WPs

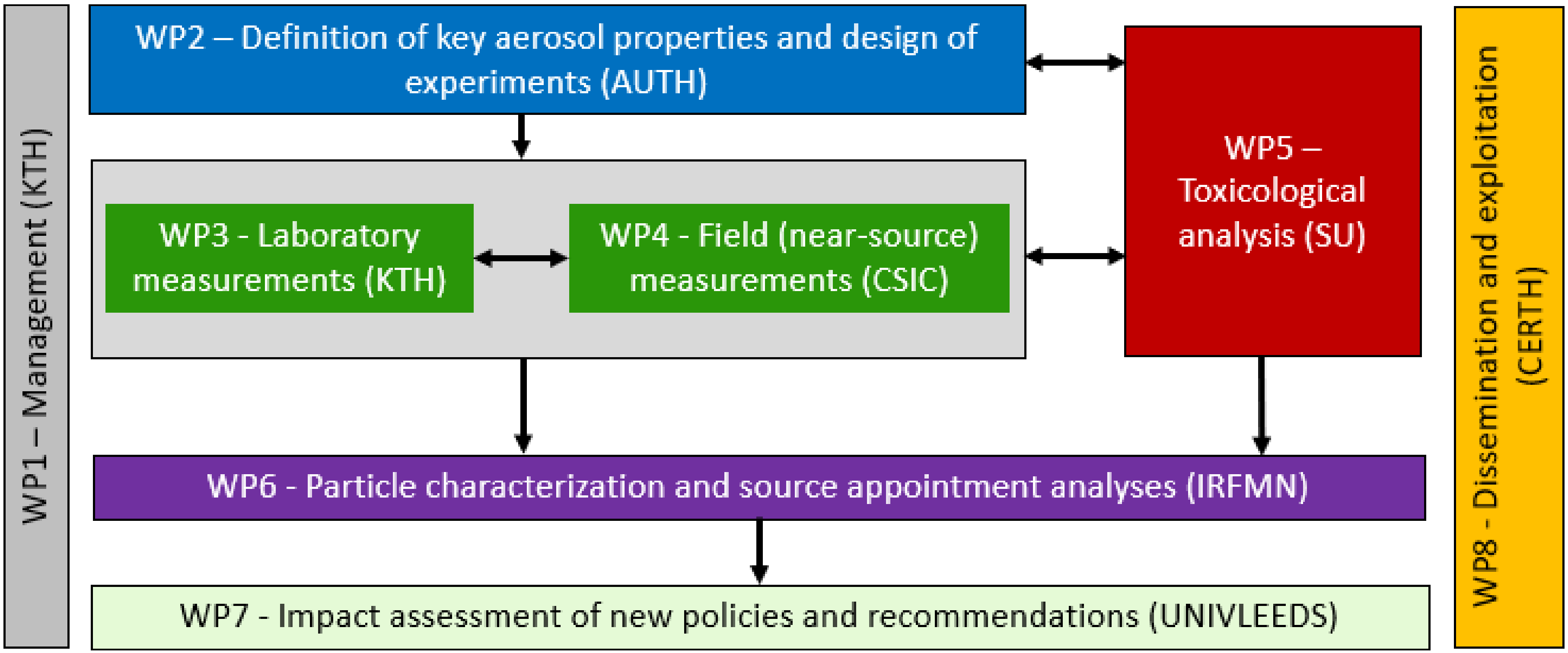

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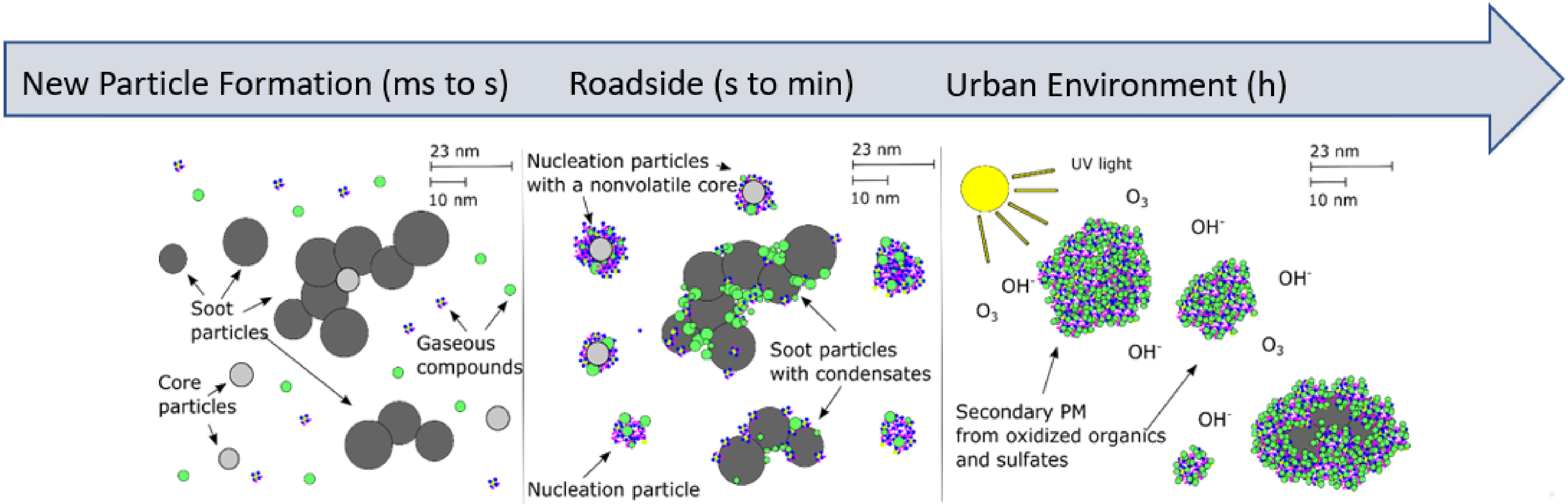
Illustration of New Particle Formation (NPF) transformation from source to urban environment



Primary, fresh and secondary particles
Engine Lab, Tribo Lab, Disc brake dynamometer

Near source particles
Road and Railway tunnel, Airport, Harbour

Aged and Secondary particles
Urban background

Simonen, P., Saukko, E., Karjalainen, P., Timonen, H., Bloss, M., Aakko-Saksa, P., Rönkkö, T., Keskinen, J., and Dal Maso, M.: A new oxidation flow reactor for measuring secondary aerosol formation of rapidly changing emission sources, Atmos. Meas. Tech., 10, 1519-1537, doi:10.5194/amt-10-1519-2017, 2017.
Down To Ten, HORIZON 2020 Call: H2020 GV 2016 2017 Technologies for low emission light duty powertrains, Final Review Meeting, Brussels 28th February 2020.

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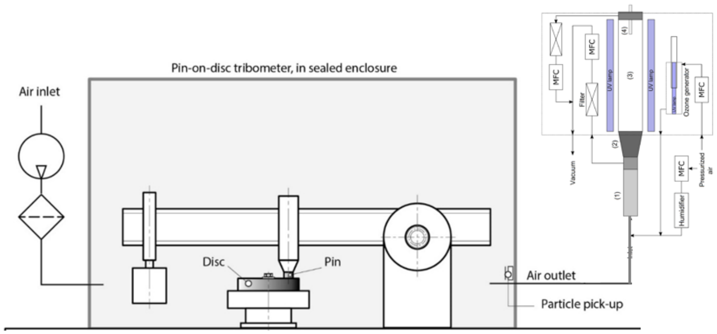
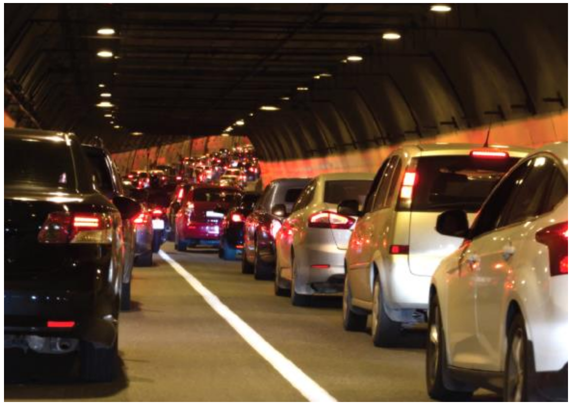
Illustration of New Particle Formation (NPF) transformation from source to urban environment

New Particle Formation (ms to s) Roadside (s to min) Urban Environment (h)





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nPETS instrumentation

Since there is no common methodology for comparable measurement of sub 100 nm particle emissions from the transport sector, all quantification and monitoring will be performed with the same instruments to ensure comparable measurement results.

ELPI+ (number of UFPs and size distribution)

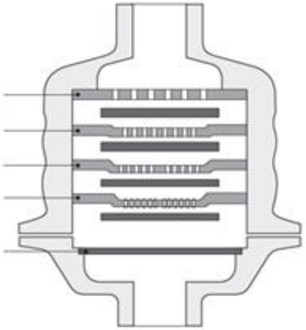
- Size distribution (6, 16, 30, 54, 94 nm…10 µm)
- Number of particles
- Particles on filters

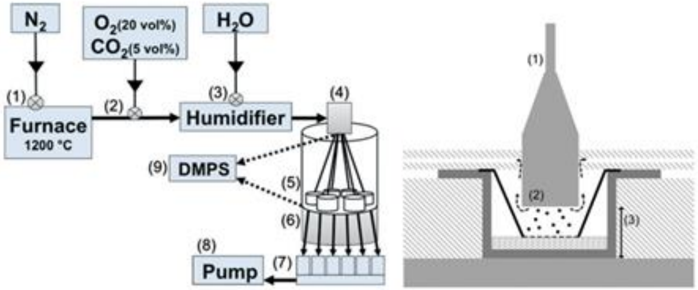
DGI (high volume sampling)

- Particles on filters (4 stages: 2 µm – 100 nm)

ALI (mobile cell exposure module)

- Particles on cells





Two mobile ALI-systems

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Lab measurements

Type of emission source/type of wearing interface					
Exhaust	Mechanical brake	Clutch	Tyre-to-road	Wheel-rail	Third-rail
Chassis dynamometer (LAT/AUTh)	Brake dynamometer (Brembo)	Clutch tribometer (LTH)	Tribometer (KTH)	Tribometer (KTH)	Tribometer (KTH)
Engine lab (KTH)	Brake tribometer (KTH)				

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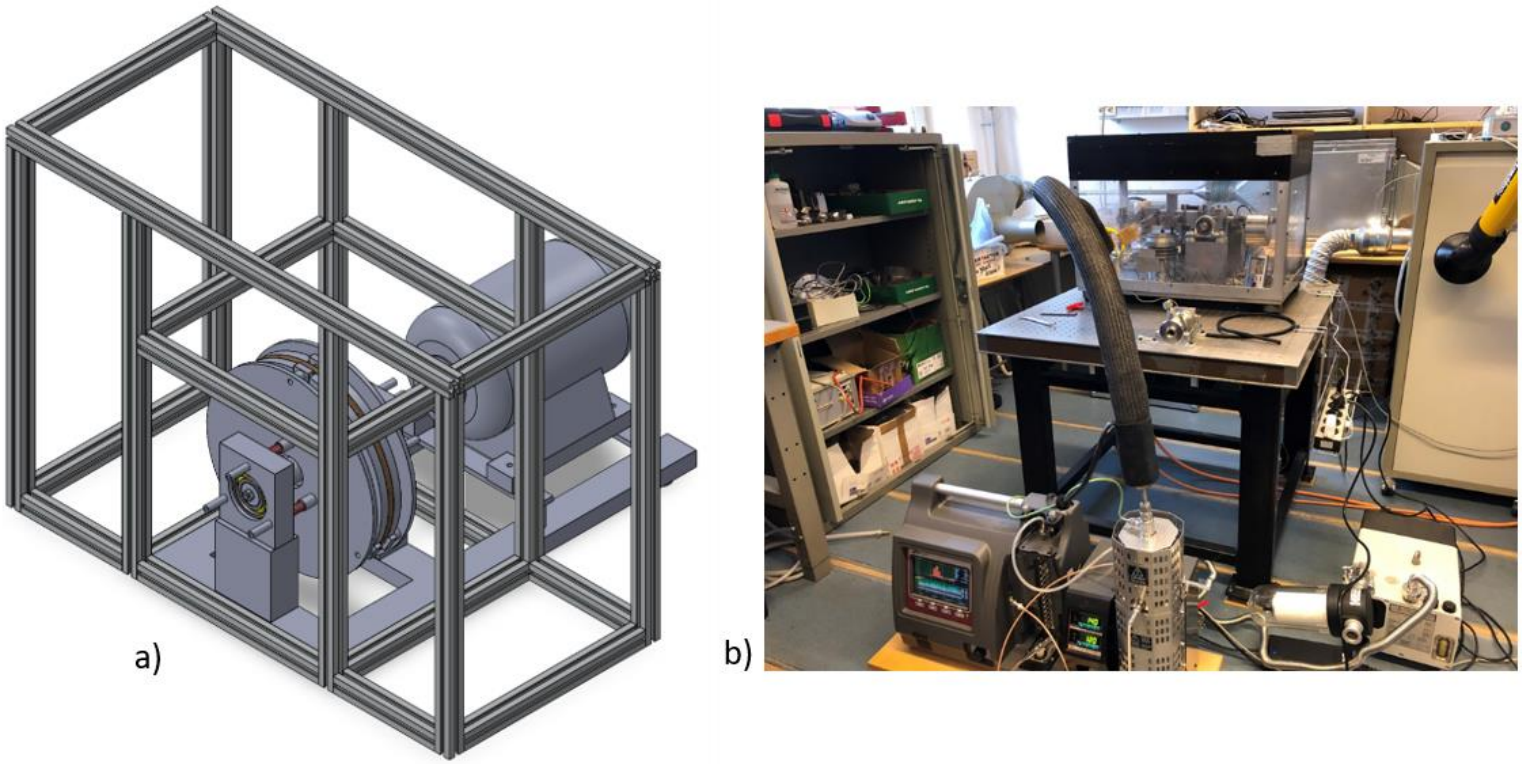
Lab measurements – tribometers



a) CAD-model visualising the clutch tribometer at LTH and b) a photo of the pin-on-disc tribometer in the lab at KTH for studying brake particles from trains.

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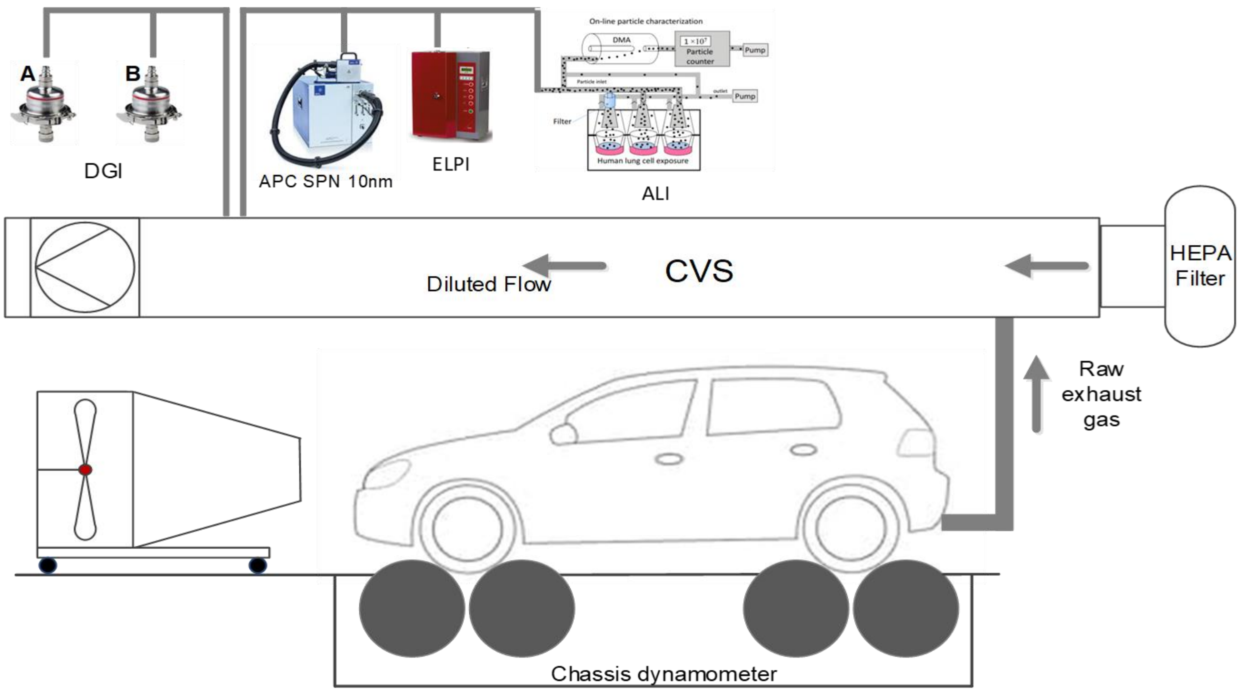
Lab measurements – chassis dynamometer



Measurement setup utilized for tailpipe and CVS PN/PM measurement

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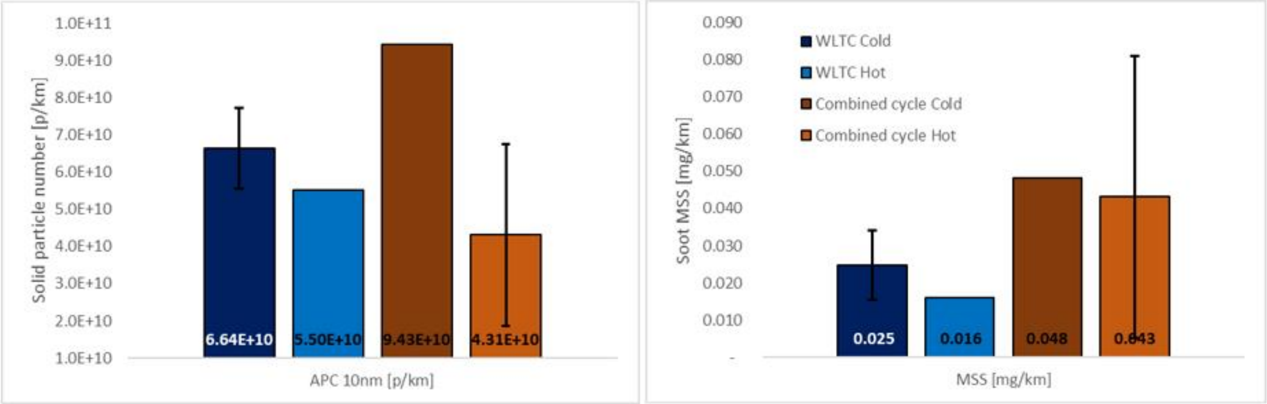
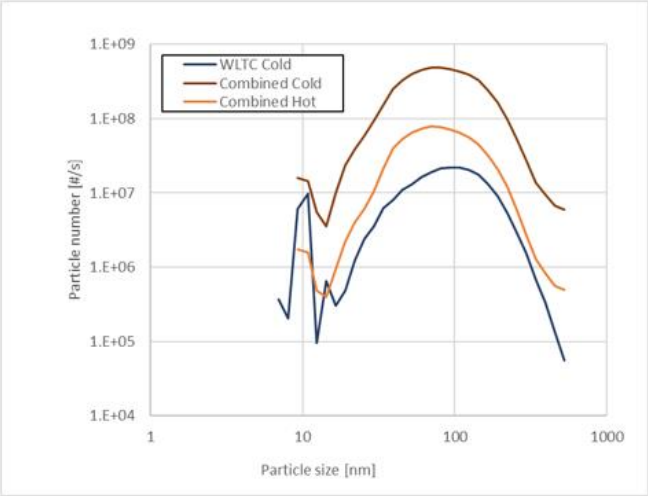
Lab measurements – chassis dynamometer

a)



b)



a) Average PN and soot emissions of the two cycles and b) Particle size distribution on the two cycles.

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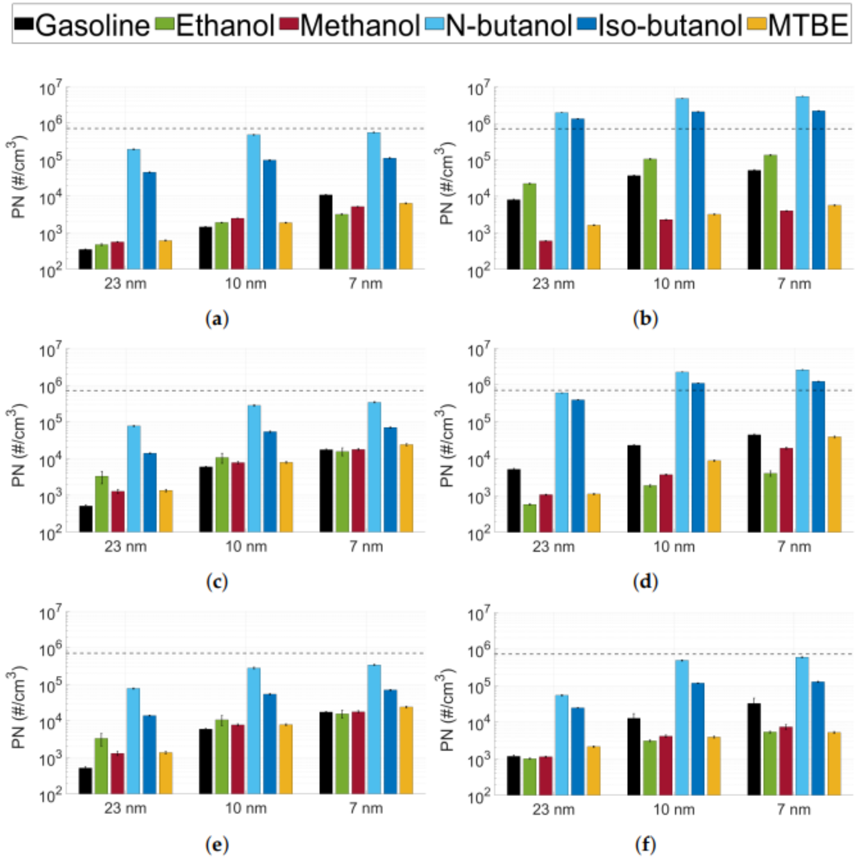
Lab measurements – Gasoline-Optimised DISI Engine



The particle number emissions at different cut-off sizes and different operating conditions measured using the CPCs.

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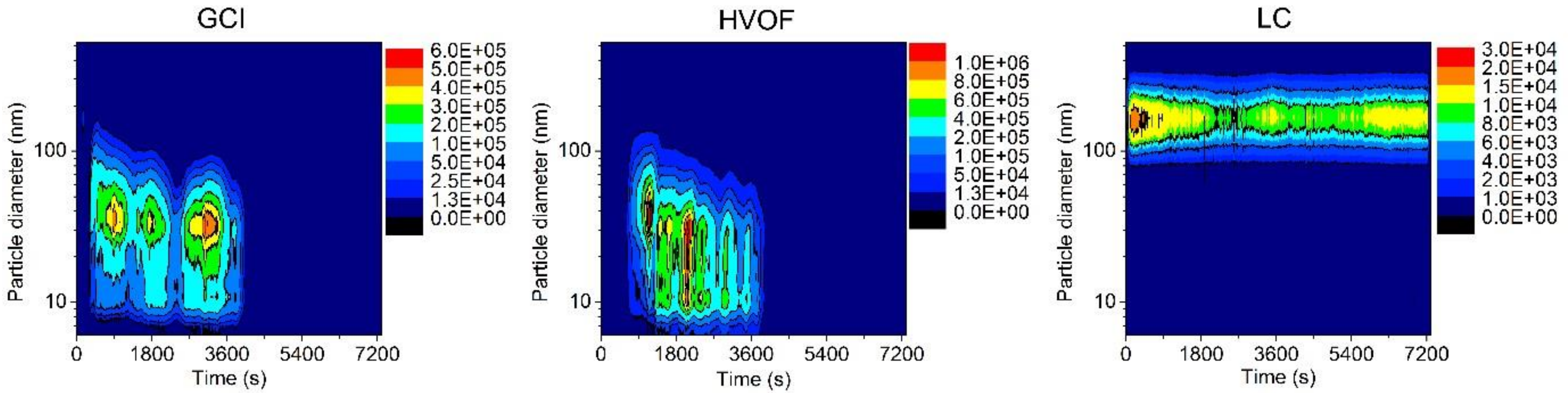
Lab measurements – Mechanical brake



3D contour plots of particle concentration dN/dlogDp (#/cm^3) from three brake disc materials.

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Field (near-source) measurements

	Road	Rail	Air	Sea	Urban background
Barcelona	Roma Avenue	Valencia metro	Josep Terradellas	Barcelona Harbour	Palau Reial
Stockholm	Söderledstunneln	Tekniska Högskolan metro station			Maria Hospital
Thessaloniki	Egnatia & Ionos Dragoumi		Thessaloniki Airport	Thessaloniki Harbour	Thessaloniki
Milan	Viale Marche	Saronno railway station	Milan Linate Airport		Milano Pascal

Each field campaign is estimated for four weeks. Most of the campaigns will cover two seasons.

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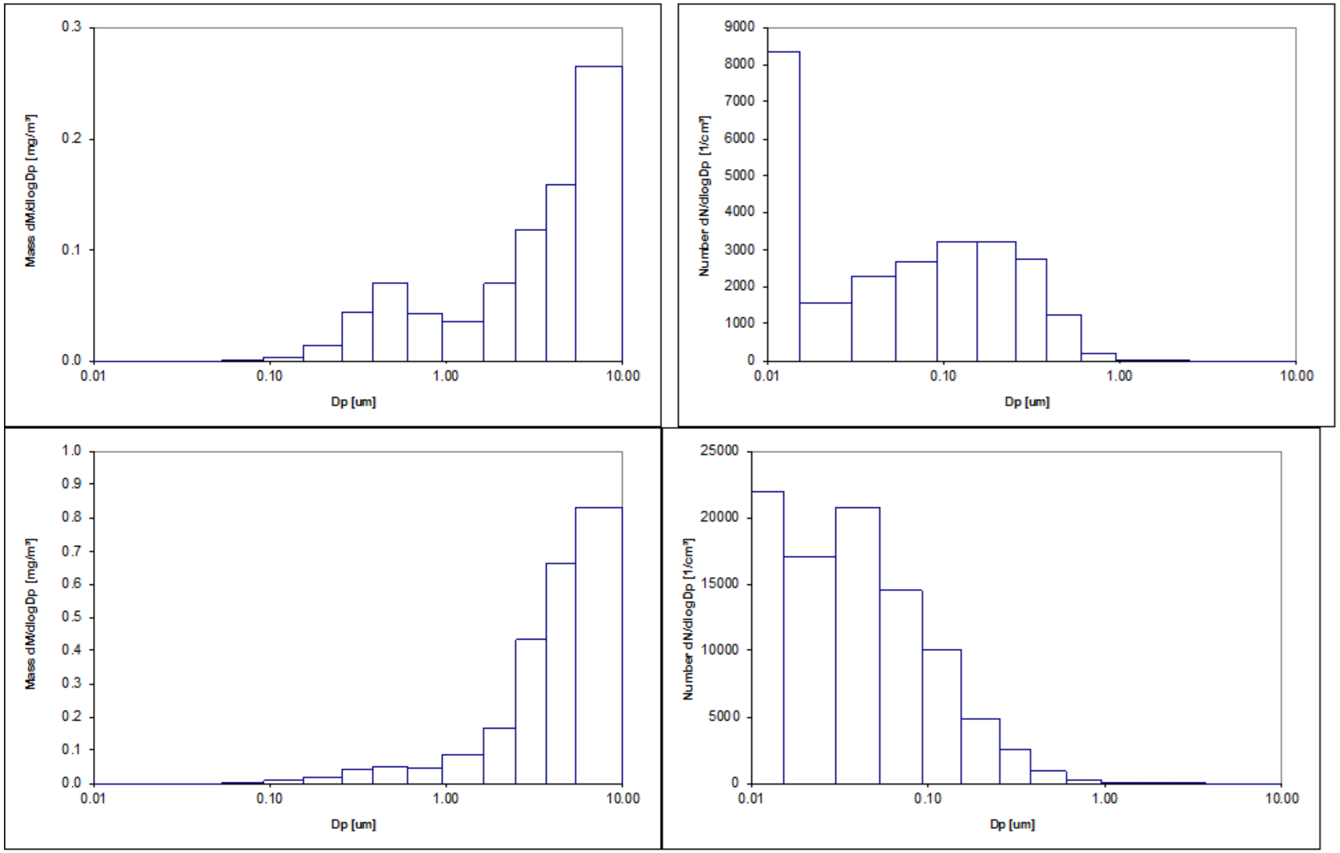
Field (near-source) measurements



Example of daily averaged mass size distribution (left) and number size distribution (right) in the urban background site (top) and traffic site (bottom).

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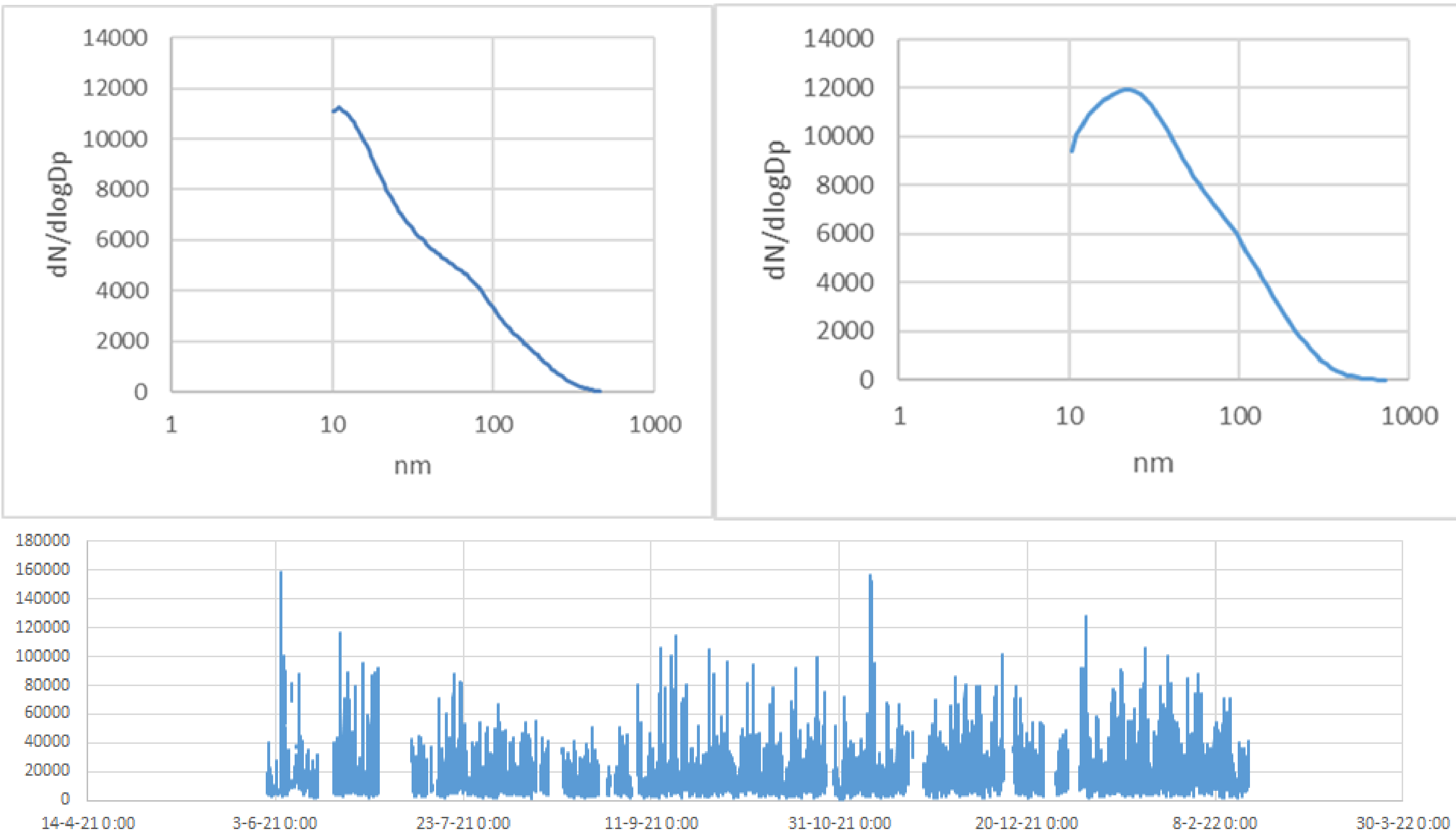
Field (near-source) measurements



Top: SMPS Number size distribution in the Barcelona urban background site (Palau Reial) in the period July-August 2021 (left) and January-February 2022 (right). Bottom: CPC total particle number (>3 nm) time series at the same site.

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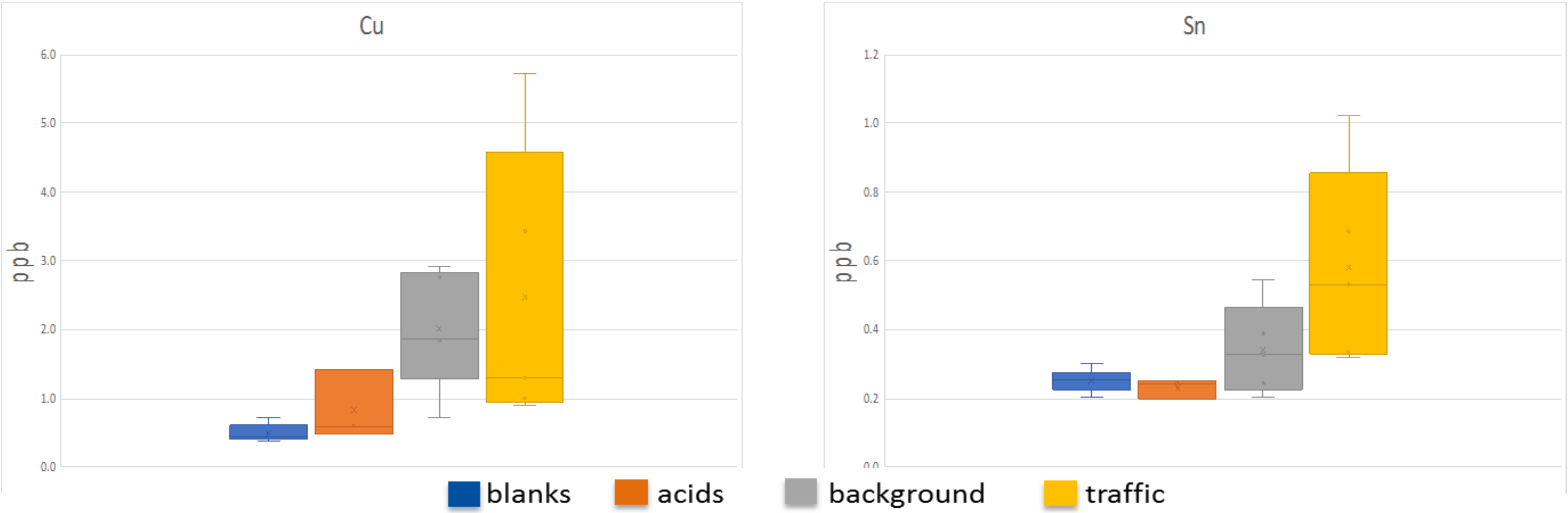
Field (near-source) measurements



ICP-MS results for Cu and Sn in <100 nm samples obtained at background and traffic site in Barcelona, in comparison with blank filters and blank acids used for digestion.

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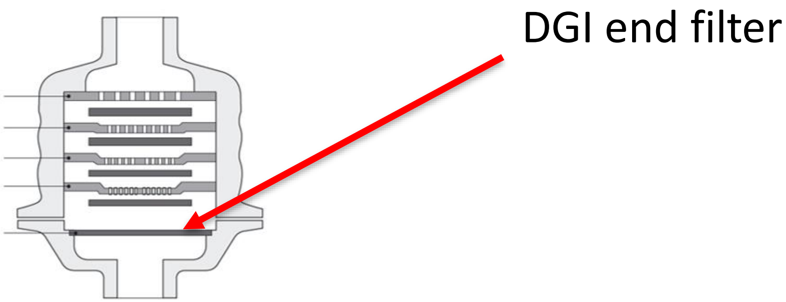
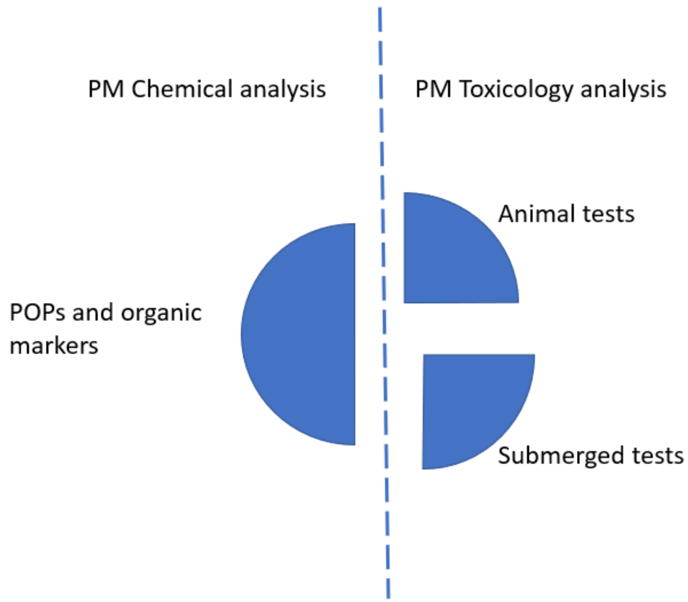
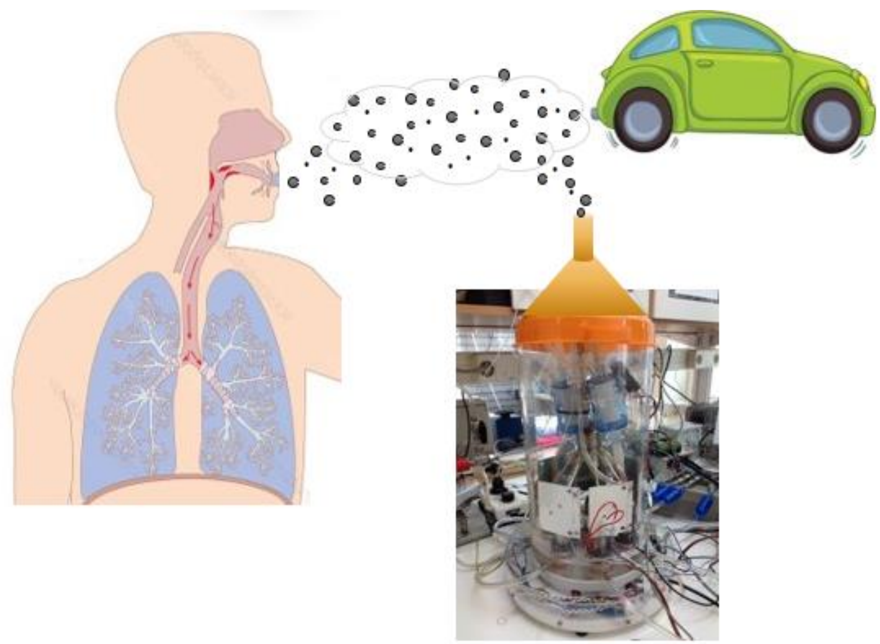
Particle analysis consists of chemical and toxicology analysis







The ALI-system enables deposition of un-changed airborne particles

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Chemical analysis

1. **Size and morphology characterization using SEM and TEM (the structure of the sampled particles will be analysed for size, shape and presence of agglomerations)**
2. **Source specific toxicological scores based on physical, chemical, ageing and toxicological analyses**

	Fuels Exhaust	Brakes Non-Exhaust
Overall Inorganic Fraction	Secondary	Dominant
Main Elements	P, Ca	Fe
Secondary Elements	Mg, Fe, Zn	Si, S, Sn, Cr, Zn
Trace Elements	Cr, Ni, Cu	P, V, Cu
Not Assessed Elements	Al, Si, K, Ti, V, S, Mn	Al, Mn, Ti

Summary of the obtained results during the chemical analysis of the inorganic fraction of fuel exhaust and brake non-exhaust nano-particulates from laboratory tests.

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Toxicology analysis

We analyse particle toxicology in three main ways:

1. **Using the ALI system,**
2. **particles on filters for submerged tests to study toxicological inflammatory markers and**
3. **exposing zebrafish embryos to particles.**

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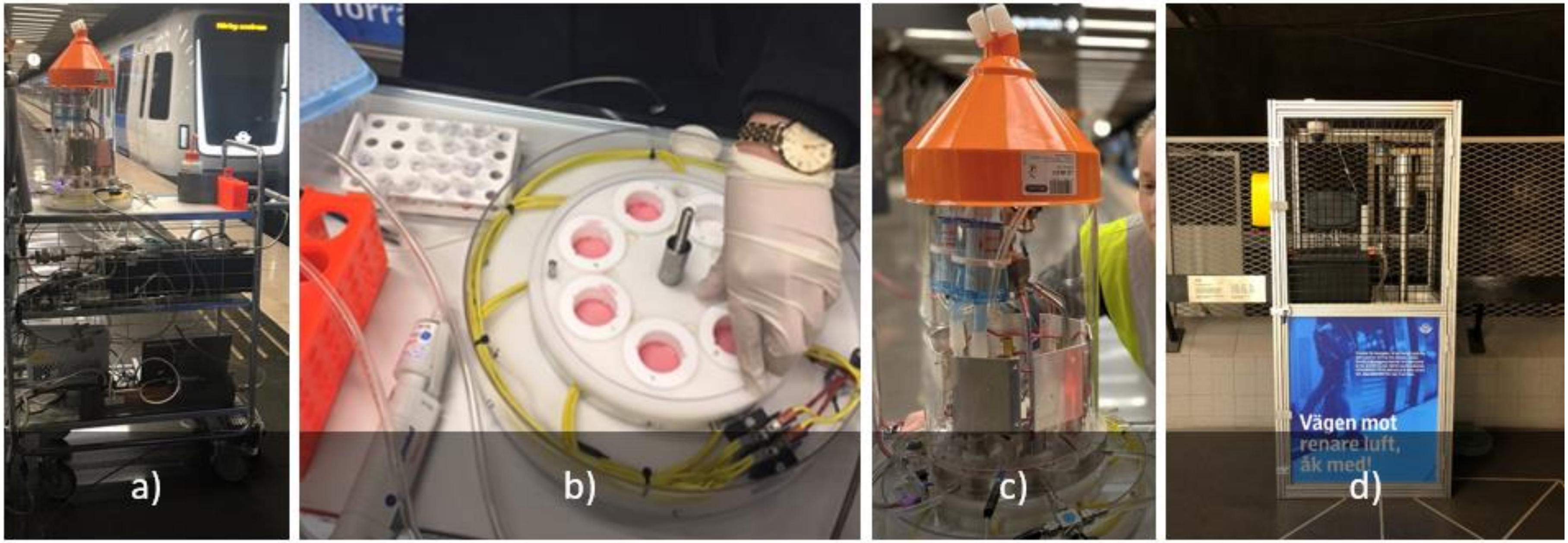
ALI-system



Photos from: a) when setting up the mobile ALI-system; b) a close up of the separate chambers; c) the assembled system and d) the permanent measurement station at Tekniska Högskolan metro station, Stockholm.

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ALI – Set-up of ALI system

Testing of the ALI system:

1. Transport of the cells in outdoor environments
2. ALI cell culturing
3. Humidity of the ALI system
4. Temperature of the ALI system
5. Flows in the ALI system
6. → Find conditions where the cells survive

Micol is testing outdoor transportation of cells

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ALI – concentration and temperature

Particle generation at laboratories:

- **High particle concentration**
- **Room air temperature**

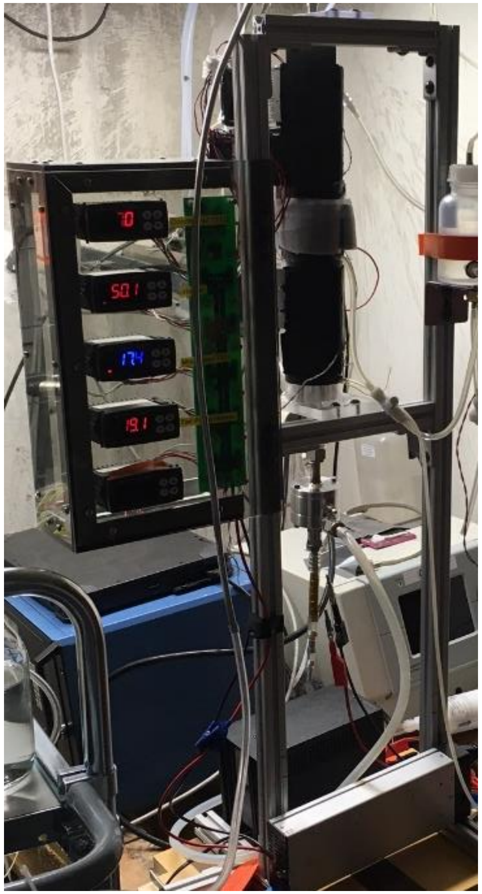
Ambient air particles:

- **Lower particle concentrations**

→ need a concentrator

- **Ambient air temperature**

→ can only run when it is OK temp



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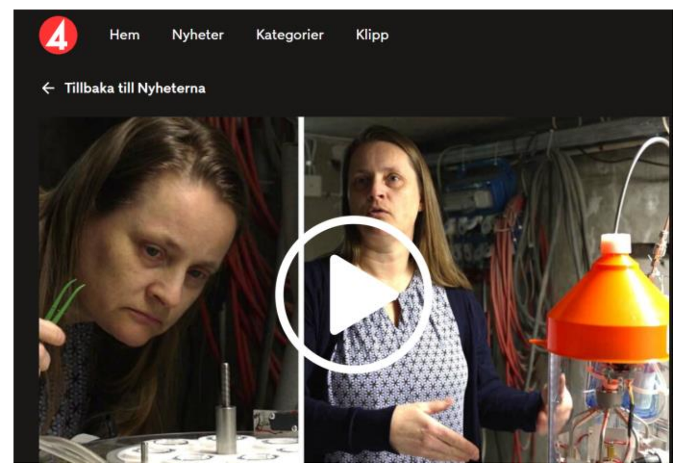
nPETS online

Web page: https://www.npets-project.eu/

Follow us on ResearchGate & LinkedIn

Ulf Olofsson and Karine Elihn presented nPETS project on the Swedish national TV4. Please follow the link (in Swedish): https://www.tv4play.se/program/nyheterna/13757432



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Journal publications

1. Lyu Y et al, Tribology and Airborne Particle Emission of Laser-Cladded Fe-Based Coatings versus Non-Asbestos Organic and Low-Metallic Brake Materials, Metals 2021, 11, 1703. https://doi.org/10.3390/met11111703
2. Larsson T et al, Undiluted Measurement of the Particle Size Distribution of Different Oxygenated Biofuels in a Gasoline-Optimised DISI Engine, Atmosphere 2021, 12, 1493. https://doi.org/10.3390/atmos12111493
3. Rahimi M, et al , Input Parameters for Airborne Brake Wear Emission Simulations: A Comprehensive Review, Atmosphere 2021, 12, 871. https://doi.org/10.3390/atmos12070871
4. Lyu Y., Sinha A., Olofsson U., Gialanella S., Wahlström J., Characterization of Ultrafine Particles from Hardfacing Coated Brake Rotors, Friction 2022. https://doi.org/10.1007/s40544-021-0585-2
5. [To be submitted] Journal paper about Literature study from WP2 by the LAT team. The suggested journal is Critical Reviews in Environmental Science and Technology

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Conferences (coming marked in yellow)

1. Ridolfo Sharon., et al. Ultrafine particles from different transport sectors: the nPETS experimental campaigns in Spain. X Convegno Nazionale sul Particolato Atmosferico - PM2022, Bologna, Italy, May 2022.
2. Ulf Olofsson. Framework of nPETS at the Analytica Conference in Munich on Thursday June 23rd, the topic “Aerosol and Health”. The proposed title of the presentation is: "Ultrafine particles from the transport sector: the nPETS first results from road and rail tunnels"
3. I. Vouitsis, A. Kontses and Z. Samaras, AEROSOL PHASES FROM DIFFERENT TRANSPORTATION SOURCES AND THEIR RELATION TO TOXICOLOGY, 13th International Conference on Air Quality, 27 June – 1 July 2022, Thessaloniki, Greece [Abstract submitted]
4. Ridolfo Sharon., et al. Physico-chemical characterization and source apportionment of UFP at airport, harbor, subway and road: the nPETS experimental set-up in Barcelona. European Federation of Clean Air and Environmental Protection Associations (EFCA) International Symposium, Brussels, Belgium, July 2022.
5. Mara Leonardi, et al. nPETS - nanoParticle Emissions from the Transport Sector: health and policy impacts -. PM2022, Bologna (Italy), 18-20 May 2022.
6. Ridolfo Sharon., et al. Ultrafine particles monitoring and characterization at airport, harbor, subway and road: the nPETS experimental campaigns in Barcelona. 11th International Aerosol Conference - IAC2022, Athens, Greece, September 2022.
7. A. Mancini, B. Tsyupa, M. Federici, M. Leonardi, A. Piglione, F. Bertasi and A. Bonfanti. “Chemical Characterization of Nanoparticle Emissions from Brakes - the nPETS Project”, SAE Brake Colloquium 2022 conference, September 2022.
8. Bergseth E., Olofsson U. et al., Accepted paper for 9th Transport Research Arena TRA Lisbon 2022, Portugal. Authors from all partners. Title: Nanoparticle emissions from the transport sector: health and policy impacts – The nPETS concept

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Thank you
for your attention!

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