Extending Particle Number Limits to below 23 nm: First Results of the H2020 DownToTen Project

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Project Objectives

- Quantitatively describe the nature and the characteristics of particles <23 nm
- Develop and set up a synthetic aerosol bench and use it for fundamental studies at instrument level
- Evaluate existing, proposed and under development particle measurement instruments
- Analyze and compare a large number of possible sampling and sample conditioning configurations
- Set-up an appropriate particle number - portable emission measurement system (PN-PEMS) demonstrator
- Explain the nature of particles not included eventually in the method
- Develop and propose an appropriate sampling and measurement methodology for sub-23 nm particle emissions for both constant volume sampling (CVS) and real driving emissions (RDE)
- Model the particle transformation (tailpipe-out to the inlet of the measurement equipment)

Issue to Address

Current legislation limit at 23 nm potentially leaves out a large fraction of exhaust particles observed in real vehicle operation [1]. Figure 1 shows the sub-23 solid particle fraction for different technologies.

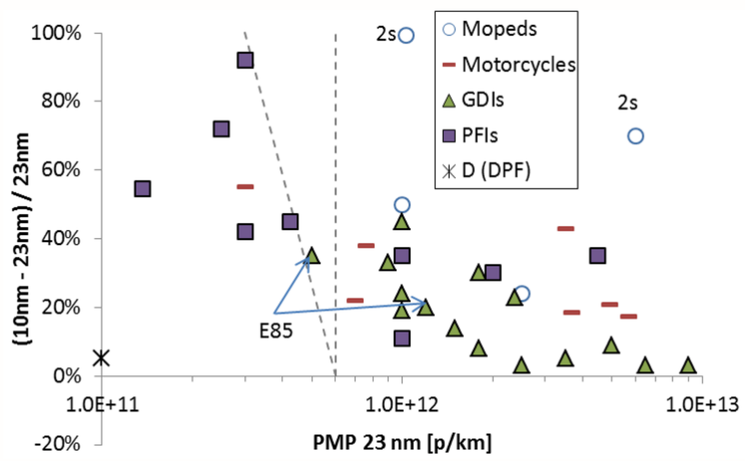

***Figure 1**: Sub-23 nm fraction of solid particles for different technologies without loss correction (a factor of 1.7-2.0). Estimation based on the difference of 10 nm and 23 nm cut size CPCs. The dashed lines indicate the current 6x10[11] p/km limit for particles <23 nm (vertical) and particles <10 nm. Figure taken from [1] (w. permission).*

[1] Giechaskiel, B., and Martini, G. (2015). PMP-37-03 JRC exhaust particles work items status Presentation for the PMP group. Available at: https://wiki.unece.org/display/trans/PMP+37th+session

Results

Evaluation of different components to design a sampling system for particles <23 nm with low losses and high volatile removal efficiency.

Particle Losses

- **Thermophoretic** losses (Figure 2) are mainly caused by cooling down the sample with an ejector diluter (ED). Using a porous tube diluter (PTD) reduces thermophoretic losses to almost zero.
- The catalytic stripper (CS) is the dominating source of **diffusional** losses (Figure 3). They are reduced by downsizing the CS.

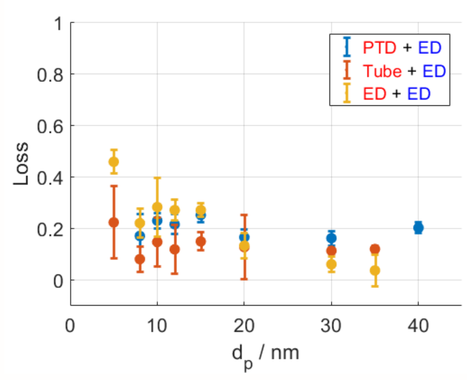

***Figure 2** : Thermophoretic losses of different dilution systems.*

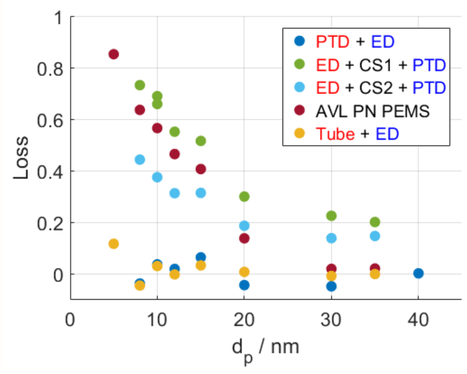

***Figure 3**: Diffusional losses of different sampling systems.*

Artefact Formation

- Particle growth experiments (Table 1) showed that artefact formation is very low for all systems tested.

***Table 1**: Solid silver particle growth from re-condensed material downstream of the thermal pre-treatment units for different sampling systems. The growth values are below the resolution of the method used.*

Sampling system	Concentration / 1/cm3	Fraction counted	Growth/ nm
Primary	NA	8.3E-04	0,0
ED + ED	990	2.5E-02	1,4
PTD + ED	2200	5.4E-02	1,7
PTD + CS1 +ED	65	1.6E-03	0.3
PTD + CS2 +ED	130	3.3E-03	0.5

Summary and Outlook

Based on experiments at the aerosol bench a prototype DownToTen sampling system (Figure 4) was designed that shows very low losses, low artefact formation and is suitable for secondary aerosol characterizations.

As a next step tests at the CVS tunnel are performed to evaluate sampling conditions and appropriate test protocols.

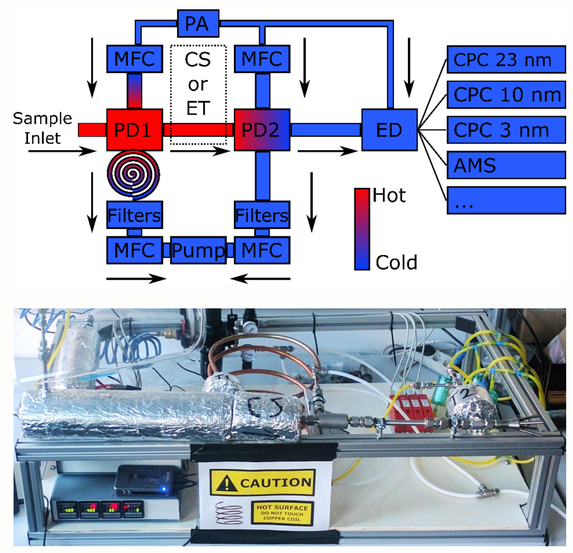

***Figure 4**: Schematic (top) and photo (bottom) of the designed sampling system.*

PROJECT PARTNERS

In collaboration with:
The University of California at Riverside
National Traffic Safety and Environmental Lab (Japan)
National Metrology Institute (Japan)

HORIZON 2020
Call: H2020-GV-2016-2017
Technologies for low emission light duty powertrains
Action:
"Measuring automotive exhaust particles down to 10 nanometres – DownToTen"