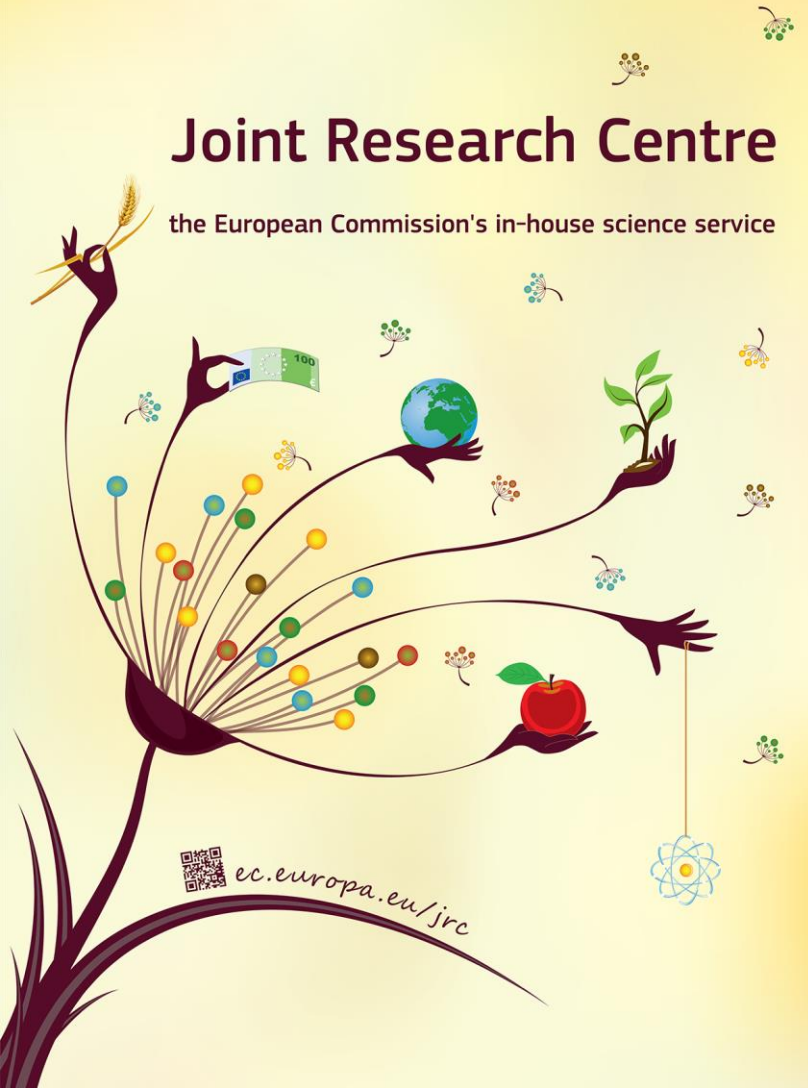


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Engine exhaust particles: Current EU legislation and future developments

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Overview

- Background of the existing European particle number standards and future developments
 - Why
 - How
 - When

Why a particle number limit?

- A proven causal relationship exists between exposures to PM_{2.5} and adverse effects on human health and mortality
- It remains a challenge to determine relationships between specific constituents or sources of PM_{2.5} and the various health effects observed
- However it is well known that traffic represent one of the most important contributor to PM_{2.5} – Basically all the primary particles emitted by internal combustion engines fall in the PM_{2.5} fraction and are actually much smaller (the mode of exhaust particles is below 0.1 micron).

Why a particle number limit?

- European Governments felt that previous PM limit values (Euro 4/ Euro V, EEV) had intended, but failed, to mandate the use of DPFs in passenger cars and HD vehicles
- Despite the large reduction of the PM mass emission limit, the particle number was still very high
- 'Precautionary principle' invoked – elimination of carbon particles from engines via the use of DPFs (best available technology) was considered necessary
- A simple further reduction of the PM mass standards was not considered sufficient to force the use of DPFs - a new measurement method and related limit was considered necessary

Objective of the PMP

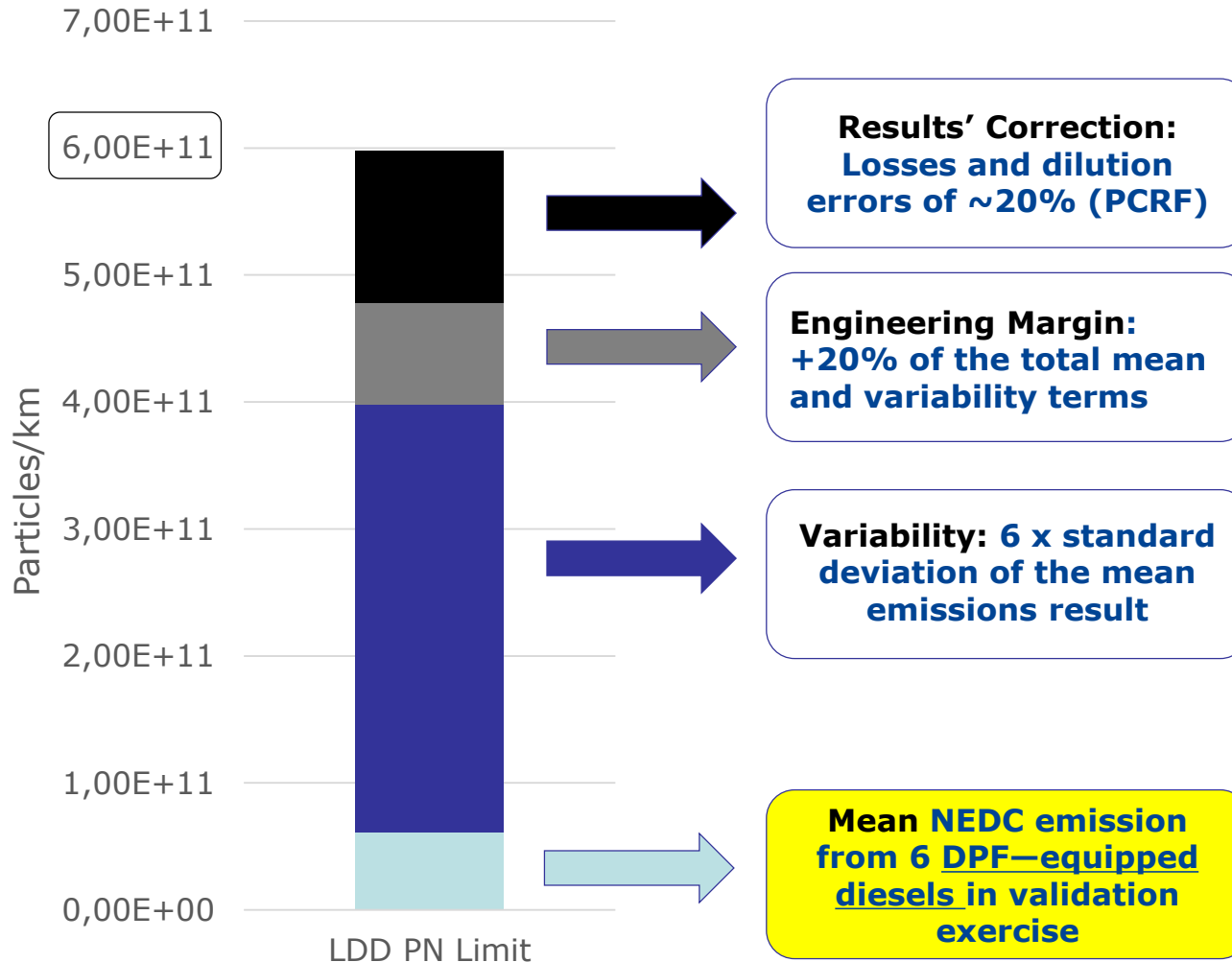
- ❑ UN-ECE Particle Measurement Programme (PMP) was conceived in 2000, chaired by the UK with strong political backing from France, Germany, Holland and Sweden

- ❑ Develop a new method complementing or replacing the existing mass measurement method
 - Suitable for diesel engines equipped with DPFs
 - High sensitivity to distinguish “good” and “less good” filters
 - Good repeatability and reproducibility suitable for regulatory purpose
 - Compatible with existing test facilities
 - Relatively simple and robust
 - Understandable metric

What is measured by the PMP method

- Solid particles defined by the measurement equipment :
 - Particles with a size from \sim **23nm** to $2.5\mu\text{m}$ and surviving evaporation in the range $300\text{ }^{\circ}\text{C}$ to $400\text{ }^{\circ}\text{C}$
 - Particles are counted by means of a condensation particle counter, but the sample is pre-conditioned to eliminate most volatile particles which may contribute significantly to variability

Determination of Particle Number Limit Value (LD Diesel)



Limit value constructed from several factors

Typical non-DPF PN emissions value was 5×10^{13} /km

Slide from Jon Andersson - Ricardo

Determination of Particle Number Limit Value – General strategy

- Aim to be easily complied with wall-flow DPF diesel, but not with partial / open filters (efficiencies $\sim 60\%$)
- Filtration efficiency required $> 98\%$

Particle Number limit in the EU emission legislation

- **Euro 5** step introduced in 2011, first in the world, a particle number limit for **diesel passenger cars** forcing the use of DPFs on such vehicles
 - 6.0×10^{11} #/km (NEDC driving cycle)
- The particle number limit was extended to **heavy duty engines** with the **Euro VI** step (2012)
 - 6.0×10^{11} #/kWh - WHTC (transient) test cycle
 - 8.0×10^{11} #/kWh - WHSC (stationary) test cycle

Particle Number standard: a success

- All new LD and HD on-road diesel engines are equipped with DPFs – about 30 million applications with DPFs
- Robust and reliable procedure for engine/vehicle certification
- Thanks to DPFs PM emissions have been effectively reduced - Post-DPF PN vehicle emissions levels are often lower than in the intake air
- High sensitivity of measurement enables development of better filters for low back pressure and high efficiency
- New Diesel Technology vs. Old Diesel – Health Effect Institute (HEI) report ACES
 - Dramatic reductions of emissions: 98% reduction in mass; 90%-99% reduction in ultrafine particles – Most cancer-causing chemicals now below “limits of detection”
 - No evidence of lung cancer

Particle Number limit: Extension to gasoline engines

- REGULATION (EU) No 459/2012 states:
 - Particles emitted by vehicles may be deposited in the alveoli of human lungs, potentially leading to respiratory and cardiovascular illness and increased mortality. Therefore it is in the public interest to have a high level of protection from those particles.
 - Based on today's knowledge, the level of particle emissions from conventional, port fuel injection (PFI) engines (...) is low. Therefore, it appears to be justified to limit regulatory action for the moment to vehicles equipped with direct injection engines, without excluding further research and monitoring of the particle emission performance of all positive ignition engines (...)
- and has therefore extended the particle number limit to passenger cars with **gasoline direct injection engines**
 - 6.0×10^{12} #/km from 2014
 - 6.0×10^{11} #/km from 2018

Further developments : NRMM

- Non-Road Mobile Machinery - In September 2014 the EU Commission has presented a new proposal for the Stage V :
 - (15) In order to ensure that emissions of ultrafine particulate pollutants (size of 0,1 μm and below) are controlled, the Commission should be empowered to adopt a number-based approach to emissions of particulate pollutants, in addition to the mass-base approach which is currently used.
 - (16) In order to achieve these environmental objectives, it is appropriate to indicate that the particle number limits are likely to reflect the highest levels of performance currently obtained with particle filters by using the best available technology.
 - This new Regulation is going to introduce a particle number limit of **1.0 x 10¹² #/kWh** for the majority of the NRMM engine categories
- The proposal has been approved by the Parliament and will soon be officially published

Further developments: L-Cat vehicles

- L-category vehicles (two/three-wheelers and quadricycles): An environmental effect study has been requested by the EU Parliament by the end of 2016 to confirm the Euro 5 step
- Among other issues, typical particle emission levels of these vehicles are also investigated
- Main technical challenge: abundance of volatile material in the exhaust (rich mixtures or lubricant from two-stroke engines) potentially leading to artefacts
- Main question: relevance for human health of volatile particles?

Conclusions

- The European standards on particulate emissions from diesel engines have been conceived and designed to force the use of the best available technology (i.e. DPF)
- This piece of legislation has proven to be very effective in reducing primary particle emissions from diesel engines
- As a result, the same approach is being followed for other vehicle/engine categories, including gasoline engines and non-road applications

**Thank You
for
your attention!**