Particles from Gasoline Direct Injection Engines: Abatement Options

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The effect of particle size on cardiovascular disorders — The smaller the worse

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ABSTRACT

Background: Previous studies observed associations between airborne particles and cardio-vascular disease. Questions, however, remain as to which size of the inhalable particles (coarse, fine, or ultrafine) exerts the most significant impact on health.

Methods: For this retrospective study, data of the total number of 23,741 emergency service calls, registered between February 2002 and January 2003 in the City of Leipzig, were analysed, identifying 5326 as being related to cardiovascular incidences. Simultaneous particle exposure was determined for the particle sizes classes <100 nm (UFP), <2.5 μm (PM2.5) and <10 μm (PM10). We used a time resolution of 1 day for both parameters, emergency calls and exposure.

Results: Within the group of cardiovascular diseases, the diagnostic category of hypertensive crisis showed a significant association with particle exposure. The significant effect on hypertensive crisis was found for particles with a size of <100 nm in diameter and starting with a lag of 2 days after exposure. No consistent influence could be observed for PM2.5 and PM10. The Odds Ratios on hypertensive crisis were significant for the particle size <100 nm in diameter from day 2 post exposure OR = 1.06 (95% CI: 1.02–1.10, p = 0.002) up to day 7 OR = 1.05 (95% CI 1.02–1.09, p = 0.005).

Conclusion: Ultrafine particles affect cardiovascular disease adversely, particularly hypertensive crises. Their effect is significant compared with PM2.5 and PM10. It appears necessary, from a public health point of view, to consider regulating this type of particles using appropriate measurands as particle number.
OR and 95% confidence interval in emergency calls related to hypertensive crises depending on time of exposure to airborne particles and size of particles (ultrafine[UFP]–fine [PM2.5]–coarse [PM10])

## EU Emission Limits

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<td><strong>Regulation</strong></td>
<td>Euro 6b</td>
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<td>Euro 6c</td>
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<td>Euro 7*</td>
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<td><strong>Test</strong></td>
<td>NEDC</td>
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<td>NEDC or WLTP**</td>
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<td><strong>Real Driving Emissions</strong></td>
<td>RDE Step 1</td>
<td>PEMS*</td>
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<td>RDE Step 2</td>
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<tr>
<td><strong>Particle Number Limits</strong></td>
<td>CI: 6x10^{11} #/km</td>
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<td>CI and PI-DI: 6x10^{11} #/km</td>
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<td><strong>CO₂ Fleet Average</strong></td>
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</table>

PEMS: Portable Emission Measurement System
CI: Compression Ignition
PI-DI: Positive Ignition-Direct Injection

*not finalized

Source: Harth et al, Wiener Motorensymposium 2013
Emission Abatement
Options for Emission Abatement

- From the beginning of the introduction of stricter emission limits always two option were followed:
  1. Internal engine measures
  2. Exhaust after treatment

- Examples are the conflict between lean burn engine and three way catalyst or between diesel particle emission control by high injection pressure and diesel particle filter.
Example of an Internal Engine Approach

Source: Klauer et al. Wiener Motorensymposium 2013
Examples of an Exhaust Aftertreatment Approach

Solutions with non-catalyzed filter

- Filter added in under-floor position
- Solution to ensure low particle number emissions over lifetime
- Reference system for solutions with filter
- Low porosity substrate needed to ensure high filtration efficiency

Solutions with c-GPF

- UF-TWC replaced by c-GPF
  - Use in CC+UF systems with no space for c-GPF in CC position
  - Use instead of uncoated filter for system optimization: potential to reduce volume of TWC and gain advantage for OBD
- CC-TWC replaced by c-GPF-only
  - Euro 6 emission limits with similar amount of PGM achievable
  - OBD functionality to be further evaluated
  - Optional use of underfloor TWC for OBD purposes
- c-GPF replaces 2nd TWC in close coupled CC1+CC2 system
  - Euro 6 emission limits with similar amount of PGM achievable
  - OBD handled by CC TWC

Source: Harth et al, Wiener Motoresymposium 2013
# Estimated Cost of Gasoline Particulate Filters 2011

<table>
<thead>
<tr>
<th>Engine Displacement</th>
<th>Estimated Long-Term Production Cost (USD 2010)</th>
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<td>1.5</td>
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</table>
Measurements of GDI Engines by DUH and VCD

Two measurement series were performed in 2011 and 2012 by ADAC and TÜV Nord. Different testing cycles and conditions were measured.

Conventional pollutants and particle mass and particle number were measured.

One vehicle has been retrofitted with an particle filter.
Test Cycles

Neuer Europäischer Fahrzyklus (NEFZ)

Testzyklus Autobahn
Particle Mass (mg/km) in different Test Cycle

Particle Mass (PM) in g/km

- VW Golf 1.2 TSI:
  - NEFZ (cold): 0.0010
  - NEFZ (hot): 0.0024
  - ADAC-Autobahn: 0.0023

- BMW 116i:
  - ADAC-Autobahn: 0.0077

PM-Limit Diesel (Euro 5b)
Particle Number (PN/km) in different Test Cycle

Particle Number (PN/km)

- **VW Golf 1.2 TSI**
- **BMW 116i**

**PN-Limit Diesel (Euro 5b)**
NO$_x$ - Emissions of GDI vehicles in different Driving Cycles

g/km

- VW Golf 1.2 TSI
- BMW 116i
Particle Emission in the NEFZ at different Temperatures

PM mg/km

PM-Grenzwert: Benziner (Euro 6/II)

NEFZ (20°C) 1,46
NEFZ (-7°C) 2,10

Mercedes B180 GDI
Particle Emission in the NEFZ at different Temperatures

PN in PN/km

- NEFZ (20°C): $2.65 \times 10^{11}$
- NEFZ (-7°C): $2.81 \times 10^{12}$

PN-Grenzwert: Benziner (Euro 6/II)

Mercedes B180 GDI
Particle Number (PN/km) Comparison of the PN- Values without Filter, with Filter and after 8000 km Driving (with filter)

BMW 116i GDI
Conclusion

1. Particle emissions of GDI vehicles should not be higher than these of Diesel vehicles.

2. Particle emission should be minimized (best available technology) under all driving conditions, e.g. all speeds and temperatures.

3. Today only particle filters fulfill these requirements.

4. GDI vehicles should be equipped with closed particle filter as this is state of the art with Diesel vehicles.
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