ON-ROAD NO\textsubscript{x} EMISSIONS OF 15 EURO 6 DIESEL CARS

Veerle Heijne
INTRODUCTION

- 15 Euro 6 passenger cars measured on the road in 2015-2016
  - in real-world operation

Goal of measurements

- Representative emission factors for
  - air quality models
  - national emission registration
- Insight in real-world emission performance
- Screening of in-service conformity
TRIPS

On-road NOx emissions of 15 Euro 6 diesel cars

- Den Haag
- Utrecht
- Amsterdam
- Rotterdam

Motorway:
- 80 km/h
- 130 km/h

Rural

Urban

Motorway morning congestion

Motorway evening congestion

GPS location velocity [km/h]

TNO innovation for life
TRIPS

On-road NOx emissions of 15 Euro 6 diesel cars

80 km/h motorway

80 km/h rural

GPS location

NOx [mg/km]

80 km/h

urban

Den Haag

Amsterdam

Utrecht

Rotterdam

03 November 2016
<table>
<thead>
<tr>
<th>Brand</th>
<th>Model</th>
<th>Category</th>
<th>Power [kW]</th>
<th>AT</th>
<th>Odometer [km]</th>
<th>Test Mass [kg]</th>
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<tbody>
<tr>
<td>Citroen</td>
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SMART EMISSION MEASUREMENT SYSTEM

› SEMS registers sensor info and OBD signals
› Validated with PEMS results
› 1Hz signal
› Measures NO\textsubscript{x}, NH\textsubscript{3}, CO\textsubscript{2}
NORMALISATION

- Direct comparison of different vehicles over the same trips is unfair due to:
  - ambient temperature
  - number of DPF regenerations
  - start/stop system
  - congestion → the same motorway route at different times:

- Options for normalisation with respect to velocity and acceleration:
  - VERSIT+
  - CLEAR, EMROAD (RDE tools)
VERSIT + NORMALISED RESULTS

<table>
<thead>
<tr>
<th>Test temperature Range</th>
<th>Urban congestion</th>
<th>Urban</th>
<th>Rural</th>
<th>Motorway</th>
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<tr>
<td>Vehicle [°C]</td>
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<td>Mercedes C220</td>
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<td><strong>LNT equipped vehicles</strong></td>
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</table>
VERSIT + NORMALISED RESULTS

Report: TNO 2016 R11177

NOx [mg/km] Urban congestion
NOx [mg/km] Urban
NOx [mg/km] Rural
NOx [mg/km] Motorway

NOx limit: 80 mg/km

SCR

LNT

On-road NOx emissions of 15 Euro 6 diesel cars

03 November 2016
On-road NOx emissions of 15 Euro 6 diesel cars

NOx limit: 0.08 g/km

Results vary between RDE trips

Different normalisation

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03 November 2016
EMROAD / CLEAR

- Different behaviour of normalisation tools
- Might evoke selective use of tools
- Tools are insufficiently transparent to enable full evaluation of the causes for different behaviour
FURTHER ASSESSMENT OF EMISSION BEHAVIOUR

- Influence of velocity and acceleration
- Local effects due to large spread in emissions
- Cold start
- Ambient temperature
VELOCITY BINNING

- VERSIT+ parameterises data based on velocity and acceleration
- Velocity binning shows varying behaviour between vehicles

- Emissions always high
- Optimal behaviour in certain regions of velocity
  - Under the 80 mg/km limit!
VERSIT+ parameterises data based on velocity and acceleration

- Introduce acceleration axis:
  - NOx per second logarithmic scale!

- Emissions always high
  - More emissions over short period of time
  - Constant driving → low emissions
  - Overall low emissions
PEAKED EMISSIONS - LOCAL EFFECTS

- Not only velocity and acceleration determine the emission behaviour
- For some vehicles, over 50% of the emissions occur during only 5% of the driving time
- Possibly creating emission ‘hotspots’ at intersections, motorway entranceways, etc.

Volvo V40
- Variations in emissions

Variations in emissions

Den Haag

Amsterdam

Utrecht

Rotterdam

GPS location NOx [mg/km]
**PEAKED EMISSIONS - LOCAL EFFECTS**

**Opel Zafira**
- High emissions everywhere

**Volvo V40**
- Variations in emissions

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RESIDUAL ANALYSIS

- Not only velocity and acceleration determine emissions
  → Find secondary effects
    (cold start, SCR/LNT behaviour, …)
- Plot residual NO\textsubscript{x} versus other variables:
  - Ambient temperature
  - Engine coolant temperature
  - …
- Gives the ‘extra’ emission due to this variable

Take average NO\textsubscript{x} [g/s] per v-a bin
Calculate the difference of the current measurement with the average in that bin:

\[
\frac{NOx[i] - <NOx>}{<NOx>} = \text{Residual}
\]
COLD START

- Actual cold start longer than 5 minutes (RDE cut-off)
- LNT: limited effect
- SCR: 10% extra NO\textsubscript{x} on urban part of RDE trip
- Relative contribution expected to increase in future

Additional emission at start

Duration of cold start

Systematically higher emissions (small error band)
AMBIENT TEMPERATURE

- Mercedes C220 initially tested at temperatures < 7°C
- Second test over large range of temperatures
- Clear dependency of emissions on ambient temperature

Additional emission at low temp

![Graph](image.png)

- Residual NO\textsubscript{x} [mg/s] with error band
- Amount of data

**Table:**

<table>
<thead>
<tr>
<th>Ambient temperature [°C]</th>
<th>NO\textsubscript{x} residual [mg/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>-15</td>
</tr>
<tr>
<td>10</td>
<td>-10</td>
</tr>
<tr>
<td>15</td>
<td>0</td>
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<td>20</td>
<td>5</td>
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<tr>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>30</td>
<td>15</td>
</tr>
</tbody>
</table>
AMBIENT TEMPERATURE

For other vehicles: not enough data over full range of temperatures, however:

- average temperature per trip always 3-14 °C
- residuals show no significant dependency on ambient temperature
CONCLUSION

- Diesel euro 6 passenger cars show complex emission behaviour and large variations

- Large improvement required to meet the on-road RDE limits, also for the best performers (300 days till phase 1 RDE for new type approvals)

- A comprehensive measurement programme is needed to capture the full complexity of emission behaviour

- More info:
  - TNO 2016 R11177: NOx emissions of fifteen Euro 6 diesel cars
  - TNO 2016 R11123: Relation between ambient temperature and NOx emissions
TNO report
TNO 2016 R11177
NO\textsubscript{x} emissions of fifteen Euro 6 diesel cars:
Results of the Dutch LD road vehicle emission testing programme 2016

www.tno.nl/voertuigemissies
www.tno.nl/vehicle-emissions