Assessing New Delhi’s vehicle emissions using remote sensing techniques

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Why should we care about vehicle emissions?

- High NO$_x$ emissions in European Cities
- NO$_2$ concentrations exceeding annual 40 μg m$^{-3}$ health limit
- Bad for public Health (respiratory and cardiovascular diseases)
- Direct emission of NO$_x$ from diesel vehicles major source
Why should we care about vehicle emissions?

- Underestimation of vehicle emissions (standard rolling-road tests)
- Vehicles emitting higher $\text{NO}_x$ under real-world driving conditions
- Need for real-world measurements of vehicles
Real-world assessment

Portable emission measurement system (PEMS)
Monitor individual vehicles
Expensive, only get individual car information

Remote sensing measurements
Non-invasive spectroscopy
Capture entire fleet emission characteristics
Fuel Efficiency Automobile Test (FEAT)
Fuel Efficiency Automobile Test (FEAT)

- UV/IR Source
- IR Detector
- UV Detector
- Camera
- Speed bar

Speed: XCO/CO2: X NO/CO2: X
NH₃/CO2: X HC₃s/CO2: X NO₂/CO2: X
Fuel Efficiency Automobile Test (FEAT)

- Remote sensing measurements of vehicle tailpipe emissions
- Nondispersive Infrared (NDIR) measurements of $\text{CO}_2$, $\text{CO}$ & $\text{HCs}$
- Dispersive Ultra-Violet (UV) measurements of $\text{NO}$, $\text{NO}_2$, $\text{NH}_3$ & $\text{SO}_2$
- Vehicle speed and acceleration measurements
- Vehicle number plate capture for manufacturer comparison
Previous UK Work

Ambient UK trends for NO\textsubscript{2} & NO\textsubscript{x}

Comparison of NO\textsubscript{x} Type Approval emission standards to remote-sensing measurements of diesel vehicles
Current UK Work

- Remote-sensing measurements (FEAT instrument, University of Denver)
- London (Putney High Street & Ealing) and York
- October 2017 - March 2018
- ~50,000 vehicles measured (CO, HCs, NH₃, NO and NO₂ emissions)
UK Diesel Vehicles

Emissions of NO\textsubscript{x} (g kg\textsuperscript{-1} fuel) as a function of vehicle manufacture date for diesel passenger cars.

Emissions of NO\textsubscript{2} (g kg\textsuperscript{-1} fuel) as a function of vehicle manufacture date for diesel passenger cars.

Carslaw, et al., The diminishing importance of nitrogen dioxide emissions from road vehicle exhaust. Atmospheric Environment: X, 1, p.100002.
New Delhi Measurements

Project background

- Indian vehicle emission factors poorly understood
- No previous independent real-world vehicle emission data

Project aims:

- Generate new emission factors from remote-sensing
- Refine vehicle source in SAFAR Emissions Inventory
New Delhi Measurements

- Measurements at entrance to Indira Gandhi Delhi Technical University for Women (IGDTUW)
- >200 vehicles (Cars, lorries, motorbikes, …)
- Compare findings to European remote-sensing data
- Merge data with larger remote-sensing studying by International Centre for Automotive Technology (ICAT)
New Delhi Measurements

Tool Booth - Gurugram

IGDTUW - New Delhi
New Delhi Measurements

Private Car

Motorbike

Auto Rickshaw

Lorry (Medium Goods Vehicle)
New Delhi Vehicles

Emission of NO, NO$_2$, NO$_x$

Emission of CO, HC$_s$, NH$_3$
Mean and 95% confidence

**Motorbikes**

**Emission of NO, NO₂, NOₓ**

- Car vs. Motorbike comparison

**Emission of CO, HCs, NH₃**

- Car vs. Motorbike comparison
Private Vehicles

Mean and 95% confidence

Emission of NO, NO₂, NOₓ

Emission of CO, HCs, NH₃
## Private Vehicles

<table>
<thead>
<tr>
<th>Species</th>
<th>Mean emission/ g kg⁻¹ fuel</th>
<th>London emission/ g kg⁻¹ fuel</th>
<th>Ratio/ Delhi to London</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO</td>
<td>10.94</td>
<td>4.43</td>
<td>2.47</td>
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<tr>
<td>NO₂</td>
<td>0.76</td>
<td>1.22</td>
<td>0.62</td>
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<tr>
<td>NOₓ</td>
<td>11.67</td>
<td>8.00</td>
<td>1.46</td>
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<tr>
<td>CO</td>
<td>77.45</td>
<td>13.28</td>
<td>5.83</td>
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<tr>
<td>HCs</td>
<td>30.81</td>
<td>6.18</td>
<td>4.97</td>
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<tr>
<td>NH₃</td>
<td>0.41</td>
<td>0.29</td>
<td>1.41</td>
</tr>
</tbody>
</table>
Vehicle Driven Emissions

BT Tower - London

IGDTUW – Kashmere Gate New Delhi
Emission Measurements

- Measure emission rates via eddy-covariance
- Calculate covariance between instantaneous deviation from the mean between vertical wind speed and concentration
- Sample from an elevate point, fast measurements (>1 s)
Higher NO\textsubscript{x} emissions in London

High NO\textsubscript{x} concentrations in Delhi
Emission Measurements

- BT Tower influenced by larger vehicles and other sources
- Less primary NO\textsubscript{2} emitted in New Delhi
- Older exhaust after-treatment technology

- Meteorology and regional transport probably the cause of the very high Nox levels in Delhi
CONCLUSIONS

- Novel insight into New Delhi vehicle fleet
- Initial findings show high NO, CO and HCs from vehicles
- Low NO$_2$ emissions from private vehicles in New Delhi
- Difficult to compare two cities in relation to vehicle driven emissions
FUTURE WORK

- Compare FEAT data to OPUS Inspection measurements (ICAT)
- 195,000 vehicles measured over 6 months (May-October 2018)
- Multiple measurement sites around New Delhi (Toll booths, main roads)
- Vehicle emission data of: CO, HCs, NH$_3$ and NO in g/(kg fuel)
- Vehicle information from New Delhi database
ACKNOWLEDGEMENTS

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