Black Sheep - Detecting polluting vehicles on the road using roadside particle measurement

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Introduction & Background

- Fine particle air pollution ($PM_{2.5}$) is the most harmful pollutant for human health - every year 428 000 people die prematurely in Europe because of $PM_{2.5}$ [1]. Traffic is the main contributor to PM2.5 pollution in urban areas with diesel engine as main source
- Despite strict regulation since 2011 EURO 5b that induced use of diesel particulate filters (DPF) for all new diesel vehicles, PM2.5 levels do not show notable reduction.
- Periodic technical inspection (PTI) proves to be largely ineffective - mild test procedures, obsolete instrumentation, relaxed limits and ways to circumvent it.
- Poor air quality leads some cities to extreme measures like limiting or banning vehicles entering them

Objective

Detect excessively PM emitting vehicles on the road so that majority of vehicles that are clean can stay on the road.

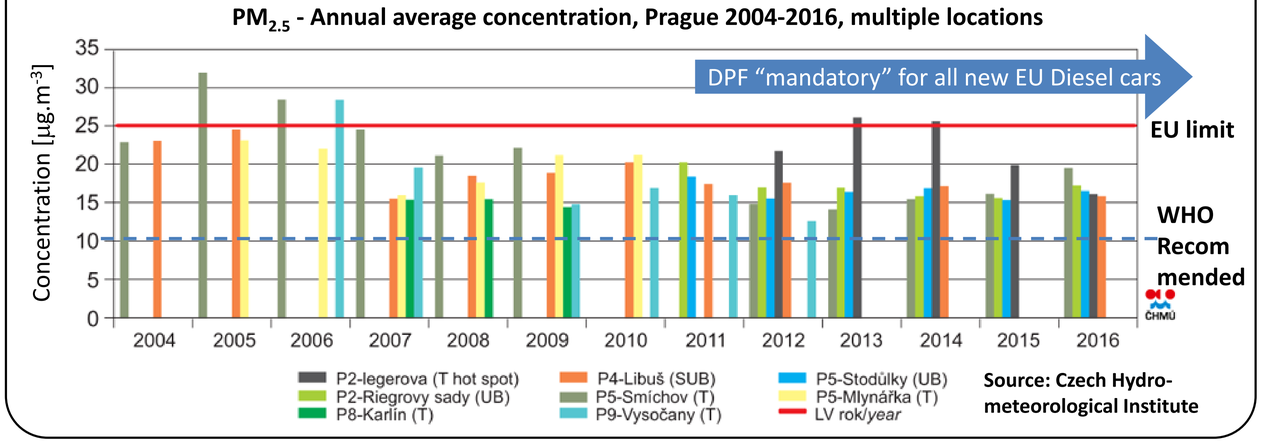
Hypothesis:

- Small number of non-compliant and/or older vehicles outweigh all clean ones
- DPF equipped vehicles are not maintained properly – DPF is tampered with or removed

Verification:

- Roadside emission measurement – real life data from affected locations
  – matching individual vehicle with its emission levels and technical data

$PM_{2.5}$ - Annual average concentration, Prague 2004-2016, multiple locations



Methodology

Vehicle remote sensing used to detect - high emitters as preselection for subsequent roadside inspection
- large dataset for further analysis

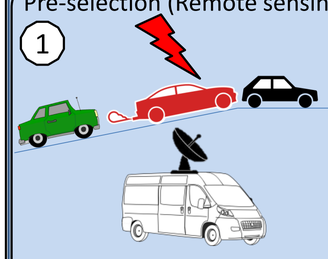
Measured values: PM, PN and gaseous emissions - CO2, CO and NOx - CO2 is used to determine specific particle emissions per liter of fuel and per km travelled

For detailed analysis vehicle number plate also recorded - vehicle technical data from the registry

Assumptions: All CO_2 generated by fuel combustion, fuel consumption 5kg(~6l)/100km (when not known)

3-phase detection – 3 Stations

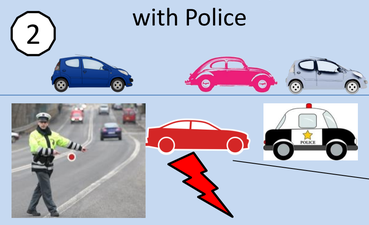
Pre-selection (Remote sensing) — 1



Remote sensing measurement of passing vehicles, pre-selection of probable polluters
Goal: Detecting high emitters - eliminating false positives for Roadside Technical Inspection

TSI EEPS – PN, size distribution
AVL MircoSootSensor – PM
FTIR – CO_2, NO, NO_X

Roadside Technical Inspection with Police — 2



Roadside measurement of suspected vehicles + Online access to vehicle technical records => Comparison of allowable & measured exhaust opacity values, vehicles above limit escorted to Emission Inspection Station (PTI)

MiniPEMS - CO_2, NO, NO_X
Testo NM3 – PM & PN
AVL Opacimeter

Vehicle Emissions Inspection Station — 3

Standard emission measurement at Periodic Inspection Center

AVL Opacimeter

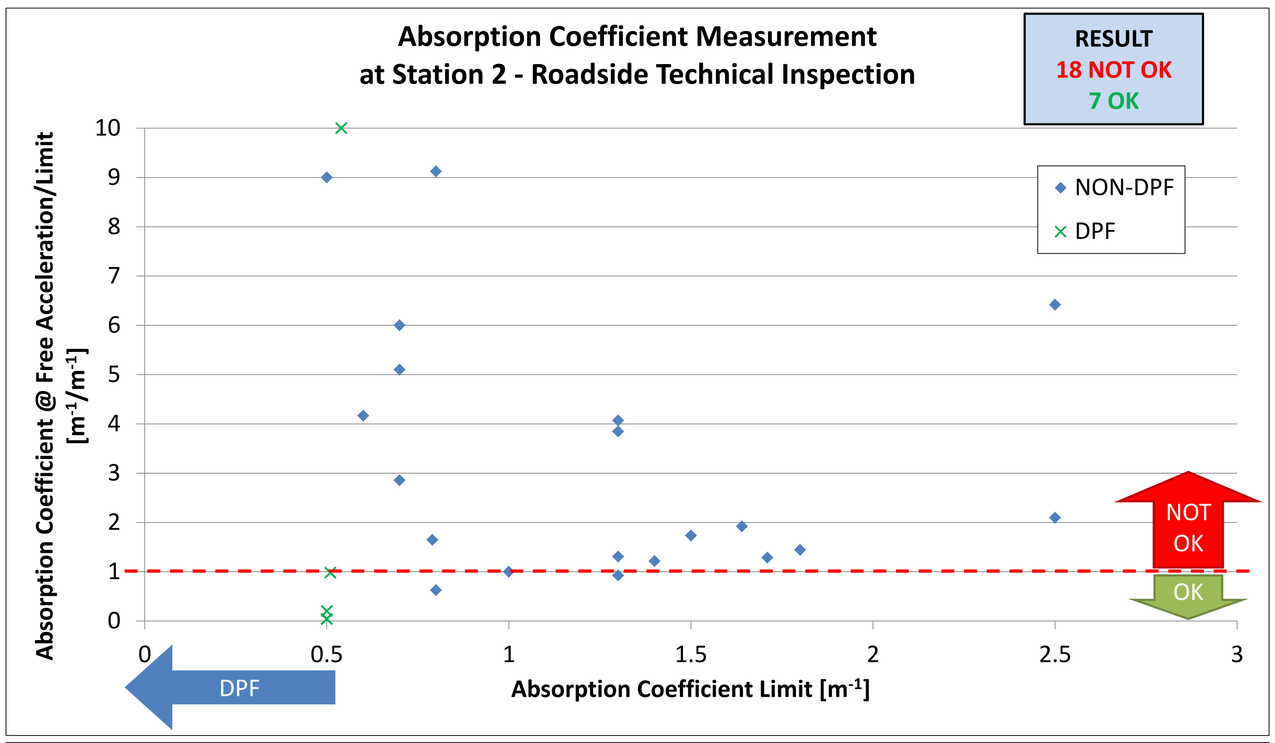
Station 1 Pre-selection (Remote sensing)

Campaign	Number of Vehicles			Notes Status
	Station 1	Station 2	Station 3	
Prague	~25 000	N/A	N/A	Number plates & Emission data processed, Waiting Technical Data from Registry
Trutnov	~700 (266 w. emission trace)	28	12	Complete, no Camera @ station 1, 9 vehicles failed Technical Inspection @ station 3

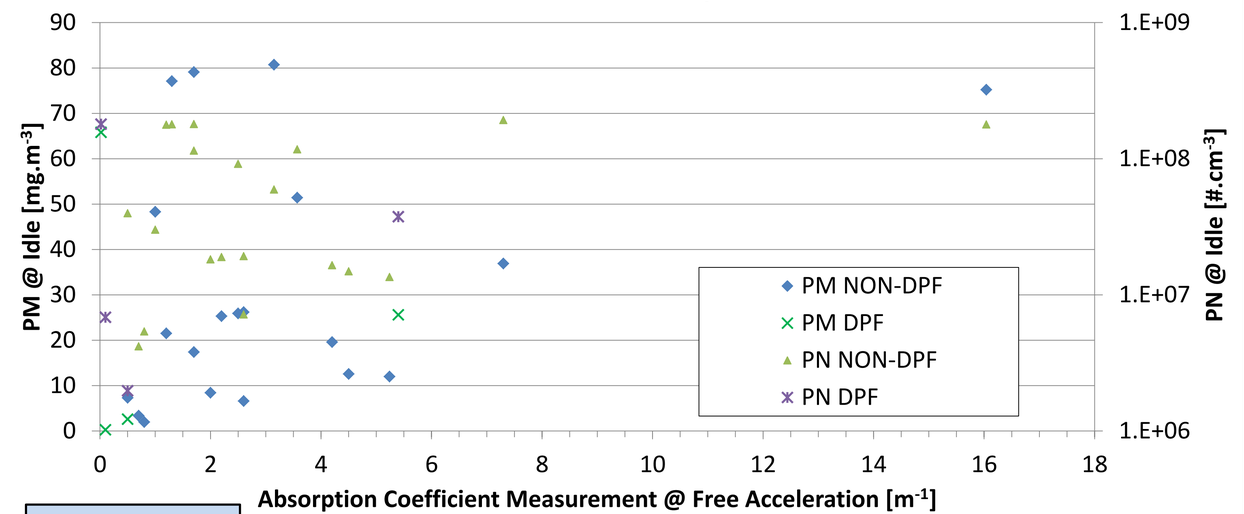
Results – Measurement in Trutnov

Absorption Coefficient Measurement at Station 2 - Roadside Technical Inspection

RESULT
18 NOT OK
7 OK

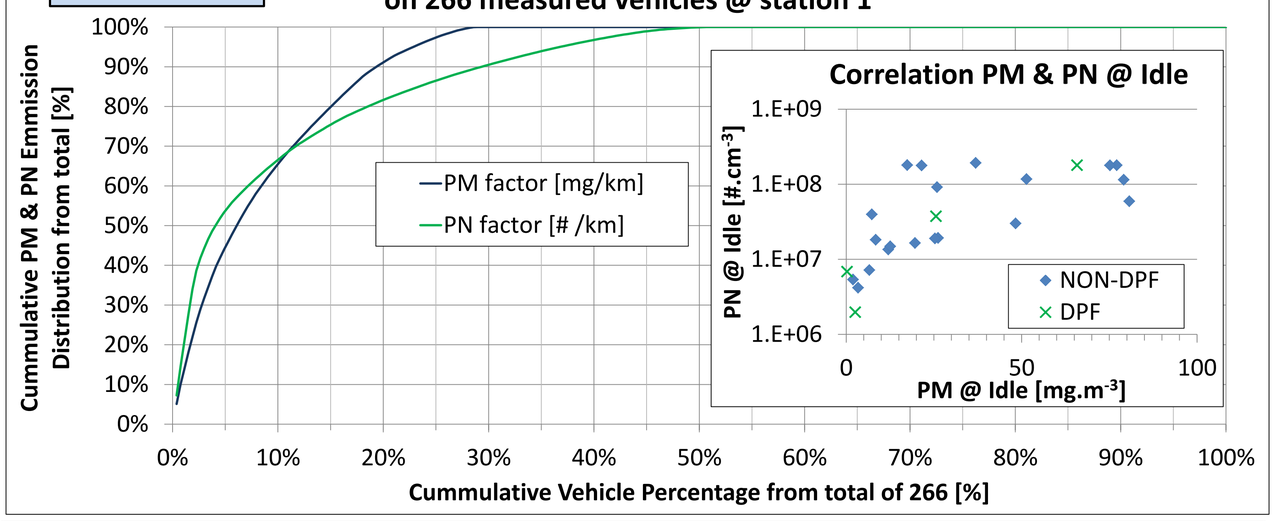


Absorption Coefficient, PM and PN Measurement at Roadside Technical Inspection

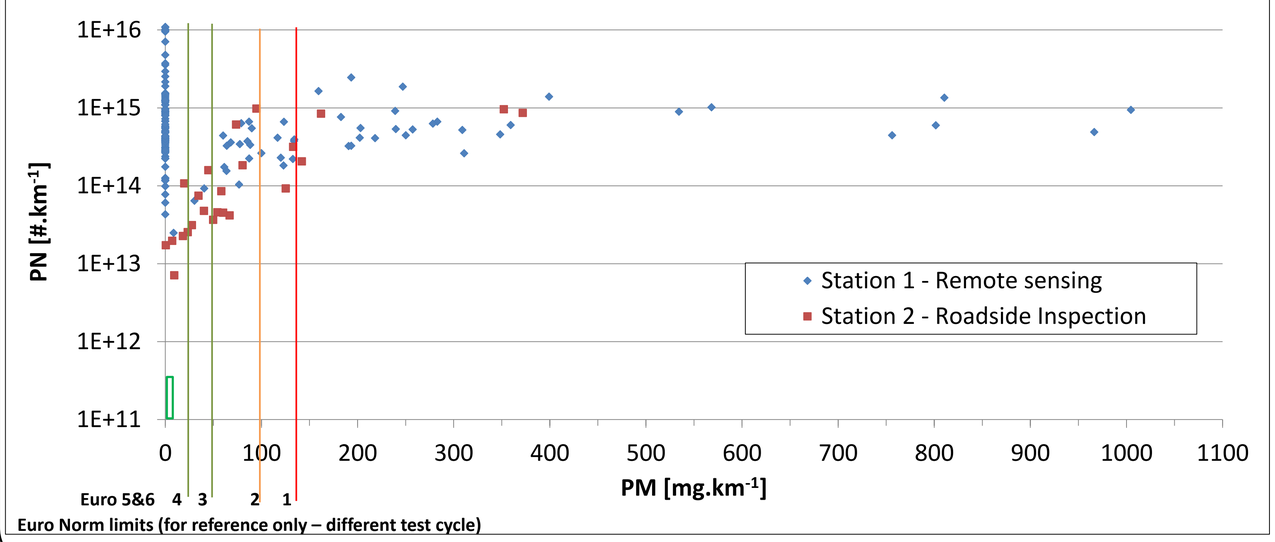


RESULT
10% vehicles = 65% emissions

Cummulative PM & PM Emmission Distribution on 266 measured vehicles @ station 1



Particulate Mass & Count Emission Factor per 1 km from Remote sensing



Conclusion & Discussion

- Over 25 000 vehicles identified in Prague , 266 vehicles detected in Trutnov
- Small percentage of vehicles constitutes majority of the particulate emissions.
  5% vehicles = 50% emissions, 10% vehicles = 65% emissions for both PM and PN
- Therefore efficient air pollution improvement measure would affect small percentage of vehicles that would have to be fixed or kept of the road.
- Remote sensing efficient as pre-selection of suspected vehicle – ¾ identified vehicles failed roadside inspection
- Opacity measurement not very sensitive for DPF performance assessment - PM/PN not correlating well to K
- Key challenge appears to be matching vehicle and emission trace due to high frequency of passing vehicles and variability in sampling delay.

[1] European Environment Agency: Air quality in Europe — 2017 report

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