

Remote (=contact-free) Sensing (=measurement) of Vehicle Exhaust Emissions

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Remote sensing (top-down scheme)



NO₂ exceedances & RS campaigns in Europe



EEA Air Quality in Europe, 12/2018

NO₂ exceedances & RS campaigns in Europe



Issues with remote sensing

- Legislated power is important for serious use
 - EURO 6: "...to inform for market surveillance..."

- High-emitter thresholds (for in-use compliance)
- Low-emission zones
- Increasing applications in Europe and in particular China (>200 devices around country)
- Data handling, QA/QC issues analytical options and statistical power but ...

How many records are enough?



CONOx db has ~1 mio RS records from 20+ individual campaigns, each contributing 10...100,000 records.

Would a campaign sufficient with 1000...10,000....100,000 records?





Reference value = mean of all records [66,000 for PC D5]

Monte Carlo simulation: Choose 100 random records and compute mean. Repeat => Probability distribution around reference value. Repeat with different sample sizes => Distribution of sample size as function of probability & tolerance...

Minimum sample size diesel EURO 5 cars – for 10% tolerance



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Minimum sample size diesel EURO 5 cars – for 10% tolerance





Minimum sample size diesel EURO 4/5/6 cars – for 10% tolerance

Minimum sample size EURO 5 d. cars by temperature for 10% tolerance



Minimum sample size EURO 5 d. cars by eng. power - for 10% tolerance



Minimum sampling duration for diesel EURO 4/5/6 cars – for 10% tolerance for NO emission rate

~2000 cars per day	154
@50% diesel share	1000 diesel cars
@25% EURO 4 & older	250 PC D4
@50% EURO 5	500 PC D4
@25% EURO 6	250 PC D6

 ~2 days of measurements for probing fleet average emission rate (NO!) – more days for other components

⇔ Good for moving RS around for better coverage of fleets and driving conditions

 ~10-20 days of measurements for dissecting by broad vehicle families / technologies

Perspective

- Create network of (semi-)mobile remote sensing
 - In-use emissions of cars, **trucks**, buses
 - Track emission performance over time
 - Flag suspicious vehicles by model and model year
- Coordinate measurements & exchange data
 - Increase coverage of vehicle models,
 - Gain leverage,
 - Design complementary measurements
- Measure in Central & Eastern Europe, in Africa, India, Indonesia, Russia, ...
 Remote sensing for representative overview



Backup slides

Chassis dynamometer / PEMS	Remote sensing
13 vehicles per day	~5000 vehicles per day
1000 continuous records	1-2 snapshots per veh.
Chosen cycle / test route, incl. idle & brake	As passing under load
Dedicated testing possible	Observation only
Thorough single veh. test	Classification of fleet & models
Is (can be) defeated	Hard to defeat
~5-25,000€ per test	~100,000€ for 100,000 records

Fleet average (not just cars)

By vehicle category



By emission standard

ICCT RS White Paper Borken-Kleefeld & Dallmann, 2018





By vehicle age, by ambient temperature, by catalyst technology, by last inspection,

Quality depends on sample size – collaborate & exchange data! -> CONOx -> TRUE

ICCT RS White Paper Borken-Kleefeld & Dallmann, 2018

References – further reading

• ICCT Papers on

 Remote sensing of motor vehicle exhaust emissions (2018)

https://www.theicct.org/publications/vehicle-emission-remote-sensing

- On-road vehicle emissions remote sensing (2013) https://www.theicct.org/publications/road-vehicle-emissions-remotesensing
- CONOx reports on remote sensing data and methodological advances

published by the Swiss Federal Office for the Environment (BAFU)

- <u>https://www.bafu.admin.ch/bafu/en/home/topics/air/publications-</u> <u>studies/studies.html</u>
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Sources for ambient NO₂ at traffic site - EU28



All traffic stations (Borken-Kleefeld, Kiesewetter et al. 2016)