Results from controlled characterisation experiments involving different remote emission sensing techniques and PEMS on a vehicle test track

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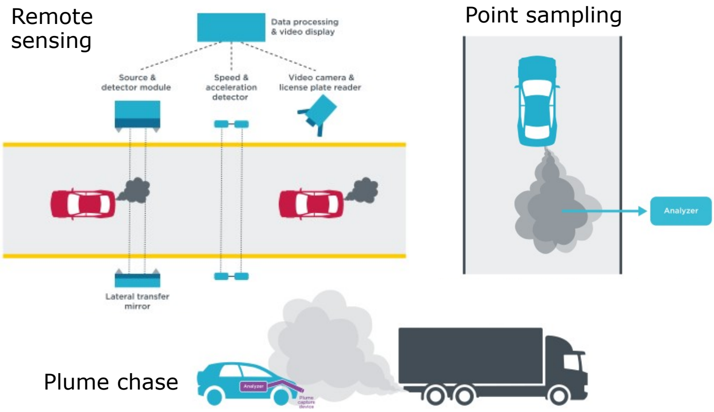
12th October 2022

CITY AIR REMOTE EMISSION SENSING

Introduction

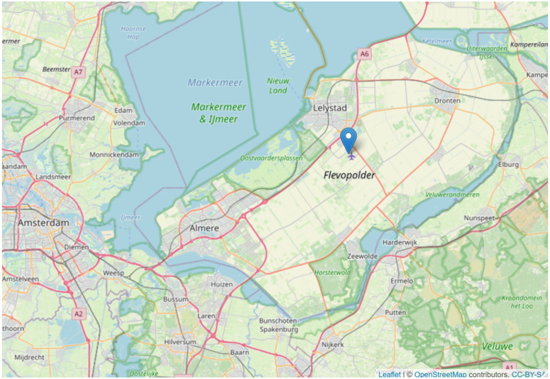
Evaluate the performance of a range of remote emission sensing technologies based on the findings from controlled characterisation experiments at a test track.



Measurement location

Test Centre Lelystad, Netherlands

Located 15 km southeast of Lelystad, in an isolated location away from major emission sources. Stable background ideal for controlled characterisation experiments.



Experimental design

- Six test vehicles selected to be representative of wider vehicle fleets.
- A total of 1,435 vehicle passes were recorded.
- Carefully designed program of experiments to evaluate the performance of the different technologies under a wide range of driving conditions.
- Constant speed and acceleration tests.
- Variation of vehicle order and delay time between vehicles.
- Tampering of after-treatment systems (SCR and DPF).

Test vehicles

Category	Vehicle	Manufacturer	Fuel type	Euro class
L3	NMAX Scooter	Yamaha	Gasoline	5
L3	MT-07 Motorbike	Yamaha	Gasoline	5
M1	Touran	Volkswagen	Gasoline	5
M1	Transporter	Volkswagen	Diesel	6
N1	Caddy	Volkswagen	Diesel	6
N3	F-Max Truck	Ford	Diesel	VI

Table 1: Test vehicles used for the characterisation experiments.

Point sampling and remote sensing

Gases

- Opus remote sensing device
- ICAD NO_2, NO_x, NO analyser
- LICOR CO_2 analyser
- Fourier Transform Infrared Spectroscopy

Particles

- Black carbon tracker
- Diffusion Counter
- Engine Exhaust Particle Sizer
- Aethalometer
- Condensation Particle Counter

Plume chasing

Gases

- ICAD NO_2, NO_x, NO analyser
- CO_2 analyser

Particles

- Condensation Particle Counter
- Scanning Mobility Particle Sizer

On-board emissions measurements

- Smart Emissions Measurement System (SEMS)
- Miniature Portable Emissions Measurement System (miniPEMS)

After-treatment system tampering

- Vehicles tampered and untampered for different experiment sessions.
- Blind testing approach
- SCR systems switched on/off and DPF bypass installed

Condition	Transporter SCR	Truck SCR	Caddy SCR	Caddy DPF
C1	0	0	0	0
C2	1	1	1	1
C3	0	1	1	1
C4	1	0	0	1

Table 2: After-treatment system combinations. '0' refers to normal conditions (SCR on, DPF bypass closed) and '1' refers to tampered conditions (SCR off, DPF bypass open).

Time delay between passing vehicles

Delay (s)	AE33	BCT	DC	CPC 1	CPC 2	EEPS	ICAD
2	4	27	10	0	4	0	4
4	12	31	23	28	32	29	5
7	19	31	20	26	39	33	21

Table 3: Effect of the time delay between passing vehicles on the percentage of valid emission factors for different point sampling devices.

The fast response times of the point sampling devices allowed valid emission factors to be obtained down to a time delay between vehicles of approximately 2 seconds. The black carbon tracker (BCT) and Diffusion Counter (DC) successfully measured emissions for 27% and 10% of vehicle passes respectively at a 2 second delay time.

Point sampling inlet position

Sampling	BCT	LICOR
Side	1095	1584
Centre	3431	3417

Table 4: Dependance of sampling position on the mean ΔCO_2 (ppm s) recorded using the BCT CO_2 channel and the LICOR CO_2 device.

Sampling	BCT	LICOR
Side	58	46
Centre	78	65

Table 5: Percentage of valid CO_2 measurements obtained using the BCT CO_2 channel and the LICOR CO_2 device, at different sampling positions.

The average ΔCO_2 values increased by a factor of 2–3 when the sample inlet was moved from the side of the road to the centre of the road and the proportion of valid measurements increased by approximately 20%. However, sampling from the centre of the road may not be practical for all measurement campaigns.

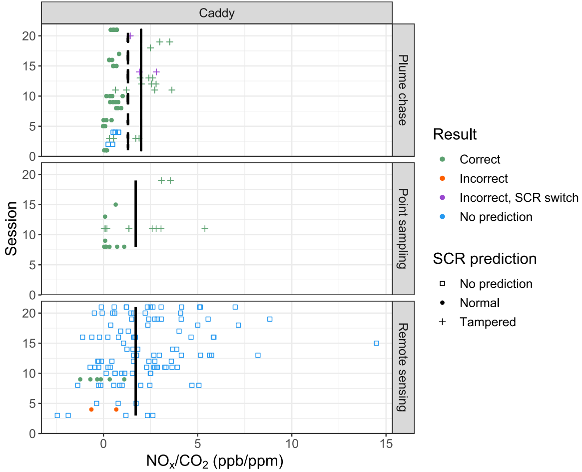
Vehicle driving conditions

Delay (s)	AE33	BCT	DC	CPC 1	CPC 2	EEPS	ICAD
Constant speed	4	10	–	5	7	7	13
Normal acceleration	5	12	4	3	28	20	42
Sporty acceleration	16	19	17	18	43	49	49

Table 6: Effect of vehicle driving conditions on the percentage of valid emission factors for different point sampling devices.

The percentage of valid emission factors is typically lower under constant speed conditions compared to when the vehicles accelerate past the point sampling instruments. In most cases there is an increase in the percentage of valid measurements obtained at increased levels of acceleration, i.e. normal vs. sporty acceleration.

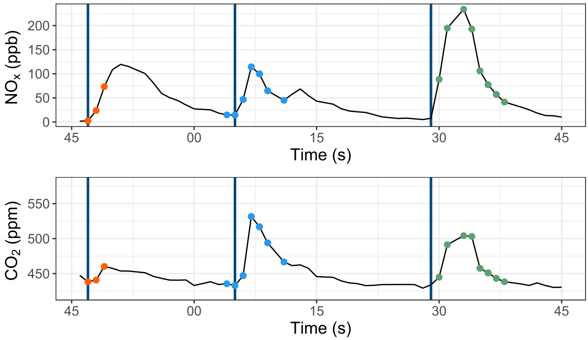
Detection of SCR system tampering

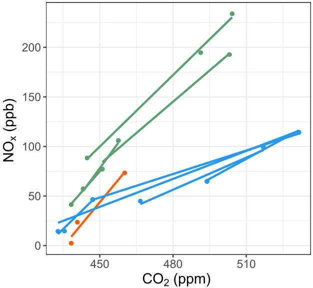


- Emission ratio for a single chase or vehicle pass.
- Shape - predicted SCR system state.
- Colour - whether the prediction is correct.
- Incorrect predictions due to cold starts, switching SCR on/off, influence of nearby high emitters.
- Trade off between accuracy and number of vehicles measured in a given amount of time.

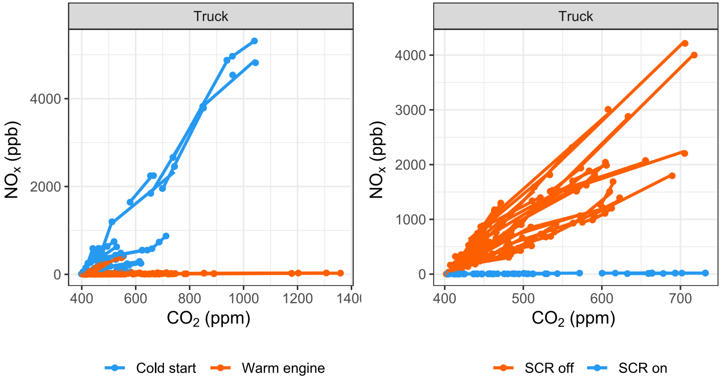
Data processing approach

- Development of a short-term (3 s) rolling regression method.
- A single approach for point sampling, plume chasing, and mobile monitoring.
- Multiple pollutants can be used as variables, background subtraction not required.





Example analysis



Multiple short-term linear regressions are generated using this approach, and the resulting patterns can be used to detect changes in vehicle driving conditions, engine temperatures, aftertreatment system states, and so on.

Acknowledgements

- TNO, NL
- RDW, NL
- Airyx/UoH, DE
- TU Graz, AT
- IVL, SE
- UoY, GB
- Opus, ES
- ACEM, BE
- Yamaha, NL
- CTU, CZ
- CZU, CZ
- UoL, GB

Publications

Deliverable reports

- D1.1 - Measurement technology intercomparison and evaluation. https://cares-project.eu/measurement-tech-compare-d1-1/
- D1.2 - Monitoring of vehicle tampering. https://cares-project.eu/monitoring-vehicle-tampering-d1-2/

Scientific paper in preparation

- A single approach for quantifying local combustion events measured using a range of remote emission sensing techniques

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