



Assessment of road based air pollution control

An independent measurement study of the effectiveness of Pollution Solution technology deployed in a full scale "Roadvent" installation

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Rationale

- To quantify (where possible) the effectiveness of the full scale model of Pollution Solution's "Roadvent" emission control system via the issuing of nitric oxide* tracer gas as a source pollutant and a fast response chemiluminescence detector (CLD) as the analyzer
- To deploy the above technique in a variety of scenarios
- To provide visual evidence of the effectiveness of the system via smoke visualisations
- To measure real time nitrogen dioxide using fast response laser induced fluorescence (LIF)
- Measure both NO and NO₂ in real time at points of interest (server hatch, school drop-off child nose height etc)
- To measure real time nitrogen dioxide (using fast response laser induced fluorescence (LIF)) produced from 3 diesel passenger cars of an age before NO_x catalyst systems were fitted thereby producing both NO&NO₂ in significant quantities representative of in-service vehicles
- The measurement of effectiveness within this study has been categorised as either "pollutant and gas capture" or "pollutant exposure reduction" for each respective experiment

Overview of Pollution Solution Roadvent installation

Suction fan to induce flow

Compressed activated carbon pellets

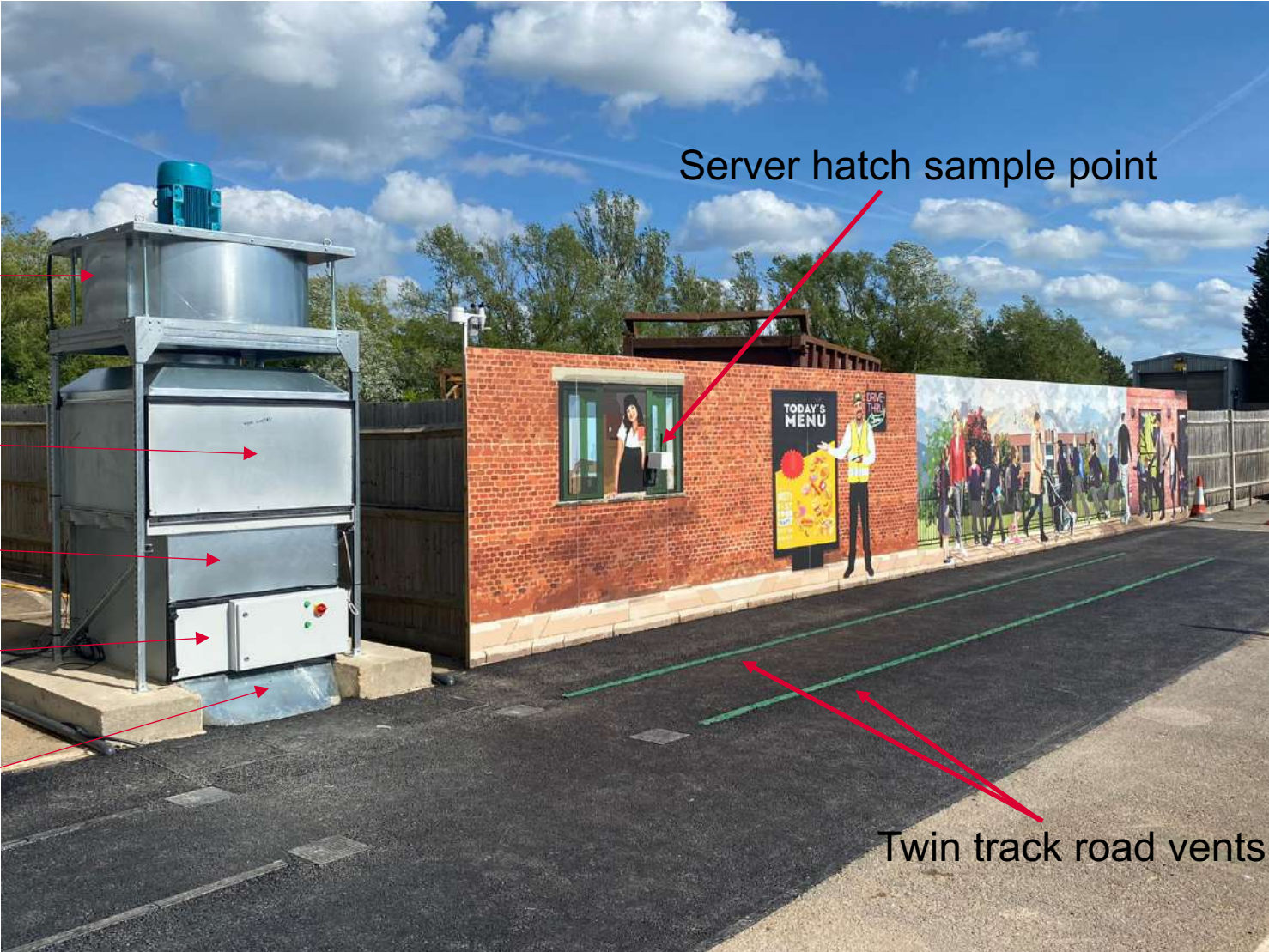
HEPA filter

Electrostatic Precipitator

Intake Plenum sample point

Server hatch sample point

Twin track road vents



Additional equipment

NO_x analyzer

- Cambustion CLD50 (with LIF) fast response NO&NO₂ analyzer

Tracer gas

- 1% NO balance N₂ calibration gas (Air Products with certificate)

PPE

- GasAlert personal NO sensors set to 2ppm alarm level

Candidate polluting vehicles

- 2006, Euro 4 diesel passenger car (VW Golf, 105k miles)
- 2007, Euro 4 diesel passenger car (Vauxhall Astra, 165k miles)
- 2011, Euro 5 diesel passenger car (Ford Galaxy, 120k miles)

Exhaust tailpipes on LHS for all of the above vehicles

Smoke visualisation source

- “Pea Soup” commercial visual effects smoke machine

Non-polluting “vehicles”

- Tesla Model S electric vehicle (carrier for tracer gas without additional NO_x production)
- Lab trolley



Ambient conditions

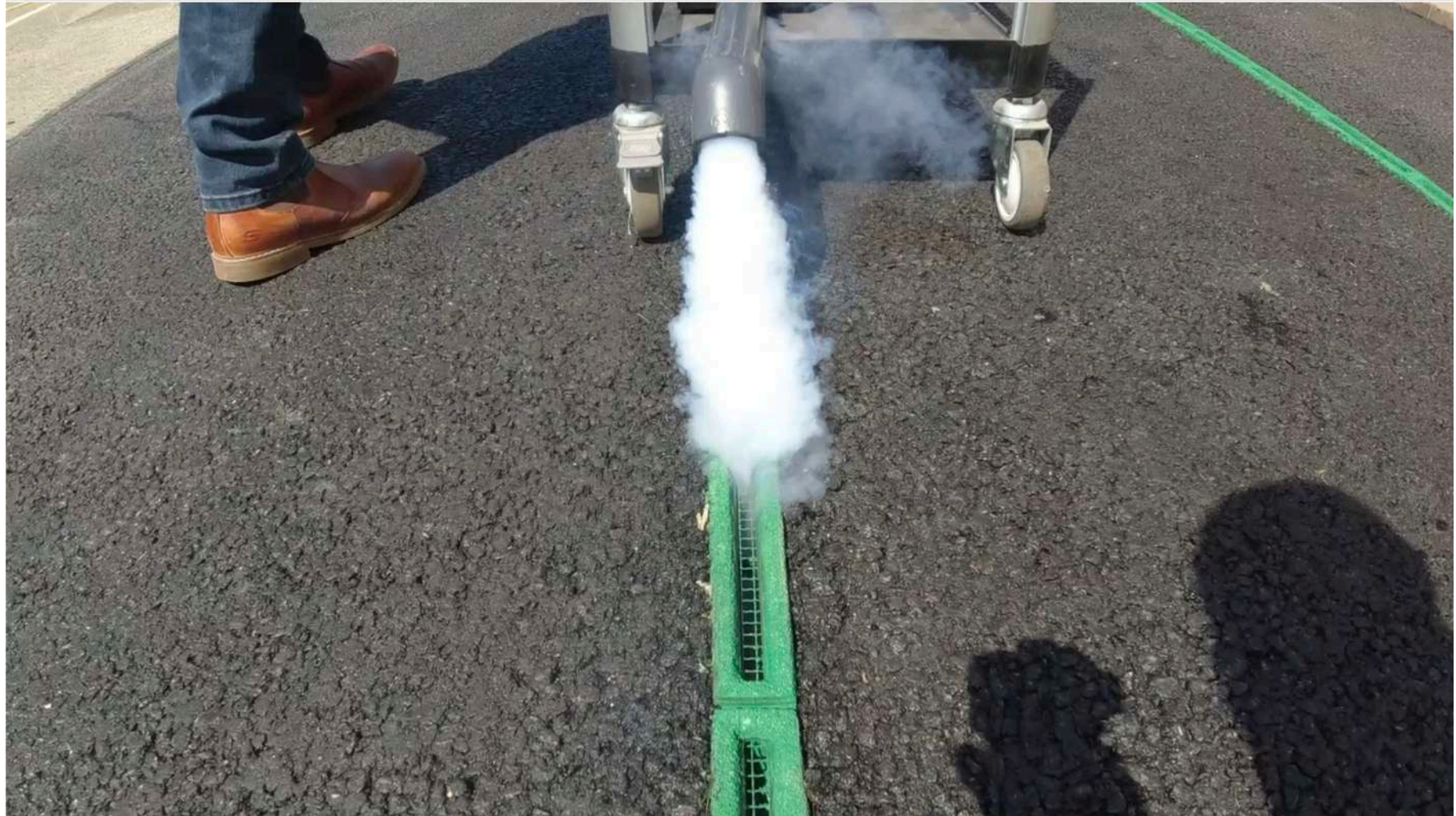
- 14th May 2022, 8am – 3pm
- Ambient temperature, 15°C – 23°C
- Light winds from South West (1-5 KPH)
- Local conditions were variable with wind speed and direction changeable but light. It was appreciated that the capture efficiency would be strongly affected by local wind conditions and that this data applies to the conditions at time of testing.
- The study was undertaken at Pollution Solution's site within the grounds of the confidential vehicle proving ground facility located at UTAC Millbrook in Bedford, UK.
- Note also that the lack of flow through the plane of the hoarding would create wall effects unlike a real open hatch which would likely allow through-flow (depending on –ve or +ve room pressures).
- Driving “style” (e.g. rates of acceleration and wait/idle times) were kept as similar as possible by drivers subject to human error.

Smoke visualisations

Fan Off: Increased exposure to server at window



Fan On: Roadvent capture of smoke from a moving vehicle



Fan On: wind disturbance (birds eye view)



Fan On: Tailpipe between slots with wind gusts



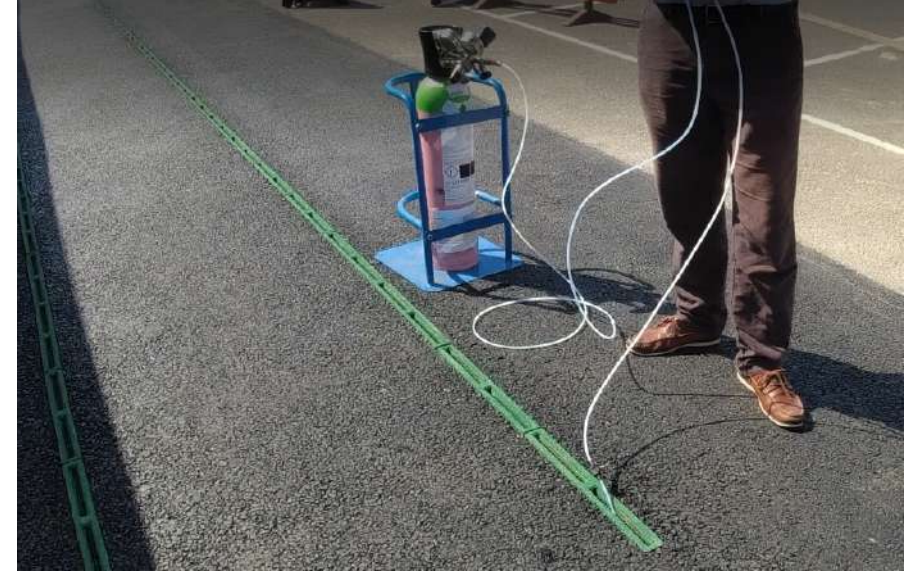
Fan On: Area of influence with light winds



Flow system dilution validation

System Dilution Check - Overview

- Flow REDACTED tracer gas directly in to intake flow ducts



Measure the (diluted) resulting concentration at plenum in to treatment stack. Traverse measurements show sample is well-mixed here.

Use this measured concentration to represent 100% capture of tracer gas

System Dilution Check - Results

- Controlled release of known concentration gas
- Concentration then measured in inlet plenum

Density of Air (16°C & 1022mbar)	1.2313	kg/m ³
Measured Concentration at Plenum	780	ppb
	0.78	ppm
Concentration from Bottle	10000	ppm
Dilution Ratio (Measured/Actual)	REDACTED	
Bottle Flow Rate (1% NO in N)	REDACTED	
	REDACTED	
Estimated Fan Flow Rate (Bottle Flow Rate*Dilution)	REDACTED	
Theoretical Fan Flow Rate (from fan spec sheet)	REDACTED	

Experiment 1: “Synthetic gas release and capture” (Simulated exhaust)

Synthetic (simulated) exhaust - Overview

- Produce fixed flow and known [NO] issuing from pipe at rear of electric vehicle
- Drive vehicle through typical collection hatch manoeuvre, repeat
- Measure the resulting concentration at plenum
- Compare with known 100% capture rate and calculate capture efficiency



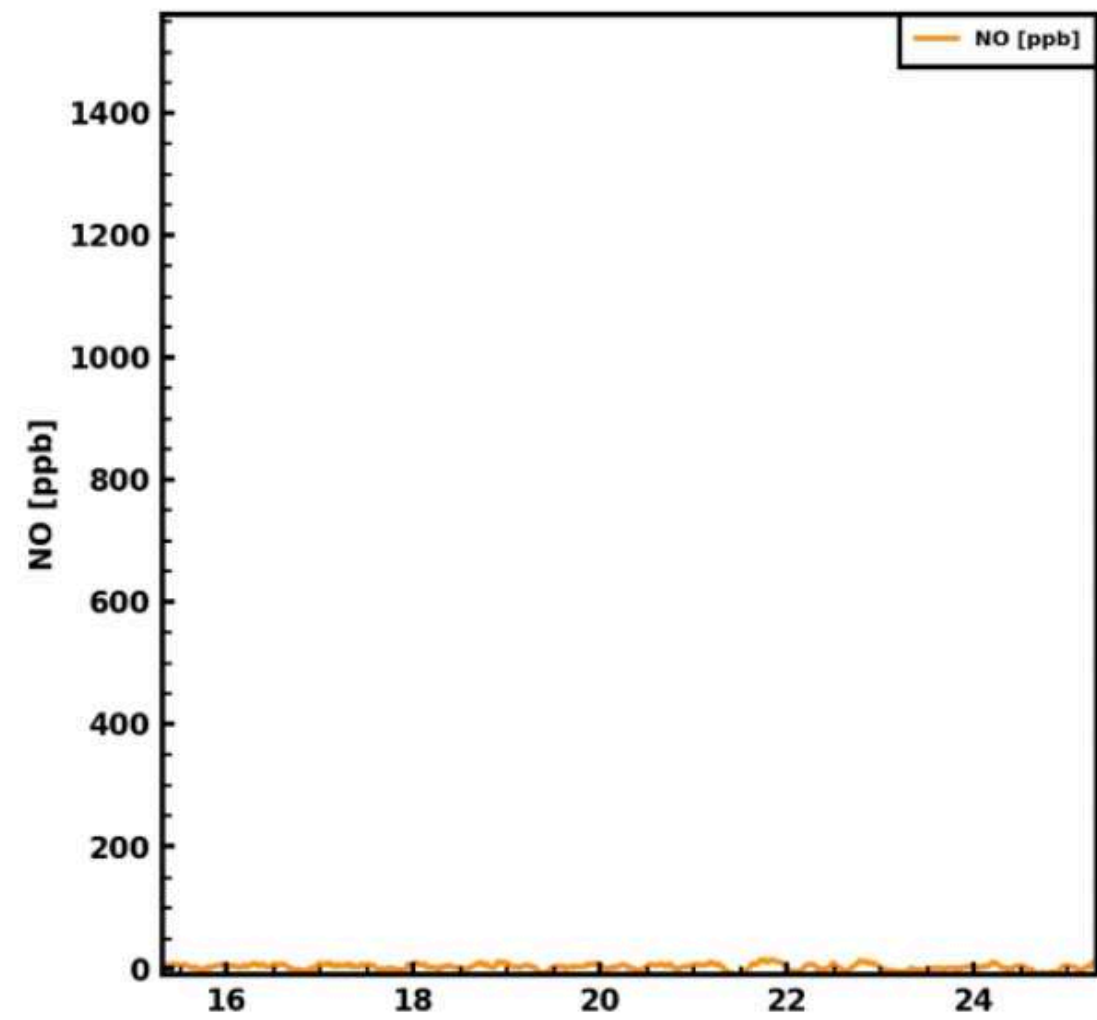
Discharge 6mm pipe exit at
180mm above road surface



Synthetic (simulated) exhaust - Overview



Simulated exhaust – Plenum [NO] capture results, system running



Average capture rate after 3 vehicle passes

- Cumulative mass emitted from bottle = 25.7g
- Cumulative mass entrained by system = 20.8g
- Capture rate = 80.9%

*Mass emitted known by fixed flow rate multiplied by time the valve was open.

*Mass entrained calculated by average measured concentration at the plenum over course of run, multiplied by the calculated flow rate at the plenum. Controlled NO release assumed to be only source of NO.

Experiment 2: “Reducing drive-thru employee pollutant exposure” (Server hatch measurements)

Pollutant measurements at server hatch - Overview

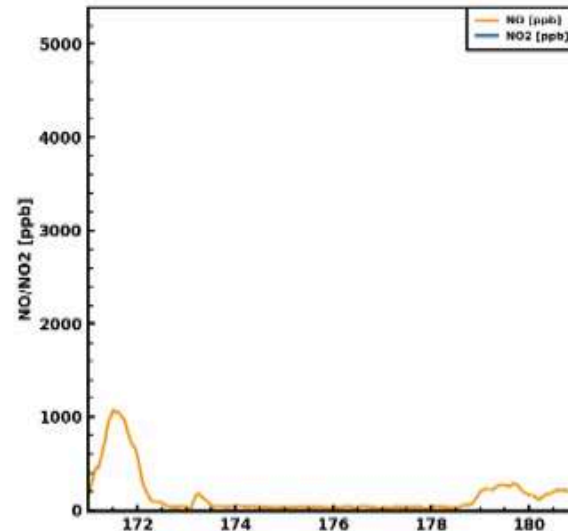
- Three warmed-up candidate diesel vehicles passing delivery hatch point
- Real time [NO] and [NO₂] measured at server face position
- Vehicles queuing for delivery and remain idling
- 5 passes of each vehicle
- Note that vehicles' approach, alignment and drive style was at discretion of each driver and thereby not accurately controlled, but was repeated to the best of the individuals' ability
- All vehicle exhausts were located on LHS (furthest point from the serving hatch)

Pollutant measurements at server hatch - Overview

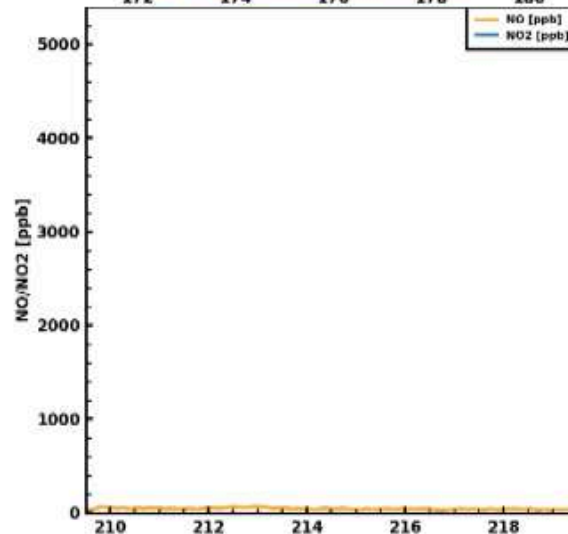


Pollutant measurements at server hatch – real time example results

Roadvent **OFF**



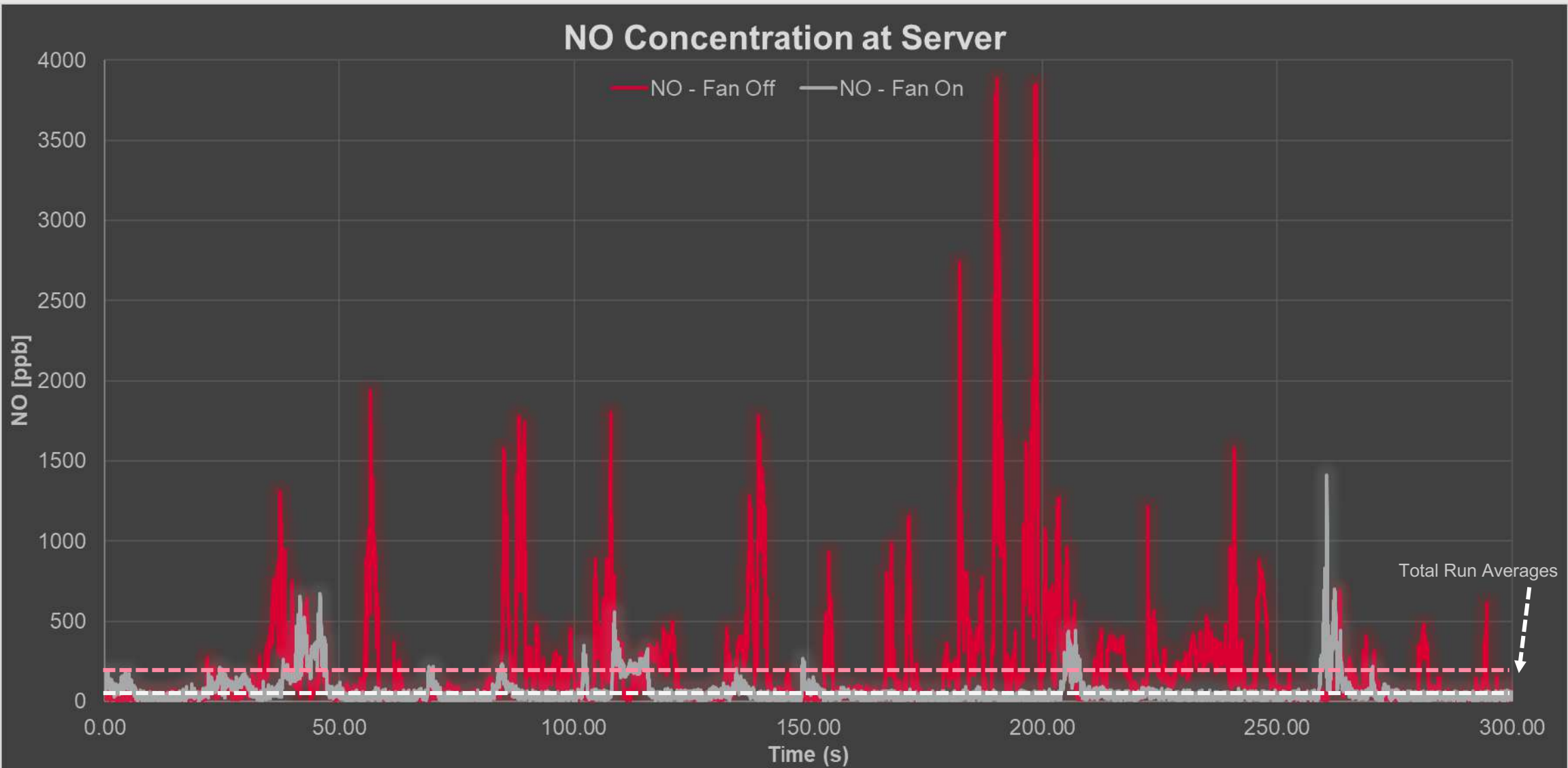
Roadvent **ON**



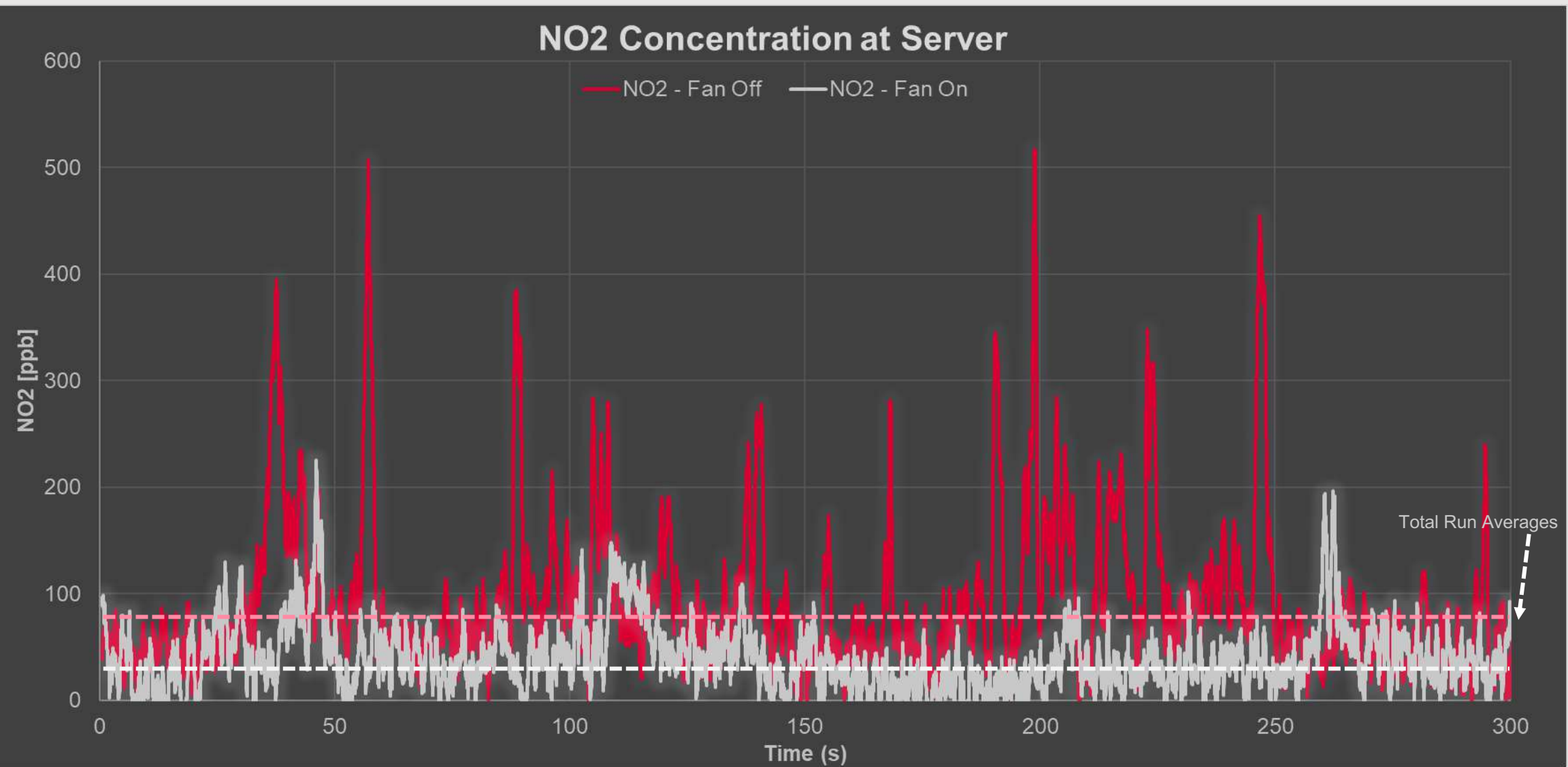
Pollutant measurements at server hatch – full results

- 3x repeats from Tesla and controlled release
 - Fan off: Average concentration = 18ppb
 - Fan on: Average concentration = 3ppb
 - Exposure reduction at serving hatch of 83.3%
- 8x loops with 3 candidate diesel vehicles*
 - Fan off: Average concentration = (Run 1: 607ppb, Run 2: 231ppb)
 - Fan on: Average concentration = (Run 1: 55ppb, Run 2: 65ppb)
 - Exposure reduction at serving hatch of 79.0%

Comparison at server hatch [NO]



Comparison at server hatch [NO2]



Experiment 3: “Pollution reduction for children at school drop off point” (Child pedestrian measurements)

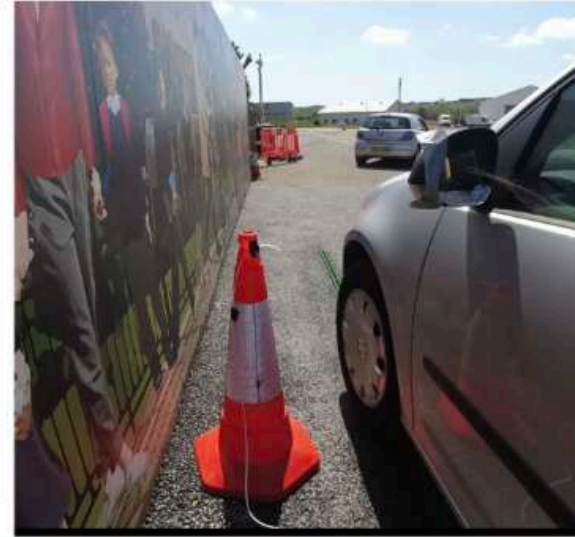
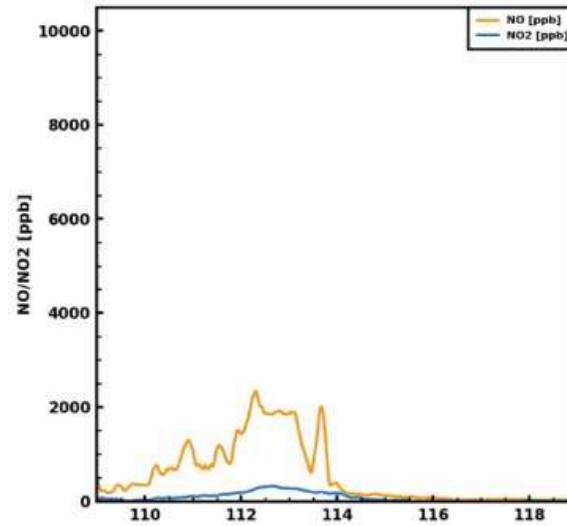
Pollutant measurements at child nose height - Overview

- School drop-off simulation
- Three candidate diesel vehicles on continuous loop and ~10s drop-off pause
- Sample pipe set at 0.8m above ground
- Sample pipe approx. 0.8m from exhaust

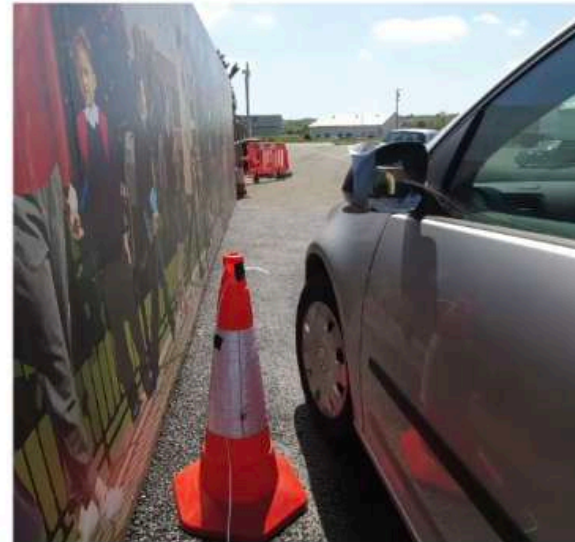
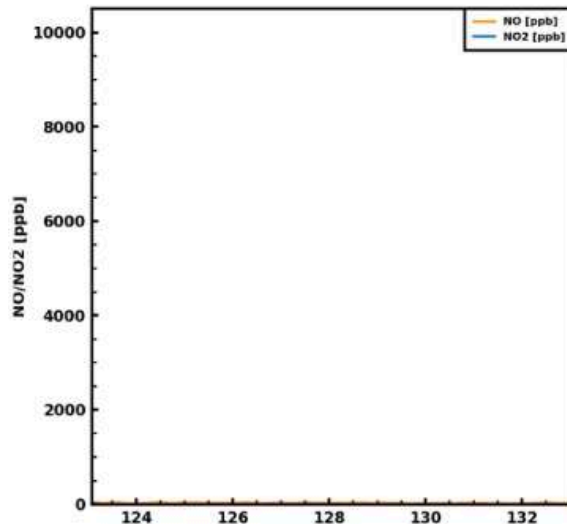


Pollutant measurements at child nose height (exhausts on LHS)

- Roadvent **OFF**



- Roadvent **ON**



Pollutant measurements at child nose height - Results

- 3x loops with 3 candidate diesel vehicles
 - Fan off: Average concentration = 746ppb
 - Fan on: Average concentration = 67ppb
 - Exposure reduction = 91.1%
- 5x repeats with only VW Golf
 - Fan off: Average concentration = 100ppb
 - Fan on: Average concentration = 11ppb
 - Exposure reduction = 89.0%

Experiment 4: “In-car pollution reduction” (Cabin air measurements from queuing traffic: polluting car pull-away in front)

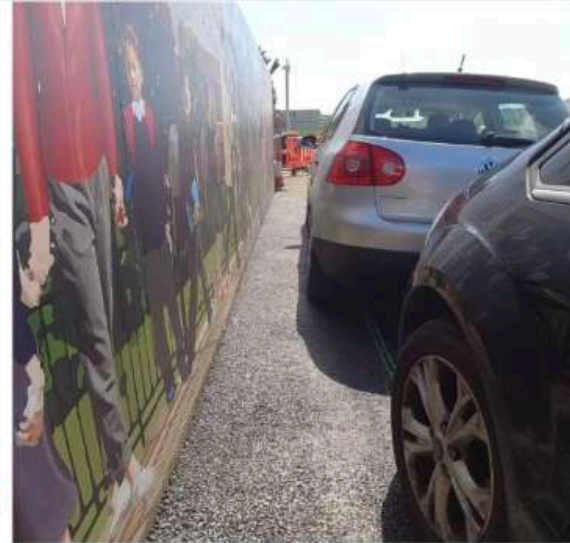
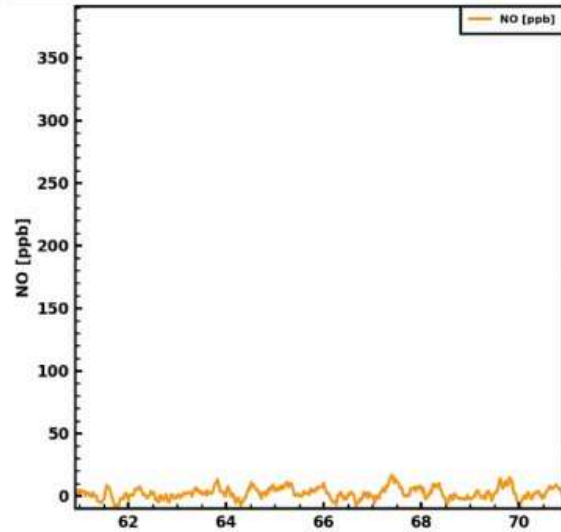
Cabin air vent measurements: Roadvent OFF & ON



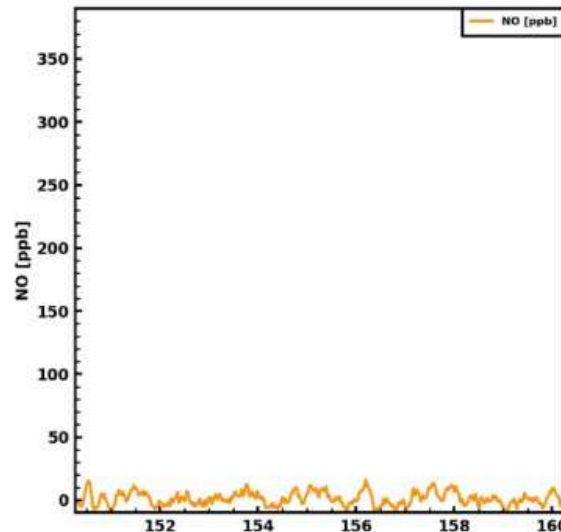
- All cabin air vents closed except for one
- Fan speed set to lowest setting
- Note: air intake under windscreen end of vehicle bonnet/hood

Cabin air vent: Roadvent OFF/ON comparison

- Roadvent **OFF**



- Roadvent **ON**



Cabin air vent - Results

- 5 x repeat tests with vehicle exhaust
 - Fan off: Average concentration = 57ppb
 - Fan on: Average concentration = 9ppb
 - In-vehicle exposure reduction = 83.8%

Experiment 5: “Brake particle simulation”

Brake particle discharge simulation - Overview

Tracer gas released at brake calliper, front wheel parked over Roadvent

Resulting concentration measured at plenum



Brake particle smoke simulation



Brake particle discharge simulation - Results

- 3x repeats with known gas release
- Cumulative mass released = 3.9g
- Cumulative mass entrained by system = 3.8g
- Capture rate = 97.4%

Experiment 6: “Tyre wear particle simulation”

Tyre particle discharge simulation - Overview



- Tracer gas discharged at exit contact position of tyre and road surface
- Resulting concentration measured at plenum

Tyre particle discharge simulation - Results

- Cumulative mass released = 7.65g
- Cumulative mass entrained by system = 7.47g
- Capture rate = 97.6%

Conclusions (1)

- **Experiment 1:** Under the prevailing conditions and using known tracer gas, the system was measured as being 81% effective at displacing NO pollution from the road surface
- **Experiment 2:** Using real vehicle diesel vehicles and under the prevailing conditions, the system was measured as being 79-83% efficient at reducing server hatch occupant exposure
- **Experiment 3:** Using real vehicle diesel vehicles and under the prevailing conditions, the system was measured as being 89-91% efficient at reducing child height exposure near idling and accelerating vehicles
- **Experiment 4:** The trailing vehicle in-cabin air vent NO concentrations are reduced by 84% with the system enabled
- **Experiments 5 & 6:** On the assumption that brake dust and tyre abrasion particles have similar mobility to tracer gas, the system was measured to be 97% effective at their removal

Conclusions (2)

- The system total flow rate when compared with blower performance specifications with measured dilution flow was [REDACTED] (vs quoted [REDACTED])
- Higher wind speeds and direction are likely to reduce system effectiveness, although such conditions would be expected to aid immediate human exposure by improving dilution and dispersion of pollutants
- Discharge position of tailpipe relative to the Roadvent system has some effect on capture efficiency but this was not measured or choreographed on the day and positioning was therefore random.

Efficacy results

			ROADVENT ON		ROADVENT OFF			
Application	Source	Sample Location	Average Conc (ppb)	AVG. Conc Microgram per Cubic Metre (µgm-3)	Average Conc (ppb)	AVG. Conc Microgram per Cubic Metre (µgm-3)	Capture Rate (%)	Roadside Exposure Reduction (%)
Golf idling cabin air vent	Golf	Following vehicle cabin air vent	9	11.42	57	72.33		83.8
Tesla Drive through with bottle x3	Bottle	Plenum	274	347.71			80.9	
Child height hard pull away	Golf	Child height cone by server	10.5	13.32	99.7	126.52		89.5
Child height lay-by multiple cars	All cars	Child height cone by server	67	85.02	746	946.69		91.1
Server all cars x3	All cars	Server hatch	55	69.80	607	770.30		91.0
Tesla Drive through with bottle x3	Bottle	Server hatch	3	3.81	18	22.84		83.3
Server all cars x5	All cars	Server hatch	65	82.49	231	293.14		71.7
Brake disc front	Bottle	Plenum	258				98.2	
Tyres	Bottle	Plenum	444				97.6	