In-Cabin Air Quality and Ride Comfort

Douglas Booker[1], Nick Molden[2], Dr. David Booker

NAQTS Ltd.[1] | Emissions Analytics Ltd.[2] | Lancaster University, UK[1]

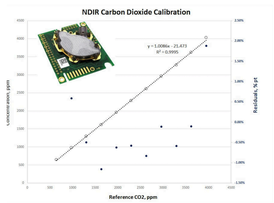
ABSTRACT

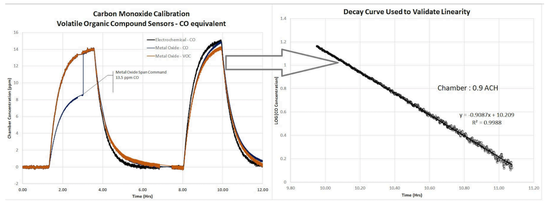
Many studies have addressed outdoor air pollution that arises from traffic, and its associated negative impacts on public health. However, less is being done to understand indoor air pollution, despite the average person now spending more than 90% of their time indoors (European Commission, 2004). In-cabin air quality represents around one hour of this exposure (Müller et al. 2011), but is especially important given the immediate proximity to motor vehicles, plus, in urban areas, high ambient concentrations compared to other micro-environments.

To address the dearth of research on this topic, an NAQTS V1000 air quality monitor, conveniently housed in a mannequin ("Justin"), was used to monitor inside vehicles: five pollutants were monitored (PN, CO, CO_2, NO_2, VOCs) along with environmental and road comfort parameters.

TECHNOLOGY & METROLOGY

PN: CPC with 50:1 pre-dilution.
CO, NO_2, VOCs, NH_3, O_3: Metal Oxide and Electrochemical sensor technology: Dual technologies for key gas measurements enables improved cross sensitivity correction algorithms to be employed. For VOC speciation, the unit controls 4 event-driven thermal desorption tubes for post GC-MS analysis.
CO_2: NDIR
T, P, RH: BME280
Noise: dBA
Location: GPS
Vibration: 3D -accelerometer & -gyro
Data Storage: SQL database
GUI: WIFI HTML interface





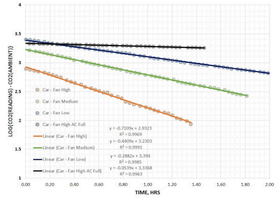
OBJECTIVE / RESULTS

The objective of this research is to develop a procedure to benchmark vehicles on Indoor Air Quality (IAQ) and Ride Comfort. This includes HVAC characterisation, in-cabin air quality, and ride comfort. The arising database will provide relevant data to inform drivers on pollution mitigation strategies and vehicle comfort, as well as to manufacturers to inform them how to best develop models/hardware to automate HVAC systems to reduce occupants exposure to air pollution.

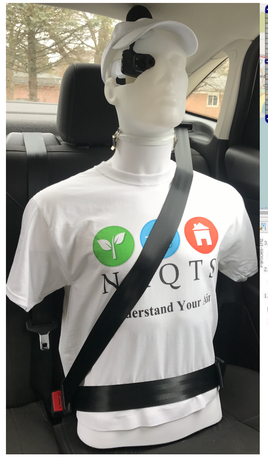
VEHICLE HVAC CHARACTERISATION

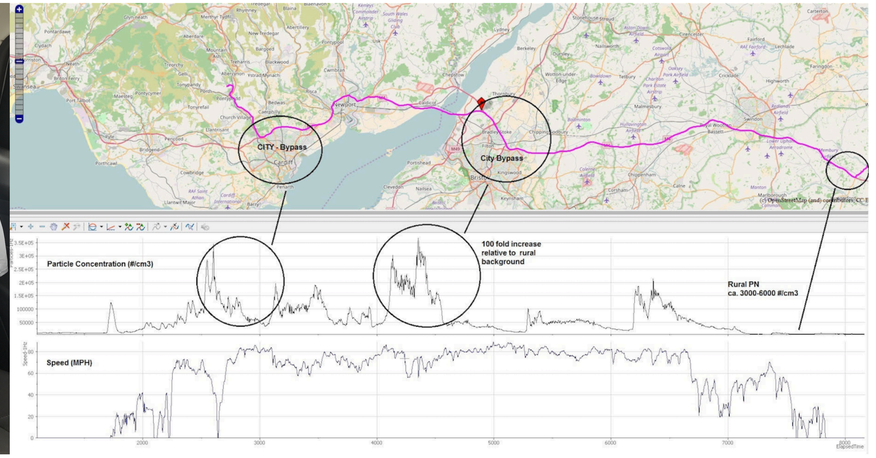
Prior to on-road monitoring, the air change rates (ACH) were characterized under a wide range of HVAC operating conditions using the CO_2 concentration decay method. The following charts illustrate the ACH inside the vehicle. The data is linearised by plotting the logarithmic relationship, with the slope being the number of air changes per unit of time (ACH). In addition, HVAC control options for particulate penetration and removal were characterized using the V1000 CPC technology.

The data illustrates air quality related concerns associated with very low ACH under certain HVAC operating conditions (for example, under recirculation mode). Notably, significantly elevated levels of both CO_2 and CO were monitored.

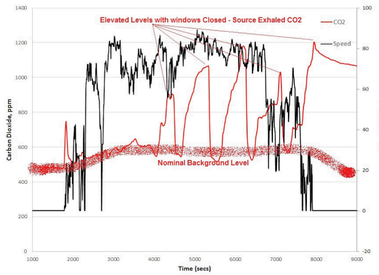


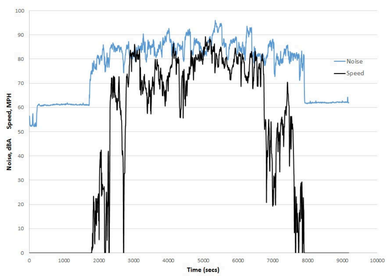
IN-CABIN AIR QUALITY– PN, CO, VOCs, NO2

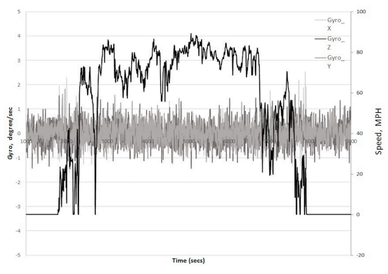




ENVIRONMENTAL COMFORT– CO2, T, RH, NOISE, VIBRATION, AND HARSHNESS (NVH)







CONCLUSION

Consistent with other research (CARB, 2015; Müller et al. 2011), our data shows that the measured pollutants are often several times higher than those outside, due to factors of passenger habits, location, and release of VOCs from the vehicle interior components. By driver education, and/or automation of HVAC controls, exposure can be reduced significantly.

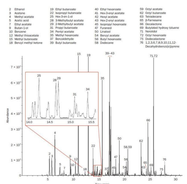
FUTURE RESEARCH POTENTIAL

The V1000 unit provides a fully holistic and easy way to study in-cabin air quality and environmental conditions. From the preliminary results presented here, the unit provides a clear methodology for in-cabin benchmarking. For example:

Static Vehicle Testing:
- ACH as a function of the cars HVAC Controls by CO_2 injection

Dynamic Vehicle Testing:
- Noise as a function of speed, engine, and acceleration
- Vibration as a function of speed, engine, acceleration, and route
- T, P, RH control
- HVAC leakage rates as a function of speed
- Pollution – gases and particulates (absolute and ratio to outside)

Moreover, the unit can also be used for micro-environmental and mobile air quality monitoring. The exposure to solid vs. total particle number (using a NAQTS VPR) inside/outside a vehicle is currently being investigated using 2 NAQTS V1000 units.



6.35mm OD thermal desorption tubes for VOC speciation – V1000 accommodates 4 Active TD tubes that can be configured to sample on events, or on a timer basis.

REFERENCES

California Air Resources Board; *"Car and Bus Exposure Studies*." CARB. Last modified *February 6, 2015*. https://www.arb.ca.gov/research/indoor/carbus.htm

D. Müller, D. Klingelhofer, S. Uibel and D.A. Groneberg. "Car indoor air pollution - analysis of potential sources." *Journal of Occupational Medicine and Toxicology* 6, no. 33 (2011): 1-7.

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CONTACT

Douglas Booker, Managing Director
dbooker@naqts.com
National Air Quality Testing Services Ltd. (NAQTS)
www.naqts.com
@NAQTS