# Quantifying Solid and Total Particle Number Concentrations from an Array of Vehicles Using the "Plume Chaser Method"


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## ABSTRACT


Despite the relatively short period of time spent in cars, exposure levels are of concern given the immediate proximity to motor vehicles, plus in urban areas, high ambient concentrations compared to other micro-environments. For vehicle-related pollutants such as particulates, this contribution is particularly important.

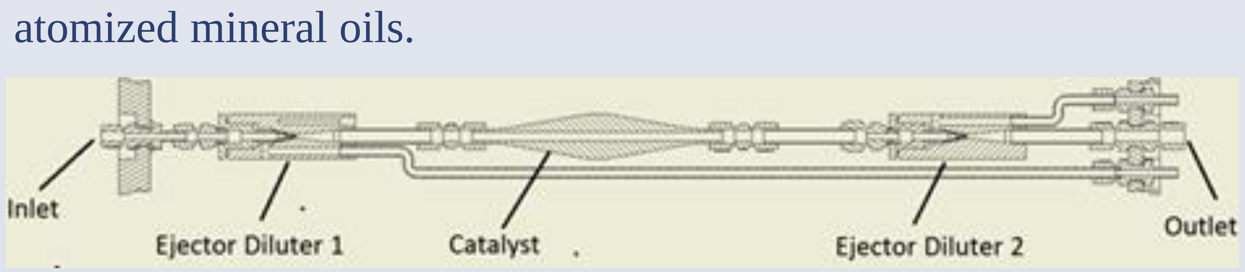
The adverse health effects of particulate matter (PM) have been clearly established in the scientific community, and it has frequently been proposed that ultrafine particles (UFPs) -those with an aerodynamic diameter of ≤0.1 μm- have a more significant effect on human health per unit mass of similar chemical composition than larger particles (Delfino et al. 2005; Harrison et al. 2012; Seaton et al. 1995). The development of a Solid Particle Number (SPN) measurement programme -under the Particle Measurement Programme (PMP) has standarised the measurement protocol for vehicular UFPs. The PMP protocol has been extensively scrutinized, with its repeatability and reproducibility being widely lauded. However, several studies have shown that a significant number of sub-23 nm particles can remain present downstream from the PMP system (Giechaskiel et al. 2009; Herner et al. 2007; Johnson et al. 2009). Consequently, a number of studies were conducted to investigate the composition of these sub-23nm particles, demonstrating that most of them were formed through the renucleation of semi-volatiles, and therefore not of a solid state (Zheng et al. 2011; Zheng et al. 2012).

In developing informed public policy to protect public health, it is important that the concentrations of SPN as well as Total Particle Number (TPN) -including particles of a non-solid state- within vehicles are better quantified, as it is understood that the health concerns associated with PM are a function of particle size, rather than particle state of matter.


## TECHNOLOGY

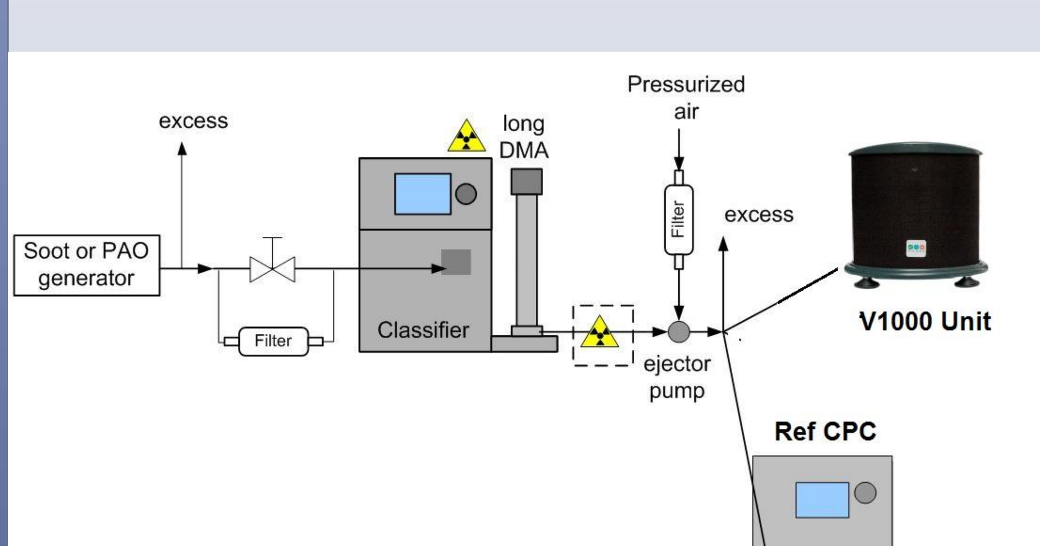
This study used two NAQTS V1000 units -with its core component being a "regulatory compliant" Condensation Particle Counter (CPC)- for measuring TPN.

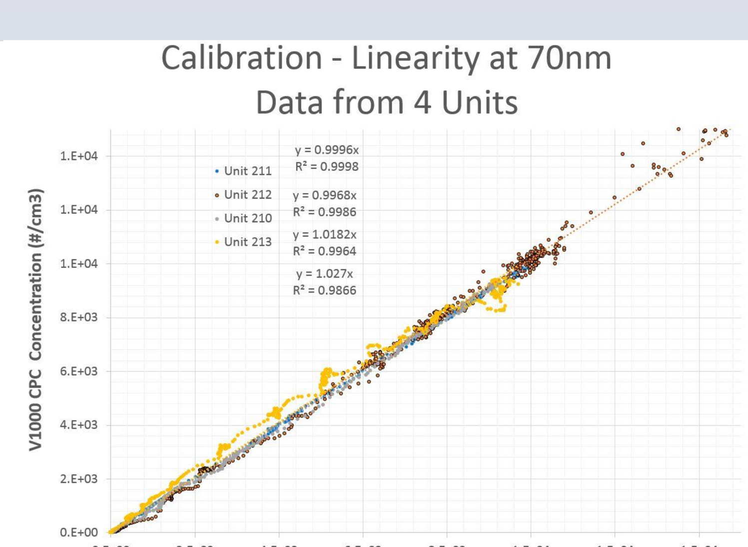
For the SPN, the NAQTS V1000 Volatile Particle Remover (VPR) was used: a hot pre-diluter (PND1), a catalyst / evaporator tube, and a second diluter (PND2) for cooling and further dilution to keep the CPC in single count mode. The VPR was shown to exceed PMP criteria for both removal of tetracontane and atomized mineral oils.




## METROLOGY

Four NAQTS V1000 units were calibrated at Ricardo Plc for both linearity, accuracy, and particle size measurement efficiency. The four units showed excellent linearity from 0-10,000 #/cm3 (single count mode) with $r^2$ >0.99. Slopes were within 3%. The effective d50 for all 4 CPCs was ca. 10nm. Note that the V1000 unit has an internal ejector diluter (nominal 50:1) to correspondingly extend the single count mode.




## METHODOLOGY

This study used the NAQTS V1000 -with its core component being a "regulatory compliant" CPC for measuring TPN- in a "chaser" vehicle to "sniff" SPN and TPN concentrations from an array of vehicles (for example, old and new, petrol and diesel etc.) in the Greater London area.

For the solid measurements the PMP approach was used; namely a hot pre-diluter (PND1, a catalyst / evaporator tube, and a second diluter (PND2) for cooling and further dilution to maintain the CPC in single count mode.

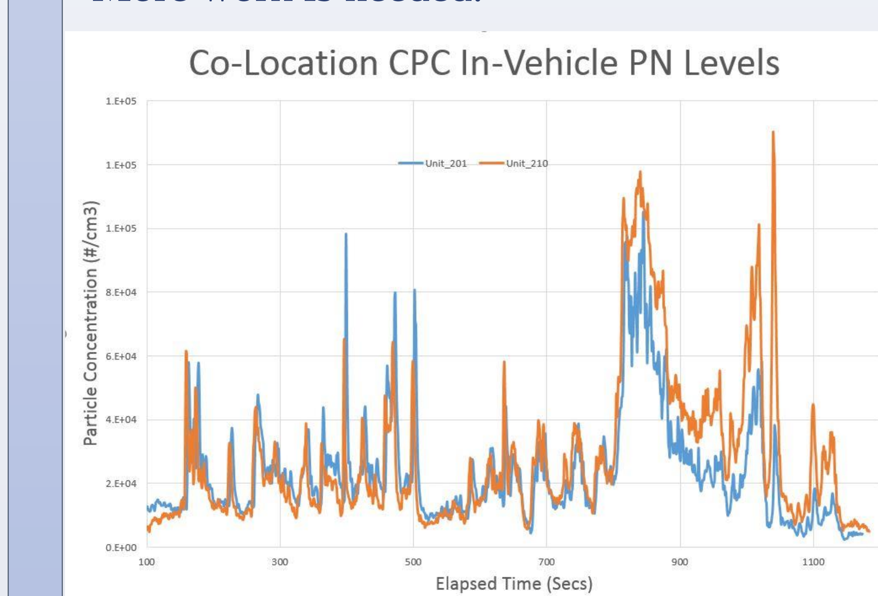
Two NAQTS V1000 units were co-located and their respective particle measurements recorded over a series of "real-world driving" cycles, in city, urban, and rural environments to examine the in-cabin differences.

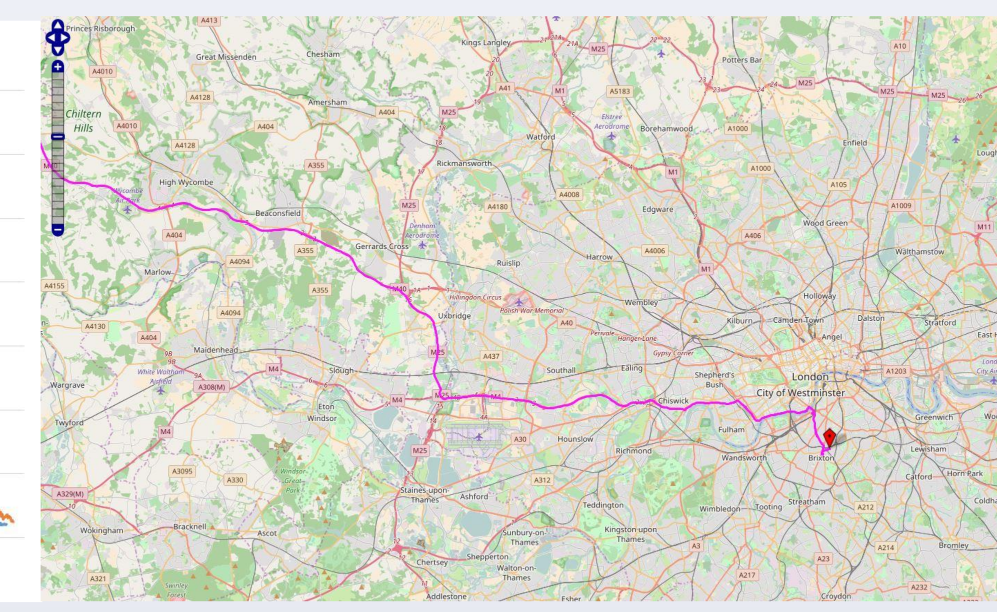
## RESULTS

Although the source was regarded consistent (the air surrounding and entering the vehicle) the results showed different levels of SPN and TPN. Moreover, the decay of the high-peak events was examined to look at vehicle heating, ventilation, and air conditioning and the absorption/desorption of different vehicle interior fabrics.

Despite the data set being limited, the results highlight that vehicles behave differently, moreover that vehicle interior materials may have a significant effect on in-cabin levels.

More work is needed.



## FUTURE RESEARCH POTENTIAL

The characterisation of in vehicle air quality compliments the work that Emissions Analytics Ltd carries out in providing real-driving emissions data across a wide variety of both light-duty and heavy-duty vehicles in both Europe and the USA. This area is predicted to become more topical in the near-future as some OEMs start to pro-actively promote in-cabin air quality management for their customers.

*"The air filtration system was put to the test in real-world environments from California freeways during rush hour, to smelly marshes, landfills, and cow pastures in the central valley of California, to major cities in China. We wanted to ensure that it captured fine particulate matter and gaseous pollutants, as well as bacteria, viruses, pollen and mold spores….."* – (TESLA, 2016)

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