ILAQH

WHO Collaborating Centre for Global Burden of Disease due to Air Pollution

Queensland University of Technology

# Nanoparticle emissions from a fleet of CNG busses in transient and steady state operating.

Z.D. Ristovski, N.K. Meyer,E.R. Jayaratne, O. Weitten, L. Morawska

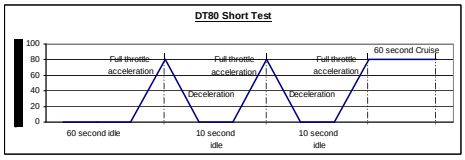
International Laboratory for Air Quality and Health,
Queensland University of Technology.

Particle emission measurements from a fleet of 14 CNG and 5 Diesel buses were measured both for transient and steady state mode s on a chassis dynamometer with a CVS dilution system. Several transient DT80 cycles and 4 steady sate modes (0, 25, 50 100% of maximum load) were measured for each bus tested. Particle number concentration data was collected by three CPC's (TSI 3022, 3010 3782WCPC) having D50 cut-offs set to 5, 10 and 20nm respectively. The size distributions were measured with a TSI 3080 SMPS with a 3025 CPC during the steady state modes. Particle mass emissions were measured with a TSI Dustrak. Particle mass emissions for Diesel buses were upto 2 orders of magnitude higher than for CNG buses. Particle number emissions during steady state modes for Diesel busses were 2 to 5 times higher than for CNG busses for all of the tested loads. On the other hand for the DT80 transient cycle particle number emissions were up to 3 times higher for the CNG buses. More detailed analysis of the transient cycles revealed that the reason for this was due to high particle number emissions from CNG busses during the acceleration parts of the cycles. Particles emitted by the CNG busses during acceleration were in the nucleation mode with the majority being smaller than 10nm. Volatility measurements have also shown that they were highly volatile.

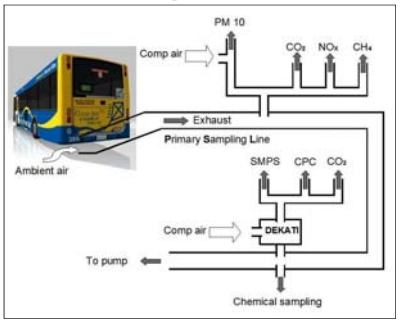
## Methods

Five diesel and 15 CNG buses were tested. Measurements were carried out at

1. 4 steady state modes defined as 0% (idle), 25%, 50% and 100% maximum power loads at a steady speed of 60 kmph, and
2. 4 DT-80 transient cycles, for each bus.




### Measurement setup




## Results

### Steady State modes

- The median particle number emission rate/factor increased with engine load for both diesel and CNG buses. At a given load, the emission rate/factor varied widely between buses.

| Engine Load | Median Values part/min | part/km | 25% perc | 75% perc |
|---|---|---|---|---|
| **Diesel** | | | | |
| **0** | 3.2E+13 | | 1.5E+13 | 6.6E+13 |
| **25** | | 1.1E+14 | 2.9E+13 | 2.5E+14 |
| **50** | | 1.8E+14 | 6.0E+13 | 4.1E+14 |
| **100** | | 2.5E+15 | 2.1E+15 | 5.7E+15 |
| **CNG** | | | | |
| **0** | 2.0E+12 | | 1.4E+12 | 1.2E+13 |
| **25** | | 6.9E+12 | 5.1E+12 | 8.1E+13 |
| **50** | | 1.8E+13 | 1.4E+13 | 1.1E+14 |
| **100** | | 6.5E+14 | 4.6E+14 | 4.3E+15 |

- The median particle number emission rate/factor in each of the four modes was greater for the diesel buses over the CNG buses, but the difference was not statistically significant in any of the four modes.

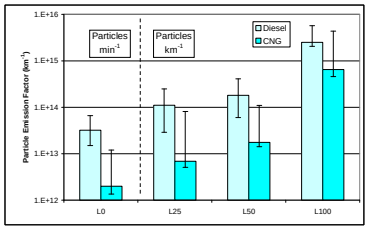



Fig 2: Comparison of median particle number emissions between the two types of buses. The idle mode values are emission rates in units of particles min-1. The other three modes are emission factors in units of particles km-1. The error bars indicate the 25% and 75% percentile ranges.

### Transient DT80 modes

- The median particle number emission factor for the CNG buses was about **three** times higher than that for the diesel buses. The difference was **statistically significant** at a confidence level of 99%.

| | | Diesel | | | CNG | | |
|---|---|---|---|---|---|---|---|
| | | **Median** | **25%** | **75%** | **Median** | **25%** | **75%** |
| P No | $km^{-1}$ | 4.7E14 | 3.5E14 | 8.6E14 | 1.4E15 | 3.6E14 | 2.7E15 |
| $PM_{10}$ | mg $km^{-1}$ | 320 | 60 | 690 | 2.5 | 1.3 | 4.9 |

- Closer inspection of the time resolved particle number data indicated that the emission factors increased significantly during the three acceleration segments.

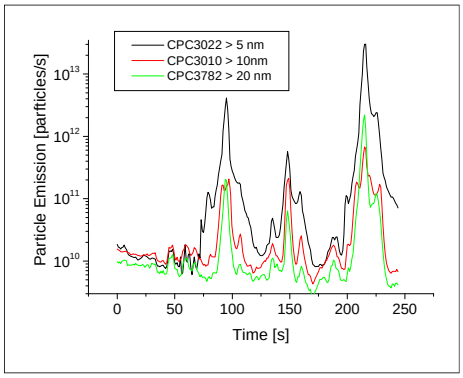



Fig 3: Particle number emission rates for a CNG buss measured with the 3 CPC's as a function of time during the DT80 transient cycle. The CPC's used were 3022, 3010, and 3782 with cuttof points set at 5nm, 10nm, and 20nm respectively.

- Considering the observed differences in the measured particle mass, as well as the data from the 3 CPC's, suggests that, during the acceleration periods, the emission factors of the CNG buses increases to values greater than that of the diesel buses; and that the large majority of the increased number of particles are smaller than 10nm.