

## Abstract

The goal of this study was to measure ultrafine particle concentrations with diameters less than 100 nm emitted by diesel buses and to assess resulting human exposure levels. The study was conducted at the Woolloongabba (W'Gabba) Busway station in Brisbane, AUS during the winter months of 2002. The exhaust of buses contain a significant quantity of diesel particulate matter (DPM) to which passengers waiting at the station were exposed to. The obtained data are very significant as animal studies have shown that diesel exhaust can cause cancer.

## Introduction

Despite considerable amount of basic research, neither the formation of DPM in the combustion chamber, nor its physico-chemical properties or human health effects are fully understood at present. However, DPM is perceived as one of the major harmful emissions produced by diesel engines. From a population exposure point of view, air quality in a street canyon (Fig.2) is of major importance, since the highest pollution levels and the larger targets of impact are often concentrated in this kind of settings.



Fig. 1: Eastern view of the W'Gabba Busway station

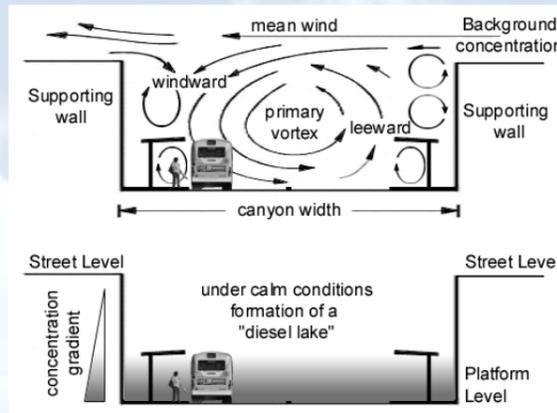


Fig. 2: The W'Gabba Busway station resembles a street canyon. Idealized pollutant dispersion under windy conditions (top) and calm &amp; cloudy conditions (bottom).

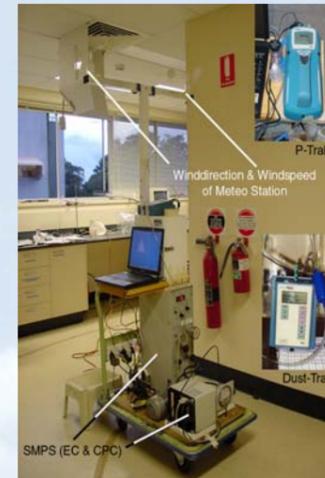


Fig. 3: Real-time particle number measurements were done with the TSI Model 3934. Additional equipment included the TSI-Model 8525 (P-Trak), the TSI-Model 8520 (Dust-Trak), and the Monitor Sensor Meteo station.

## Methods

**Data Gathering** - A manual bus census as well as passenger data (frequency and waiting time, based on video surveillance cameras) were performed. Based on this information, the outbound platform was eventually chosen as the main particle concentration sampling location (Fig.1). **Particle Inventory** - A typical particle sampling day (using the instruments shown in Fig.3) started at 10:00 in the morning and lasted till 19:00 in the evening and was clustered in intervals of 30 minutes each. Thus, about 20 sets consisting of 6 samples each were taken throughout each day for 7 days.

**Exposure Assessment** - Exposure ( $E$ ) itself is defined as the average concentration of a toxin multiplied by the time an individual is exposed to that concentration:

$$E = c_{\text{particle}} \cdot t_{\text{waiting}}$$

where  $t_{\text{waiting}}$  is the time exposed to DPM in [min] and  $c_{\text{particle}}$  the averaged number concentration of DPM in  $[\#/cm^3]$ . Bus related concentration is calculated as the platform concentration minus background (street level) concentration (Fig.4). Passenger exposures are calculated for 7 consecutive days using the census data (a total of 2547 individual cases).

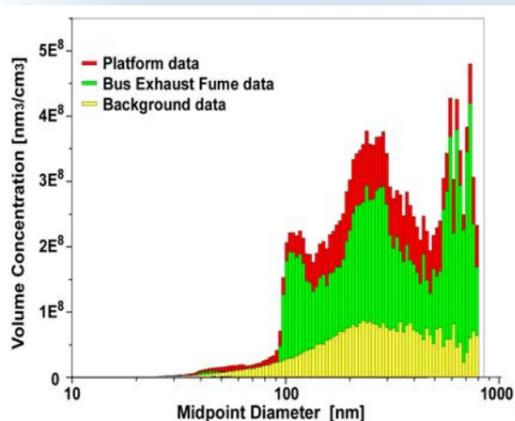
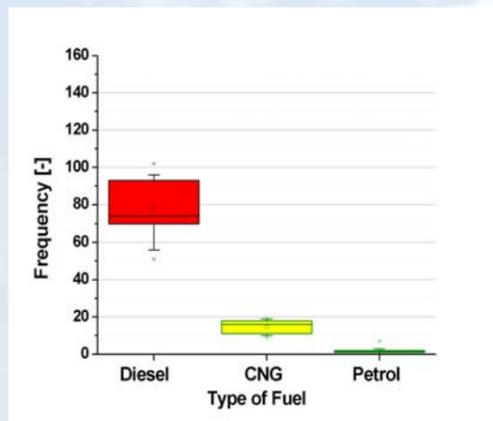

 Fig. 4: Half-hour sample file (Mon. 17<sup>th</sup> of June: 11<sup>00</sup>-11<sup>30</sup>). Exhaust fumes distributions are calculated by deducting the background from the platform concentrations.


Fig. 5: Fuel type of vehicles. Comparison of hourly bus frequencies based on the fuel utilized.

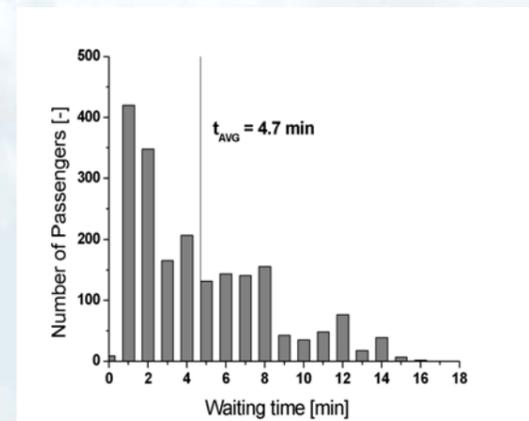


Fig. 6: Frequency distribution of passenger waiting times.

## Results

The vehicle number grouped in fuel classes visiting this station on an hourly basis consisted of 78 for diesel powered buses, 15 for compressed natural gas (CNG) buses and an insignificant amount of less than 2 for petrol driven pickup-type service vehicles (Fig.5). Average passenger waiting time was found to be 4.7 min (Fig.6). Particle number exposure for that period resulted to be  $14.1 \cdot 10^3$  particles/cm<sup>3</sup>. Based on a standard density of 1g/cm<sup>3</sup> this corresponds to a mass concentration of 1.64 pg·cm<sup>-3</sup> (compare Fig.8).

As some passengers waited longer, so did their exposure to particles increase (Fig.9). Based on the fact that the average passenger spends approximately 5 minutes on the platform, particle number concentration dominates the 10 and 40 to 60% range of bus related exhaust fumes. This changes dramatically when considering the particle mass exposure concentration, where most passengers are exposed to about 50 to 80% of exhaust fumes originating from the buses (Fig.7).

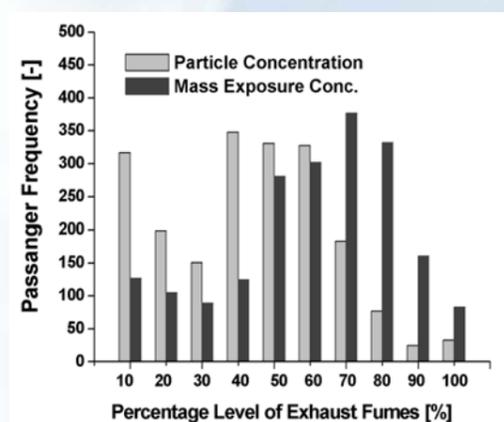


Fig. 7: Histogram representation revealing the number of passengers exposed partially or entirely to bus fumes.

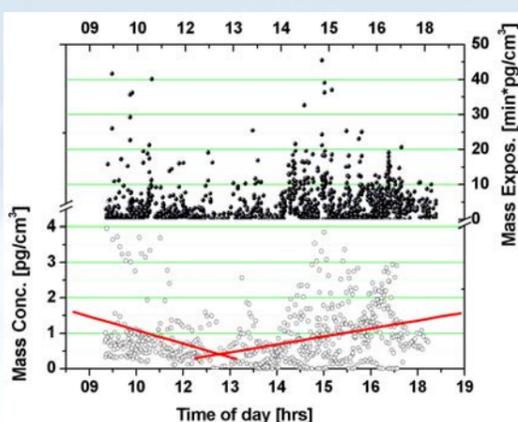
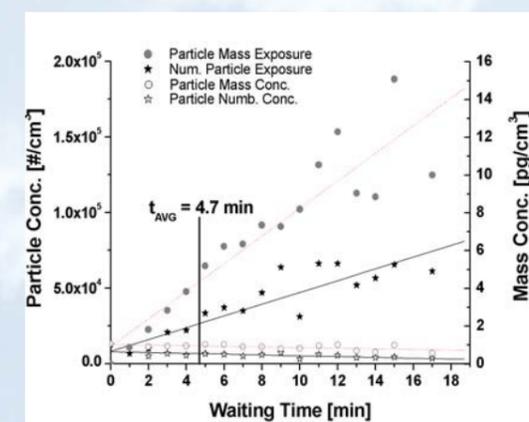


Fig. 8: Diurnal particle mass concentration below and the particle mass exposure above of bus related exhaust fumes.


 Fig. 9: Number and mass concentration of bus-related exhaust fumes to which waiting passengers at the platform are exposed to. Conversion from number to mass concentration was done using a standard aerosol conversion density of 1g/cm<sup>3</sup>.

## Conclusion

This study has shown that significant particle exposure concentrations to humans are present at the W'Gabba platform. A significant amount of the particle mass exposure on the platform originates from bus exhaust fumes (56%).

Thus, adverse health effects for long-term exposure cannot be excluded. The canyon-like setting, in which the bus station is embedded, prevents the dilution and dispersion of exhaust gases and particles. The authors recommend that major changes should be imposed in the architectural design to improve the exchange of air masses.

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