

AIR QUALITY IN NATURALLY VENTILATED CARPARKS

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1 ABSTRACT

There is an increasing move towards off-street parking in cities, often with multi-storey naturally ventilated car parks, but little is known about the factors that affect air quality in the car parks. Measurements of air quality (including carbon monoxide, particulates, traffic volume and air movements) in a naturally ventilated car park built on a hillside at the edge of a forest. Air quality measurements over several months revealed a difference in the pollution patterns with wind speed and the time of day. Vehicles arriving in the morning had warm engines and produced less carbon monoxide per vehicle than vehicles leaving in the afternoon, but the amount increased with the traffic volume when there was little air movement. Less distinct relationships with the traffic volume were found with particulates.

2 INTRODUCTION

Air quality in open spaces used as car parks is not usually a concern nor is air quality in enclosed and underground car parks, as the latter has to be mechanically ventilated to AS 1668.2-1991 "The use of mechanical ventilation and air-conditioning in buildings" (Standards Australia 1991.). As public policy in large cities moves cars from on-street to off-street parking, the question of air quality in naturally ventilated multi-storey car parks will become an increasing issue. However little has been published on air quality in naturally ventilated multi-storey car parks. This study attempts to address the issue.

A naturally ventilated multi-storey car park built into the hillside of the Nathan Campus of Griffith University, Brisbane provided an ideal site for the work as it was close to the research laboratories and access was easy. The car park was in the middle of a forest, with one long access road passing it, minimising the effects of local air pollution.

The traffic to work in the morning and one in the afternoon were expected to produce two peaks. Complex pattern could be expected, as the degree of natural ventilation could vary considerably through the day and level-to-level; the emission rates and composition would depend on the engine temperature and vehicle speed. Some of the basic findings will be presented for two of the key determinants of air quality, carbon monoxide and PM10.

3 EXPERIMENTAL

The study took several phases – a survey of the car park on several days with hand-held instruments (CO, NO, NO₂ and particulates) to determine the variation between levels, and a more intense survey at set locations using more sensitive instruments and logging passing vehicles.

Air speed was measured with a TSI VelociCalc Air Velocity Meter; air direction with Dräger smoke tubes, temperature gradients with a Questemp heat stress meter; CO and SF₆ tracer gas with a Brüel & Kjær 1302 Multi-gas Monitor. The 1302 had a stated sensitivity of 0.001 ppm for CO and the detection limit of 0.229 mg/m³ (0.20 ppm) at 25°C and 1 atmosphere pressure. NO and

NO₂ (and CO) were measured with a Quest Multi-log 2000, though the NO and NO₂ measurements proved unsatisfactory, as the sensors needed replacement. Particulates were measured with a DustTrak Aerosol Monitor Model 8520 with a 10- μ m size-selective inlet. A Microsoft Excel macro was written to timestamp comments about each passing vehicle. The Brüel & Kjær 1302 Multi-gas Monitor was calibrated for CO with a gas bag using a certified CO source in nitrogen. The maximum error was 2.2%.

The sampling sites are indicated in Figure 1, with vehicle entry on level zero.

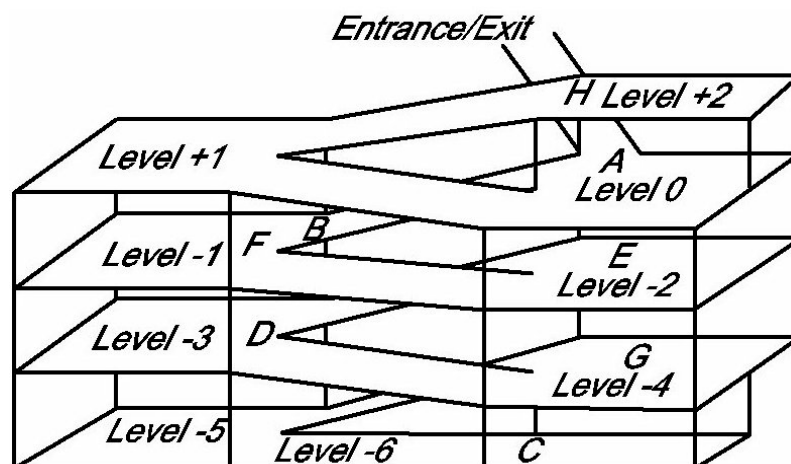


Figure 1 Sampling sites

Selection of representative sites was important. Some locations, particularly on corners and near the entry/exit gave high peaks due to the directed plume from the vehicle tailpipes. For health problems associated with transient high exposures, these could be important, but it was felt that the overall air quality deserved the main focus of this study.

4 RESULTS AND DISCUSSION

4.1 Variation between levels

The wind had a large influence on air quality and the air speed in the different levels was significant. The lower levels, -2 down, has less air movement as the carpark was dug into the side of a hill. The entry levels (0 to -2) received more air movement and the upper levels were best exposed to the elements and there was more air movement. The direction of the air movement was generally in the same direction all day but on some days the wind moved across the car park.

On the upper levels, the CO levels were low as the traffic was light and the natural ventilation was better. On the lowest levels the CO was also low, despite the poor ventilation as the traffic volume was very low. The highest levels were on the entry levels as all vehicles had to pass this point. Parking was preferentially close to the entry on the western end, as this was close to the main university footpaths. These measurements enabled a number of sites to be selected to examine the variation in air quality over a day.

4.2 Carbon Monoxide

As expected the carbon monoxide levels peaked with the morning and afternoon peaks (Figure 2), but on lower levels, there was a delay in the morning peak. A smaller lunchtime peak was also found, as people left for lunchtime activities. The afternoon peaks were larger than the morning peaks, as the cars generally started with a cold engine, increasing CO emissions until the catalytic

converter reached an operational temperature. Some car makes, notably Hyundai produced more CO.

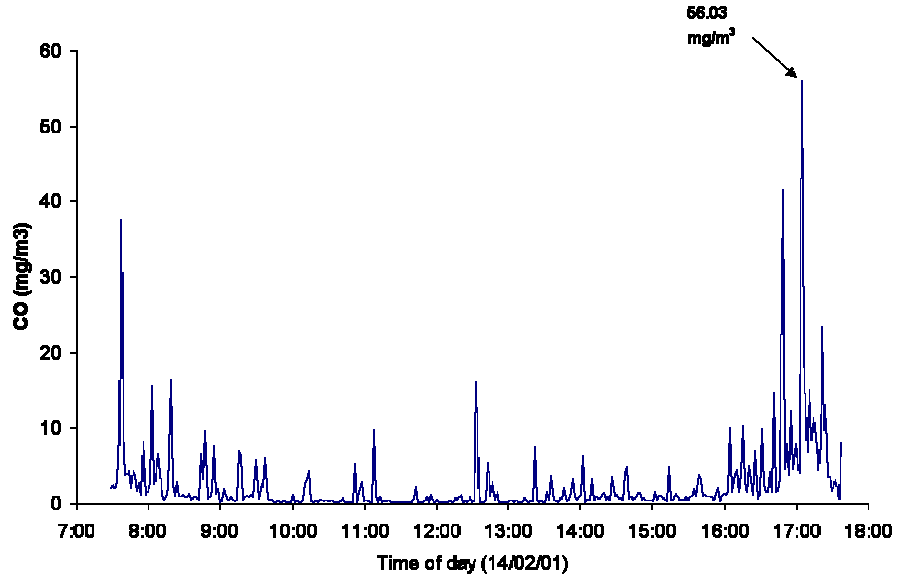


Figure 2 CO concentrations at site “A”

The CO concentrations in this car park were well below the Australian exposure standard for CO (34 mg/m³) (NOHSC 1995) and the NHMRC IAQ recommendation of 10 mg/m³ (NHMRC 1996). These results were much lower than those from studies in the enclosed or underground car parks (Chow 1996; Singer, Kirchstetter et al. 1999).

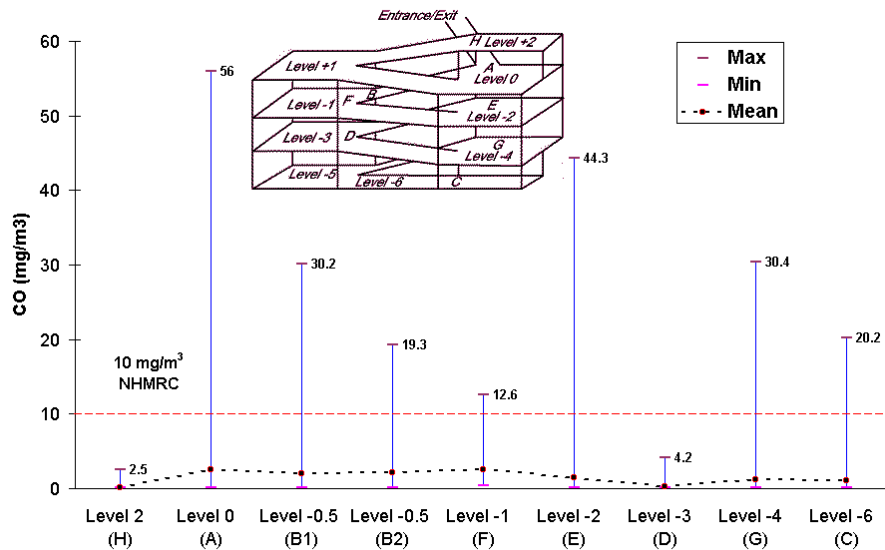


Figure 3 CO concentrations at the sampling sites

As expected the CO levels increased with the traffic volume (Figure 4).

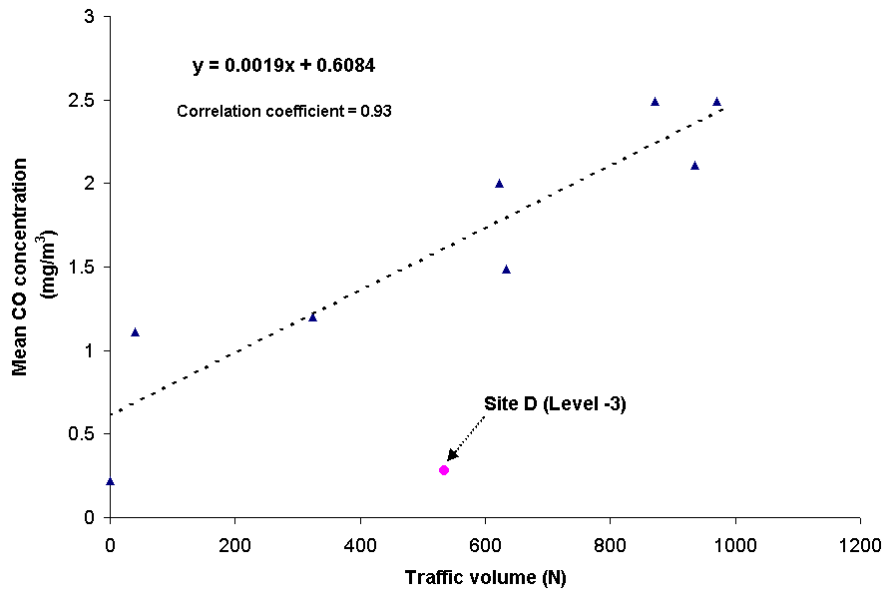


Figure 4 Traffic volume and the mean CO concentration at sampling sites

There were strong correlations ($r^2 = 0.88-0.99$) between the 60-min moving average CO concentration and traffic volume in the afternoon peak, but much weaker correlations in the morning peak and off-peak. When the CO concentration was low, other factors like wind speed were more important in determining the CO concentration.

A simple mathematical model was formulated to predict the mean CO concentration (Y) in this car park:

$$Y = K \times \left(\frac{N}{W} \right) + C$$

where:

- Y is the mean CO concentration at a certain location (mg/m^3);
- N is the traffic volume passing through (cars passing per day);
- W is the mean wind speed (m/s);
- C is 0.4464 (mg/m^3);
- K is 0.0007 ($\text{mg}/\text{m}^2/\text{s}$).

4.2.1 PM10

PM10 results were much more erratic than the CO data (Figure 5). This may have been due to additional particulates from the road and re-suspended dust by the wind. Running hourly averages gave produced some patterns. The mean PM_{10} at site H (without any vehicle passed through) was $16.5 \mu\text{g}/\text{m}^3$, which is comparable to the background value ($15.1 \mu\text{g}/\text{m}^3$) of PM_{10} in Brisbane in 1999 (Donald and David 2001). All of these mean PM_{10} concentrations are below the Australian national ambient 24-h average air standard value for PM_{10} of $50 \mu\text{g}/\text{m}^3$ (NEPC 2000).

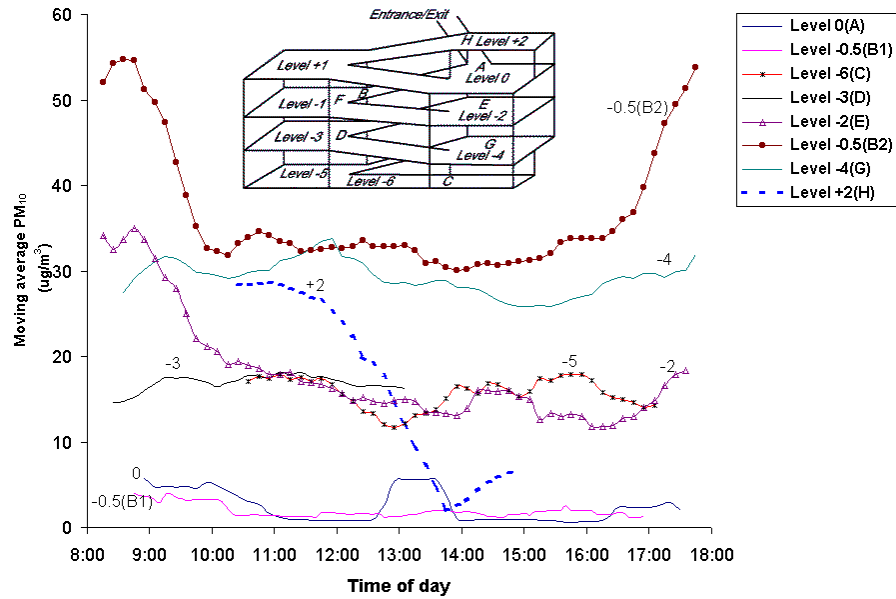


Figure 5 Moving average PM₁₀ in 60-min interval with time

When CO and PM10 levels were compared on different levels of the carpark, only weak trends at best were detected (Figure 6).

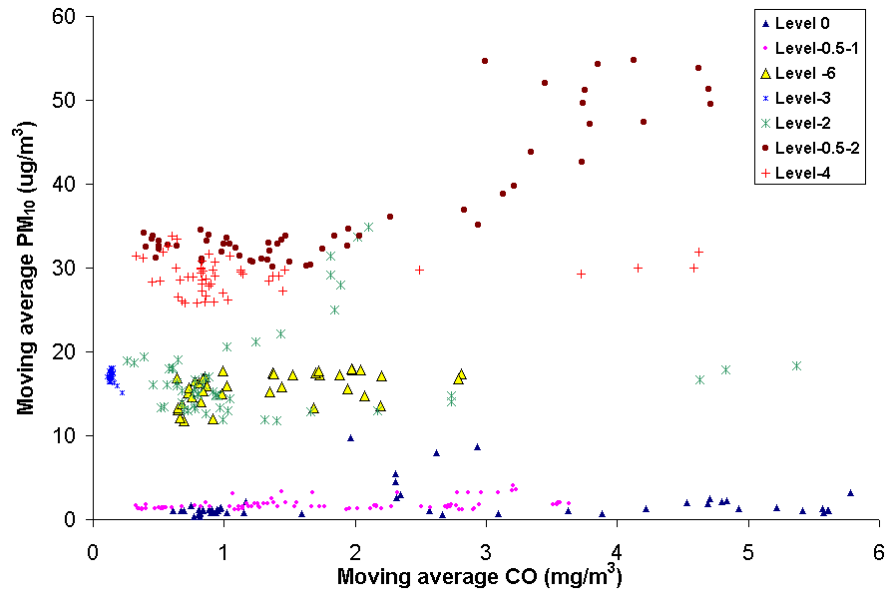


Figure 6 Moving average PM₁₀ and CO in 60-min interval at sampling sites

5 CONCLUSIONS

Air quality in the naturally ventilated multistorey carpark were acceptable during the study period and levels could be predicted based on daily traffic volume and the mean wind speed. Carbon monoxide correlated best with traffic volume and PM10 concentration correlated poorly with traffic volume, indicating that vehicular emissions were not the major source of PM10 particulates. Cold starts in the afternoon contributed to higher CO levels per vehicle. Directional plumes of exhaust gases caused transient high levels of CO from vehicle tailpipes.

Continuous logging of airspeed and direction would have permitted a more precise model of air quality in the carpark.

6 REFERENCES

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