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The effect of proximity to major roads on indoor air quality in typical Australian dwellings

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ABSTRACT

An Indoor Air Quality Study of residential dwellings was carried out in Melbourne, Australia, and a subset of the data was analysed to investigate the effect of proximity to major roads on indoor air quality (IAQ). Seven-day measurements of PM_{10}, NO_2, benzene, toluene, ethylbenzene and xylenes, along with continuous CO and $PM_{2.5}$ measurements were utilised. The measurements were made indoors and outdoors in 27 dwellings; 15 Near Road (<50 m from a major road) and 12 Far Road (>300 m from a major road). Dwellings were sampled for one week each in Winter/Spring 2008 and Summer/Autumn 2009, over an eight month period. Analysis of 7-day measurements showed that NO_2 and toluene were elevated at the 5% significance level both indoors and outdoors at Near Road Dwellings compared to Far Road Dwellings. Indoor/Outdoor (I/O) ratios of NO_2 and toluene were not significantly different between Near and Far Road dwellings giving no evidence of any anomalous dominant indoor source for NO_2 and toluene in Near Road dwellings. Indoor NO_2 was significantly correlated to gas stovetop and oven use in both Near and Far Road dwellings. In the absence of gas cooking, indoor NO_2 was elevated in Near Road dwellings relative to Far Road dwellings by approximately 4 ppb and this can be attributed to infiltration of outdoor air. I/O ratios for NO_2 were <1 for Near and Far Road dwellings, indicating that outdoor NO_2, and hence roadway emissions can potentially contribute a significant proportion to the indoor NO_2 concentration. Mean toluene I/O ratios were >2 indicating that indoor sources dominate with minor contribution from outdoors. Hence the relative contribution of roadways to indoor NO_2 is potentially greater than the relative contribution of roadways to indoor toluene. Findings elsewhere suggest that a similar outdoor enhancement of traffic related NO_2 (~5 ppb) increases risk of lung cancer and childhood asthma (Brauer et al., 2000; Nyberg et al., 2000). A simple conceptual model indicated spatial and temporal variance in the concentrations was the biggest limitation in detecting roadway influence outside Near Road dwellings for PM_{10}, $PM_{2.5}$ and NO_2 while measurement uncertainty was also important for CO.

1. Introduction

The potential for vehicle emissions to degrade Indoor Air Quality (IAQ) in dwellings is an important and complex issue. People who live near busy roads have a high level of exposure to traffic related pollutants (WHO, 2005) so it is crucial to understand the relationship between proximity to major roads and IAQ. Despite ongoing improvements in emission technologies, continuous expansion of urban areas, traffic congestion and long commuting times as well as increased vehicle ownership and usage in developing countries will likely increase exposure to transport-related emissions.

Estimates in Europe suggest transport-related air pollution is responsible for tens of thousands of death per year, similar to the toll from traffic accidents (WHO, 2005). Pollutants of particular concern are particulate mass (PM), NO_2, CO and benzene. Studies have found an increased risk of cardiovascular morbidity related to transport-related air pollution and increased incidence of respiratory diseases (WHO, 2005) and relationships between childhood respiratory illness, including asthma, and living near a major road (Brauer et al., 2000; McConnell et al., 2006; Oosterlee et al., 1996). Long term exposure of adults to traffic pollutants results in increased incidence of lung cancer (Nyberg et al., 2000), and increased risk of mortality due to lung cancer and respiratory disease (Nafstad et al., 2004).

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Numerous studies have observed elevated concentrations of pollutants alongside busy roadways and explored dispersal of pollutants with increasing distance from the road. A subset of these studies have investigated how proximity to the roadway influences indoor air by making measurements in buildings located at varying distances from roads. The findings of these studies have been varied and reflect the complexity of the issue. O'Connell et al. (2008), Ilgen et al. (2001), Fischer et al. (2000), Janssen et al. (2001), Roorda-Knape et al. (1998) and Sheppeard et al. (2006a,b,c) found an influence of proximity to major roads on IAQ, whereas Kingham et al. (2000) did not.

With the exception of Sheppeard et al. (2006a,b,c) previous studies have not been representative of Australian dwellings and conditions where suburban dwellings are typically freestanding, single storey and set back from the road on large blocks of ~700 m^2. In contrast, dwellings in studies by Ilgen et al. (2001), Fischer et al. (2000) and Kingham et al. (2000) were attached or semi-attached multistorey townhouses and apartments, and in the case of Ilgen et al. (2001), in street canyon microenvironments. Janssen et al. (2001) and Roorda-Knape et al. (1998) made IAQ measurements inside schools.

Horizontal and vertical mixing of roadside air along with any removal processes leads to pollutant concentrations decreasing with distance from the roadside. If dwelling ventilation is significant and the outdoor pollutant concentration from the roadway emissions is significant compared to other indoor or outdoor sources, an elevation of the pollutant concentration should be seen both outdoors and indoors at dwellings near the major road, compared to those dwellings further away. Thus to establish that roadway emissions are affecting IAQ, one must establish that increased outdoor concentrations at the dwelling are due to roadway emissions and elevated indoor air concentrations are due to the elevation of the outdoor concentrations.

This effect may be confounded in several ways. Background concentrations of pollutants vary significantly, both temporally and spatially, confounding the roadway contribution at dwellings. Roadside pollutant concentrations vary with traffic volume, meteorology and topography and the dispersal is highly dependent on meteorology and topography. Infiltration of roadway air at the dwellings is dependent on dwelling structure and ventilation. Finally, activities or sources of pollutants occurring inside and outside dwellings may dominate or confound the contribution from the road.

This study aims to determine the contribution of major roadways to IAQ in typical Australian dwellings. We present observations of indoor and outdoor air pollutants from 27 dwellings in Melbourne, Australia, 15 located near major roads and 12 located further away. We explore differences in pollutant levels both indoors and outdoors between Near Road and Far Road dwellings, and investigate the possible contribution of indoor activities and sources to the differences observed.

We propose a simple conceptual model that describes the influence of roadway emissions on ambient air quality. The model quantifies the temporal, spatial and measurement uncertainty that influences pollutant concentrations in background air which may confound the contribution of a major road. Our model differs from a recent model of roadway particulate on IAQ (Hahn et al., 2009) in that it is explanatory rather than predictive.

2. Materials and methods

2.1. Measurement period and location

Measurements were made indoors and outdoors of residential dwellings in Melbourne Australia for 7 days in Winter/Spring (28 August–4 December 2008) and 7 days in Summer/Autumn (12 January–4 May 2009). Measurements represented the full range of meteorological and seasonal conditions. The dwellings were located in residential suburbs, ranging from 4 km to 40 km from the Melbourne city centre (see Fig. 1).

2.2. Selection of dwellings

2.2.1. Near road–far road selection strategy

Measurements were made at 40 dwellings in a wider indoor air study. A subset of 27 dwellings was selected for this analysis based on the criteria that the dwelling front boundary must be less than 50 m of a major road (Near Road dwellings), or greater than 300 m from a major road (Far Road dwellings). Dwellings between 50 and 300 m from busy roads were excluded. Based on these criteria 15 dwellings were classified as Near Road (ranging from 5 m to 47 m from major road), and 12 as Far Road (ranging from 330 m to 2500 m from major road). These Near and Far road distances were selected based on reports that pollutant concentrations decrease rapidly with distance from the roadside (Jones et al., 2000; Karner et al., 2010; Kwon et al., 2006; Naser et al., 2009) and typically approach background concentrations after several hundred metres (Hitchins et al., 2000; Karner et al., 2010; Kwon et al., 2006; Pirjola et al., 2006; Roorda-Knape et al., 1998; Zhu et al., 2002). Major roads were classed as having a traffic volume of 30,000–73,000 vehicles per day (mid week).

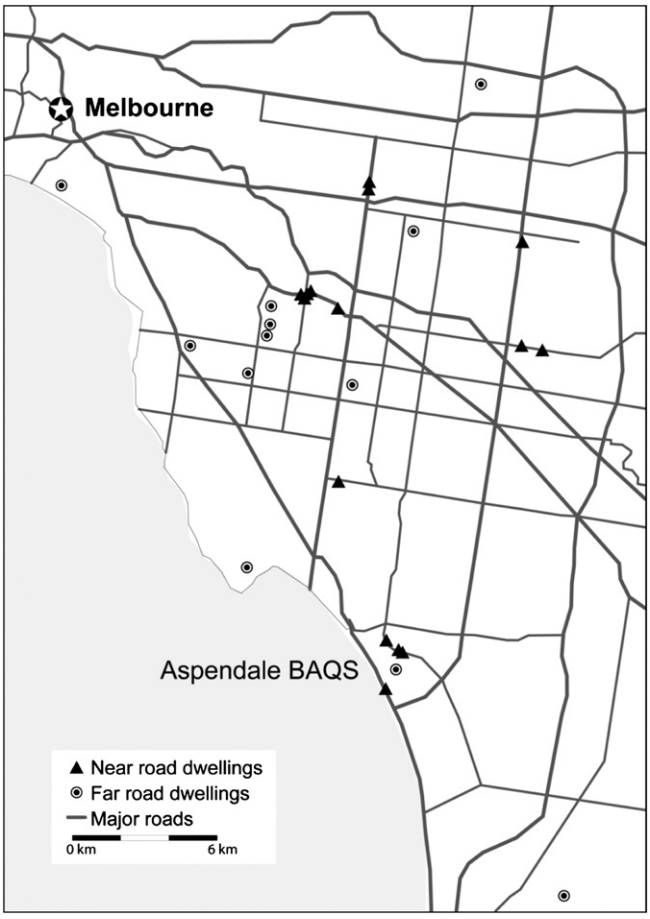

Fig. 1. Location of Near and Far Road dwellings in Melbourne, Australia. The location of Aspendale Bayside Air Quality Station (BAQS) is also shown.