

**NON-INDUSTRIAL PERSONAL BENZENE EXPOSURE
IN A MEDITERRANEAN CLIMATE**

THIS THESIS IS PRESENTED FOR THE DEGREE OF DOCTOR OF
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by

Anthony Michael Horton

BEnvSc (Hons)(Murdoch University, Western Australia)

SCHOOL OF ENVIRONMENTAL SCIENCE
DIVISION OF SCIENCE AND ENGINEERING,
MURDOCH UNIVERSITY,
WESTERN AUSTRALIA

I declare that this thesis is my own account of my research except where duly acknowledged, and contains as its main content work which has not been previously submitted for a degree at any tertiary education institution

Anthony Horton

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ABSTRACT

Benzene is a volatile organic air pollutant that is ubiquitous in the environment. It is frequently reported in urban airsheds, principally as a result of evaporative emissions from motor vehicles. Increasingly stringent fuel quality standards have resulted in lower mean benzene concentrations in many urban airsheds, however the concentrations reported indoors can be higher than those in urban airsheds. Mean indoor benzene concentrations can reach one order of magnitude higher than those reported in urban airsheds. Long term exposure to very high benzene concentrations can result in leukemia, however the health risks of long term non-industrial exposure in the general public are currently uncertain.

An important part of determining the risks of non-industrial benzene exposure is to first determine the influence of various activities on 24-hour personal benzene exposure. Previous research has identified commuting in a private motor vehicle and refuelling with low benzene fuel as statistically significant contributors to non-industrial benzene exposure in the Northern Hemisphere, however none has quantified the increase in benzene exposure as a result of these activities over a 24-hour period in the Mediterranean climate. The results of the 1987 TEAM study in the South Bay section of California reported that automobile exhaust was a significant contributor to non-industrial benzene exposure based on exhaled breath concentrations ($p < 0.05$) and commuting in a private vehicle ($p = 0.0003$) and refuelling (0.05) were important contributors based on personal benzene exposure concentrations (Wallace *et al.*, 1988).

The aims of this thesis were to identify the roles and importance of selected activities in personal exposure to benzene, to determine the increase in 24-hour personal benzene exposure attributable to these activities and quantify the risk posed by these activities in a Mediterranean climate. In particular, the aim of this thesis was to investigate whether commuting in a private motor vehicle and refuelling are significant contributors to non-industrial personal benzene exposure in a Mediterranean climate, or whether lifestyle and climate interact.

This research was composed of a personal exposure study, a source monitoring study and a risk assessment. A cross-sectional personal exposure study was conducted for two reasons. Firstly, to quantify the mean personal benzene concentrations to which a representative sample of the general public of Perth was exposed as a result of their daily activities and behaviours. Secondly, to quantify the frequency of commuting by private motor vehicle and refuelling with low benzene fuel in Perth. Fifty participants were recruited for the personal exposure study, and asked to wear a monitor for 24-hour periods (including weekends) in summer and winter and record their activities and locations in a diary. Prior to the monitoring they were asked to complete a questionnaire seeking background information on their home, lifestyle and behaviours. The results of the research revealed that there was not a statistically significant difference between the personal benzene exposure concentrations in summer and winter. An analysis of the questionnaire and time activity diary data using a generalised linear mixed model revealed that the time spent commuting in a private motor vehicle ($\beta= 0.281, p<0.0001$) and refuelling with low benzene fuel ($\beta = 0.194, p=0.033$) were statistically significant contributors to non-industrial benzene exposure. Each hour spent commuting resulted in a mean increase in 24- hour

personal exposure of $0.74 \mu\text{g m}^{-3}$ ($\beta= 0.729 \mu\text{g m}^{-3}$, $p< 0.0001$). The mean increase in exposure per hour of commuting in a private motor vehicle was larger in winter ($\beta= 0.8 \mu\text{g m}^{-3}$, $p=0.008$) than summer ($\beta= 0.67 \mu\text{g m}^{-3}$, $p=0.004$). Refuelling increased personal exposure by $1.50 \mu\text{g m}^{-3}$ (1.49 , $p<0.0001$) in each 24-period when refuelling was reported.

Benzene source monitoring was conducted at selected locations in Perth for two reasons. Firstly, data quantifying non-industrial personal benzene exposure during refuelling and commuting in a private vehicle in Perth was needed, and secondly, to make an assessment of risk attributable to these activities.

Benzene source measurements were conducted in two carparks in the Central Business District (CBD), in the vicinity of the northbound and southbound lanes of the Kwinana Freeway, and at a petrol station. The 7- day arithmetic mean benzene concentrations in the carparks were $4.49 \mu\text{g m}^{-3}$ and $1.23 \mu\text{g m}^{-3}$. The 7- day mean benzene concentrations northbound on the Kwinana Freeway was $2.78 \mu\text{g m}^{-3}$, and the mean benzene concentration southbound was $2.57 \mu\text{g m}^{-3}$. Benzene emissions in the carpark and on the Kwinana Freeway were measured during vehicle idling, which is representative of vehicle speed during heavy vehicle traffic. Benzene emissions at the petrol station were monitored in the vicinity of the petrol bowser, which is representative of emissions during refuelling. The 24- hour mean benzene concentration at the petrol station bowser was $38.15 \mu\text{g m}^{-3}$.

The results of this research revealed that refuelling and commuting in a private vehicle are the most significant contributors to non-industrial benzene exposure in

Perth, and that the contribution of these two activities in Perth is far greater than in previous published research, on the basis of the results obtained from the generalised linear model. The results of this research quantified the increase in non-industrial benzene exposure from refuelling and commuting in a private motor vehicle in a Mediterranean climate for the first time, and quantified the lifetime excess cancer risk attributable to these activities in a Mediterranean climate for the first time. The lifetime excess cancer unit risks of these two activities in a Mediterranean climate were 7.4×10^{-5} or 7.4 per 100000 population for commuting and 15.03×10^{-4} or 15 per 10000 for refuelling.

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LIST OF PUBLICATIONS

The research in this thesis has facilitated the following publications:

- “Personal Monitoring of Benzene in Perth, Western Australia: Results of a Pilot trial” A. Horton and F. Murray, presented at Indoor Air 2002, Proceedings of the 9th International Conference on Indoor Air Quality and Climate, Monterey California July 2002 Volume 1 pp. 221-225.
- “A review of the contribution of benzene hotspots to non-industrial personal exposure” A. Horton and F. Murray, presented at the 15th Conference for the International Society of Environmental Epidemiology, September 2003 (abstract published in Epidemiology Volume 14 number 5, September 2003.
- “On diffusive badges and VOC sampling in IAQ investigations” S Rastan, A Horton, F Murray, J-P Farant and F. Haghghat, presented at Healthy Buildings 2003, Proceedings of International Society of Indoor Air Quality and Climate, the 7th International Conference Singapore, Volume 1 pp. 337-342.
- “Personal Monitoring of benzene in Perth, Western Australia: The contribution of sources to non-industrial personal exposure” A. Horton, F. Murray, M. Bulsara, A. Hinwood and D. Farrar, Atmospheric Environment Volume 40 number 14, pp. 2596-2606.