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# An approach for the evaluation of exposure patterns of urban populations to air pollution

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**Abstract**

Exposure concentrations of aromatic compounds were correlated with variables derived from time-microenvironment-activity (TMA) diaries to understand the relationship between exposure patterns and commuting behaviour of the population in a case study in Madrid. Approximately 200 air pollution samples were taken during a one-day campaign by means of diffusive samplers. An approach to determine the importance of selected activities and locations relative to a baseline condition, defined by a sample of approximately 100 commuters is described. A regression model is applied to determine the relative importance of identified situations, whether related directly to transport behaviour or through a labelled situation. The regression defines a baseline exposure concentration level where activities act as multiplying factors. The relationship of this baseline level and the set of activity factors, assigned to the population considered, to the ambient background is explored for its application to future studies. The calculation of exposure concentration gradients from the regression provides a means to characterise of the relative importance of different activities. A good level of agreement, in particular for benzene, was evident between the observed exposure concentrations and those calculated using the regression model.


*Keywords:* Air quality monitoring; Personal exposure; Exposure assessment; Diffusive samplers; Aromatic compounds; Benzene

## 1. Introduction

In recent years the influence of even low concentrations of air pollutants on human health has re-emerged as an important scientific issue (Dockery et al., 1993; Pope et al., 1995; Laden et al., 2001). Numerous studies have linked various acute and chronic health impacts to air pollution (Clancy et al., 2002; Goodman et al., 2004). Regardless of the pollutant considered, a major concern has been the use of various measures of ambient air quality as a surrogate for pollution exposure, either due to underestimating the importance of indoor air quality (Roosbroeck et al., 2007) or overestimating the applicability of background sites (Field et al., 2005). Epidemiological studies that relate air pollution with the health of human populations often rely upon measurements undertaken to

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determine compliance of limit values required for air quality legislation (Jerrett et al., 2005). Such compliance monitoring sites are situated within areas of higher population density, usually away from the influence of local emission sources. This approach is necessary given air quality monitoring network design, as background levels allow for an understanding of longer term trends related to the relationships between emission sources, meteorology and pollution control policies.

The application of air quality standards, through limit values, has been successful in reducing urban concentrations (WHO, 2000). Nevertheless, in recent years the scientific community has become increasingly concerned with the determination of actual levels of exposure for the general population to air pollutants (WHO, 1999). In order to address this central question in the field of urban air quality the European Commission instigated the Population Exposure to Air Pollutants in Europe (PEOPLE) project. A previous paper reported on the broad relationships observed between ambient background, hot spot and commuting populations for six European capital cities. For these cities, the commuting population was exposed to air pollution levels 1.5 times that of background levels and 0.6 times that of hot spot levels (Pérez Ballesta et al., 2006). While the afore-mentioned relationship reinforces the importance of background monitoring, it does not explain the causes for the elevation of pollution levels of the monitored volunteers above the urban background level.

The purpose of this study is to introduce an approach that determines the relative importance of time spent in a variety of labelled activities and locations measured through time-microenvironment-activity (TMA) diaries. This was achieved through a regression analysis approach that estimates the importance of these different situations relative to a baseline condition. This approach is different from other methodologies that aim to either define factors that attribute sources with exposure concentrations or estimate population exposure. The former approach, attribution, relies upon statistical methods such as principal components analysis (Kim et al., 2002). The latter approach, estimation, can be broadly categorised as: (i) surrogate or (ii) microenvironmental. Both of these indirect approaches expand measured or modelled situations to apply to wider populations. Surrogate approaches are often represented through extension of air quality networks or other base data through land use or other GIS-based transformations (Madsen et al., 2007) that often focus upon the importance of traffic emissions (Buliung and Kanaroglou, 2006; Beelen et al., 2007). The approach adopted depends on the pollutant and spatial scale considered, and is often based upon dispersion modelling (Bellander et al., 2001) although statistical models (Brauer et al., 2003) and even satellite imaging techniques have also been applied (Liu et al., 2005). Nitrogen dioxide has been evaluated in a number of different urban areas, due to the large amount of available network monitoring data and the ease of measurement through diffusive sampling (Stedman et al., 1997; Kanaroglou et al., 2005). Despite confounding factors, namely; indoor emission sources related to cooking and heating and outdoor stationary combustion sources, a number of studies have developed good relationships between predicted and measured levels of population exposure through both dispersion and emission modelling approaches (Bartonova et al., 1999; Kousa et al., 2002). A number of studies have focused upon the applicability of urban air quality networks as an indicator of air pollution exposure (Baldauf et al., 2001; Chow et al., 2002; Kanaroglou et al., 2005). Microenvironmental approaches developed from total human exposure methodologies (Wallance et al., 1986) often combine activity profiles concentration data (Edwards et al., 2001, 2005) This approach is analogous to building an air pollution inventory that represents the total emissions into a given area. The methodological limitations of both of these approaches, due primarily to the uncertainty associated with input data or applied factors, are accepted given the high financial and organisational costs associated with the wide scale direct monitoring of population exposure.

In this paper, we do not attempt to predict population exposure, through extrapolation of data or use of surrogate information. Instead, we describe an approach to determine the importance of activities and locations relative to a baseline condition, defined by a sample of approximately 100 commuters. Commuters were selected as they are representative of a large portion of the urban population. The exposure of urban populations is known to be affected predominately by emissions from transportation. This study differs from previous transnational European studies, MACBETH and EXPOLIS in that it considers commuters. While all three of these studies considered the relationship between background air quality and