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Microenvironment particle measurements in Thessaloniki, Greece

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ABSTRACT

Monitoring of particulate concentrations in Thessaloniki, Greece, was carried out during April 2011, to assess differences in commuters' exposure to traffic related particulate pollution. Three routes were monitored in the two directions while bicycling, driving car and travelling by bus. The length of each route was about 8 km and individual journey times ranged between 18 and 34 min. Car trips were made with windows closed and with the ventilation system at moderate setting and with co-driver's window open. The results indicate that mean inhalation doses while bicycling is higher than those during travelling by bus (15% for PM, 55% for black carbon and 40% for particle number) and by car (60% open window – 70% closed window for PM, 50% open window – 78% closed-window for black carbon and 54% open window – 77% closed window for PN). Individuals who change their travel mode from car to bicycling and bus commuting in response to policies aimed at encouraging a modal shift in travel behavior, are thus likely to experience increased journey-time personal exposures to traffic-related air pollution. Commuting by car with closed windows is the transport mode by which a person experiences the least exposure to particulate pollution.

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1. Introduction

Exposure to air pollution in traffic has been related to both long- and short-term cardiovascular and respiratory health effects in a number of studies (Katsouyanni et al., 2011; Bernstein, 2012; Hoek et al., 2013; Chiu et al., 2013). Measurements from fixed monitoring stations have been commonly used as surrogates for personal exposure levels to represent community exposure to pollutants and they have been the basis of air quality guidelines and policy. However, several studies revealed that these measurements significantly underestimate or have little or no association with the exposure of population sub groups, thus highlighting the need for direct personal exposure measurements (Loth and Ashmore, 1994; Vellopoulou and Ashmore, 1998; Adams et al., 2001 and Adams et al., 2009; Gulliver and Briggs, 2004; Lai et al., 2004; Peters et al., 2004; Riediker et al., 2004; Adar et al., 2007; McCreanor et al., 2007; Zuurbier et al., 2010). Particulates which are recognized as the main pollutant of concern in terms of human health are of specific interest and short-term exposure (e.g. while commuting) to peak particle concentrations may be associated with adverse health effects (Katsouyanni et al., 1997; Brook et al., 2011; Lim et al., 2012).

In the last decade, smaller devices for automatic monitoring of particulates at high temporal (i.e. several minutes to 1 h) have become available. The new generation of monitors are light and portable making them ideal for personal monitoring. Most of the studies looking at specific microenvironments have been done in transport and comparisons have generally been made in levels of concentrations between different transport modes (e.g. walking, in-car, bus etc.) and between transport modes and fixed-site ambient monitoring. Up to now, published studies report high levels of particle concentrations inside public means of transport (Chan et al., 2002; Kaur et al., 2005) and that pedestrians and cyclists experience lower exposure concentrations than individuals inside vehicles (Kaur et al., 2007; Int Panis et al., 2010; Knibbs and de Dear, 2010; Geiss et al., 2010; Wang and Gao, 2011; Knibbs et al., 2011; Dons et al., 2012).

The findings indicate that particulate pollution varies largely from street to street and from city to city. There are numerous variables potentially affecting personal exposure in transit conditions, including personal/individual factors, mode of transport, traffic characteristics, fuel type, cabin ventilation, meteorology as well as country's socioeconomic conditions (developing countries are facing most serious air pollution problems from both industrialization and urbanization processes (Cao et al., 2012; Wu et al., 2013a and Wu et al., 2013b), and thus the traffic microenvironment may be more complicated).

Thessaloniki is one of the most polluted cities in Europe (Kassomenos et al., 2011; Vlachokostas et al., 2009; EEA, 2006), in part due to climate and geography, but also because of high traffic density. Previous measurements (Vouitsis et al., 2008) indicate that main street average concentrations were significantly higher than those of city's nearby background which is not affected by traffic: 7.3×10^4 vs. 1.4×10^4 particles cm^{-3} during working days and 6.1×10^4 vs 0.8×10^4 particles cm^{-3} during weekends. For an improved characterization of the situation, the current study was carried out aiming at estimating exposure concentrations during commuting and the corresponding inhalation doses during trip for PM1.0, PM2.5, black carbon (BC) and PN. The study was part of the EC funded research project TRANSPHORM which aimed to improve the knowledge of transport related airborne particulate matter. To this aim, we conducted measurements at different locations representing street background. The main aims of the study were (1) to compare average particulate exposure/inhalation dose in different transportation modes, (2) to evaluate the additional exposure/inhalation dose (as compared to ambient levels) experienced while commuting, and (3) to provide information for planning and policing applications. It is the first time that kind of data are available for Thessaloniki and will be very useful for probabilistic exposure estimates based on individual activity data, including the population while in traffic or in other activities besides home and work.

2. Materials and methods

2.1. Study design

A seven-day long monitoring campaign was performed in Thessaloniki from April 05 to April 13, 2011. Three commute routes using three modes of travel (bicycle (BL), bus (B) and car (C)) were

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