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Identification of particulate matter determinants in residential homes

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ABSTRACT

Particulate matter (PM) has well-known negative health effects on humans. PM exposure occurs mainly indoors because people spend most of their time inside buildings, especially in their homes. This study aimed at investigating the impact of the principal outdoor factors, house characteristics and indoor activities on size-fractionated PM concentrations in a real exposure scenario consisting of 60 living rooms in the province of Lodi (River Po Valley, Northern Italy), characterized by high pollution levels. Nearby road traffic played a pivotal role for all the studied fractions, with heavy duty vehicles affecting the coarser fractions especially when building density was lower. $PM_{2.5-10}$ arose also from indoor determinants linked to cleaning activities and house occupancy and was inversely related with house volume. Statistical analysis showed that ambient PM_{10} was a reliable predictor of PM fractions <2.5 μm, but other indoor sources should be considered, such as ETS for $PM_{0.5}$ and open fireplaces use for the $PM_{0.5-1}$. Some protective factors were identified, such as the use of exhaust ventilation in kitchens ($PM_{0.5-1}$) and sealed windows and doors ($PM_{0.25}$). Some determinants were also season-related (open fireplaces use, floor level, built-on garages). In conclusion, the study provides an insight on the main PM determinants commonly present in residential environments. The results can be useful in addressing some self-corrected choices by home occupants and in developing meaningful risk mitigation strategies by local institutions.

1. Introduction

Particulate matter (PM) is one of the most critical pollutants because of its association with increases in mortality and morbidity. The short-term effects of PM are mainly acute cardiovascular and respiratory diseases [1,2]. The association between long-term exposure to PM_{10} and lung cancer was recently confirmed by a European meta-analysis [3]. Moreover, diesel and gasoline engine exhaust, one of the main outdoor-generated sources of PM, was classified in group 1 of the International Agency for Research on Cancer classification [4]. The increase in human life expectancy associated with a reduction in PM pollution stresses the importance of implementing strategies in order to maintain exposure levels below the health-based guideline limits [5].

There is evidence indicating that specific biomarkers of cardiovascular diseases and tumours depend more on personal exposure to PM than on urban background concentrations [6], and indoor PM levels can be generally considered as reliable proxies of personal exposure [7]. Furthermore, the chemical composition of particles can vary widely indoors compared with local-scale outdoor scenarios; indoor-generated particles are often substantially different from outdoor particles. Such differences between indoor and outdoor exposures can influence health outcomes [8].

Among indoor microenvironments, dwellings often contribute significantly to total daily exposures because people spend 80–90% of their time in confined environments, most of this time living in their homes [9].

In general, size-dependent indoor particle source emission rates are difficult to measure in most cases. Residential indoor PM concentrations can arise from various sources that are often

Abbreviations: PM, particulate matter; d_a, aerodynamic diameter; ETS, environmental tobacco smoke; AER, air exchange rate; rH, relative humidity.

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concomitantly generated both indoors and outdoors. The primary indoor source of PM is environmental tobacco smoke (ETS) [10,11]; however, using gas stoves and heating systems, burning wood, house cleaning and walking are other significant contributors to indoor PM [12–15].

Indoor PM concentrations can also be produced by outdoor-generated particles, depending on the degree of ventilation in houses [16]. Air exchange rates (AER) significantly impact PM indoor concentrations and size distributions, affecting the infiltration of pollutants from outdoor sources and their accumulation/removal indoors [13].

The main microenvironmental and behavioural factors and the outdoor determinants that could affect 24-h size-fractionated PM indoor levels in residential homes were investigated. This aim was accomplished by collecting house characteristics, local area features and indoor activities via checklists and time-activity diaries, and applying statistical models to assess the strength of their association with indoor concentrations of size-fractionated PM. The present study was the continuation of a previous study carried out in the province of Lodi [17]. This area is highly polluted because of its geographic position (River Po Valley) and meteorological conditions that adversely affect the dilution of air pollutants, besides the presence of specific local pollution sources, such as NH_3 emissions from intensive livestock farming. Additionally, data were collected during periods of heating and non-heating to account for different exposure scenarios, pollutant sources and meteorological conditions.

The study can offer a better understanding of the potential impact of indoor and outdoor determinants on indoor PM levels in residential homes. Moreover, the results will be useful for improving indoor air quality in dwellings and reducing undesirable exposures by modifying individual habits and developing future public health policies.

2. Material and methods

2.1. Study design

The study was carried out in 60 homes, randomly distributed in the province of Lodi, during the periods May–September 2007 (non-heating period, i.e., 'summer') and December 2007–March 2008 (heating period, i.e., 'winter'). The distribution of homes and the geographical area under study are shown in Fig. 1.

A multi-pollutant monitoring station was installed in the living room of each home on one weekday between Monday and Thursday and used to collect two 24-h samples (one per season/per home). Monitored pollutants included size-fractionated PM (PM_{10}, $PM_{2.5}$, PM_1, $PM_{0.5}$ and $PM_{0.25}$). Ambient levels over the same time period were estimated using data from the monitoring station closest to the sampled homes, operated by the Regional Environmental Protection Agency network. Out of the 60 'winter' samples, 7 were lost for technical reasons.

PM fractions were collected on Teflon filters using a Personal Impactor Cascade Sampler (SKC Inc., Eighty-Four, PA, USA) and weighed using a microbalance (M3, Mettler-Toledo GmbH, Giessen, Germany) with a resolution of 1 μg. Direct reading instruments were used to monitor microclimatic parameters, such as temperature (T) and relative humidity (rH) (Telaire 7000, cabled to a HOBO–H8 data logger, Onset Computer Inc., Pocasset, MA, USA).

Characteristics of the building and of the surrounding environment were recorded by technicians in a questionnaire, together with possible indoor determinants. Additionally, a time-activity diary was kept by the occupants, thus collecting quantitative data on each activity that could influence indoor PM levels. This included smoking during the 24-h monitoring period expressed as the number of cigarettes smoked by both occupants and visitors. The number of occupants and the time spent indoors during

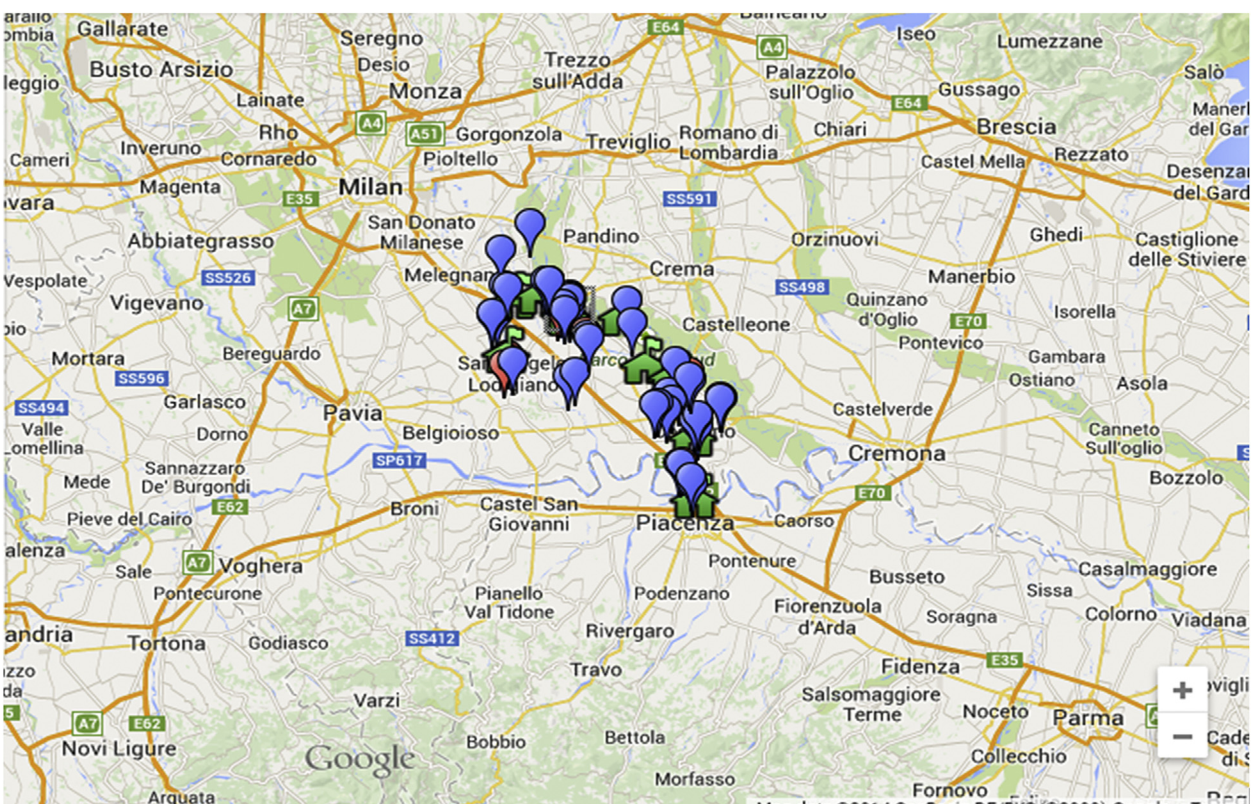

Fig. 1. Map of the study area and sampling sites ('drop icon' represents homes studied and 'house icon' the monitoring stations).