Atmospheric Environment 49 (2012) 77–84

Contents lists available at SciVerse ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

Particle Exposure Assessment for Community Elderly (PEACE) in Tianjin, China: Mass concentration relationships

Jian Zhou[a], Bin Han[a], Zhipeng Bai[a,b,*], Yan You[a], Jiefeng Zhang[a], Can Niu[a], Yating Liu[a], Nan Zhang[a], Fei He[a], Xiao Ding[a], Bing Lu[a], Yandi Hu[a]

[a] State Environmental Protection Key Laboratory of Urban Ambient Air Particulate Matter Pollution Prevention and Control, College of Environmental Science and Engineering, Nankai University, Tianjin 300071, China
[b] Chinese Research Academy of Environmental Sciences, Beijing 100012, China

ARTICLE INFO

Article history:
Received 23 July 2011
Received in revised form
5 December 2011
Accepted 8 December 2011

Keywords:
Elderly population
Particulate matter
Personal exposure
Time-activity pattern
Personal cloud

ABSTRACT

Particle Exposure Assessment for Community Elderly (PEACE) in Tianjin, China was to characterize personal PM_{10} exposure, and provide data support for an epidemiological study investigating potential health effects of PM pollution on Chinese elderly population. In this study, a total of 80 elderly participants were recruited for a two-consecutive-day personal exposure measurement, and simultaneously residential indoor, residential outdoor and community PM_{10} were monitored in the summer and winter of 2009. Personal PM_{10} concentrations were 192.8 ± 100.6 μg m^{-3} in summer and 154.6 ± 105.4 μg m^{-3} in winter. Modeled personal exposures were less than measured personal exposures while a high coefficient of determination (R^2) of 0.71 was obtained. Based on measured and modeled exposures, a mean personal cloud of 30.2 μg m^{-3} was estimated in summer and 16.5 μg m^{-3} in winter. Moderate correlation emerged between personal and community PM_{10} concentrations in summer ($r = 0.39$), and stronger correlation was found in winter ($r = 0.82$). Analysis of variance (ANOVA) shown that smoking, cooking and cleaning activities did not produce significant effect on personal exposures. Further more, multivariate regression analysis performed in this study revealed that community PM_{10} level contributed most of personal PM_{10} exposure, 32% in summer and 64% in winter, respectively. The findings of this study indicated that PM_{10} personal exposures were considerably influenced by outdoor particulate matter rather than typical indoor sources, and ambient PM_{10} level measured at community monitoring sites may be used as a surrogate of personal exposure to PM_{10}.

1. Introduction

Numerous epidemiological studies have reported significant associations between ambient particulate matter (PM) level measured at community monitoring sites and adverse health effects such as lung dysfunction, hospitalization, and even mortality (Brunekreef et al., 1995; Pope et al., 1995; Pope, 2000; Atkinson et al., 2001). Since the 1980s, a series of population-based PM exposure studies have been conducted in the United States and Europe. These mainly include the TEAM (Total Exposure Assessment Methodology) study (Wallace et al., 1985), the EXPOLIS (Air Pollution Exposure Distribution Within Adult Urban Populations In Europe) study in numerous European cities (Koistinen et al., 1999; Kousa et al., 2002) and the RIOPA (Residential Indoor, Outdoor, and Personal Assessment) study (Reff et al., 2004; Meng et al., 2005; Weisel et al., 2005). More recently, the DEARS (The Detroit Exposure Aerosol Research Study) study was designed to examine the spatial variability of $PM_{2.5}$ and $PM_{10-2.5}$, and the suitability of conducting health outcome studies using a central site monitor in metropolitan Detroit (Williams et al., 2009; Rodes et al., 2010). In general, these studies have shown that: (1) personal exposures to fine particles and to PM_{10} generally exceed both indoor and outdoor concentrations; (2) cross-sectional correlations between personal exposure and outdoor concentrations are weak with Pearson's r correlations ranging from −0.08 to 0.62, and the correlations are usually higher in longitudinal studies (ranging from 0.26 to 0.68); (3) personal PM exposure and its correlation with outdoor PM level vary significantly depending on geographical setting, subpopulation, human activity patterns and PM size distribution.

Elderly people have been described as a susceptible population in view of a general physical decline. Previous studies indicated that

* Corresponding author. State Environmental Protection Key Laboratory of Urban Ambient Air Particulate Matter Pollution Prevention and Control, College of Environmental Science and Engineering, Nankai University, #94 Weijin Road, Tianjin 300071, China. Tel./fax: +86 22 23503397.
E-mail address: zbai@nankai.edu.cn (Z. Bai).

1352-2310/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.atmosenv.2011.12.020

individuals over the age of 65 may be 1.5–3 times more susceptible than younger individuals to various health effects associated with ambient PM_{10} exposure (Schwartz, 1995; Williams et al., 2000a). Recently, several human exposure/epidemiological studies targeting at elderly population have been reported (Williams et al., 2000a,b,c; Janssen et al., 2000). For example, 1998 Baltimore Particulate Matter Epidemiology-Exposure study successfully recruited 21 elderly participants from a retirement facility for personal exposure monitoring, and results revealed that mean $PM_{2.5}$ personal exposures were highly correlated to those measured in indoor ($r = 0.90$) and ambient sites ($r = 0.89$), and estimated mean $PM_{2.5}$ personal cloud was 3.1 $\mu g\ m^{-3}$ (Williams et al., 2000b).

In China, particulate matter has been the primary air pollutant of concern in recent decades, and the mean value of the annual average concentrations of PM_{10} was 89 $\mu g\ m^{-3}$ in 113 medium to large Chinese cities according to Environmental Status Report 2009 (Ministry of Environmental Protection of China, 2009). Serious PM pollution and potential health risk are threatening Chinese residents (Kan, 2009). On the other hand, China has an elderly population of 143 million, the largest in the world, and is expected to hit 437 million by 2051 (China National Committee on Aging, 2006), therefore China is facing severe challenge of an aging society. To date, however, PM personal exposures have not been well characterized in the mainland of China, less is known about personal PM exposures for elderly population.

Therefore, the Particle Exposure Assessment for Community Elderly (PEACE) study was conducted in Tianjin, China to characterize personal PM_{10} exposure, and provide data support for an epidemiological study investigating potential health effects of PM pollution on elderly population. The present study was conducted in the summer and winter of 2009 with a group of 80 elderly subjects in urban Tianjin, which has a large population and a poor air quality. The main objectives of this study were:

- Collect information on housing characteristics and time-activity patterns of the elderly using questionnaire and time-activity diary, and investigate the effects of specific activities on personal PM_{10} exposure;
- Characterize the level and variation of personal PM_{10} exposure in an elderly population;
- Determine the statistical relationships between personal PM_{10} exposure and residential indoor, residential outdoor and community PM_{10} mass concentrations.

The present work only reports the findings of the PM_{10} mass concentration monitoring. A more comprehensive exposure assessment involving PM_{10} chemical compositions and associated epidemiological study will be presented later.

2. Methods

2.1. Study design

Tianjin, a typical metropolis of China, is adjacent to the Bohai Sea in North China and encompasses an area of over 11,000 km^2. It has a population of approximately 13 million, and elderly population over the age of 65 account for 8.52% (District committee on Aging in Tianjin, 2011).

A retirement community located at a residential zone of Dongli district in urban Tianjin was chosen for this study. The community was built about 5 years ago with an area of 1855 m^2, mainly including one 3-story activity center building, one 6-story and two 14-story residential buildings. This community was about 300 m from an urban express way with high traffic volume, therefore traffic emission might be a major PM source. This community was selected primarily because it met multiple exposure monitoring requirements: an adequate population size for participant recruitment, minimum number of known local PM sources and administrative cooperation (Williams et al., 2009).

A total of 80 elderly with an average age of 71(range, 58–82 years), ambulatory individuals living in this community agreed to participate in personal exposure as well as corresponding residential indoor and residential outdoor PM_{10} monitoring. In particular, these participants included 25 couples and 30 individuals. Most of the elderly participants were retired from military research institutions, and they presented good sense of organization, discipline and great passion for participating in a scientific research, which supported a successful completeness of sampling.

All daily measurements (personal, residential indoor, residential outdoor and community) were performed on a 9 a.m.–9 a.m. time frame (±1 h) during summer and winter of 2009 (18 August–24 September and 11 November–18 December, respectively). Personal and micro-environmental measurements were conducted for 4–8 participants during a 2-day sampling session within each season due to samplers availability and field staffing considerations.

Residence surveys concerning general characteristics and residential conditions of participants were carried out before sampling. During the monitoring period, participants were required to keep a time-activity diary with a 30-min resolution to record time they spent in four primary microenvironments (residential indoor, outdoor, transportation and others), and activity information of potential exposure to smoking, cooking and cleaning.

2.2. Personal, residential indoor, residential outdoor and community monitoring

Personal monitoring was conducted using a backpack with PEM (PEM-PM_{10}; BGI inc., Waltham, MA) inlets on the shoulder straps near the breathing zone (Fig. 1A). Each sampling backpack was consisted with two pumps (Buck inc, Orlando, Fl) connected to two samplers: one sampler was loaded with a 37 mm Teflon filter and the other with a 37 mm quartz filter (Pall-Gelman, Ann Arbor, MI). Both Teflon and quartz filters were used in an effort to obtain a comprehensive understanding of PM chemical components. The pumps were enclosed with sound deadening material, and operated at a flow rate of 2 ± 0.2 L min^{-1}. Participants were asked to wear the backpack at all times with exception of sleeping, bathing and clothing changes. In addition, participants were also allowed to put backpack nearby in cases of sitting on a couch for long periods considering elderly people's physical affordability.

Residential indoor monitoring was performed with two PEM impactors fixed to a 1.5 m-high Aluminum alloy stand, and connected to two lightweight portable pumps. The monitoring system above was carried by a luggage cart for easy transportation (Fig. 1B). For residential outdoor monitoring, the monitoring system was similar while two impactors were reached out at least 1 m from the main window in each residence (Fig. 1C). All pumps were operated at a rate of 4 ± 0.4 L min^{-1}, and put in wooden boxes with sound deadening material. 37 mm Teflon filters and quart filters (Pall-Gelman, Ann Arbor, MI) were used for residential indoor and outdoor PM sample collection.

Daily, community-based (ambient) PM_{10} monitoring was conducted on the roof of 3-story activity center (Fig. 1D). Ambient particulate samplers PQ200 (BGI inc., Waltham, MA) loaded with 47 mm Teflon and quart filters were used for community PM_{10} monitoring, operating at a normal sampling rate of 16.7 L min^{-1}.

Before and after sampling, all filters were conditioned in our controlled lab (21 ± 2 °C and 40 ± 5% relative humidity) for at least 48 h. Collected filters were kept in Analyslide Petri dishes and returned to the balance-laboratory for gravimetric analysis using