Atmospheric Environment 104 (2015) 79–87

Contents lists available at ScienceDirect

Atmospheric Environment

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

Source apportionment of air pollution exposures of rural Chinese women cooking with biomass fuels

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ARTICLE INFO

Article history:
Received 23 August 2014
Received in revised form
24 December 2014
Accepted 30 December 2014
Available online 31 December 2014

Keywords:
Source apportionment
Personal exposure
Molecular marker
$PM_{2.5}$
Positive matrix factorization (PMF)

ABSTRACT

Particulate matter (PM) from different sources may differentially affect human health. Few studies have assessed the main sources of personal exposure to PM and their contributions among residents of developing countries, where pollution sources differ from those in higher-income settings. 116 daily (24-h) personal $PM_{2.5}$ exposure samples were collected among 81 women cooking with biomass fuels in two villages in rural Yunnan, China. The PM samples were analyzed for mass and chemical composition, including water-soluble organic carbon (WSOC), black carbon (BC), and molecular markers. We found black carbon, *n*-alkanes and levoglucosan dominated the most abundant fractions of the total measured species and average personal $PM_{2.5}$ exposure was higher in winter than that in summer in both villages. The composition data were then analyzed using a positive matrix factorization (PMF) receptor model to identify the main PM emission sources contributing to women's exposures and to assess their spatial (between villages) and seasonal variation in our study setting. The 6-factor solution provided reasonably stable profiles and was selected for further analysis. Our results show that rural Chinese women cooking with biomass fuels are exposed to a variety of sources. The identified factors include wood combustion (41.1%), a cooking source (35.6%), a mobile source (12.6%), plant waxes (6.7%), pyrolysis combustion (3.0%), and secondary organic aerosols (SOA; 1.0%). The mean source contributions of the mobile source, cooking source, and wood combustion factor to $PM_{2.5}$ exposure were significantly different between women living in the two study villages, whereas the mean SOA, wood combustion, and plant waxes factors differed seasonally. There was no relationship between source contributions and questionnaire-based measurements of source-specific exposures, implying that the impacts of source contributions on exposure are affected by complex spatial, temporal and behavioral patterns that are difficult to quantify using questionnaire-based measurements. Epidemiologic studies, health risk assessments, and intervention programs would benefit from a better understanding of the sources impacting PM exposure among populations in developing countries.

1. Introduction

Air pollution poses large health risks in China and globally (Lim et al., 2012) and increasing evidence suggests that particulate matter (PM) from different sources may differentially affect human health (Baumgartner et al., 2014; Bell, 2012). However, few studies have assessed the main sources of personal exposure to PM and their contributions among residents living in developing countries, where the pollution sources and resulting human exposures differ considerably from those common in urban areas or higher-income settings (Begum et al., 2009; Gadkari and Pervez, 2008; Miguel et al., 1995; Pervez et al., 2012; Zhou et al., 2014). For example, almost half the world's population cooks with biomass fuels (Bonjour et al., 2013), the majority of whom live in rural areas of

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http://dx.doi.org/10.1016/j.atmosenv.2014.12.066
1352-2310/

developing countries.

A small number of studies have measured personal PM exposure among rural populations cooking with biomass fuels, though most have exclusively measured mass (Balakrishnan et al., 2002, 2004; Baumgartner et al., 2011a; Dasgupta et al., 2006; Dionisio et al., 2012; McCracken et al., 2013), with few exceptions (Baumgartner et al., 2014; Van Vliet et al., 2013). In addition to combustion PM from biomass fuel burning, people's exposure may be affected by other combustion and non-combustion sources including cooking grease, tobacco smoke, traffic, or secondary air pollutants. The relative impact of different sources may vary seasonally and with various spatial or behavioral patterns including distance to roadways or time spent indoors.

In the present study, the chemical composition of personal exposure to fine PM with aerodynamic diameter less than 2.5 μm ($PM_{2.5}$) among 81 Chinese women in winter and summer was measured using samples previously analyzed for PM mass (Baumgartner et al., 2011a). The measured composition data was then used to both identify and quantify the contributions of sources of personal PM pollution exposures in each season with positive matrix factorization (PMF) models. This study is among the first to characterize the chemical composition and quantitative source apportionment of personal PM exposure, and its seasonal and spatial variability, among residents in a developing country setting. A better understanding of the complex mixture of sources contributing to PM exposures in rural, low-income settings will help improve exposure assessment for epidemiologic studies and health risk assessments, and will lead to more informed intervention strategies to mitigate air pollution exposure and improve the health of populations in developing countries.

2. Experimental and statistical methods

2.1. Study design

24-h personal exposures to $PM_{2.5}$ were measured in winter and summer among 81 Chinese women living in two rural villages in northwestern Yunnan Province, China between December, 2008 and August, 2009. All participants used biomass fuels (e.g., wood and crop residues) for cooking and space heating, and were drawn from an epidemiological study of biomass smoke exposure and blood pressure in 280 women (Baumgartner et al., 2011b). In the current study, women whose villages were at varying distances from the highway running through the study site (Anshang and Meizi, shown in Fig. 1) were selected as the participants. None were previous or current tobacco smokers, though 76% of participants lived with at least one tobacco smoker. Details about the study site, weather conditions, housing, and common household fuel and stove use patterns are presented elsewhere (Baumgartner et al., 2011a). The Institutional Review Boards at the University of Wisconsin–Madison and Yunnan Provincial Health Bureau approved our research protocol. We obtained informed verbal consent from all participants.

2.2. Sample collection and chemical analysis

Data collection took place in winter (December, 2008–February, 2009) and summer (June–August, 2009). Personal exposure sampling was performed for the current study and integrated over indoor and outdoor exposures that occurred during their normal activities. There were 1–3 24-h PM exposure samples for each

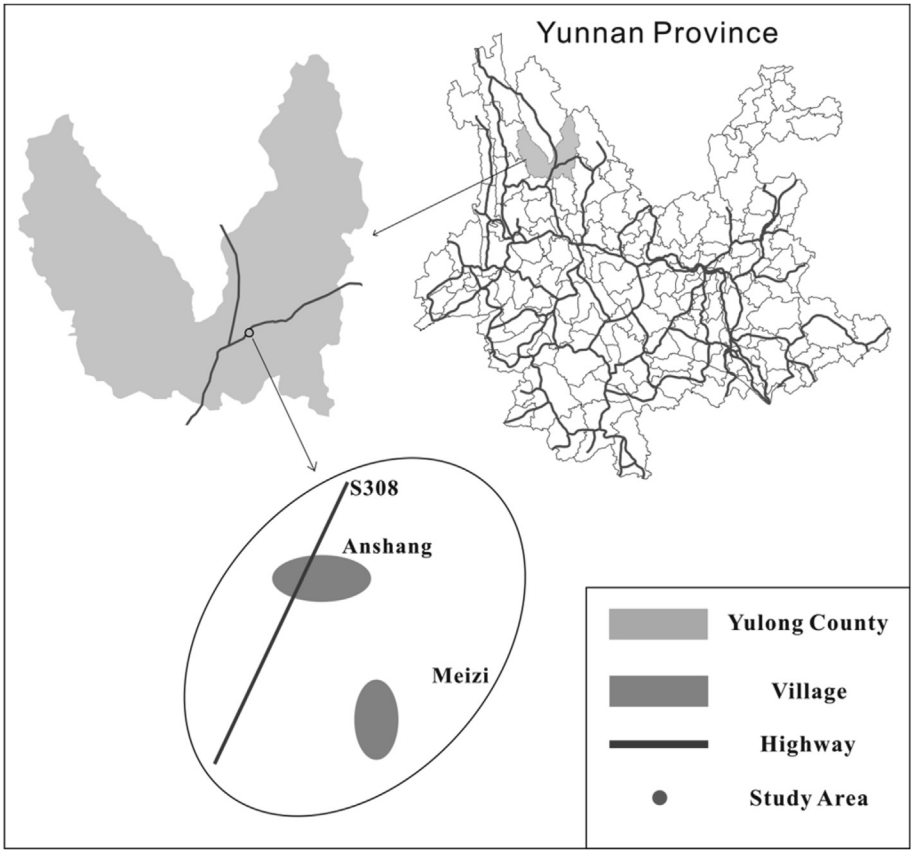

Fig. 1. Location of the study area. The two study villages are situated alongside the Yunnan–Tibet Highway (S308) in the Himalayan foothills.