

Effects of Indoor Particulate Matter Pollution from Biomass Fuels Burning: A Case Study in Six Shenyang Households, Northeastern China in Summer Season

by Ruoting Jiang, MEdSc 2007

Introduction

Visitors to Liaozhong County, a rural county near Shenyang city, the capital city of Liaoning Province, will be struck by the sight of piles of corn stalks stacked in front of each home. Approximately 90% of the households in this county rely on corn stalks for cooking and heating. The combustion of corn stalks generates dense smoke in the kitchens, where the rural cooks who participated in the study spend approximately 5.5 hours per day on average cooking. During that time, smoke causes acute symptoms such as coughing, lachrymation, etc, which are understood as “a part of life” by rural cooks. A major component of the smoke is particulate matter.

Particulate matter, also known as PM, is a complex mixture of extremely small particles and liquid droplets found in the air. The US Environmental Protection Agency has grouped PM pollution according to particle size: coarse particles (PM₁₀) are larger than 2.5 micrometers and smaller than 10 micrometers in diameter; and fine particles (PM_{2.5}) are 2.5 micrometers in diameter and smaller (US EPA

2007). The smallest particles are a particularly serious health problem because they can penetrate deep into the lungs. Previous epidemiological studies have linked PM with a number of negative health outcomes, including irritation of the airways, coughing, difficulty in breathing, decreased lung function, aggravated asthma, heart attacks and premature death in people with heart or lung disease (Smith et al. 2000; Bruce et al. 2000; Ezzati et al. 2001; Berg et al. 1991; Burchfiel et al. 1986; Chiltonczyk et al. 1993; Mitchell et al. 1993; Taylor et al. 1995).

Assessment of human exposure to PM pollution in the indoor environment is crucial given the fact that most people spend 70% to 90% of their time indoors (Wallace et al. 2003; US EPA 1996). The major indoor sources for PM include biomass burning, smoking, burning of candles, cooking and penetration of outdoor particulate matter. Among these, combustion of biomass fuels, such as wood, crop residues, dung and charcoal, has been considered as a major contributor to the burden of diseases in many developing countries (Chai and Cheng 2002).

In Chinese rural households, around 61% of the population relies on biomass fuels as the primary source of domestic energy (Biomass energy use and emission in China, ESCAP Virtual Conference 2003). The consumption of biomass fuels is not only due to its availability and economic efficiency, but also because it is a cultural tradition. Indoor air pollution

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caused by burning wood and fires inside homes has been identified as the major health hazard in rural households. The joint statement issued by World Health Organization (WHO) and United Nations Development Program (UNDP) indicated that each year smoke from cooking in poorly ventilated homes claims 1.6 million people's lives in developing nations. Results from a study conducted in three rural counties within An Hui Province in China showed that the levels of indoor PM_{10} in homes burning biomass fuels were 1.6 times higher than the maximum levels allowed by the US Environmental Protection Agency (Pegg 2003). However, the lack of air quality data from China's rural areas makes indoor PM pollution from combustion of biomass fuels one of the most serious yet least studied environmental health problems in China.

To understand this problem, I spent the summer of 2006 performing research on the measurement of indoor PM concentrations and personal PM concentrations in six households of Shenyang city, the capital city of Liaoning Province, northeastern China. Three of the households are located in the rural areas of Shenyang city and the rest are located in Shenyang metropolitan areas. The three families in rural areas consume biomass fuels as domestic energy while the three urban homes do not. By comparing the concentrations of indoor PM concentrations and personal PM concentrations between rural homes and urban homes, I aimed to explore the effects of biomass fuel combustion on indoor air pollution and human exposure.

Results from this study show that rural homes using biomass fuels for cooking experienced significantly higher levels of indoor PM_{10} than urban homes using natural gas. Particles were produced primarily from combustion of biomass and the process of cooking. Additionally, rural cooks were exposed to significantly higher levels of personal $PM_{2,5}$ compared to rural non-cooks, urban cooks and

urban non-cooks. This is due to the fact that biomass burning in kitchens during cooking periods is associated with overall higher levels of indoor particulate matter pollution, rural cooks spent longer time in the kitchens (to burn biomass and to cook), and that rural kitchens lack air pumps which are present in most urban kitchens.

Study location

Shenyang City is located in the northeastern part of China at latitude $41^{\circ}47'N$ and longitude $123^{\circ}25'E$ (Figure 1). It is the largest city and also an important industrial base in northeastern China with a population of 7.2 million. The annual average precipitation of Shenyang is 721.9 mm and the annual average temperature is $8.1^{\circ}C$. The highest temperature is $36.1^{\circ}C$ in July, and the lowest is $-28.5^{\circ}C$ in January. Three households were selected from Shenyang metropolitan area and another three were from Shenyang rural area in Liaozhong County. In the Liaozhong County, the primary occupations are crop cultivation and animal husbandry. Approximately 90% of all the households rely on agricultural products, corn stalks for example, as domestic fuels for cooking and heating.

Methodology

Monitoring of indoor and outdoor PM concentrations

Each of the six selected households was monitored on a daily basis for a continuous ten-day period. A short questionnaire was administered to each household to collect the basic information such as fuel type, kitchen location, cooking duration, cooking frequency, and presence or absence of an air pump in the kitchen. PM_{10} concentrations were monitored using P-5L2C Digital Dust Indicators (Beijing Binta Green Technology Co., LTD, China). For rural households, the monitors were placed

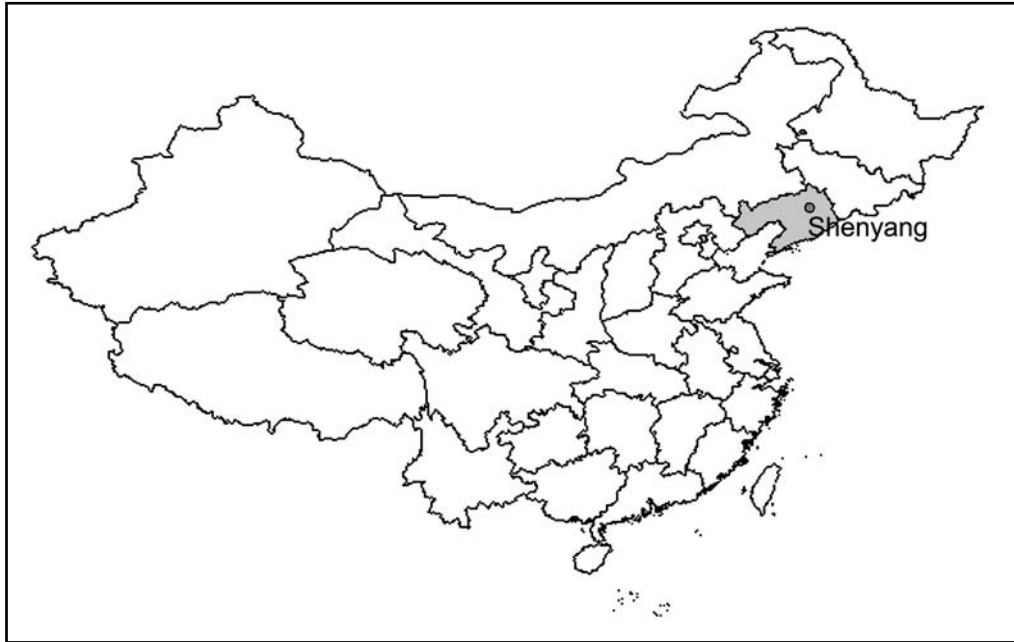


Figure 1. Map of sampling locations: Rural and urban areas of Shenyang city, the capital city of Liaoning Province, northeastern China

both in kitchens and in the house yards at a height of 0.6 meters. For urban households, the monitors were stationed in kitchens and sitting rooms at the same height. The monitors operated continuously for approximately 18 hours on a daily basis throughout the sampling period.

Monitoring of personal $PM_{2.5}$

Ten individuals participated in the personal monitoring of $PM_{2.5}$ including six cooks from six households and four non-cooks. Model AM510 SidePak Personal Aerosol Monitors (TSI, Co., MN, USA) were employed to measure personal exposure for $PM_{2.5}$. The small monitor was equipped with a personal pump and attached on the subjects' belts. The inlet of this monitor is connected by a short piece of tubing to the subject's breathing zone. Each subject was requested to carry the small monitor both indoors and outdoors for approximately 20 hours per day throughout the sampling period, except while sleeping, showering, and using the restroom.

Results

1. Indoor PM_{10} concentrations

PM_{10} concentrations were obtained from ten locations including three rural kitchens, three urban kitchens, three urban sitting rooms and one rural outdoor location. Figure 2 describes the overview of PM_{10} exposures at each location. Exposures to indoor PM_{10} in rural kitchens were significantly higher than outdoor exposure in rural areas and indoor exposures in urban households. Figure 3 describes the concentrations of PM_{10} during cooking times across households using different fuels. One way ANOVA (Table 1) showed that PM_{10} levels in kitchens using biomass fuels is significantly different ($p < 0.05$) from levels in kitchens using natural gas. Combustion of corn stalks resulted in higher indoor PM_{10} pollution than use of natural gas.

2. Personal $PM_{2.5}$ exposure profile

All the participants of personal $PM_{2.5}$ exposure monitoring were divided into four

Figure 2. Distribution of PM₁₀ concentrations at three rural households and three urban households, abbreviations: SRM, sitting room

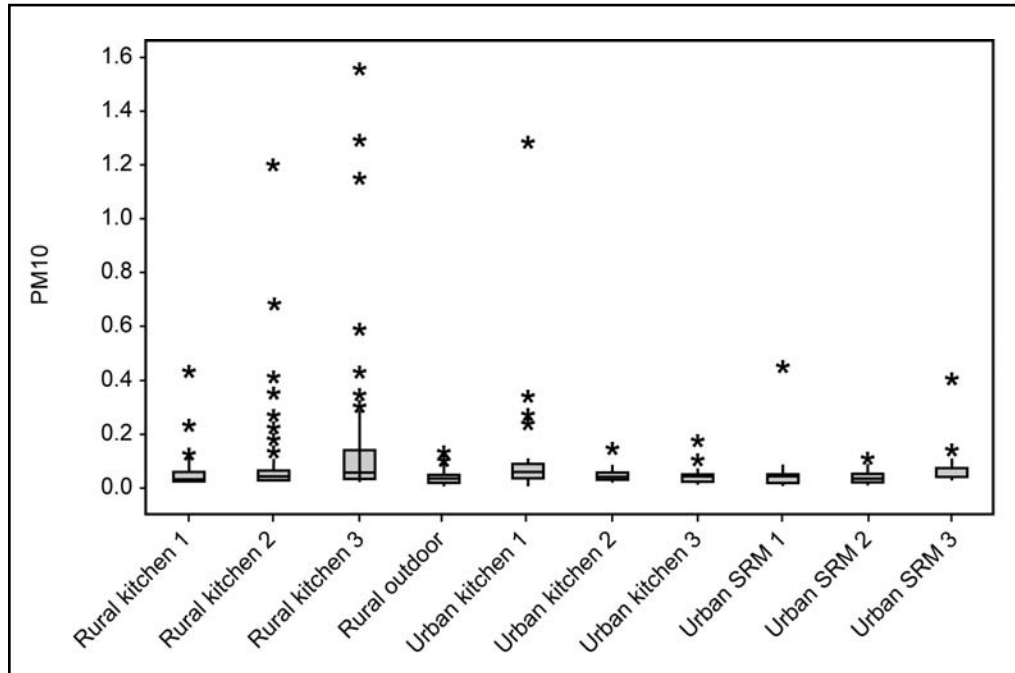


Figure 3. Distribution of indoor PM₁₀ in kitchens using biomass fuel and natural gas

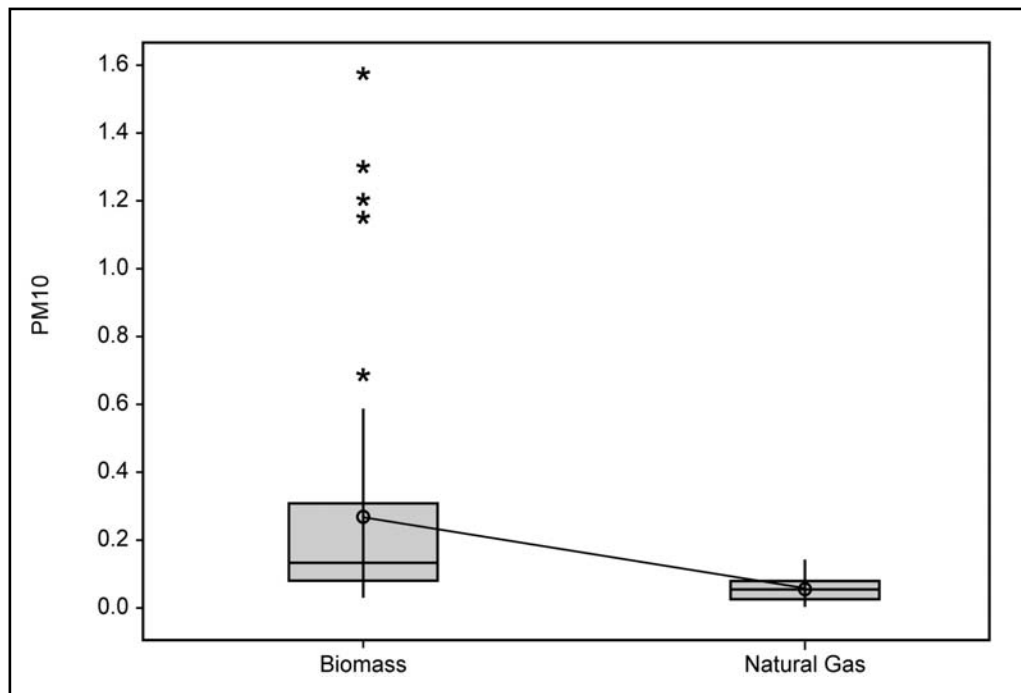


Table 1. Results of two-sample T test for indoor PM₁₀ concentration in kitchens using different fuel types for cooking

Fuel Types	Concentrations of PM ₁₀ (mg/m ³)		
	N	Mean	St Dev
Biomass	52	0.2669	0.3376
Natural gas	43	0.0548	0.0294
P=0.000			

categories: rural cooks, rural non-cooks, urban cooks and urban non-cooks. The distribution of hourly personal PM_{2.5} exposures in these four categories is shown in Figure 4 and describe in Table 2. One-way ANOVA (Table 2) showed that personal PM_{2.5} exposure of cooks was significantly different ($p < 0.05$) across kitchen fuel types (between rural cooks using biomass fuel and urban cooks using natural gas). Cooks using biomass fuels were exposed to significantly higher levels of personal PM_{2.5} (0.1572 ± 0.2856 mg/m³) than cooks using natural gas (0.0634 ± 0.0305 mg/m³).

Also, personal exposures of PM_{2.5} are significantly different ($p < 0.05$) between rural cooks (0.1572 ± 0.2856 mg/m³) and rural non-cooks (0.0538 ± 0.0318 mg/m³). This is not surprising because compared to total non-cooks, rural cooks spent more time in the kitchen, where there were higher levels of PM_{2.5} resulting from both the combustion of biomass fuels and cooking. However, no significant difference of personal PM_{2.5} exposures in urban cooks and urban non-cooks was ob-

served. This is presumably due to the fact that urban cooks use cleaner fuel (natural gas) for cooking, spend less time in the kitchen, and their kitchens all have air pumps.

Diurnal variability in personal PM_{2.5} exposures was investigated by examining the differences in secondary PM_{2.5} concentrations across a day. Figure 5 shows the daily variations of personal PM_{2.5} exposures in the four categories: rural cooks, rural non-cooks, urban cooks and urban non-cooks. Significant peaks of personal PM_{2.5} episodes, which correspond to the three cooking periods during the day, were found in rural cooks but not in other categories.

Discussion

This study, for the first time, has employed personal monitoring in conjunction with indoor monitoring to assess an individual's exposure to indoor particulate matter pollution for a cross-section of rural homes using biomass fuels and urban homes using natural

Table 2. Results of one-way ANOVA for personal PM_{2.5} exposures in rural cooks, rural non-cooks, urban cooks and urban non-cooks

	Personal PM _{2.5} (mg/m ³)		
	N	Mean	St Dev
Rural cook	123	0.1572	0.2856
Rural non-cook	45	0.0538	0.0318
Urban non-cook	47	0.0637	0.0292
Urban cook	94	0.0634	0.0305

Figure 4. Distribution of personal $PM_{2.5}$ exposures in rural cooks, rural non-cooks, urban cooks and urban non-cooks. The median is marked by a line within the box. The two whiskers outside the box extend to the smallest and largest observations with in 1.5IQR.

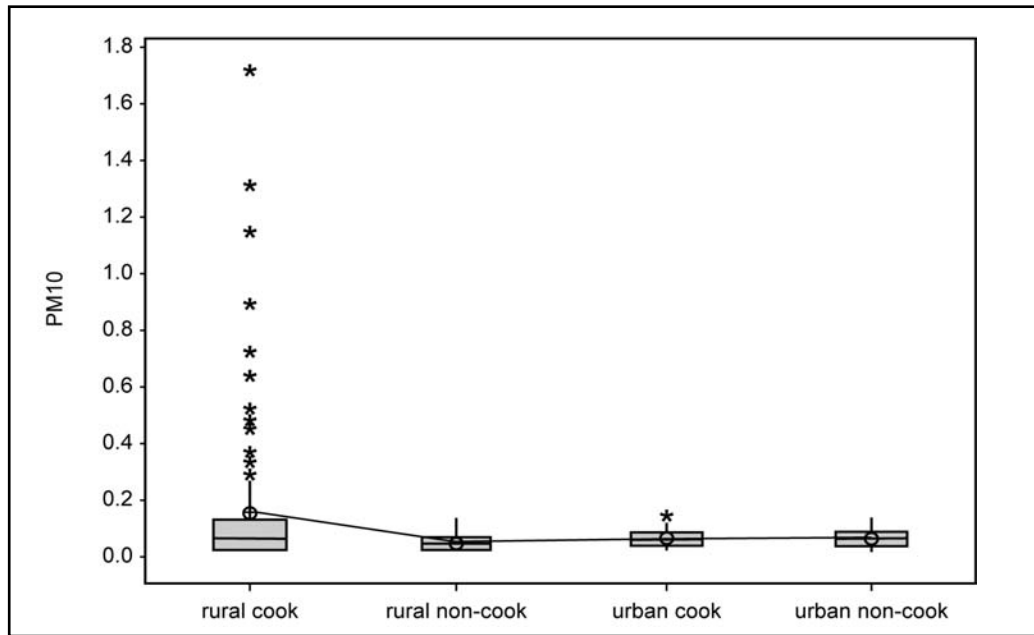
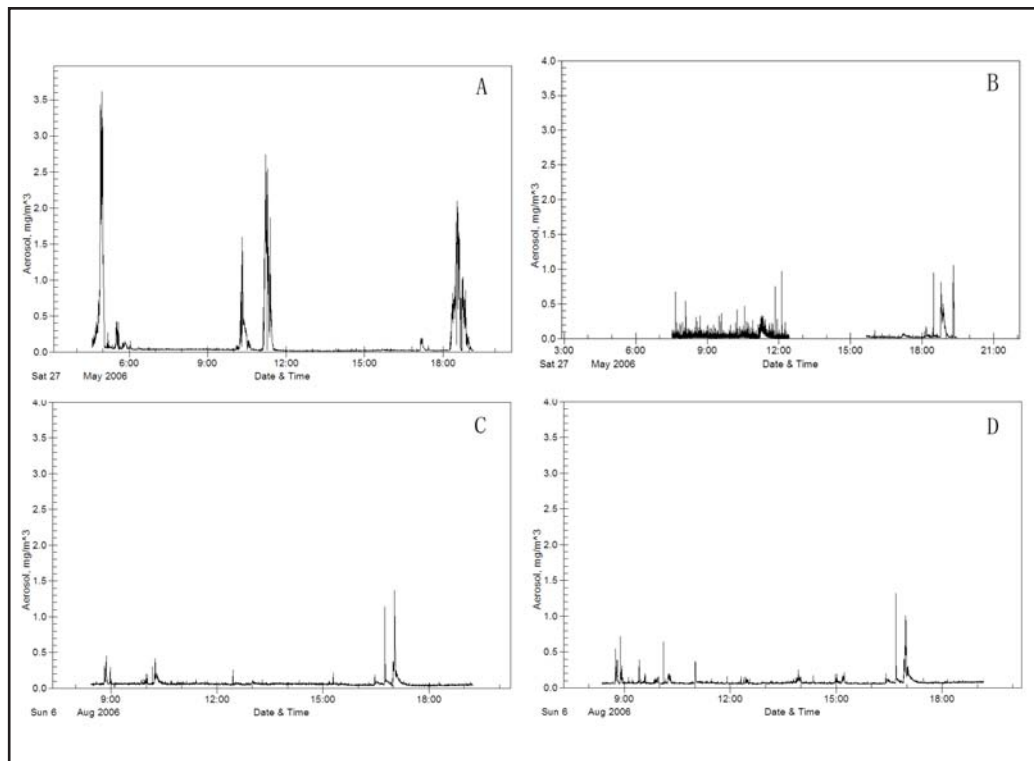


Figure 5. Daily variations of personal $PM_{2.5}$ in (A) a rural cook, (B) a rural non-cook, (C) an urban cook, (D) an urban non-cook. Data are based on PM concentration by second.



gas in the northeastern part of China. This monitoring scheme collected indoor, outdoor and personal PM concentration data which, when coupled with information on fuel type and pollution source, provides a better understanding of the nature of indoor PM pollution in rural and urban homes.

The findings of this project have important policy and program implications for China. Exposure to PM has been associated with a suite of negative health outcomes, such as acute respiratory infection, chronic respiratory disease, asthma, cardiovascular malfunction, lung cancer, low birth weight and increased risk of mortality (US EPA 2004). However, most rural residents who participated in this study were not aware of the air pollution resulting from the combustion of biomass. Seventy percent did not realize the health impact of indoor PM pollution. Therefore, results of this study provide necessary information to raise public awareness about the risk of exposure to the PM pollution resulting from combustion of biomass fuels.

Second, design and development of new technologies that improve energy efficiency and reduce indoor air pollution should be promoted by government. Traditional rural cook stoves are seldom effectively ventilated. This is due to the ignorance of the negative health risks posed by biomass smoke and the fact that people's desire to keep their homes as warm as possible. Therefore, improved cook stoves with long chimneys or air pumps in kitchens can improve ventilation and reduce human exposure to PM pollution. In the meantime, better design of housing structures is desired to keep living areas warm especially during winter.

A third possible solution is for rural communities to transfer to cleaner domestic fuel types, such as electricity, natural gas, and renewable resources such as biogas, solar energy and wind energy, instead of biomass fuels. While natural gas and electricity are much more expensive to use for cooking and heating,

biogas seems to be a good alternative type of energy.

In 2005, Shenyang city promoted the installation of biomass gasification stations in several rural communities nearby. Ten new stations were built in Dong Ling County and Yu Hong County. Over 5,000 households began to burn biogas instead of biomass fuels for cooking. Follow-up investigations showed that these residents appreciated the shift from burning solid biomass fuels to consumption of biogas (Shenyang Technological News 2005).

Lower fuel prices and reduced indoor air pollution are some of the benefits of changing to biogas, as well as improved quality of life, health and the environment. As rural communities become aware of such benefits, they will be more willing to make that change.

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