The Contribution of Household Solid Fuel Use to Ambient Particulate Pollution in a Village in Peri-Urban Beijing

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Background: Considerable media attention was focused on high particulate matter (PM) concentrations measured in Beijing and other Chinese cities during the last two winters. Less well recognized is that China's peri-urban and rural populations, which rely mainly on solid fuels for household heating and cooking, also suffer heavy outdoor air pollution. Combustion of coal and biomass, collectively called solid fuels, in inefficient stoves and heating devices is a significant source of particulate matter (PM) pollution, especially outside cities. Ambient PM pollution and household air pollution from residential solid fuel use are the fourth and fifth leading risk factors for premature death and disease in China, respectively. Few direct ambient PM measurements are made outside China's cities. Thus, the contribution of household solid fuel use to ambient pollution remains poorly characterized.

Objectives: In this pilot study, we quantified the contribution of household solid fuel combustion to ambient $PM_{2.5}$ and PM_{10} in a village 40 km southwest of central Beijing during June 2012 – May 2013.

Methods: Ambient $PM_{2.5}$ and PM_{10} concentrations were measured continuously at two village rooftop sites using gravimetrically calibrated DustTrak Aerosol Monitors. Meteorological data were also collected. To characterize temporal stove and heating device use patterns over four seasons, cooking and heating devices in 33 village homes and the main village office building were instrumented with Stove Use Monitors (SUMs), small robust temperature sensors with data logging capacity. A series of temperature peak selection algorithms were used to detect solid fuel device use events from SUMS temperature data by household and device type. Time series methods were used to determine the relationship between solid fuel combustion and ambient PM patterns.

Results: Participating households used a range of fuels, stoves, and heating devices throughout the study period. In winter, 98% of space heating devices used in study houses relied on burning solid fuels. Space heating devices monitored included honeycomb coal briquette stoves, coal furnace and radiator systems, biomass heated platform beds called 'kang', and biomass floor heating systems. In contrast, only 19% of household cooking devices used were solid-fuel based. Each participating household had at least one gas or electric cooking device. The greatest number of solid fuel use events occurred during the winter space heating season; over 800 solid fuel use events were measured with SUMS during each month from November 2012 – March 2013. Solid fuel device use peaked in January when approximately 2,700 solid fuel heating or cooking events were detected across 30 households; trends in total solid fuel use events per month were mainly driven by coal combustion. Mean annual $PM_{2.5}$ concentration measured in the study village was 100 $\mu g/m^3$, and mean PM_{10} concentration was 131 $\mu g/m^3$ for the four months measured. Mean 24-hour $PM_{2.5}$ concentrations in the village exceeded the Chinese 24-hour standard (75 $\mu g/m^3$) on 55% of days and the WHO 24-hour guideline (25 $\mu g/m^{3)}$ on 87% of days, respectively. Mean monthly $PM_{2.5}$ concentrations declined with each successive month from January through April 2013, closely mirroring longitudinal trends in household solid fuel use during that period. During the winter heating season, household solid fuel device use and PM concentrations also exhibited similar diurnal trends with greater solid fuel heating device use and PM concentrations occurring at night.

Conclusions: Household combustion of solid fuels for cooking and heating contributes to seasonal trends in ambient PM concentrations in peri-urban Beijing. A comprehensive pollution control strategy for Beijing should address a full range of pollution sources, including household solid fuel combustion in surrounding areas, particularly during the winter heating season.