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Guofeng Shen

# Emission Factors of Carbonaceous Particulate Matter and Polycyclic Aromatic Hydrocarbons from Residential Solid Fuel Combustions

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Guofeng Shen

# Emission Factors of Carbonaceous Particulate Matter and Polycyclic Aromatic Hydrocarbons from Residential Solid Fuel Combustions

Doctoral Thesis accepted by
College of Urban and Environmental Sciences,
Peking University, Beijing, China

Springer

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(2) **SHEN, G.F.**; Wang, W.; Yang, Y.; Zhu, C.; Min, Y.; Xue, M.; Ding, J.; Li, W.; Wang, B.; Shen, H.; Wang, R.; Wang, X.; Tao, S.*. Emission factors and particulate matter size distribution of polycyclic aromatic hydrocarbons from residential coal combustions in rural Northern China. **Atmospheric Environment** 2010, 44, 5237–5243. ***(REUSE WITH PERMISSION)***

(3) **SHEN, G.F.**; Wang, W.; Yang, Y.; Ding, J.; Xue, M.; Min, Y.; Zhu, C.; Shen, H.; Li, W.; Wang, B.; Wang, R.; Wang, X.; Tao, S.;* Russell, A. Emissions of PAHs from indoor crop residue burning in a typical rural stove: emission factors, size distributions and gas-particle partitioning. **Environmental Science & Technology** 2011, 45, 1206–1212. ***(REUSE WITH PERMISSION)***

(4) **SHEN, G.F.**; Tao, S.;* Wang, W.; Yang, Y.; Ding, H.; Xue, M.; Mi, Y.; Zhu, C.; Shen, H.; Li, W.; Wang, B.; Wang, R.; Wang, W.; Wang, X.; Russell, A. Emissions of Oxygenated Polycyclic Aromatic Hydrocarbons from indoor solid fuel combustion. **Environmental Science & Technology** 2011, 45, 3459–3465. ***(REUSE WITH PERMISSION)***

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# Supervisor's Foreword

Residential solid fuel combustion is a major source of incomplete combustion pollutants including particulate matter (PM), black carbon (BC), organic carbon (OC), polycyclic aromatic hydrocarbons (PAHs), and many more. This is particularly true for developing countries like China. Until recently, a majority of data on emission factors (EFs) of these pollutants from the residential sector had been measured in developed countries. However, residential stoves are very different between developed and developing countries. Because of the shortage of data on EFs for developing countries, emission inventories of pollutants generated by solid fuel combustion used for residential heating and cooking are associated with relatively large uncertainties, leading to biases in air quality modeling, exposure assessment and health analyses.

To fill the data gap, Guofeng's doctorial thesis focused on the measurement of EFs for solid fuel combustion from the residential sector in China. A simulated kitchen with real stoves commonly used in China was built particularly for this purpose. He tested a variety of residential solid fuels including coal, crop residues, and firewood in the measurements during a year-long experimental study. In addition, field measurements were conducted at selected rural sites to confirm the laboratory measurements.

As a result, a large volume of EF data of PM, BC, OC, and PAHs have been generated, which help fill a major data gap in the field. Soon after the publication, much of the data have been adopted for use in updating global emission inventories of BC, PAHs, and PM. Moreover, EFs of derivative PAHs including nitro-PAHs and oxy-PAHs for residential solid fuels and EFs of various pollutions for biomass pellet fuels, which are really scarce, were reported.

In addition to helping to fill the data gap, factors affecting EFs have been carefully investigated. It was found that modified combustion efficiency and fuel moisture are the most influential factors influencing EFs, and the knowledge gained in this work can be used to help quantify EFs for individual fuels. The models developed in this study can provide us with a better understanding of the generation mechanism of air pollutants during combustion.

Although the majority of the data collected in his study have been published in a series of papers internationally, we hope that an English version of this thesis with a collection of all measurements and key findings can help readers to use these results more efficiently.

Beijing, January 2014 Prof. Shu Tao

# Foreword

Both emission inventories and ambient measurements indicate that residential solid fuel combustion is a major contributor to emissions of incomplete combustion products, particularly in developing countries. In the recent World Health Organization's (WHO) Global Burden of Disease study, of the over 60 factors quantified, indoor exposures to such pollutants is the second leading cause of premature death in developing countries, and the International Agency for Research on Cancer has determined such combustion products to be a Group 1 carcinogen. Further, the soot derived from incomplete solid fuel combustion absorbs radiation and can potentially exacerbate global change. Given the importance of this source to human and the environment health, it is important to improve our understanding of the emission characteristics of residential solid fuel combustion and to use that knowledge to develop more accurate estimate emissions from that source. This involves characterizing the physical and chemical properties of the emissions, emission factors, and the associated activity levels. However, unlike more concentrated point sources, conducting the appropriated analyses is difficult due to the variable nature of the sources, the need to conduct detailed laboratory analyses, and collect and analyze information from a large and diverse literature. This is a particular issue in developing countries, which is also where such information is so valuable.

Dr. Guofeng Shen, as described in this thesis, took on a great challenge to help provide such information. He conducted a series of measurements on emissions of carbonaceous particulate matter and polycyclic aromatic hydrocarbons from residential solid fuel combustion in rural China. This work provides a firsthand data of emission factors from a large number of tests that can be used in the development of more reliable inventories. In addition, the work identified key factors affecting pollutant emissions from the combustion process which can provide information for pollution control strategy development. Not only did he look at more traditional solid fuel use, he considered pollutant emissions from biomass pellets which are considered as a cleaner, alternative fuel to replace traditional solid fuels.

The results of his work have appeared in international journals, including Environmental Science and Technology and Atmospheric Environment. Given my interest in air pollution and health, and the important issues addressed by Dr. Shen,

the publication of this thesis provides valuable information on pollutant emissions from residential solid fuel combustion. The outcome can be useful for emission inventory, health and climate impact analysis, and also the development of effective pollution control strategies. Further, this thesis can provide a foundation for future research in this area.

Georgia, Atlanta, November 18, 2013 Armistead G. Russell

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*THANKS* to my family. My grandparents and parents in my hometown and my beloved wife Vicky Xue in Beijing support and encourage me all the time. Without their help, it was impossible to get into the university, and more important, graduate with satisfied harvest.

2012.07 @ PKU

In the publication of this English version, special thanks to the editors from the Springer office. They provide the opportunity to publish the thesis so that many friends all over the world can access it. It is my pleasure if the result can be helpful in their work. Wishes!

Guofeng Shen @ Nanjing

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