CARBONACEOUS AEROSOL FROM RESIDENTIAL WOOD COMBUSTION

J.A. Rau and J.J. Huntzicker

Department of Chemical, Biological, and Environmental Sciences
Oregon Graduate Center, 19600 N.W. Walker Road, Beaverton, Oregon 97006

Because of rising conventional energy prices wood has made a resurgence as a residential heating fuel. As a result residential wood smoke aerosols are becoming a major component of fine ambient aerosols in many areas. However, the quantification of the impact of residential wood smoke on the ambient aerosol concentration has been difficult because these aerosols are variable in composition and size and have no unique elemental tracers.

The purpose of this study has been to examine the size distribution and composition of residential wood smoke aerosols which have been sampled from cooled, diluted smoke plumes. Particles sampled in this manner should be more representative of wood smoke aerosols as they exist in the atmosphere than those sampled with EPA Method 5. Sampling was usually done about 1.5 m from the stack on days when the breeze was sufficient to move the plume in a mostly horizontal direction. Carbon dioxide measurements in the flue gas and in the sampled air indicated that the dilution factor was from 50 to 100. Air sampled from the plume was taken into a mixing chamber which was a 2 m long, 20 cm diameter aluminum pipe. Six samplers were located in the far end of the pipe. Each sampler consisted of a section of 5 cm diameter pipe which contained an impactor at its upstream end and a filter holder at its downstream end. Bypass air flow was maintained in the pipe to provide isokinetic sampling conditions. Single stage impactors with cut points at 2.5, 1.2, 0.6, 0.3, and 0.1 μm were used. One sampler which contained no impactor was used to sample the total aerosol concentration. Samples were collected on 37 mm diameter quartz filters for organic and elemental carbon analysis by thermo-optical carbon analysis (1,2). Samples were also collected on Teflon filters for analysis by x-ray fluorescence.

The composition and size distribution of wood smoke aerosols are a function of the burning conditions, fuel type, and stove type. In order to examine the range of variation of wood smoke characteristics, a series of tests which bracketed the typical burn conditions in residential applications was used. These consisted of burning hot (with the damper full open) and burning cool (with the damper closed). Testing was done with a conventional box type air-tight stove installed in a residence. The flue pipe was 20 cm in diameter and rose vertically from the top of the stove for a distance of 3.5 m. Enough air leaked into the stove with the damper closed to maintain combustion. This is a typical burn condition for residential heating. Fuel loads were usually three to four pieces of well-aged Douglas fir (quarter sections out of a 25 cm diameter log) that were about 0.5 m long. With this size fuel load (about one-quarter of the stove capacity) a reasonably intense fire could be maintained when the damper was fully open. By opening or closing the damper, operating conditions could be changed from hot operation to cool operation or vice versa. A test was started by adding the fuel load to a bed of coals. Sampling was started 10-15 minutes after fuel addition so as to be representative of average continuous burning where wood is added periodically to maintain a constant heat output. The length of the sampling period was chosen to obtain appropriate samples for analysis, usually 10-20 minutes.

In all cases the particles emitted during hot burning were significantly different from those emitted during cool burning. Qualitatively the mass loading in the sampled air was from three to six times greater for cool burn plumes than it was for hot burn plumes. However, the heat output of the stove was much less during a cool burn than it was for a hot burn. During hot burning the plume was almost invisible. The color of the collected aerosol was black and up to 60% of its carbon content was in the form of elemental carbon. The aerosol mass was primarily in particles below 0.6 μm in diameter. Table 1 lists several aerosol mass distributions during hot burn conditions.

For cool burn tests the plume was always very visible and similar to plumes typically associated with residential wood burning. The color of the collected aerosol ranged from light yellow to dark tan. Table 2 shows some typical aerosol mass distributions as a function of size for cool burn tests.

In both hot and cool burns 70 ± 10% of the aerosol mass was carbon. In hot burns, as noted previously, elemental carbon predominated, but in cool burn conditions most of the carbon was organic. Size distributions of organic, elemental, and total (i.e., organic plus elemental carbon) are given in Table 3 for both hot and cool burn conditions. These results indicate that the mass distribution of carbon in cool burns is shifted to larger particle sizes relative to the hot burn cases.

In summary these results show that residential wood stove smoke particles are broadly distributed in the fine aerosol mode and that their composition can vary widely as a function of burn temperature. Studies on both source and ambient aerosols are continuing.

Acknowledgment. This research was sponsored in part by U.S. Environmental Protection Agency Grant R810091. The paper has not been subjected to EPA's peer review and therefore does not necessarily reflect the views of EPA.

References.

1. J.J. Huntzicker, R.L. Johnson, J.J. Shah, and R.A. Cary. "Analysis of Organic and Elemental Carbon in Ambient Aerosols by a Thermo-Optical Method." In Particulate Carbon Atmospheric Life Cycle, G.T. Wolff and R.L. Klimisch (editors), Plenum Press, New York, 1982, pp. 79-88.
2. R.L. Johnson, J.J. Shah, R.A. Cary, and J.J. Huntzicker. "An Automated Thermo-Optical Method for the Analysis of Carbonaceous Aerosol." In Atmospheric Aerosol: Source/Air Quality Relationships, E.S. Macias and P.K. Hopke (editors), American Chemical Society Symposium Series No. 167, American Chemical Society, Washington, D.C., 1981, pp. 223-233.

TABLE 1

Percent of aerosol mass in given size ranges for hot stove burns.

Stove Temperature (°C)	<0.3 μm	0.3-0.6	0.6-1.2	>1.2
650	39	41	20	0
550	56	30	9	5
550	40	18	21	21
430	56	28	0	15

TABLE 2

Percent of aerosol mass in given size ranges for cool stove burns.

Stove Temperature (°C)	<0.3 μm	0.3-0.6	0.6-1.2	>1.2
260	53	5	36	7
230	46	7	15	32
220	35	0	60	5
200	36	2	32	30

TABLE 3

Percent of organic, elemental, and total carbon in given aerosol size ranges.

Size Range	Organic Carbon	Elemental Carbon	Total Carbon
	HOT BURN		
<0.3 μm	37	43	39
0.3-1.2	39	49	42
>1.2	24	8	19
	COOL BURN		
<0.3 μm	18	22	19
0.3-1.2	49	37	47
>1.2	33	41	34