

Semi-volatile and Volatile Organic Compound Emissions from Outdoor Wood-Fired Hydronic Heaters

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Summary

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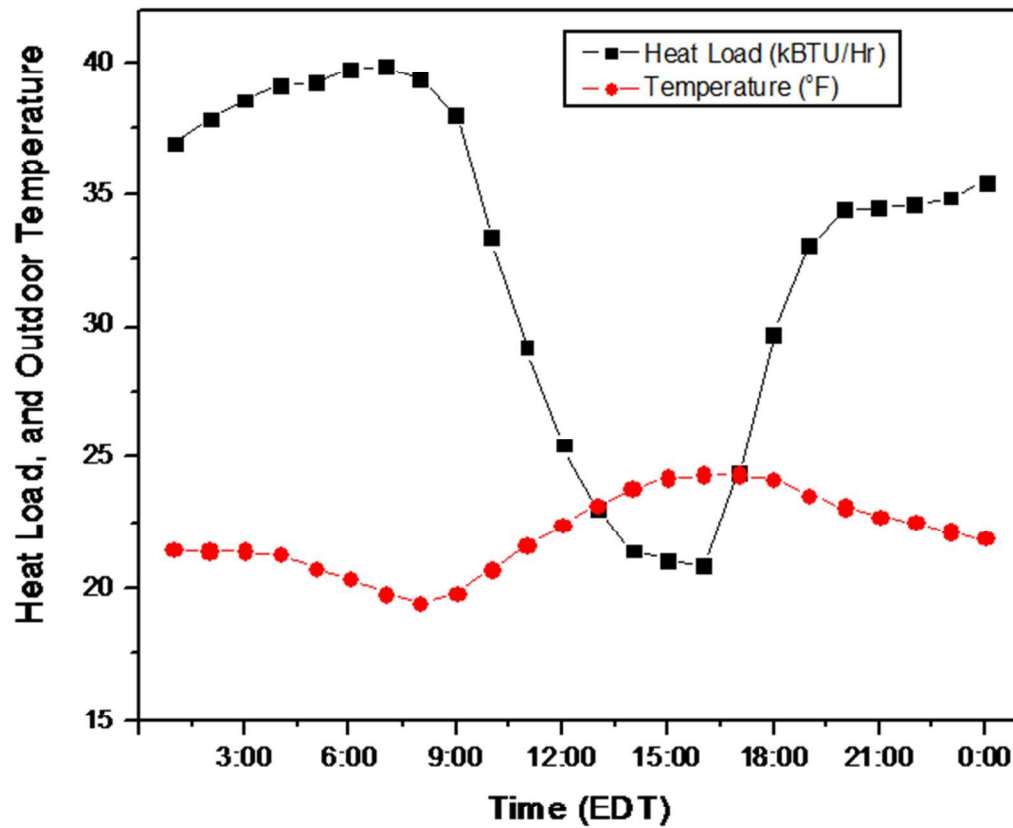


Figure S3. Twenty four hour heat load profile for a 232 m² home in Syracuse, New York, USA.

Table S1. Fuel properties.

Properties	Fuel			
	Red oak	White pine	White ash	Hardwood pellets
Ash (%)	1.5	0.44	0.75	0.52
Moisture (%)	22	9.6	9.0	7.2
Volatile Matter (%)	84	88	NA	84
Fixed Carbon (%)	14	11	NA	14
Carbon (%)	49	52	51	50
Chlorine (ppm)	38	36	NA	44
Hydrogen (%)	6.0	6.6	NA	5.9
Nitrogen (%)	<0.5	<0.5	NA	<0.5
Sulfur (%)	<0.05	<0.05	<0.05	<0.05
Heating Value (MJ/kg)	19.5	21.6	15.0	19.8

* NA – Not analyzed.

Table S2. PCDD/PCDF Emission Factors (ND = DL; ND = 0 within parentheses).

Unit	Fuel	Number of Samples	PCDD/PCDF WHO-TEQ		Total PCDD/PCDF	
			ng TEQ/kg _{input}	ng TEQ/MJ _{input}	ng/kg _{input}	ng/MJ _{input}
Conventional HH	Red oak	3	1.1 (1.0)	0.054 (0.053)	26	1.3
	STDV		0.76 (0.78)	0.039 (0.040)	27	1.4
Conventional HH	Red oak + refuse	2	1.9 (1.8)	0.098 (0.093)	75	3.8
	RDV		0.45 (0.59)	0.023 (0.030)	4.5	0.23
Conventional HH	White Pine	3	0.63 (0.24)	0.029 (0.011)	11	0.53
	STDV		0.21 (0.077)	0.0097 (0.0036)	1.6	0.075
Conventional HH	White Ash	2	0.37 (0.37)	0.025 (0.024)	13	0.89
	RDV		0.064 (0.078)	0.0061 (0.0052)	2.0	0.38
Three stage HH	Red oak	3	0.11 (0.079)	0.0056 (0.0041)	4.2	0.22
	STDV		0.022 (0.036)	0.0011 (0.0018)	1.5	0.075
U.S. Downdraft	Red oak	3	0.080 (0.023)	0.0041 (0.0012)	2.0	0.10
	STDV		0.0077 (0.0087)	0.00039 (0.00044)	0.60	0.031
European pellet [#]	Red oak	1	0.28 (0.25)	0.014 (0.012)	26	1.3

STDV = standard deviation, RDV = Relative deviation (only two tests), # = STDV Not applicable (only one test).

Table S3. PCDD/PCDF emission factors for the different heater/fuel combinations, in ng TEQ/MJ_{input}.

	Conventional HH				Three stage HH	U.S. Downdraft	European pellet
	Red Oak	Red Oak + Refuse	White Pine	White Ash	Red Oak	Red Oak	Red Oak
2,3,7,8-TCDD	0.0047 [0.0035]	0.0088 [0.0054]	0.0044 [0]	0.00094 [0]	0.0006 [0]	0.00066 [0]	0.0035
1,2,3,7,8-PeCDD	0.020	0.029	0.010 [0]	0.011	0.0018 [0.0011]	0.0012 [0]	0.0011 [0]
1,2,3,4,7,8-HxCDD	0.0010	0.0012	0.0010 [0]	0.00037	0.00014 [0.000076]	0.00015 [0]	0.00010 [0]
1,2,3,6,7,8-HxCDD	0.0018	0.0033	0.0011 [0.00031]	0.00094	0.00022 [0.00028]	0.00015 [0]	0.00010 [0]
1,2,3,7,8,9-HxCDD	0.0012	0.0027	0.00092 [0.00045]	0.00078	0.00021	0.00015	0.00010 [0]
1,2,3,4,6,7,8-HpCDD	0.00083	0.0024	0.00040	0.00056	0.00011	0.000057	0.000071
OCDD	0.000085	0.00024	0.000049	0.000055	0.000011	0.0000056	0.0000053
Sum PCDD	0.029 [0.028]	0.048 [0.045]	0.018 [0.0012]	0.013 [0.013]	0.0030 [0.0018]	0.0024 [0.00021]	0.0050 [0.0036]
2,3,7,8-TCDF	0.0038	0.013	0.00094 [0]	0.0015	0.00042	0.00010 [0]	0.0062
1,2,3,7,8-PeCDF	0.0013	0.0024	0.00043 [0.00034]	0.00033	0.00010 [0.000085]	0.000050 [0.000033]	0.00026
2,3,4,7,8-PeCDF	0.0088	0.021	0.0049	0.0037	0.0010	0.00062 [0.00046]	0.0018
1,2,3,4,7,8-HxCDF	0.0037	0.0048	0.0017	0.0012	0.00035	0.00031	0.00035
1,2,3,6,7,8-HxCDF	0.0038	0.0040	0.0015	0.00089	0.00028 [0.00015]	0.00017 [0.00011]	0.00027
1,2,3,7,8,9-HxCDF	0.00028 [0.00018]	0.00064 [0]	0.00063 [0.00033]	0.00017 [0]	0.00010 [0.000028]	0.00018 [0]	0.000094 [0]
2,3,4,6,7,8-HxCDF	0.0018	0.0022	0.00093	0.00060	0.00024 [0.00022]	0.00016 [0]	0.000083 [0]
1,2,3,4,6,7,8-HpCDF	0.00066	0.00069	0.00044	0.00024	0.000089	0.000042	0.000039
1,2,3,4,7,8,9-HpCDF	0.00012	0.00015	0.000056 [0.000031]	0.000051	0.000041	0.000034 [0]	0.0000079 [0]
OCDF	0.000013	0.000017	0.000016	0.0000058	0.0000041	0.0000048 [0]	0.0000018
Sum PCDF	0.024 [0.024]	0.049 [0.049]	0.011 [0.10]	0.085 [0.085]	0.0026 [0.0023]	0.0017 [0.0010]	0.0091 [0.0089]
Sum PCDD/PCDF	0.054 [0.053]	0.10 [0.093]	0.029 [0.011]	0.022 [0.022]	0.0056 [0.0041]	0.0041 [0.0012]	0.014 [0.012]

* Average value for congeners with not detectable congener equal to 0 within brackets. 2005 WHO-TEF.

Table S4. PAH Emission Factors in mg/MJ_{input}.

	Conventional HH				Three stage HH	U.S. Downdraft	European
	Red Oak	Red Oak + Refuse	White Pine	White Ash	Red Oak	Red Oak	Pellets
Naphthalene	12	6.6	22	18	2.4	6.9	0.23
Acenaphthylene	3.7	2.3	15	4.6	0.67	1.40	0.058
Acenaphthene	0.27	0.23	1.3	0.32	0.07	0.092	0.0035
Fluorene	0.96	0.70	3.2	1.2	0.18	0.28	0.013
Phenanthrene	2.0	1.5	6.1	3.0	0.58	0.86	0.074
Anthracene	0.46	0.33	1.3	0.75	0.10	0.17	0.012
Fluoranthene	0.60	0.34	1.3	1.2	0.13	0.28	0.041
Pyrene	0.62	0.32	1.2	1.1	0.10	0.26	0.043
Benzo(a)anthracene	0.18	0.093	0.45	0.36	0.027	0.072	0.0049
Chrysene	0.17	0.093	0.42	0.33	0.029	0.077	0.0047
Benzo(b)fluoranthene	0.09	0.055	0.24	0.22 [#]	0.019	0.037	0.0035
Benzo(k)fluoranthene	0.13	0.047	0.28	0.26 [#]	0.007	0.043	0.0014
Benzo(a)pyrene	0.16	0.076	0.36	0.33 [#]	0.021	0.049	0.0031
Indeno(1,2,3-cd)pyrene	0.065	0.041	0.15	0.15 [#]	0.011	0.023	0.0027
Dibenz(a,h)anthracene	0.0070	0.29	0.040 [#]	0.035 [#]	0.19 [#]	0.85 [#]	0.00021
Benzo(ghi)perylene	0.093	0.046	0.15	0.19 [#]	0.0090	0.025	0.0025
Total PAH	21	13	54	32	4.6	11	0.49

Method reporting limit.

Table S5. PAH Emission Factors in mg/kg_{input}.

	Conventional HH				Three stage HH	U.S. Downdraft	European
	Red Oak	Red Oak + Refuse	White Pine	White Ash	Red Oak	Red Oak	Pellets
Naphthalene	229	128	485	274	47	135	4.5
Acenaphthylene	73	44	323	69	13	27	1.1
Acenaphthene	5.3	4.4	29	4.8	1.4	1.8	0.069
Fluorene	19	14	70	18	3.6	5.4	0.26
Phenanthrene	38	30	132	45	11	17	1.5
Anthracene	9.0	6.5	29	11	1.9	3.3	0.24
Fluoranthene	12	6.7	28	18	2.5	5.4	0.82
Pyrene	12	6.3	26	17	2.0	5.1	0.86
Benzo(a)anthracene	3.5	1.8	9.7	5.4	0.52	1.4	0.10
Chrysene	3.4	1.8	9.0	5.0	0.56	1.5	0.094
Benzo(b)fluoranthene	1.8	1.1	5.1	3.0 [#]	0.37	0.72	0.069
Benzo(k)fluoranthene	2.5	0.92	6.1	3.7 [#]	0.14	0.84	0.029
Benzo(a)pyrene	3.1	1.5	7.7	4.6 [#]	0.41	0.96	0.061
Indeno(1,2,3-cd)pyrene	1.3	0.80	3.3	1.9 [#]	0.22	0.45	0.053
Dibenz(a,h)anthracene	0.13	5.5	0.86 [#]	0.37 [#]	3.6 [#]	17 [#]	0.0041
Benzo(ghi)perylene	1.8	0.90	3.3	2.6 [#]	0.18	0.48	0.049
Total PAH	415	254	1166	483	89	223	9.8

Method reporting limit.