Emissions of gases and $PM_{2.5}$ during combustion of wood logs in a stove or a fireplace

V. Martins[1], A.I. Calvo[1], C. Alves[1], T. Nunes[1], R. Hillamo[2], K. Teinilä[2], M. Duarte[1], L. Mendes[1] and L.A.C. Tarelho[1]

[1]Centre for Environmental and Marine Studies, Department of Environment and Planning, University of Aveiro, Aveiro, 3810-193, Portugal
[2]Finnish Meteorological Institute, Erik Palmenin aukio 1 FIN-00560, Helsinki, Finland
Keywords: biomass, domestic combustion, flue gas, organic tracers, $PM_{2.5}$
Presenting author email: celia.alvest@ua.pt

Combustion gases from biomass burning in domestic equipments has been recognised as a significant emission source of air pollutants (McDonald *et al.*, 2000). It is responsible for large impacts on air quality, as well as significant potential effects on public health and global climate change (Bølling *et al.*, 2009; Hellén *et al.*, 2008).

The aim of the current study was to characterise the emissions of residential wood combustion. Logs of threes common in Spain (*Quercus pyrenaica*, *Populus nigra* and *Fagus sylvatica*) were burned in two different combustion appliances, a fireplace and a woodstove. Measurements were carried out at the biomass combustion facility of the University of Aveiro (Portugal). During each combustion experiment, which lasted between 60 and 90 minutes, about 2.0 kg of wood were burned. Three or four combustion experiments were performed for each biomass type. The flue gas composition was monitored continuously in the exhaust ducts of both burning appliances. Total hydrocarbons (THC) and carbon oxides (CO_2 and CO) were measured using automatic analysers with flame ionisation and non-dispersive infrared detectors, respectively. Particulate matter with aerodynamic diameter below 2.5 µm ($PM_{2.5}$) was sampled in a dilution tunnel under isokinetic conditions, onto quartz fibre filters, using a low volume sampler. Filters were analysed by a thermal-optical transmission method in order to obtain the elemental and organic carbon (EC and OC) content. Furthermore, levoglucosan, mannosan, and galactosan, commonly used as tracers for biomass burning, were determined by high-performance anion-exchange chromatography with electrospray ionisation mass spectrometry detection (Saarnio *et al*., 2010).

The flue gas composition and emission rate of some compounds varied widely depending on fuel type, characteristics of the combustion equipment, and operating conditions. Generally, CO, CO_2, THC and $PM_{2.5}$ emissions from the fireplace were higher than those observed for the woodstove (Table 1). In an open fire, the large quantity of bypass air leads to high heat losses in the flue gases. The very high air flow through the fireplace also increases the total smoke emission by lowering the flame temperature and sweeping away unburned fuel gases before they can be heated to their ignition temperature. The carbonaceous matter represented 73-85% of the particulate mass emitted, regardless of species burned and combustion appliances. This carbonaceous content was dominated by OC. The EC mass fractions in particles emitted from the woodstove were substantially higher than those of the fireplace, whereas the opposite was observed for OC.

Table 1. Emission factors (g kg^{-1} biomass burned, dry basis).

		Q. pyrenaica	*P. nigra*	*F. sylvatica*
Fireplace	$PM_{2.5}$	12.5±4.1	14.0±5.1	5.8±1.3
	OC	9.0±3.0	10.5±3.4	3.9±0.9
	EC	0.60±0.09	0.79±0.19	0.43±0.23
	Levogl.	1.02±0.45	0.66±0.24	0.35±0.02
	Mann.	0.052±0.020	0.061±0.022	0.023±0.003
	Galact.	0.094±0.034	0.035±0.011	0.022±0.002
	CO_2	1618±83	1765±179	1749±92
	CO	86.0±14.1	115.8±11.7	74.4±6.7
	THC	24.7±6.3	27.8±4.8	13.7±2.1
Woodstove	$PM_{2.5}$	13.3±3.8	4.4±1.4	2.8±0.7
	OC	9.1±2.7	2.9±1.1	1.6±0.5
	EC	0.90±0.20	0.88±0.05	0.43±0.13
	Levogl.	1.09±0.17	0.21±0.15	0.20±0.05
	Mann.	0.056±0.012	0.014±0.009	0.013±0.007
	Galact.	0.105±0.013	0.011±0.009	0.013±0.007
	CO_2	1415±136	1879±29	1748±59
	CO	95.6±7.8	84.1±4.9	54.9±3.9
	THC	23.2±1.2	8.6±2.2	5.2±0.9

The mean levoglucosan mass fractions in $PM_{2.5}$ emitted by the two combustion equipments were very similar. The anhydrosugar yields from the combustion of *Q. pyrenaica*, *P. nigra* and *F. Sylvatica* represented around 8, 5 and 6-7% of the $PM_{2.5}$ weight, respectively. Percentages always lower than 1% were obtained for the levoglucosan stereoisomers. Anhydrosugar emissions were strongly enhanced during the start-up phase and decrease progressively until the glowing combustion phase.

This work was supported by the Portuguese Science Foundation (FCT) through the project BIOEMI, PTDC/AMB/65706/2006. Ana I. Calvo acknowledges the posdoc grant SFRH/BPD/64810/2009 from FCT.

Bølling *et al.* (2009) *Part. Fibre Toxicol*. **6**, doi:10.1186/1743-8977-6-29.
Hellén *et al.* (2008) *Sci. Total Environ*. **393**, 283-290.
McDonald *et al.* (2000) *Environ. Sci. Technol*. **34**, 2080-2091.
Saarnio *et al*. (2010) *Anal. Bioanal. Chem*. **398**, 2253–2264.