Wood combustion contribution to PM: results of five years campaigns (2005-2009) in Lombardy (Italy)

A. Piazzalunga[1], V.Bernardoni[2], P. Fermo[3], G. Valli[2], R.Vecchi[2]

[1]Department of Environmental and Territorial Sciences, Università degli Studi di Milano-Bicocca, Milan, Italy
[2] Department of Physics, Università degli Studi di Milano e INFN- Milano,Milan, Italy
[3] Department of Inorganic, Metallorganic and Analytical Chemistry, Università degli Studi di Milano, Milan, Italy

Email: **andrea.piazzalunga@unimib.it**

introduction

Very scarce data on the contribution of particles emitted by residential wood combustion (fireplaces and wood stoves) are available in Italy in spite of typically high PM winter levels (especially in the Po valley, Northern Italy); thus, a deeper knowledge of wood consumption as heating source and wood emission factors is mandatory.

A recent investigation show (ARPA, 2007) that the 19.9 % of Italian families commonly use wood as heating source with a yearly wood.

In Lombardy (Po valley, Northern Italy) - one of the major pollution hot-spot areas in Europe - residential wood-fired heating systems are quite widespread too, as resulted from a recent investigation carried out by the Environmental Agency of the Lombardy region (i.e. 31.8% of the families in Lombardy use wood as heating source).

In this work a assessment of the wood smoke contribution to PM, OC, and EC in Lombardy was carried out.

To this aim, analyses on wood burning tracers (i.e. anhydrosugars), OC, and EC were carried out on samples collected during one week in wintertime at six different locations.

To estimate the wood burning impact on PM and OC concentrations, emission factors calculated by recovering data on wood type and consumption in Lombardy were used in the macro-tracer-approach (Schmidl et al., 2008) and a comparison with average wood smoke emission factors reported in the literature was carried out. Moreover, an alternative approach was introduced, using the Positive Matrix Factorization source profile to derive levoglucosan to PM, levoglucosan-C to OC (i.e. carbon contained in levoglucosan), OC/EC, and levoglucosan to mannosan ratios in ambient air.
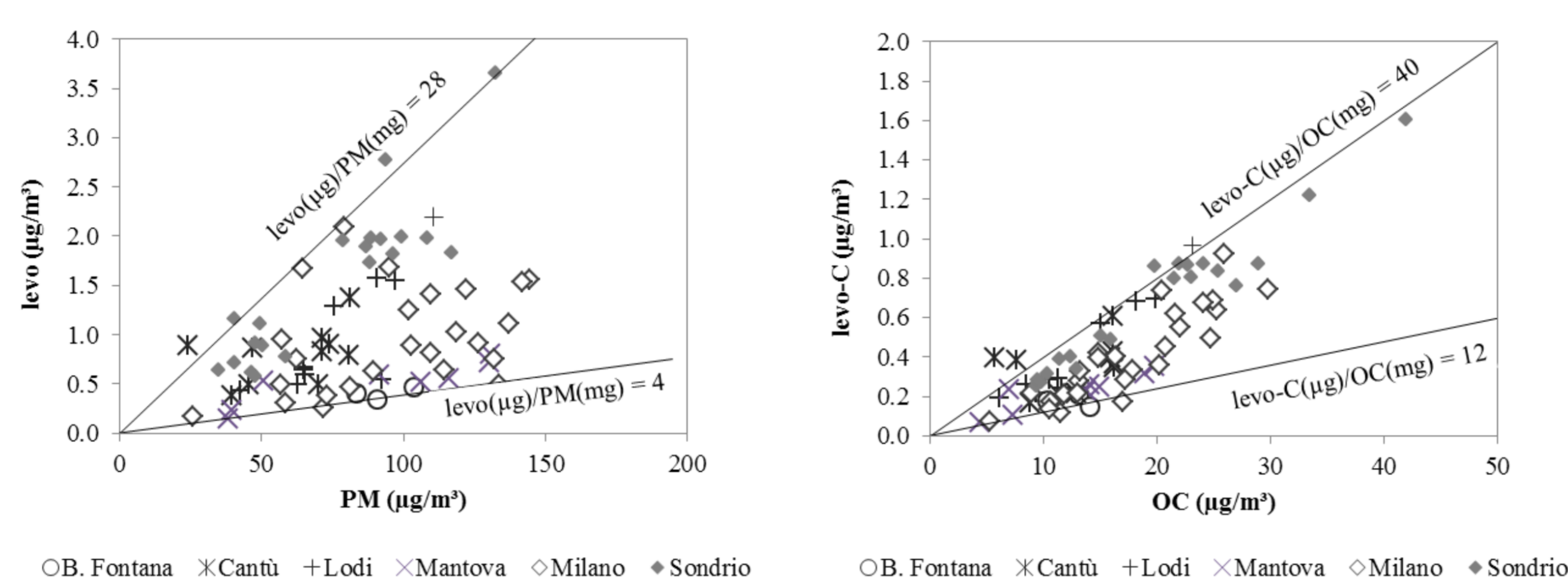
sampling sites
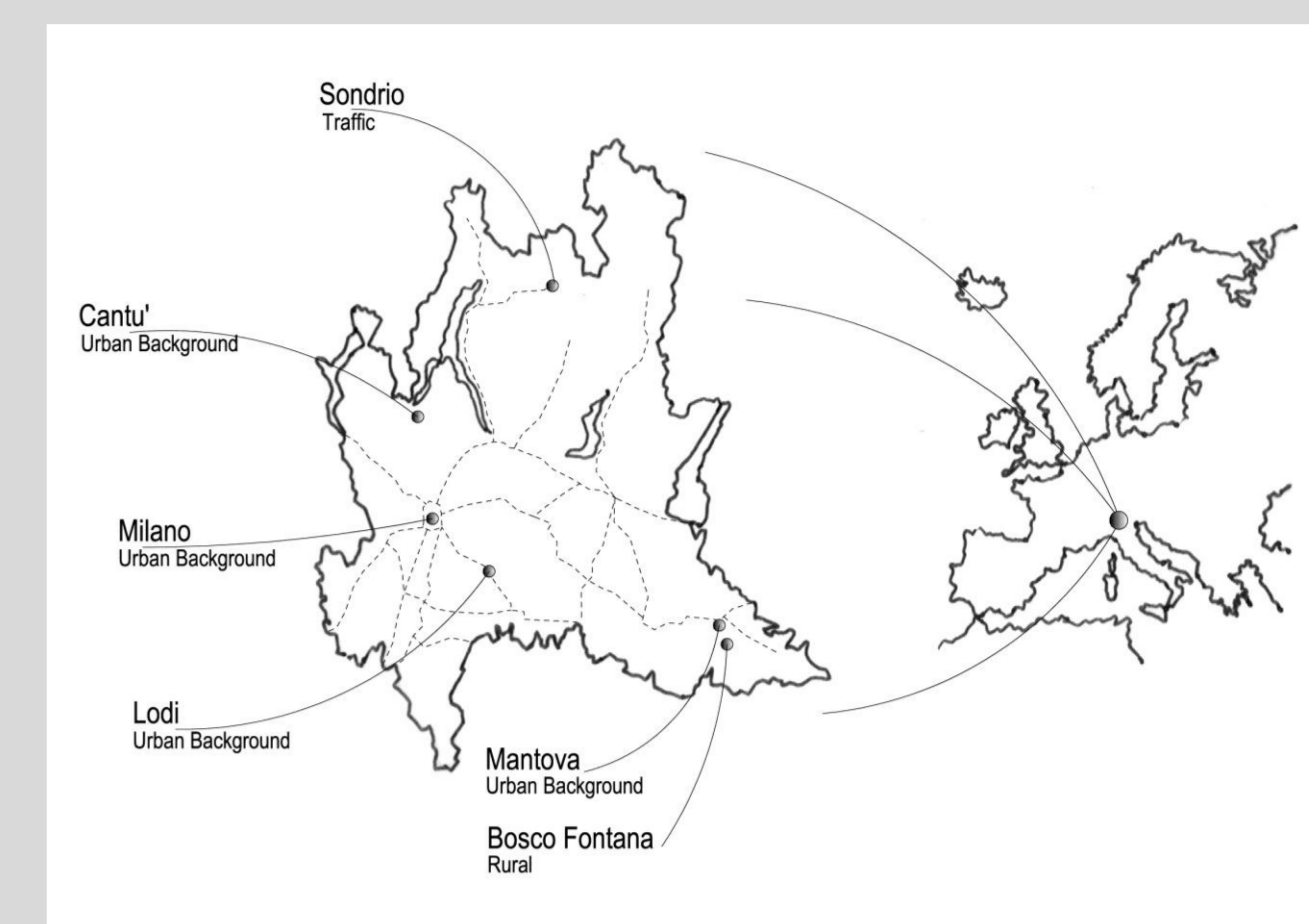
The sampling sites (Bosco Fontana, Cantù, Lodi, Mantova, Milano, Sondrio) were selected in order to cover the various typologies of sites (figure 1). **Sondrio** is an alpine town of medium size; **Cantù** is a pre-alpine town and it is famous for its industrial activity connected with wood furniture manufacturing; **Milan** is the second largest town in Italy; Lodi and **Mantova** are medium-sized towns in the Po valley; **Bosco Fontana** is a small rural village nearby Mantova and it is located in a natural reserve.

Sampling period
21-27 February 2005
23-28 January 2006
5-1 February 2007
   Intensive campaign 4 hour resolution
   (21 November – 6 December 2006)

Analytical Techniques
OC/EC   TOT(Birch and Cary 1996)
Levoglucosan   HPAEC/PAD (Piazzalunga et al., 2010)

results and dicussion

The levoglucosan to PM10 and levoglucosan-C (i.e. carbon contained in levoglucosan, in the following called levo-C) to OC, are reported in figures 2a-b for all the investigated sites. The general picture given by the regional dataset is quite fragmentary, there were significant site-to-site variations in wood burning tracers suggesting different impacts from wood burning emissions.

Biomass burning emission factors and wood consumption inventory

In order to evaluate the contribution of wood smoke to particulate matter emissions it would be necessary to know exactly the wood types burnt, since it is well known that levoglucosan and carbon components (i.e. EC and OC) concentrations in wood smoke vary remarkably. In particular, the levoglucosan to PM emission factor varies according to the type of wood burnt and appliances used as well as to burning rates, air dilution, and moisture content in the fuel

Not much information is available on wood species burned in domestic stoves in Lombardy; therefore, we consider as representative of the wood burnt in this region the wood types reported in the 2007 inventory of the tree-felling In table 3 the summary of the statistical values related to wood smoke emission values reported in the literature
are given together with emission data for the wood species felled in Lombardy. Data reported in this table highlight the extremely high variability in emission factors reported in literature works.

		Levo/PM (µg/mg)	Levo-C/OC (µg/mg)	Levo/Manno (w/w)	OC/EC (w/w)
only species from the Lombardy survey	nr. data	9	9	9	9
	average	103	78	9.2	10.0
	min	30	23	3.6	0.6
	max	224	147	20	34
	median	107	63	5.8	3.3
	25° percentile	41	44	3.9	2.6
	75° percentile	133	89	7.9	10.0
all data from the literature	nr. data	62	74	68	62
	average	113	100	13.7	14.0
	min	8.0	4.4	2.4	0.6
	max	318	299	84	69
	median	108	88	6.6	5.5
	25° percentile	61	43	4.5	2.6
	75° percentile	142	113	20	21

macro tracer approach and emmision ratio data

The estimation of the wood burning impact on PM10 and OC concentrations in Lombardy were performed following the macro-tracer approach proposed by Schmidl et al. (2008).

It should be taken into account that the estimates of the wood burning contribution to PM, OC, and EC may be affected by large uncertainties since the emission ratios used in the macro-tracer approach strongly depend on the wood species and the heating system in use and these data are only partially known.

The percentages of OC, EC, and PM ascribed to wood burning are reported in table 4 for the regional-scale campaign.

|	Site	PM_wb (%)	OC_wb (%)	EC_wb (%)
2005-2006	Sondrio	14.9	37.7	10.1
	Cantù	10.3	27.5	16.7
	Milano	5.5	20.4	9.3
	Lodi	n.d.	n.d.	n.d.
	Mantova	5.4	21.4	11.2
	Bosco Fontana	4.3	18.7	17.1
2006-2007	Sondrio	21.5	45.7	19.2
	Cantù	n.d.	n.d.	n.d.
	Milano	15.3	34.4	12.4
	Lodi	14.5	44.7	22.3
	Mantova	n.d.	n.d.	n.d.
	Bosco Fontana	n.d.	n.d.	n.d.
2007-2008	Sondrio	21.6	44.8	23.9
	Cantù	22.0	48.0	17.9
	Milano	7.5	23.4	9.5
	Lodi	n.d.	n.d.	n.d.
	Mantova	11.3	42.9	17.6
	Bosco Fontana	n.d.	n.d.	n.d.

macro tracer approach and PMF profile

In this work we propose a different approach to estimate average emission factors in ambient air, using the chemical profiles obtained by Positive Matrix Factorization (PMF).

Indeed, the availability of chemically speciated samples obtained during the intensive campaign allowed the application of PMF to identify and apportion major PM sources in Milan. Details on the PMF analysis are reported in Bernardoni et al. (in press).

Nevertheless, in this work we are interested more in the wood burning source profile as singled out by PMF (figure 6). Comparing the PMF-derived ratios with the average ones calculated for Lombardy a very good agreement is found for levo-C/OC (82 µg/mg by PMF versus 78 µg/mg reported in table 3) and levoglucosan to mannosan (10.2 by PMF versus 9.2 given in table 3). On the contrary, there is a significant discrepancy between levo/PM singled out by PMF (59 µg/mg) and the corresponding value calculated for the emissions of wood used in Lombardy (103 µg/mg).

Using the PMF-derived ratios in the macro-tracer approach the contribution of wood burning in **Milan** would be in the range **10-27% to PM10, 19-33% to OC, and 3.5-6.0 % to EC.**
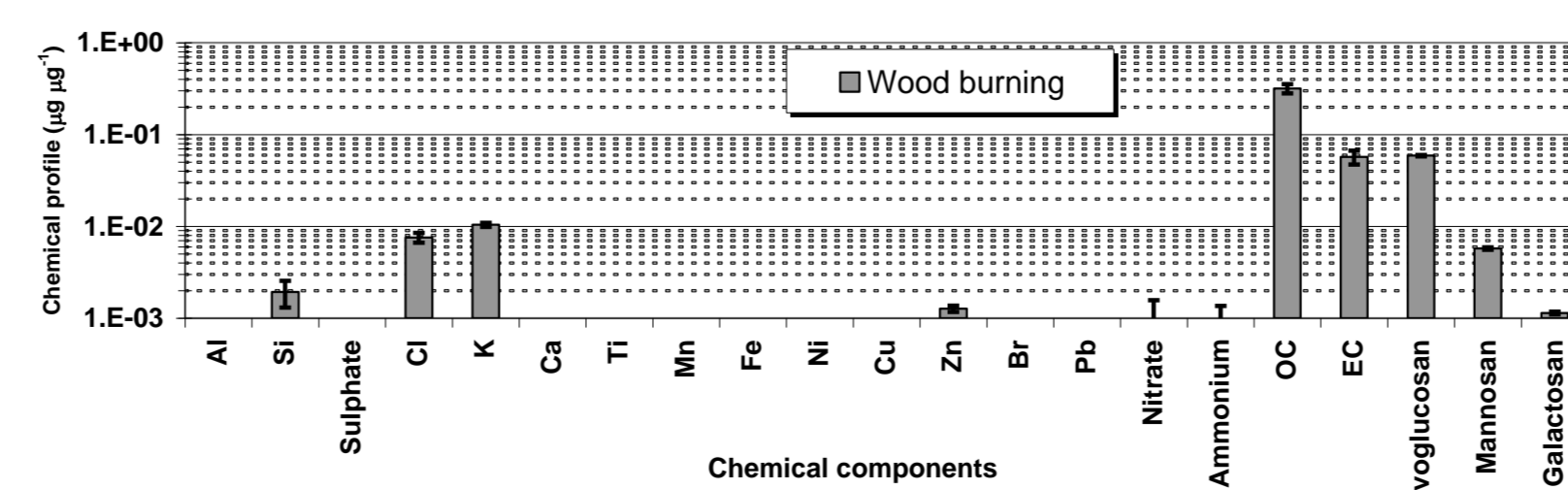
Conclucions

This work shows that in Lombardy, where often very high PM levels are registered especially during wintertime, wood smoke is one of the major contributors to organic particulate matter. Emission ratios generally reported in the literature are highly dependent on the wood types burnt and the heating system used; the emission factors used in this work, based on a survey on the wood consumption in Lombardy, are further limited by the fact that the real wood consumption in Lombardy is only partially known. To overcome these limitations, in this work we propose an alternative approach using the chemical profile obtained by a Positive Matrix Factorization
as emission ratios in ambient air and we compared them to literature ones.