Identifying tracers for traffic related PM10 emissions using SR-XRF

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Particle emissions of road traffic are generally associated with fresh exhaust emissions only. However, recent studies identified a clear contribution of non-exhaust emissions to the PM10 load of the ambient air. These emissions consist of particles produced by abrasion from brakes, road wear, tire wear, as well as resuspension of deposited road dust. For many urban environments, quantitative information about the contributions of the individual abrasion processes is still scarce. For effective PM10 reduction scenarios it is of particular interest to know whether road wear, resuspension or fresh abrasion from vehicles is dominating the non-exhaust PM10 contribution.

In Switzerland, the emissions of road traffic abrasion particles into the ambient air were characterized in the project APART (Abrasion Particles produced by Road Traffic), funded by the Swiss Federal Roads Authority (ASTRA) and the Swiss Federal Office for the Environment (BAFU). The project aimed at finding the contribution of the non-exhaust sources to total traffic-related PM10 and PM2.5 for different traffic conditions, by determining specific elemental fingerprint signatures for the various sources. This was achieved by hourly elemental mass concentration measurements in three size classes (2.5-10, 1-2.5 and 0.1-1 micrometers) with a rotating drum impactor (RDI) and subsequent synchrotron radiation X-ray fluorescence spectrometry (SR-XRF). The elemental fingerprint measurements were embedded into a large set of aerosol, gas phase, meteorological and traffic count measurements. To identify traffic related emissions, measurements were performed upwind and downwind of selected roads. For a better investigation of road wear, a road wear simulator was applied in additional experiments.

Freshly emitted brake wear particles were found to be predominantly in the size range 1-10 µm for light duty vehicles (see Figure 1), while brake wear particles for heavy duty vehicles were found to be in the 2.5-10 µm size range.

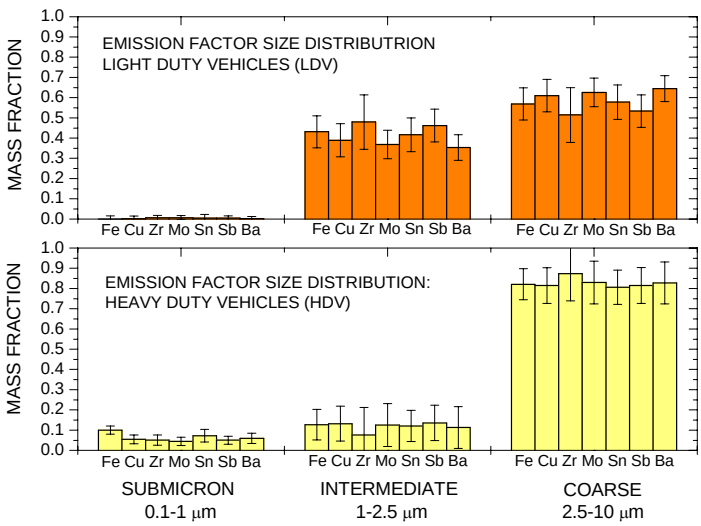

Figure 1: Fractional size contribution for LDV and HDV emission factors determined for brake wear related trace elements and stop-and-go traffic in Zürich-Weststrasse (street canyon).

Emission factors (mg per km and vehicle) for trace elements are still rare for many real-world situations. Table 1 lists emission factors for light and heavy duty vehicles for a busy street canyon in Zürich Switzerland. The reported set of elemental emission factors for LDVs and HDVs in Table S2 are split in three health-relevant particle size classes. This will help to refine existing emission inventories.

Table 1: Light duty vehicle (LDV), heavy duty vehicle (HDV) and average fleet emission factors (EF) for Zürich-Weststrasse (street canyon).

		Traffic related mass concentration (Δc)		MDL*b	Emission Factor LDV (EF_{LDV})		Emission Factor HDV (EF_{HDV})		Emission Factor Average Fleet (EF_{tot})*a	
		ng m^{-3}		ng m^{-3}	µg km^{-1}		µg km^{-1}		µg km^{-1}	
Coarse mode (2.5-10 µm)	Fe	614		11	977	± 259	11896	± 2503	5517	±
	Cu	42.4		5.6	75.1	± 21.5	739	± 208	391	± 540
	Zr	4.09		1.43	7.9	± 3.9	91.9	± 38.6	40	± 141
	Mo	4.43		1.18	10.4	± 2.4	79.9	± 23.0	38	± 46
	Sn	6.53		0.549	10.8	± 3.3	101	± 32	61	± 66
	Sb	6.74		0.512	10.7	± 3.1	108	± 30	61	± 67
	Ba	12.9		1.1	33.0	± 7.1	214	± 68	122	± 197
Intermediate mode (1-2.5 µm)	Fe	211		5.0	740	± 135	1846	± 1200	1129	±
	Cu	16.7		2.5	47.9	± 9.2	119	± 84	129	± 339
	Zr	1.83		0.639	7.4	± 1.6	8.0	± 15.2	15	± 57
	Mo	1.89		0.526	6.1	± 1.2	12.1	± 11.2	16	± 38
	Sn	2.49		0.245	7.8	± 1.2	15.1	± 10.1	21	± 30
	Sb	2.72		0.229	9.3	± 1.4	17.9	± 12.5	22	± 41
	Ba	5.08		0.489	18.1	± 3.2	29.2	± 28.8	37	± 122
Submicron mode (0.1-1 µm)	Fe	34.6		2.2	<1	± 27.2	744	± 270	409	± 976
	Cu	2.17		1.11	<1	± 1.7	49.3	± 16.9	26	± 55
	Zr	(0.208)		0.282	<1	± 0.2	5.3	± 1.7	2.7	± 5.4
	Mo	0.243		0.232	<1	± 0.2	4.3	± 1.7	3.0	± 5.2
	Sn	0.290		0.108	<1	± 0.3	9.1	± 3.3	3.0	± 15
	Sb	0.348		0.101	<1	± 0.2	6.7	± 2.2	4.3	± 7.4
	Ba	0.732		0.216	<1	± 0.5	15.3	± 5.2	9.3	± 17.7
Coarse mode	Zn	12.0		4.7	18.4	± 9.3	236	± 91	147	± 460
	Pb	(1.88)		3.36	4.8	± 1.6	49.3	± 18.6	13	± 74
	Cr	4.48		0.183	5.9	± 1.7	86.8	± 16.7	44	± 68
	Mn	7.88		0.154	9.6	± 3.0	134	± 29	82	± 115

*a related to an average HDV fraction of 0.1.

*b MDL (Minimal detection limit): Experimental detection limit

References

[1] N. Bukowiecki, P. Lienemann, M. Hill, R. Figi, A. Richard, M. Furger, K. Rickers, G. Falkenberg, Y. Zhao, S.S. Cliff, U. Baltensperger and R. Gehrig (2009). Real-world emission factors for antimony and other brake wear related trace elements: Size-segregated values for light and heavy duty vehicles, submitted to Environ. Sci. Tech.