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ROAD DUST AND HOUSE DUST: NEXUS OF METAL CONCENTRATIONS

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ABSTRACT. People living in industrialized countries spend most of the time indoors. Therefore, a significant factor for the intake of pollutants by humans can be indoor contaminants like house dust (HD). The two main migration pathways of inorganic contaminants into buildings are the transport of soil and road dust (RD) adhering to footwear and atmospheric particulate matter sedimented inside the building. Additional sources of contaminants can come from activities carried out within the buildings. Some results are available from studies where samples of RD and HD were collected simultaneously. These results are compared with data from two studies where RD and HD samples were collected in the same area in Austria in Spring 2016. Since these samples were analysed by size fractions size dependent concentration ratios can be calculated for various elements. This information provides additional insight on the sources of specific elements.

Keywords: Road dust, house dust, metals, Austria

1. INTRODUCTION

In industrialized countries, people spend most of the time indoors in their homes, in shops and offices. As a consequence, indoor contaminants like house dust (HD) can be an important source for the intake of pollutants by humans. The two main migration pathways of particulate matter from outside into buildings are on the one hand the atmospheric transport of suspended particles followed by sedimentation inside the building and on the other hand soil and road dust (RD) adhering to footwear [1]. In a study [2] the mass fraction of outdoor soil on HD was approximately one third. An additional source of contaminants can be activities carried out inside the buildings, for example heating, cooking, etc. [3].

From several studies [4-12] information is available on the composition of simultaneously collected samples of HD and RD. From these data the concentration ratios in HD and RD can be calculated for various elements.

In this study these concentration ratios are compared with data resulting from two studies dealing with HD [13] and in RD [14] collected in the town of Wels. Since

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the dust collection and analysis were conducted in dependence of the particle size additional insight can be gained on the sources of specific elements.

2. MATERIALS AND METHODS

Wels is a mid-size town in Upper Austria located on the river Traun, 317 m above sea level with approximately 60,000 inhabitants. The HD and RD samples collected in Wels in Spring 2016 were splitt in size fractions by air classification and analysed by ICP-OES. Details of the sample collection and preperation, chemical analyses and results were published elsewhere [13,14]. The concentration data for Sb and V were not published in these studies. In this study, additionally the Sb and V concentrations are used.

After air classification of a dust sample the concentrations of Cr and Ni in the sample are increased due to wear of stainless steel wall material of the classifyer [15]. Therefore, for Cr and Ni were not analysed in the published studies [13,14]. For this study the original dust samples were analysed for Cr and Ni after sieving through a 200 µm sieve.

The concentration of the various metals in HD and RD were calculated for an upper size limit (USL) of 200 µm from the concentrations in the size fractions smaller than the USL. The mass concentration c_A of component A results from the concentrations of this component $c_{A,i}$ in the n size fractions and the mass fraction of the respective size fraction in the dust finer than 200 µm $x_{m,i}$ according to the following equation [16]:

$$c_A = \frac{\sum_{i=1}^{n} c_{A,i} \cdot x_{m,i}}{\sum_{i=1}^{n} x_{m,i}}.$$

The concentration ratios R were calculated according to the following equation:

$$R = \frac{c_{HD}}{c_{RD}}.$$

3. RESULTS AND DISCUSSIONS

3.1. Concentration ratio R for various metals

In the available studies where HD and RD samples were collected at the same time and in the same area the USL for the collected dust applied during sample preparation differed. However, the USL applied has a significant influence on the metal concentrations [17]. In some studies, the USL for the dust samples was 500 µm [5-7]. In the other studies the applied USL was smaller (180 µm in [8], 125 µm in [12], 63 µm in [4] and 53 µm in [10]. In one study [11] the size fraction 100-250 µm was investigated

and for one study [9] no data regarding dust particle size were reported. Table 1 shows the average concentration of various metals in the HD and RD samples.

Table 1. Concentration of various metals in HD and RD (in mg/kg)

Type	Source	Al	Ba	Ca	Fe	K	Mg	Mn	Sr	Ti
c_{HD}	[5]			74000	22000		8120	373		
	[7]				18000			260		
	[8]				770					
	[11]	30900	970	68400	20200	13200		322	436	3300
	[12]	26000	492	48800	14100	10300	9830	269	255	
	[13]	5770	240	91900	18700	3600	16000	499	124	123
	[14]	4620	78	70000	5790	3040	8140	273	62	129
c_{RD}	[5]			64400	18800		5160	436		
	[7]				22200			185		
	[8]				900					
	[11]	35100	930	123000	19900	13000		312	382	2700
	[12]	47500	576	96800	18900	15000	15800	432	459	
	[13]	3270	278	184000	32600	467	43800	763	81	150
	[15]	5420	78	132000	15700	1200	25700	1240	136	251

Table 2 shows the concentration ratios R. For all metals the average value of R is close to 1.0 with the exception of K with a value for R of 3. If there are no indoor sources for an element a value of R of slightly below 1.0 could be expected since indoor dust typically has a higher content of organic matter [18].

The results found for the dust samples from Wels are mostly in the range of the results in other studies.

Table 2. Concentration ratio R for various metals

Type	Source	Al	Ba	Ca	Fe	K	Mg	Mn	Sr	Ti
R	[5]			1.15	1.17		1.58	0.86		
	[7]				0.81			1.41		
	[8]				0.86					
	[11]	0.88	1.04	0.55	1.02	1.01		1.03	1.14	1.22
	[12]	0.55	0.85	0.50	0.75	0.69	0.62	0.62	0.56	
	[13]	1.77	0.86	0.50	0.57	7.71	0.36	0.65	1.53	0.82
Average		1.06	0.92	0.68	0.86	3.14	0.85	0.91	1.08	1.02
R Wels	[14,15]	0.85	0.99	0.53	0.37	2.52	0.32	0.22	0.45	0.51

3.2. Concentration ratio R for heavy metals

The average concentrations of heavy metals in HD and RD samples available from the literature data are shown in Table 3.

Table 4 shows the concentration ratios R for heavy metals. In contrast to the results for the other metals the R values for heavy metals are generally higher. With very few exceptions the values are higher than 1.0 indicating increased heavy metal concentrations in HD. Similar results were found for the dust samples from Wels.

For Pb the value of R for the Wels samples was markedly smaller. This could be a result of the influence of older studies on the average value of R where leaded gasoline was still in use. The very fine lead-containing particles from the combustion of leaded gasoline can accumulate in house dust after atmospheric transport by

sedimentation from the indoor atmosphere. Such fine particles need stagnant air since their sedimentation velocity is less than 1 mm/s (Fig. 1). For the low value of R for Cr in the dust samples from Wels no explanation was found.

Table 3. Concentration of heavy metals in HD and RD (in mg/kg)

Type	Source	Cd	Co	Cr	Cu	Ni	Pb	Zn
c_{HD}	[4]	2.4		82.7	161	52,6	123	675
	[5]			133	157	93,2	155	926
	[6]		7.2		52.8		23	141
	[7]			15.9	74.8	27.5	74	512
	[8]				131		123	382
	[9]	1.9		11		10	517	202
	[10]			73.6	126		240	410
	[11]	6.5	8.9	86.7	206	62.9	406	717
	[12]	4.7	9.6	219	209	106	271	1210
	[13]	0.3	9.3	73[1]	230	54[1]	35.4	498
c_{RD}	[4]	1.7		84.3	100	24.4	82.3	296
	[5]			50.1	42.9	66.5	89.2	133
	[6]		5		47		27	49
	[7]			6.8	31.5	10.4	37	161
	[8]				38.7		46.7	164
	[9]	1.5		9.6		12	742	67
	[10]			73.0	168		125	116
	[11]	0.4	8.3	43.3	65.8	15.2	39.1	113
	[12]	2.2	6.7	177	139	58.5	146	912
	[14]	0.2	5.6	93[1]	127	22[1]	35.6	323

[1] Concentration of Cr and Ni analysed in original dust samples sieved with a 200 µm sieve

Table 4. Concentration ratio R for heavy metals

Type	Source	Cd	Co	Cr	Cu	Ni	Pb	Zn
R	[4]	1.43		0.98	1.61	2.16	1.49	2.28
	[5]			2.65	3.66	1.40	1.74	6.96
	[6]		1.44		1.12		0.85	2.88
	[7]			2.34	2.37	2.64	1.99	3.19
	[8]				3.39		2.63	2.33
	[9]	1.27		1.15		0.83	0.70	3.01
	[10]			1.01	0.75		1.92	3.53
	[11]	17.5[1]	1.07	2.00	3.13	4.14	10.4[1]	6.37
	[12]	2.11	1.43	1.24	1.50	1.81	1.86	1.33
Average[1]		1.60	1.31	1.62	2.19	2.16	1.65	3.54
R Wels	[13,14]	1.34	1.66	0,78	1.82	2.45	1.00	1.54

[1] Outlier value not considered in the calculation of the average

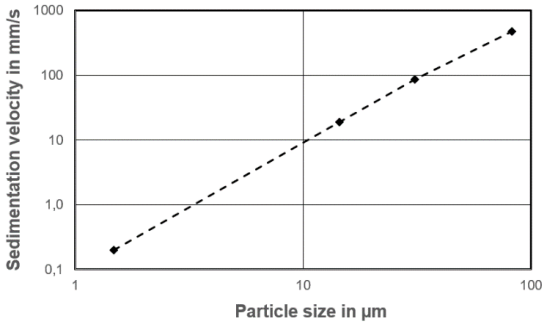

Fig. 1. ***Calculated sedimentation velocity in air for dust particles (assumed density 3000 g/cm³)***

3.3. Size dependence of the concentration ratio R

The size dependence of the concentration ratios R is shown in the following figures. Figure 2 shows the R values for elements where no strong size-dependence of R was found. These elements were Al, Ba, Fe, Mg, Mn, Sb, Ti and V.

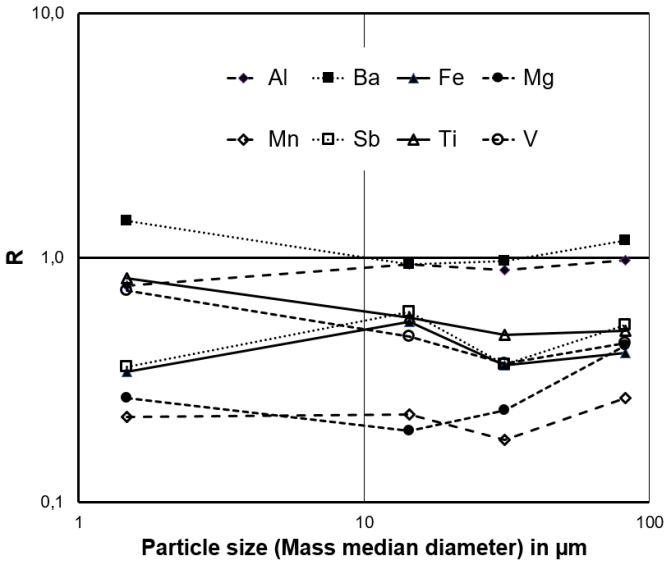

Fig. 2. ***Elements with nearly size-independent concentration ratio R***

Figure 3 shows the concentration ratios for the elements where R was significantly higher for the larger particles.

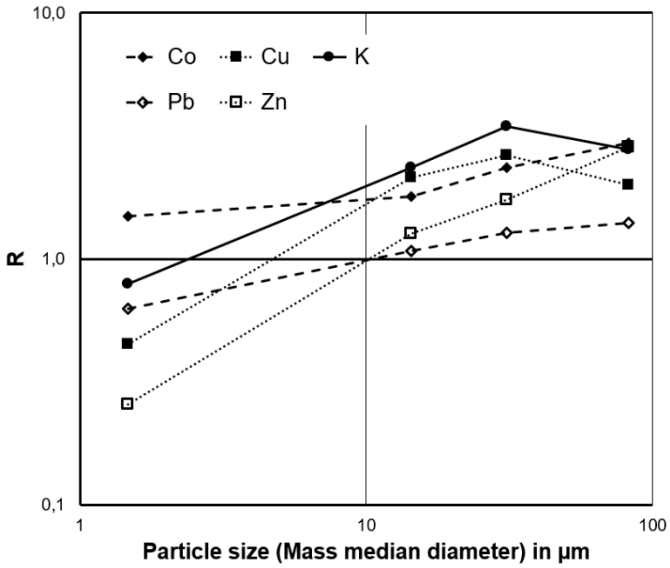

Fig. 3. ***Elements with higher concentration ratio R for larger particles***

For K a significant increase of the concentration in the coarser size fractions was found. This might be explained by indoor emissions. In this house a wood-fired tiled stove is used frequently for additional heating. Ash from biomass combustion is enriched in K and the particle size is typically larger than 10 µm even for most of the fly ash [19].

A similar strong size-dependence of R was found for Zn and Cu while for Pb and Co this dependence was less pronounced. The very similar behaviour of R for Cu and Zn might be explained by an indoor co-emission source. A possible source might be wear of parts made of brass, e.g. the door hardware which are common in the investigated house. Wear particles of brass are typically in the coarser size range [20,21].

Figure 4 shows the concentration ratios for the elements Ca and Sr where R was significantly lower for the larger particles. At the moment no explanation for the increased concentrations of Ca and Sr in the finest size fraction is available.

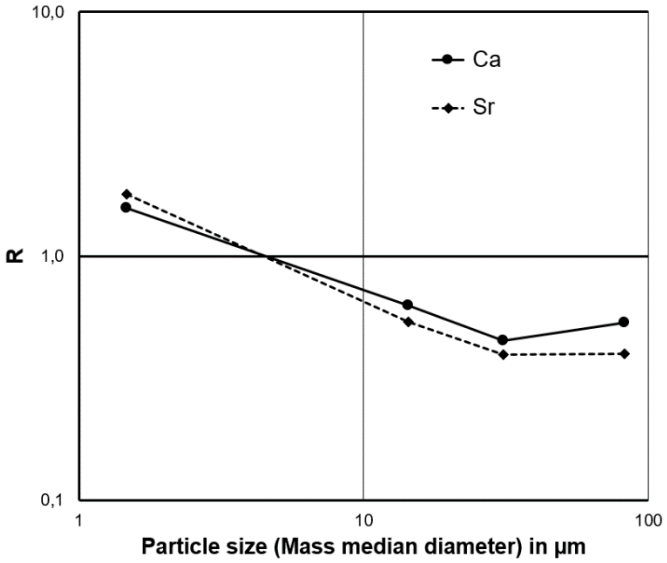

Fig. 4. ***Elements with lower concentration ratio R for larger particles***

4. CONCLUSIONS

The concentration ratios between HD and RD can vary considerably. A concentration ratio lower than 1.0 indicating negligible indoor emissions was found for the elements Al, Ba, Ca, Fe, Mg, Mn, Sr and Ti. Generally, high concentration ratios indicating significant indoor emissions were found for Cu, Ni and Zn and in most samples also for K. For Cd, Co, Cr and Pb the concentration ratios were typically between 1.0 and 2.0. However, in one study the concentration ratios for Cd and Pb were extremely high.

Size-dependent investigation of the concentration ratios was found to be an helpful tool to evaluate possible indoor sources of metals. The high concentration

ratio for K als well as for Cu and Zn in the Wels samples was indicatively assigned by this method to heating with biomass and to wear of brass, respectively.

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