Concentration ratio of copper to antimony in dust - an indicator for brake dust?

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Abstract Sources for antimony in road dust is abrasion of brake pads and brake linings and organic antimony compounds used as additives in grease and oil. Copper is also contained in brake linings and pads, but it is also contained in tire tread. Additionally, copper is released by wear and abrasion of parts made of copper, bronze and brass. In literature, the ratio of the concentration of copper to antimony is used as an indicator for the presence of brake dust in road dust. A ratio of around 5:1 is an indicator of brake-related particles, while the typical crustal ratio of the two metals is around 125:1. Reported values of the ratio for road dust samples are in the range of 20:1. Literature data of the size-dependent concentrations copper and antimony in road dust result in a ratio of copper to antimony of about 10:1 for the fine size fractions while for the coarse size fraction the ratio is higher. This result supports how reliable the ratio is as an indicator for brake dust in road dust.

Keywords: road dust, metals, brake dust, ratio copper to antimony

1. Introduction

Road dust is a complex mixture of particles found on the road surface which originates from both natural and anthropogenic sources. It contributes significantly to urban pollution, serving as a reservoir for various metals that have environmental and health consequences. The composition of road dust is influenced by factors such as traffic density, industrial activities, and local environmental conditions (Vlasov et al., 2022). Metals in road dust originate partly from the soil of the surrounding area. Additionally, metals are introduced through road traffic exhaust emissions, tire and brake wear, road surface abrasion, and atmospheric deposition. Metals detected in road dust include the heavy metals zinc, copper, lead, cadmium, chromium and nickel. The presence of these metals in road dust has significant implications for ecosystems and human health (Isinkaralar et al., 2024).

Brake wear is a notable source of antimony, as the metal is used in brake pad and lining formulations and organic antimony compounds are used as additives in grease and oil. (Iijima et al., 2007). Copper is contained in brake pads and linings as well as in tire tread and it is also released by wear and abrasion of parts made of copper, brass or bronze (Van Boheme and Van De Laak, 2003). The ratio of the concentration of copper to antimony was proposed as an indicator for brake dust in road dust with a ratio of around 5:1 being indicative of brake-related particles. In a tunnel study where the emission factors for total suspended particulate (TSP) and metals contained in TSP were determined, the ratio of copper to antimony in the TSP was between 2.9:1 and 5.4:1 (Sternbeck et al., 2002). In contrast, the typical crustal ratio for Cu and Sb is around 125:1 (Thorpe and Harrison, 2008). The ratio copper to antimony in road dust samples was for example 21:1 for Oslo, Norway (De Miguel et al., 1997) or 18:1 for Xi'an, China (Youngming et al., 2006) indicating a significant fraction of brake dust

The aim of this study was to investigate the particle size dependence of the ratio of copper to antimony in road dust. For this purpose, the literature was searched for studies reporting the size-dependent concentration of copper and antimony in road dust.

2. Material and methods

In the literature search for data, on the concentration of copper and antimony in road dust as a function of the particle size of the road dust, six studies were found. The basic information about these studies is summarized in Table 1.

For size fractions, obtained by sieving, usually only the size of the sieves is reported and no information about a representative particle size (e.g. mass median diameter) is available. In such cases, the geometric mean of the upper limit sieve size and the lower limit sieve size was used as representative particle size, except for the finest size fraction where the lower limit is zero. For this size fraction, 50% of the size of the upper limit sieve was used as a representative particle size.

3. Results and discussion

The ratio of copper to antimony as a function of the particle size resulting from the concentration data is shown in Figure 1. For the fine particle sizes, smaller than

20 µm, the concentration ratio is approximately 10:1. For the larger particle sizes, the ratio of copper to antimony increases with the particle size. This reflects the particle size distribution of brake dust generated by a brake dynamometer where the particles produced were typically smaller than 20 µm (Iijima et al., 2007).

This result supports the reliability of the ratio of copper to antimony as an indicator for brake dust in road dust.

Table 1. Road dust studies reporting size-dependent concentrations of copper and antimony

Year	Region	d_{max}* [µm]	Concentration data	Source
2000	Palermo, Italy	500	One composite sample°	Varrica et al., 2003
2006	Gela, Italy	500	Average of 8 samples from different sampling sites	Manno et al., 2006
2015	Chengdu, China	1000	Average of 27 samples from different sampling sites	Chen et al., 2016
2015	Turin, Italy	2000	Average of 29 samples from different sampling sites	Padoan et al., 2017
2016	Wels, Austria	200	Average of 4 composite samples°	Lanzerstorfer 2018
2017	Krakow, Poland	2000	Composite samples: one high traffic (H), one low traffic (L) °	Miazgowitz et al., 2020

° Composite sample: collected from a widely distributed road surface area

* Particle size of road dust included in the study

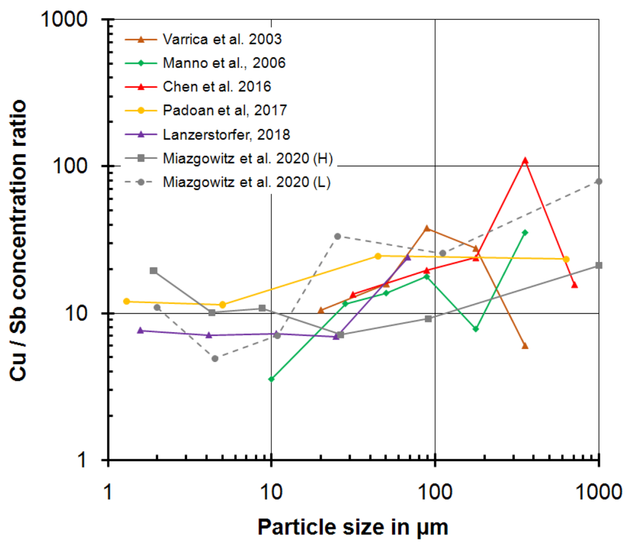

Figure 1. Size-dependence of the ratio Cu/Sb in road dust

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