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Composition and fate of mine- and smelter-derived particulates in soils from humid subtropical and semiarid areas

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Soils in the vicinity of non-ferrous metal smelters are often highly polluted by inorganic contaminants released from particulate emissions, which undergo weathering processes and release contaminants when deposited in soils. We studied the heavy mineral fraction, separated from mining- and smelter-affected topsoils, from both a humid subtropical area in the Zambian Copperbelt and a hot semi-arid area in the northern Namibia. High concentrations of metal(loid)s were detected in the studied soils: up to 1450 ppm As, 8980 ppm Cu, 4640 ppm Pb, 2620 ppm Zn. A combination of X-ray diffraction analysis (XRD), scanning electron microscopy (SEM/EDS), and electron probe microanalysis (EPMA) helped to identify the phases forming individual metal(loid)-bearing particles. Whereas spherical particles originate from the smelting and flue gas cleaning processes, angular particles either have geogenic origins or they are windblown from the mining operations and mine waste disposal sites. Sulphides from ores and mine tailings often exhibit weathering rims in contrast to smelter-derived high-temperature sulphides (chalcocite [Cu2S], digenite [Cu9S5], covellite [CuS], non-stoichiometric quenched Cu-Fe-S phases). Soils from humid subtropical areas exhibit higher available concentrations of metal(loids), and higher frequencies of weathering features (especially for copper-bearing oxides such as delafossite [$CuFeO_2$]) are observed. In contrast, metal(loid)s are efficiently retained in semi-arid soils, where a high proportion of non-weathered smelter slag particles and low-solubility Ca-Cu-Pb arsenates occur. Our results indicate that compared to semi-arid areas (where inorganic contaminants were rather immobile in soils despite their high concentrations) a higher potential risk exists for agriculture in mine- and smelter-affected humid subtropical areas (where metal(loid) contaminants can be highly available for the uptake by crops). This study was supported by the Czech Science Foundation projects (GACR 13-17501S and 16-13142S).