Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.33190

Mobility of trace metals and Cd, Zn, Pb isotopic compositions in dusts from electronic waste processing

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Dust generated during the crushing and abrasion of electronic waste materials in recycling processes poses severe environmental and health risks if released into the environment. Unlike dust from other industrial or natural processes, e-waste dust contains extremely high concentrations of toxic metals, glass and ceramic particles, and significant amounts of organic matter, primarily plastic particles.

This study investigates trace metal mobility and Pb isotopic composition in e-waste processing dusts using an isotopic approach and the BCR sequential extraction procedure. Dust samples were collected from diverse processing lines, including photovoltaic panels (PVP), LCD and CRT monitors, mixed e-waste units, and storage facilities (SF).

The results revealed extreme total concentrations, reaching up to 1,095 mg kg^{-1} Cd, 23,107 mg kg^{-1} Cu, 25,454 mg kg^{-1} Pb, and 31,082 mg kg^{-1} Zn. Sequential extraction procedure demonstrated that metal mobility is highly dependent on the type of e-waste processed. Zinc and copper generally exhibited high mobility across most samples. In mixed e-waste dusts, Cd (93–95%) and Pb (64–85%) were primarily released in the first two highly mobile fractions (acid-soluble and reducible), indicating an acute environmental hazard. Conversely, in CRT, LCD, and SF dusts, these elements were largely retained in residual fractions, as they are incorporated into stable glass or ceramic matrices.

Isotopic analysis identified three distinct Pb source clusters:

1. Cluster: Characterized by the highest $^{206/207}Pb$ and $^{208/207}Pb$ ratios, originating most probably from readily soluble salts, oxides, carbonates, and corroded coatings.
2. Cluster: Intermediate signatures representing more resistant compounds such as pigments (e.g., lead chromate), Pb–Sn solders, and PVC stabilizers.
3. Cluster: The least radiogenic Pb, corresponding to lead tightly bound within CRT glass and electronic ceramics.

The study concludes that mixed e-waste processing dusts present the highest environmental concern due to the combination of extreme concentrations and high mobility of Zn, Cu, Cd, and Li. While glass-rich dusts (CRT, LCD) pose a lower immediate risk, long-term monitoring is essential as weathering may eventually release these elements. Understanding these mobility patterns is crucial for the environmental risk assessment and management of industrial e-waste materials.

This work was financially supported by the Czech Science Foundation (GAČR), Grant No. 24-11519S.