

Mechanism of zinc and lead release from hydrothermal minerals into seawater; implications for impact assessment of seafloor metal-mining

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Sulfide minerals can be a potential source of metal-contaminated water, which has negative impacts on aqueous ecosystems. Metal dissolution process from terrestrial sulfide minerals have been extremely investigated in association with acid mine drainage (AMD) generation by mining. Recently, environmental impacts of seafloor metal-mining are discussed, however, there are less knowledges of the metal dissolution from seafloor hydrothermal sulfides into seawater. We therefore conducted seawater-based leaching experiments using fresh sulfide minerals at different temperature and redox conditions onboard D/V Chikyu. Selective dissolution of Zn and Pb from the samples were observed with different dissolution rates at different temperature and redox conditions for 1–30 h, although the solid samples contained abundantly various metals (i.e., Mn, Fe, Cu, Zn, Cd, and Pb). Two core samples containing much amounts of iron disulfide minerals (i.e., pyrite and marcasite) showed high dissolution rates of Zn ($1.6\text{--}2.9 \times 10^{-10} \text{ mol m}^{-2} \text{ s}^{-1}$) and Pb ($1.1 \times 10^{-10}\text{--}1.0 \times 10^{-11} \text{ mol m}^{-2} \text{ s}^{-1}$) under oxic condition at 20 °C. On the other hand, at the same condition, low dissolution rates of Zn ($1.6\text{--}6.6 \times 10^{-12} \text{ mol m}^{-2} \text{ s}^{-1}$) and Pb ($1.1 \times 10^{-12}\text{--}9.9 \times 10^{-13} \text{ mol m}^{-2} \text{ s}^{-1}$) the other two core samples which were abundant with sphalerite, galena, and/or silicified pyrite in the oxic condition. Fe was rarely released in the most of experimental conditions, though it was highly contained in the all samples. To estimate the dominant dissolution pathway, fragments of the mineral particulates used in the experiment were observed by scanning electron microscopy-energy-dispersive X-ray spectroscopy. Backscattered electron images of the mineral fragments showed that the high metal release samples contained lots of galvanic couplings of the iron disulfide and other sulfide minerals. In contrast, such couplings were less abundant or silicified in the other samples with less Zn and Pb releases. If oxidation of sulfide minerals is the dominant reaction, a large amount of Fe should be released with Zn and Pb because the oxidation rate of iron disulfides is similar to that of sphalerite and galena. Fe was absent at the most of experimental conditions, indicating that the galvanic interaction with iron disulfide minerals could induce greatly the selective dissolution of Zn and Pb from the natural hydrothermal minerals.

Keywords: seafloor metal-mining, metal-contaminated drainage, environmental impact assessment, galvanic cell interaction