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Column-Scale Tests of Biomagnetite Formation as a Long-Term Remediation Method for Sediments Impacted by Arsenic, Chromium, and Copper

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Shallow soils and sediments at the Collstrop site in Denmark are heavily contaminated with arsenic (As), chromium (Cr), and copper (Cu), containing an estimated 100 tons of As. Over time, these metals can be released into porewater and leach into the underlying shallow aquifer. Effective and long-term remediation approaches are needed to address surface water, soil, and groundwater contamination at the Collstrop site. Iron oxides are known to be effective sorbents for arsenic and other heavy metals, but many are susceptible to reductive transformations that can also solubilize contaminants, particularly As [1]. Magnetite is an effective sorbent and stable under a wide range of aquifer conditions. Even if co-precipitated minerals with sorbed As are transient, magnetite serves as a long-term As sink. Magnetite can be produced from the oxidation of ferrous iron by nitrate under sub-oxic conditions [2]. Microbially-induced magnetite precipitation (biomagnetite) removes dissolved As through a combination of structural incorporation and adsorption. This study investigated contaminant immobilization in two ways: (1) the effectiveness of biomagnetite and other precipitated iron oxides as a treatment method, and (2) the long-term stability of retained contaminants. We explored the potential of field-scale implementation by monitoring the injection of hundreds of pore volumes of artificial groundwater into the sediment columns. We evaluated the initial conditions, the impact of treatment, and the effect of different environmental perturbations intended to simulate future climate-change induced extremes. Column effluent was analyzed using inductively coupled plasma mass spectrometry (ICP-MS). Our results indicate that the precipitation of iron oxide minerals, including magnetite, facilitated the immobilization of As, Cr, and Cu. Dissolved pre-treatment concentrations for As and Cr were up to 4 mg/L and 500 µg/L, respectively. Consequent to treatment, dissolved As, Cr, and Cu concentrations dropped to <1 µg/L. Sustained reducing conditions released <8% of As and traces (<1%) of Cu and Cr. Increasing the quantity of Fe mineralization should decrease these releases and improve system performance. These findings have important implications for sustainable remediation of heavy metal contaminants in terrestrial environments.

[1] Nielsen, et al. (2011), *Chemosphere* 84, 383-389
[2] Sun, et al. (2016), *Environ. Sci. Technol.* 50, 10162-10171