

# Arsenic remediation by co-precipitation with magnetite: Insights from laboratory and field experiments

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Soils contaminated by anthropogenic arsenic (As) require effective remediation strategies to prevent transport of carcinogenic As to underlying groundwater. The co-precipitation of As with magnetite ( $\text{Fe}_3\text{O}_4$ ) is a promising As immobilization method for several reasons. First, magnetite can bind As in unique uptake modes, whereby As substitutes for tetrahedral Fe in the crystal structure, leading to highly effective As scavenging. Second, since magnetite contains both Fe(II) and Fe(III), this mineral might be more resistant to dissolution than Fe(III) (oxyhydr)oxides under reducing conditions known to release As. Despite these benefits, the long-term fate of As-laden magnetite and the As immobilization efficiency of co-precipitated magnetite in real soils are poorly documented.

This presentation reports two complementary datasets of As co-precipitation with magnetite: 1) laboratory studies of As-laden magnetite aging in oxic and anoxic conditions up to a year and 2) in-situ magnetite formation in soils of the Collstrop site, a large area in the Capital Region of Denmark polluted by >100 tonnes of As from previous wood preservation activities. For both datasets, changes in dissolved As were coupled with solid-phase analysis by synchrotron-based X-ray techniques, including bulk Fe and As K-edge XAS, XRF and spatially-resolved  $\mu$ -XANES.

The laboratory experiments indicated that magnetite consistently retained As over prolonged aging periods, with aqueous As levels remaining <1  $\mu\text{g/L}$  for all oxic and anoxic aging experiments. Although As was not released by magnetite, the XAS data revealed considerable changes in solid-phase As speciation with time, including a progressive increase in As incorporation, As(V) reduction during anoxic aging and As(III) oxidation during oxic aging. Consistent with the laboratory results, in-situ magnetite formation in the Collstrop soils decreased aqueous As mobility, which was attributed to (partial) As incorporation in magnetite demonstrated by the  $\mu$ -XANES analysis. However, in the same soils, particles with spectra consistent with  $\text{As}_2\text{O}_3$  were detected <1 cm from As-incorporated magnetite (Figure 1), highlighting the challenges of remediating heterogeneous soils. Taken together, these results show that As co-precipitation with magnetite is a promising immobilization strategy, but As remediation in the field can be controlled by multiple processes, with fluid flow and mixing playing key roles.

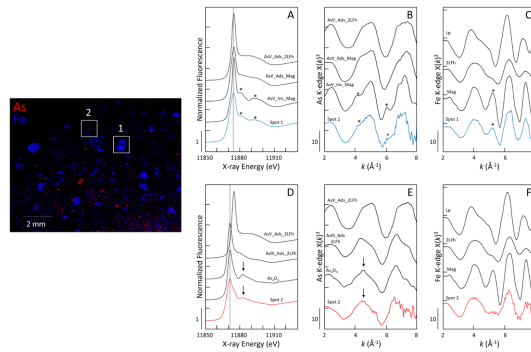


Figure 1: Synchrotron X-ray fluorescence (XRF) maps of As (red) and Fe (blue) for a sample of Collstrop soil amended with magnetite. For spots 1 and 2, the As K-edge XANES (A,D) and EXAFS (B, E) spectra are plotted along with reference spectra of As(V) and As(III) adsorbed to 2-line ferrihydrite and magnetite (AsV\_Ads\_2Lfh, AsIII\_Ads\_2Lfh, AsV\_Ads\_Mag, AsIII\_Ads\_Mag), As(V) incorporated in magnetite (AsV\_Inc\_Mag) and arsenite ( $\text{As}_2\text{O}_3$ ). The Fe K-edge EXAFS spectra of spots 1 and 2 are plotted along with ferrihydrite (f.h.) and Mag reference spectra. The \* symbols in panels A and B indicate spectral features consistent with As(V) incorporated in magnetite, whereas the arrows in D and E highlight features consistent with  $\text{As}_2\text{O}_3$ .