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Redox-driven contaminant dynamics: Fate, transformation, and remediation using inorganic oxide amendments

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Various amendments have already been tested for soil contaminant removal or immobilisation under specific laboratory conditions. However, changing external factors like water regime, which drives the redox dynamics, are usually omitted. Also, most research has been focused on contaminant behaviour rather than solid phase changes. Therefore, the main objectives of our study were to assess (i) the effect of soil water content (simulating seasonal changes, i.e. dry/wet periods) on the availability of contaminants in amended soils, (ii) the impact of various water regimes on Fe and Mn phases transformations, and (iii) Fe and Mn phases transformations in constructed wetland conditions during contaminant removal.

Following the research gap, two soil types with variable metal(loid) contents amended with nanoscale zero-valent iron (nZVI) were investigated under controlled soil moisture contents ranging from 0% up to 100% and flooded conditions. In addition, the effects of Mn oxides and Fe hydroxides as amendments were tested in experimental constructed wetlands with water-saturated (anaerobic) and unsaturated (aerobic) filtration beds, as well as in the presence and absence of plants. While inorganic contaminants were investigated in the soil system, the removal of organic micropollutants was examined in the constructed wetland.

The results showed the highest release of As for the flooded sample, while the highest Zn concentrations were observed at 60% of soil water holding capacity. The As mobilisation can be attributed to the partial reductive dissolution of Fe phases. The nZVI oxidation products showed to be highly effective for As immobilisation at around 60% of soil water holding capacity. The Fe and Mn (hydr)oxides significantly enhanced organic compound removal under saturated and unsaturated wetland conditions. Moreover, each (hydro)oxide showed efficiency for different micropollutants. In conclusion, variability of water contents strongly affected contaminant behaviour as a response to different stages of oxidation/reduction of the added Fe/Mn phases. The transformation of mineral phases provides very valuable information on the sustainable efficiency of the amendments used and can predict the fate of contaminants.