Fe and Cu isotope fractionation in acidic mine tailings: modification and application of a sequential extraction method

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As mine tailings have a high potential for contamination of the environment, it is crucial to develop methods for the prediction of their environmental impact. A sequential extraction method for the separation of potential Fe-bearing minerals was examined and modified for Cu, using a six step sequential extraction method for Fe (step 1-6: MQ-extractable, NH_4-acetate-extractable, a dithionite-leach, NH_4-oxalate-extractable, $KClO_3$/HCl-extractable and residuals). For Cu, a four step method was used (step 1, 2, 4 & 6). Metal isotope fingerprinting was in the focus of this study, thus isotope fractionation during the extraction was investigated. The procedure led to a small decrease in the element concentration, but the isotope compositions were within the error.

We applied the sequential extraction method to samples from a porphyry copper mine tailing in the Atacama Desert in Chile (Chañaral Bay) in order to gain information on the processes resulting in Fe and Cu mobilization. Both, Fe contents and Fe isotope compositions are homogeneous with depth ($\delta^{56}Fe \approx 0.2$-$0.3$ ‰) and only the deepest samples at ~60 cm exhibit lighter $\delta^{56}Fe$ values (~0 ‰). The Cu isotope compositions of all bulk samples and individual fractions (except the Cu sulfides) of one site (Ch1) exhibit a decrease of the $\delta^{65}Cu$ values from the depth towards the surface (the direction of water flow). These data in combination with the pH indicate preferential adsorption of the ^{65}Cu on Fe(oxy)hydroxides at site Ch1, associated with Cu isotope fractionation. Another site (Ch12), where the pH at depths was likely not high enough for the formation of such Fe-minerals, shows only minor Cu isotope fractionation.

Our results show that sequential extractions in combination with stable isotope analyses provide important information on the distribution of Fe and Cu between different mineral phases like sulfates, oxides and sulfides and thus improve our understanding of processes occurring in mine tailings.