Understanding the residence of Co in ore minerals - towards the development of novel Co extraction strategies for laterite deposits

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Cobalt has unique properties highly valued for many applications essential to the green economy. It has been classified as a critical raw material due to the particularly high risk of supply shortage and its importance for the value chain. Despite low crustal abundance (25ppm), Co is concentrated by various geological processes to concentrations suitable for mining, however the majority of Co is recovered as a by-product of Cu and Ni processing in three principal geological settings: hydrothermal, magmatic and lateritic.

Cobalt-rich laterites, which provide 20% of the world's Co, are mainly processed using energy-inefficient pyrometallurgical techniques or high-pressure acid leaching technologies often optimised for extraction of other elements, which can leave between 50 and 80% of the Co unrecovered. In order to develop more efficient Co extraction strategies, understanding the residence of Co in ore minerals is essential. To this end, we are undertaking a detailed mineralogical, chemical and atomistic-scale characterization of Co in samples from a range of laterite deposits.

Bulk samples representative of the average ore material were sourced from a variety of undeveloped laterite deposits: Shevchenko (Kazakhstan), Acoje (Philippines), Nkamouna (Cameroon) and Piauí (Brazil). Bulk chemical and mineralogical characterisation was undertaken with ICP-OES/MS and XRD, followed by spatially resolved chemical and mineralogical imaging at the micron scale using μXRD, EPMA, SEM and synchrotron-based μXRF. The chemical state and local environment of Co were determined using X ray spectroscopy (μXANES and μEXAFS).

The total concentrations of Co ranged from 630 to 2780 mg/kg. The ore mineral assemblage in the various samples includes goethite, maghemite, hematite, quartz, talc, serpentines, chlorites, smectites, kaolinite and chromites. Manganese oxide minerals are present but, due to their poor crystallinity and low concentration, are not routinely detectable with bulk XRD. These low abundance minerals, identified in the samples using Raman spectroscopy, μXRD and EPMA, proved however to be very important Co-hosting phases.
Electron microscopy and μ-XRF mapping revealed a strong Mn and Co association in all samples but little correlation between Co and Fe. The important determinant of Co concentration is thus its association with Mn oxides, a variety of which have been found in the samples studied. For example, in Shevchenko laterite asbolane was identified with Co concentrations varying from 0.25 to 12.4 wt% (6.3 wt% on average). Goethite was found to carry only minor Co i.e. below 0.03 wt% or 0.1-0.2 wt%. In samples from the Nkamouna laterite Mn oxide minerals were found to contain Co ranging widely from below 1 wt% in tectomanganate phases such as hollandite and pyrolusite, 5.5% wt% in lithiophorite and up to 21 wt% in lithiophorite-asbolane intermediates. No Co or minor Co (<0.1 wt%) was detected in Fe oxides and oxy-hydroxides. XANES spectroscopy shows that Co is bound in a range of Mn oxide minerals as Co^{3+}. The structural environment of Co in these minerals is very similar with Co in octahedral coordination. Analysis of the EXAFS data for asbolane shows an apparent high degree of structural order around Co which suggest that Co is present as clustered aggregates.

Our results indicate that Co should be efficiently and selectively removed from the studied laterites by targeted solubilisation of Mn oxides, which can be achieved via, for example, microbially mediated reductive mineral dissolution.