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Waste or wealth: exploring nickel pools in mining residues through sequential extraction, scanning electron microscopy and X-ray diffraction

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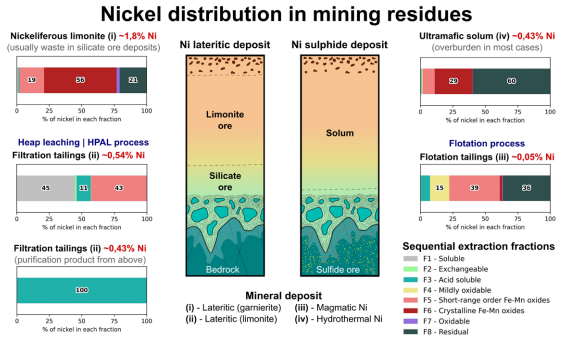

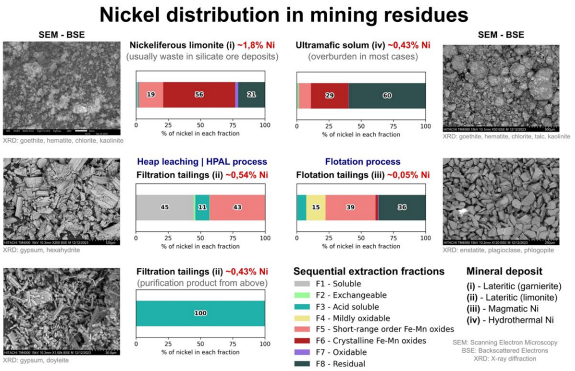

Efforts to reduce CO_2 emissions are globally increasing the demand for metals, and nickel is a key component of electric batteries. Mining residues – waste and tailings – often contain metals, but their use as a metal resource is rarely considered viable due to low grades or complex metallurgical processes. The disposal of mining residues in piles or dams can contaminate soil and water, posing health risks. Thus, it is crucial to develop ways to exploit these residues, which requires an understanding of metal distribution.

We evaluated five residues: **(a, b)** heap leaching tailings, two types of filtration cakes, **(c)** flotation tailings, **(d)** nickeliferous limonite waste, and **(e)** solum overburden; from four different types of mineral deposits in Brazil: **(i, ii)** lateritic, both nickeliferous limonite and garnierite, **(iii)** magmatic sulfide, and **(iv)** hydrothermal nickel. Samples were analyzed in triplicate using an 8-step sequential extraction[1] with the following operational fractions: soluble, exchangeable, acid soluble, mildly oxidable, short-range order Fe-Mn oxides, crystalline Fe-Mn oxides, oxidable, and residual. We also performed XRD and SEM-BSE/EDS analysis on all samples.

Our results indicate that nickel is present in concentrations ranging from 0.04% to 1.8% and its fractionation in the residues varies widely (Fig.1), ranging from highly bioavailable (>90%) to poorly bioavailable (<10%), depending on mineralogy. Tailings from heap leaching are primarily composed of gypsum and hydroxides, as shown by the diffractograms, and exhibit the highest nickel bioavailability under oxic, surface conditions. The purification process removes soluble minerals and short-range order Fe oxides, resulting in almost pure gypsum as observed in the BSE images (Fig.2). Nickeliferous limonite contains over 75% of its nickel associated with short-range order Fe-Mn oxides (19%) and crystalline Fe-Mn oxides (56%), which could become bioavailable under anoxic conditions. The same applies to the solum, although with lower bioavailability due to a higher residual fraction. In flotation tailings, nickel is likely associated with remnant sulfides after flotation, as its extraction from pyroxenes appears unlikely. Nature-based solutions, such as phytomining and bioleaching, could offer an alternative and sustainable approach to metal recovery.

[1] Filgueiras, Lavilla & Bendicho (2002), *Journal of Environmental Monitoring* 4, 823-857.