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Niobium Mobility in Mine Tailings Waters

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Niobium is one of the least mobile high field-strength elements in near-surface environments due to its strong affinity for oxygen and low solubility [1, 2]. However, ICP-MS data from carbonatite systems suggest Nb mobility may be underestimated under circumneutral conditions. This study investigates Nb speciation and transport at the Oka carbonatite complex (Quebec, Canada) using tangential flow filtration (≥5 µm, 0.65 µm, 0.22 µm, 100 kDa) combined with thermodynamic modelling [3].

The ≥5 µm permeate records the highest Nb concentrations (up to 0.50 µg/L). The 0.65 µm retentate contains the largest proportion of Nb, with concentrations much greater than smaller fractions. Minimal Nb occurs in the 0.22 µm retentate, and across permeate fractions (0.65 µm, 0.22 µm, 100 kDa). This distribution indicates Nb occurs both as dissolved $Nb(OH)_6^-$ and associated with colloids >0.65 µm. Thermodynamic modelling indicates weathered Nb occurs predominantly as $Nb(OH)_6^-$ under circumneutral pH and ionic strength conditions at Oka [3]. Negligible Nb–F complex formation suggests fluoride does not enhance mobility in this system.

Elevated Fe and Mn coincide with redistribution of Nb into the 0.65 µm fraction, particularly at site PO-13, where in situ oxidation promotes Fe–Mn oxyhydroxide colloid formation. Nb shows strong positive correlations with Fe ($R^2 = 0.806$, $P < 0.0001$) and Mn ($R^2 = 0.735$, $P < 0.0001$). This fraction-specific relationship supports Nb association with Fe–Mn oxyhydroxides rather than transport as detrital pyrochlore fragments, which would exhibit behaviour similar to Zr.

These findings show Nb mobility in near-surface carbonatite environments is controlled not only by mineral weathering but also by secondary colloidal processes that enhance transport. This reconciles thermodynamic predictions with field observations and has implications for metal transport and recovery from mine-impacted waters.

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