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Investigation of Uranium (VI) Uptake by Rhodochrosite in a Flow-Through Setup

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Widespread uranium (U) contamination exceeding 30 µg L^{-1} (WHO, drinking water limit) in Indian aquifers has been reported in recent years. Lower probabilities of U contamination in groundwaters were associated with the presence of elevated manganese (Mn), likely controlled by rhodochrosite [$MnCO_{3(s)}$] solubility.[1] A recent study on U(VI) fate in waters supersaturated with respect to $MnCO_{3(s)}$ indicated U uptake via incorporation within the lattice of precipitated rhodochrosite.[2] However, the extent and kinetics of U incorporation within rhodochrosite and the stability of such immobilized U in aquifer-relevant conditions is not well understood. In this contribution, we evaluated the fate of dissolved U in a flow-through experimental set up in the presence of 2.5 g L^{-1} $MnCO_{3(s)}$ until steady state was achieved. Ultrapure water containing 5 µM U was passed through a 58 mL continuous flow stirred tank reactor at a hydraulic retention time of ~1 h, which was sufficient for U sorption on rhodochrosite in previous batch studies. The initial U concentration was chosen to maintain undersaturated conditions with respect to any U-bearing solids. Effluents were collected at regular intervals using a fractional collector and analysed for dissolved U, Mn, and inorganic carbon. Results indicated continuous U uptake up to 80% of influent U for 2 h, which then gradually decreased to ~60% at the end of the experiment (8 h). X-ray diffraction (XRD) analysis of reacted solids confirmed the presence of rhodochrosite with no signature of any U-bearing solid phase (Figure 1(a)). Scanning electron microscopy associated energy-dispersive X-ray (SEM-EDX) spectroscopy and other solid phase characterisation techniques confirmed the presence of U in rhodochrosite (Figure 1(b)). Results from modelling of this kinetic data and longer flow-through experiments at variable flow rates and matrices will be presented to quantify the U uptake capacity of rhodochrosite and to evaluate the remobilization potential of U in such systems. Inferences from this study will aid in understanding the role of carbonate-bearing minerals in U mobilization/ immobilization in carbonate-buffered aquifers.

[1] Mohapatra et al. (2021), ACS Earth Space Chem., 5(10), 2700-2714.

[2] Sujathan et al. (2025), Langmuir, 41, 1, 140–151

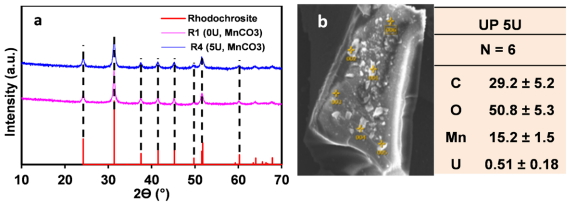

Figure 1. Solid phase characterisation of solids collected at the end of the experiment: XRD diffractogram confirming the absence of any known U-bearing solid (a) and elemental atomic percentages identified through SEM-EDX show the presence of U in reacted solids (b).