

Geochemical characteristics of petroleum coke deposits at an oil sands mine, Alberta, Canada

J. A. NESBITT AND M. B. J. LINDSAY*

Department of Geological Sciences, University of Saskatchewan, Saskatoon, SK, S7N 5E2, Canada
(*correspondence: matt.lindsay@usask.ca)

Petroleum coke is produced during upgrading of oil sands bitumen to synthetic crude oil. This carbonaceous byproduct is generally stored in large, sub-aerial deposits along the margins of tailings ponds. The water table within these deposits is commonly positioned near surface creating a shallow unsaturated zone; the geochemistry pore-water within the underlying saturated zone is initially derived from oil sands process water (OSPW). This pore water contains elevated concentrations of major ions (Na , $\text{Cl} > \text{SO}_4 > \text{Ca} > \text{Mg}$, K) and various organic carbon compounds. Consequently, the water table represents a distinct transition from oxic to anoxic conditions. A detailed geochemical investigation of three petroleum coke deposits was conducted to examine solid-phase and pore-water geochemistry. Continuous core samples were obtained at twelve locations within these deposits and multi-level monitoring wells were installed at eight of these locations.

Solid-phase geochemistry was examined to constrain both the abundance and speciation of major and trace elements. The elemental composition (w/w) of petroleum coke solids ($n = 32$) was dominated by C ($84 \pm 2.4 \%$) and S ($7.0 \pm 0.3 \%$), with lesser amounts of Si ($0.93 \pm 0.31 \%$), Fe ($0.48 \pm 0.12 \%$) and Ti ($0.14 \pm 0.04 \%$). The most abundant trace elements were V ($1300 \pm 120 \text{ mg kg}^{-1}$) and Ni ($230 \pm 79 \text{ mg kg}^{-1}$).

Depth profiles of stable isotopes of water ($\delta^2\text{H}$, $\delta^{18}\text{O}$) revealed distinct zone of mixing between meteoric waters and OSPW over a 1 to 2 m depth interval immediately below the water table. This mixing zone corresponded to elevated pore-water V (up to 3 mg L^{-1}) and Ni (up to 0.12 mg L^{-1}) concentrations. However, V and Ni concentrations decreased substantially with increasing depth below this mixing zone.

Bulk X-ray absorption spectroscopy (XAS) performed at the S, V, Fe and Ni K-edges revealed subtle variations in oxidation states and bonding. However, results of the V K-edge XAS measurements suggest V oxidation from V(IV) to V(V) may contribute to V release. Mechanisms of V attenuation remain an active topic of investigation. Results of this study suggest that oxidative weathering of oil sands petroleum coke can release V and Ni to pore water. Therefore, storage of petroleum coke in anoxic environments may reduce potential for their release.