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Managing Acid Mine Drainage in Froth Treatment Tailings: Lessons from Long-Term Column Experiments

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Oil sands surface mining in Alberta, Canada generates several tailings waste streams, including Tailings Solvent Recovery Unit (TSRU) tailings, a type of froth treatment tailings produced during solvent recovery following paraffinic froth treatment. These tailings contain elevated concentrations of pyrite and therefore have acid mine drainage (AMD) potential, posing reclamation challenges. Mitigation strategies such as soil caps may limit pyrite oxidation and support vegetation establishment. This study combines a three-year greenhouse experiment with a column leaching study to evaluate how capping design, hydrology, and weathering history influence acidity generation and solute release in TSRU tailings.

In the greenhouse study, columns containing TSRU tailings were capped with varying designs of peat mineral mix (PMM) and coarse sand tailings (CST) under upland and wetland conditions. A 30 cm PMM cap supported both upland and wetland vegetation over three years, while a multilayer cap of 30 cm PMM over 20 cm CST further improved plant survival and delayed tailings acidification. Although TSRU tailings acidified rapidly across most treatments (pH $\leq$ 2), pyrite oxidation rates differed between systems, with lower rates observed under wetland conditions, likely reflecting differences in oxygen availability and moisture conditions.

To assess the geochemical consequences of these management strategies, tailings recovered from selected greenhouse treatments were subjected to a six-month column leaching experiment under alternating wet–dry cycles. Un-weathered tailings, semi-weathered tailings capped with 30 cm PMM, and weathered un-capped tailings were compared to represent progressive stages of AMD development. Geochemical analyses of leachates and solids, supported by XRD and XPS, showed that un-weathered tailings exhibited active sulfide oxidation and increasing sulfate and metal release, while semi-weathered tailings displayed attenuated solute release. Weathered tailings maintained the lowest pH but reduced dissolved loads, consistent with advanced AMD characterized by extensive prior oxidation and sulfate retention in secondary minerals.

Together, these results demonstrate that TSRU tailings retain long-term AMD potential regardless of capping design studied, while weathering history strongly controls the dominant geochemical processes and expression of acidity. Cap designs can support vegetation establishment and alter oxidation pathways but do not fully prevent sulfide oxidation, underscoring the need for long-term geochemical controls.