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Long-term Acid neutralization and Metal(loid)s Attenuation of Oil Sand Mine Materials under Anoxic Conditions; Laboratory Column Experiments

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Northern Alberta's oil sands mining operations produce large volumes of overburden and extraction tailings with varied geochemical, mineralogical, and hydrogeological characteristics. Oxidative weathering of sulfide minerals in froth treatment tailings (FTT) has shown the potential to generate porewaters characterized by circumneutral to acidic pH (<3 to ~8) and elevated concentrations of several metal(loid)s, including Fe, Zn, Ni, Co, Cu, and As. The potential for acid generation and dissolved metal(loid)s mobilization from oxidizing FTT highlights the potential for closure designs to include mitigation strategies that enhance acid neutralization and metal(loid)s attenuation, thereby reducing dissolved mass loadings to receiving environments. Although mineral dissolution reactions within FTT deposits promote acid neutralization and metal(loid) attenuation, other mine materials could enhance these mitigation reactions within reclamation landforms. We conducted laboratory column experiments under anoxic conditions to assess the long-term acid neutralization and metal(loid)s attenuation capacity of oil sand reclamation and overburden materials (i.e., peat and glacial till) and extraction tailings (i.e., coarse sand tailings). Two simulated FTT pore waters with an influent pH of 4.5 and 7.5 were pumped through columns for 324 days. In general, all materials increased the effluent pH to near-neutral conditions (~7 to 8) and produced substantial alkalinity. Peat and glacial till maintained higher and more persistent effluent pH, whereas coarse sand tailings showed a late-time decline in both pH and alkalinity. Extensive removal (>92%) of Co, Cu, Ni, Zn, As, V, and Se was observed in all columns. In contrast, Mo exhibited strong pH-dependent behaviour, with greater retention under acidic influent conditions but limited retention under circumneutral conditions. Sequential extractions experiment on post-experiment solids and geochemical modelling indicated that metal(loid)s attenuation in these columns was governed mainly by (i) sorption, ion exchange and surface complexation on organic and mineral surfaces and (ii) association with secondary Fe phases. Our results demonstrate that these oil sands mine materials can promote acid neutralization and metal(loid)s attenuation reactions, and the geochemical reactions between FTT porewater and these mine materials could be leveraged during closure planning and landform design to provide additional mitigative capacity.