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Methane production and consumption dynamics in fluid fine tailings of an oil sands pit lake

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The reclamation of oil sands mining sites and tailings is a regulatory obligation for oil sands mine operators, ensuring the restoration of post-mining landscapes to locally common, functional ecosystems. Water-capped tailings technology, which involves capping the tailings with water to create a pit lake, is a developing oil sands mine reclamation technology. Over time, these pit lakes are expected to develop into fully functional boreal lake ecosystems, with improvements in water quality driven by freshwater inputs and in-situ biogeochemical processes. Base Mine Lake (BML) in Alberta, commissioned by Syncrude Canada Ltd in 2012, serves as the first commercial demonstration of water-capped tailings technology. While monitoring BML, methane emerged as a key component in the biogeochemical cycling of petroleum-related contaminants and the overall development of the lake. Methane is produced by the methanogens in fluid fine tailings (FFT), then transported to the water column through diffusion, advection, and ebullition. Methane ebullition has the potential to facilitate the transfer of organic compounds from FFT to the water column. A comprehensive understanding of both methane production and consumption is crucial for predictions regarding the future development of BML. Microcosm studies revealed continuous methane production in BML FFT, variable between depths and locations, with rates comparable to natural systems. The methane production rates measured in BML FFT are strongly correlated with the naphtha content, suggesting that naphtha serves as the carbon source for the FFT microbial community, resulting in methane generation. Analysis of microbial phospholipid fatty acid (PLFA) carbon isotopes, specifically the C16:1 PLFA, reveals substantial $\delta^{13}C$ depletion in shallow FFT of specific areas within BML, suggesting methane oxidation by methanotrophs despite the anoxic conditions within the FFT. The PLFA ^{13}C isotope pattern aligns with observations in the water cap from previous years, thus may be the result of physical water exchange at the FFT-water interface, potentially related to ebullition. These findings on methane dynamics in water-capped tailings technology have direct implications for optimizing oil sands reclamation in the future, and for understanding biogeochemical processes in other carbon rich methane generating sediments.