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Tracing Methane Cycling in Oil Sands Tailings Facilities through Lipid Biomarkers

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Canadian oil sands represent one of the largest oil reserves globally, with most operations concentrated in the Athabasca Oil Sands Region (AOSR). As part of the oil extraction process, oil sands facilities produce tailings – a mix of residual bitumen, lighter hydrocarbons, water, sand, fine silts, clay, and inorganic matter. Hydrocarbons present in tailings may be transformed into methane via methanogenic microbes, while methane consumption is controlled by aerobic or anaerobic methanotrophy. However, the balance of these processes is not well characterized in tailings facilities. This study investigates microbial methane cycling in oil sands tailings facilities with a range of methane fluxes using lipid biomarkers to provide insights into microbial abundance and distribution through the water column and across the sediment (fluid fine tailings - FFT) water interface. Water and FFT samples were collected from two tailings facilities within the AOSR. Aerobic methanotrophic communities were characterized using phospholipid fatty acid (PLFA) lipid biomarkers, while archaea were profiled using archaeaol and glycerol dialkyl glycerol tetraethers (GDGTs). Within this organic rich-matrix, lipid biomarkers of archaea, in particular, are not well studied.

PLFA results show a dominance of mono-unsaturated fatty acids, including the biomarkers C16:1Δ9 and C18:1Δ9, associated with type I and type II methanotrophs, respectively. The presence of oxygen within the water column and the higher methane concentration in the FFT (~5000 µmol) support the presence of methanotrophy. This pattern was consistent throughout the water column and FFT at both facilities. Moreover, lipid abundance and composition varied with depth, indicating shifts in microbial distribution. Notably, the relative abundance of C16:1 PLFAs increased at greater depths. Preliminary analysis of archaeal lipids suggests methanogen biomass is below detection down to the FFT-water-interface. Ongoing biomarker work combined with stable isotope analysis will provide greater insight into methane cycling within tailings facilities. The high abundance of hydrocarbons in tailings highlights the need for improved analytical strategies tailored to these complex matrices. Overall, this work advances our understanding of microbial methane cycling in complex oil sands tailings, which are still poorly understood.