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Compound specific isotope insights into microbial petroleum and methane cycling during oil sands reclamation

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Microbial biogeochemical cycling of petroleum hydrocarbons and methane is an important aspect of remediation and reclamation of sites impacted by residual petroleum hydrocarbons. Base Mine Lake (BML) is the first full scale pit lake in the Alberta Oil Sands Region and is an important component of site closure plans for Syncrude and for many other sites, as well as being an analogue for petroleum impacted sites such as harbours, spill sites or pipeline leaks. Assessing the extent of microbial biodegradation of petroleum hydrocarbons and the associated production and consumption of methane is critical to assessing the effectiveness of microbial processes to mitigate contaminant impacts. In BML radiocarbon contents ($\Delta^{14}C$) of phospholipid fatty acids (PLFA) demonstrated that petroleum derived carbon was the dominant carbon source throughout BML initially. Increased $\Delta^{14}C$ of PLFA in the epilimnion indicated recent inputs of photosynthetically derived carbon into microbial biomass. The increased microbial metabolism of more bioavailable organic carbon sinking from the epilimnion is hypothesized to be contributing to the development of anoxic conditions increasingly observed at depth in BML. Development of anoxia may reduce aerobic methane oxidation, the primary sink for methane within BML as indicated by depleted $\delta^{13}C$ of C:16:1 biomarker PLFA. Notably, the isotopic signature of aerobic methanotrophy persisted to 0.5 to 1 m depth at several sites in BML, despite anoxic sedimentary conditions. The source of this biosignature is not yet clear but is hypothesized to indicate downward advection of oxygen during ebullition. $\Delta^{14}C$ of methane bubbles showed that while the majority of methane was derived from petroleum, the location with the highest ebullition rate had methane with modern $\Delta^{14}C$ values, implying a distinct, high flux source to this location. The ability to resolve between microbial metabolism of more favourable, recently fixed organic carbon versus recalcitrant petroleum carbon elucidates the extent to which microbial biodegradation is removing petroleum and contributing to methane emissions, thus informing effective reclamation, remediation and mitigation strategies. Similar differentiation is required for other sites where microbial metabolism of recently fixed carbon inputs may imply biodegradation of recalcitrant carbon when this is not occurring.