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# Iron mineral-microbe interactions for hydrocarbon biodegradation predict methane dynamics in oil sands tailings

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Surface mining of shallow oil sands deposits that cover ~500 $km^2$ in Alberta, Canada, produces large volumes of fine tailings (FT). The current volume of FT in tailings ponds has increased to >1.5 billion $m^3$, requiring effective reclamation. FT is a slurry of fine solids with residual hydrocarbons from bitumen and diluent. Diluent is a distillate containing a light fraction of hydrocarbons ($C_6$-$C_{10}$ for naphtha) and is used to improve bitumen recovery during the extraction process. Indigenous microorganisms in FT biodegrade residual diluent hydrocarbons (labile fraction: ~40%) into methane under anaerobic conditions, which may affect FT reclamation in aquatic closure scenarios along with causing climate change. FT contain appreciable amount of iron containing minerals that can influence microbial metabolism. Therefore in laboratory experiments, we investigated effect of different iron minerals, including amorphous ferrihydrite ($Fe^{III}$) and crystalline magnetite ($Fe^{III,}$ $Fe^{II}$), hematite ($Fe^{III}$) and pyrite ($Fe^{II}$), on methane production from diluent naphtha biodegradation in FT. Indigenous microorganisms in ferrihydrite-supplemented FT biodegraded 27% of naphtha hydrocarbons, including monoaromatics and *n*-alkanes, under Fe-reducing conditions during ~350 days of incubation. Methane production was suppressed by ~55% relative to FT without ferrihydrite addition, suggesting a shift in carbon flow from methane to carbon dioxide under Fe-reducing conditions. Fe-reducers, *Geothermobacteraceae* and *Coriobacteriaceae,* were involved in hydrocarbon biodegradation. Crystalline mineral magnetite accelerated methane production by enhancing the kinetics of hydrocarbon biodegradation for monoaromatics, *n*-alkanes, *iso*-alkanes, and cycloalkanes (~45% of naphtha) over ~1000 days of incubation. Enrichment of *Coriobacteriaceae*, along with *Syntrophus, Smithella, Peptococcaceae*, *Methanosaeta* and *Methanoregula,* suggested the development of electric syntrophy in the presence of magnetite to facilitate methane production. Hematite and pyrite-supplemented FT produced methane from hydrocarbon biodegradation at the same extent and rate as observed in FT without Fe mineral addition during ~500 days of incubation. These findings suggest that the effects of iron minerals on C cycling vary depending on their physicochemical properties. Ferrihydrite might be a suitable amendment to reduce $CH_4$ production from oil sands tailings. Metagenomic analysis and modelling of the redox process are in progress to understand the metabolic pathways of hydrocarbon biodegradation and to predict *in situ* $CH_4$ mitigation potential.