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Understanding and modeling of biogeochemical processes in oil sands tailings for reclamation and mitigation of methane emissions

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Bitumen extraction from surface-mined oil sands that cover ~500 km^2 in Northern Alberta produces fluid fine tailings (FFT), a slurry consisting of fine solids, residual bitumen and diluent. FFT is deposited temporarily in tailings ponds pending reclamation creating an inventory of ~1.39 billion m^3. Tailings ponds also contribute 2.8 million metric tonnes CO_2 eq. primarily methane (CH_4) per year to total provincial emissions. Methane emissions result from the biodegradation of residual diluent hydrocarbons (~41% labile fraction) entrained in FFT. To manage huge FFT inventory, establishing end-pit lakes is a viable reclamation option where FFT (untreated or treated with a coagulant) are deposited in mined-out pits and covered with water, expecting the gradual development into self-sustaining aquatic ecosystems. However, ebullition of CH_4 may cause chemical flux along with bitumen transfer from underlying FFT to overlying cap water., thereby impacting sustainable management of EPL. In this context, we investigated the effectiveness of redox amendment such as sulfate (a constituent of coagulant) on CH_4 suppression from diluent hydrocarbon biodegradation. Oil sands operators treat tailings with coagulants such as alum, gypsum or ferric sulfate to accelerate tailings consolidation that eventually lead to high levels of sulfate in tailings. Our laboratory studies revealed that ~38% of diluent hydrocarbons (labile fraction), including monoaromatics, *n*-alkanes and *iso*-alkanes were biodegraded under sulfate-reducing conditions by Desulfocapsaceae, Desulfosarcinaceae, and Syntrophobacteraceae without any CH_4 production. Using the laboratory findings, an holistic model was developed to estimate kinetics of hydrocarbon biodegradation under sulfate-reducing conditions and quantification of sulfate required to mitigate CH_4 emissions *in situ.* Model application using the largest tailings pond (Mildred Lake Settling Basin) as a case scenario projected 95-100% CH_4 mitigation when sulfate amendment was calculated considering both labile fraction of diluent hydrocarbons plus other endogenous organic compounds. We are also investigating the nature of reduced sulfur compounds produced during biodegradation of hydrocarbons under sulfate- reducing condition while assessing different amendments such as ferric sulfate, alum, and gypsum to immobilize/precipitate them in FFT sediment to avoid environmental implications. The findings have great potential in devising a strategy to accelerate reclamation process at landscape level and mitigate CH_4 emissions.