Assessing the Potential of Natural Source Zone Depletion (NSZD) of Hydrocarbon as a Cold-Climate Soil Remediation Strategy

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Summary

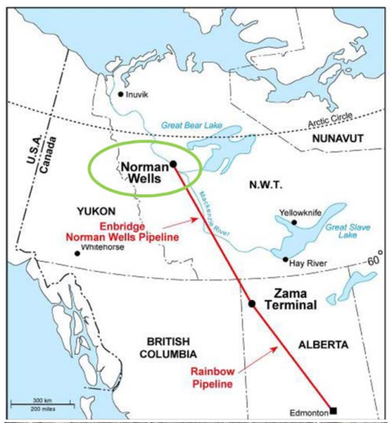
Imperial sought to determine if quantifiable NSZD could be discerned at an Arctic operating site. Using two different CO_2 efflux monitoring technologies, indications of biodegradation were observed at an LNAPL-impacted site in the late summer of 2015. However, similar observations were not made during the early spring and early fall of 2016. These observations, coupled with soil temperature data, suggests that for this test site NSZD is limited to a short duration during a calendar year at an rate on the order of 10-20 bbls/acre/year.

Background

- LNAPL can naturally attenuate in the subsurface by weathering, dilution, & biodegradation.
- NSZD refers to processes by which an LNAPL source is naturally degraded over time with biodegradation often being the dominant process.
- NSZD can be estimated by a series of parameters, including soil CO_2 efflux.
- Imperial's above-surface Arctic bioremediation projects (i.e. biocells) have proven productive and literature suggests that some cold-climate sites may be appropriate candidates for remediation via natural attenuation.[1]
- Look to determine if quantifiable NSZD is present at a future remediation site such that a natural attenuation strategy could be reasonably proposed.

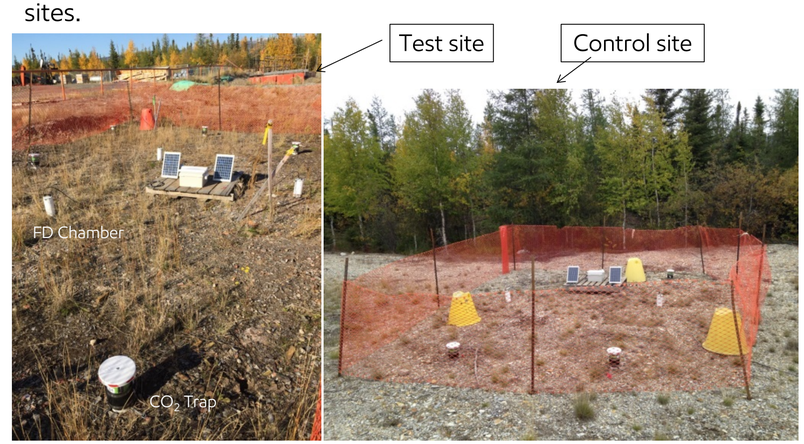
Study Area

- Norman Wells Operations, Northwest Territories, Canada
- Imperial production site since the 1920s.
- Natural crude seeps are present on and in proximity to the site.
- LNAPL-impacted test site is adjacent to former well B30-X.
- Previous test pitting has showed residual C10-C16 at 2 mbgs.
- Control site outside the fence-line
- Depth to permafrost varies at the site (generally 2-4 mbgs).

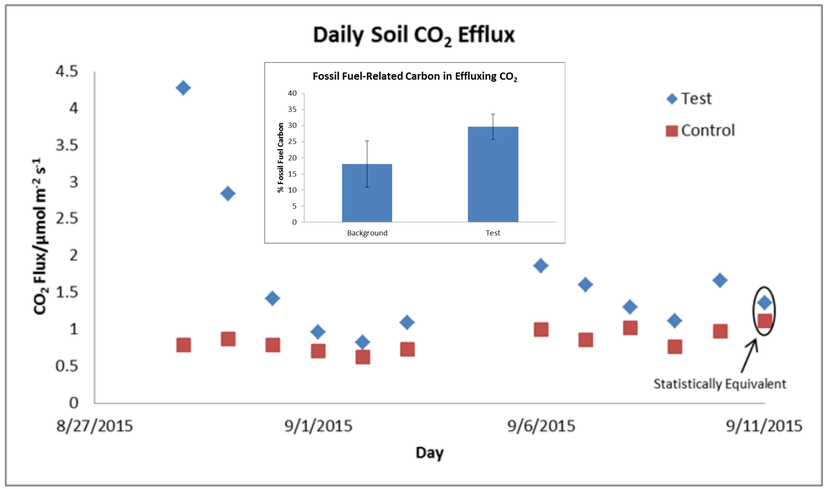


Field Study I

- From Aug. 27th – Sept. 15th, 2015, deployed EFlux CO_2 traps and Eosense forced diffusion (FD) chambers at both the test and control sites.



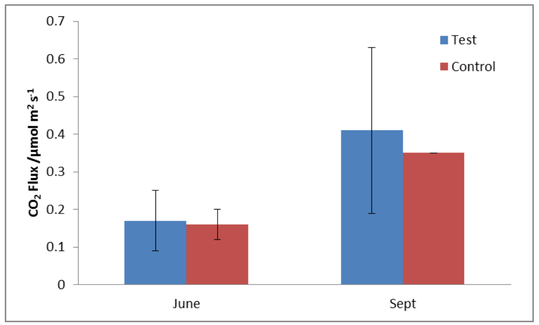
- Compared the average CO_2 fluxes between the sites as well as the portions of "fossil-fuel"-related carbon effluxed.



- Daily monitoring data (FD chamber) yielded statistically greater CO_2 effluxes at the test site compared to the control site.
- Time-averaged CO_2 effluxes (CO_2 traps) were statistically equivalent.
- A greater portion of effluxed carbon related to fossil-fuel was observed at the test site .
- Estimated NSZD of up to 150 bbls/acre/year.
- Effective biodegradation in the Arctic generally lasts 2-3 months[2] so need to better refine the estimation of on-site LNAPL degradation.

Field Study II

- From June 3rd – 17th and Sept. 11th – 24th, 2016 deployed EFlux CO_2 traps at the same locations as studied in 2015.
- The total CO_2 flux (soil respiration + LNAPL degradation) was found to be lower for both sites during the 2016 deployments.
- In several instances sufficient CO_2 could not be captured to calculate a flux CO_2 estimate.



- The proportion of fossil fuel-related effluxed carbon was found to similar at both the test and control sites during both deployments (approx. 30 %).

	Average Temperature at Ground Surface	Average Depth to Freezing/Frozen Conditions
June 15th	12°C	1 m
August 15th	14°C	2 m
September 15th	7 °C	2 m

Data compiled from 2014-2016 site soil thermistor study

Closing Thoughts

- Indications of biodegradation of residual LNAPL in the subsurface observed in a late August 2015 deployment, but not in the subsequent June and September 2016 deployments.
- Observations suggest that subsurface LNAPL degradation on-site is limited to a short summer window where ground temperatures are high and the depth to permafrost is maximized.
- % Fossil fuel-related carbon at the control site was notably high. Need to assess the impact of proximity to natural crude seeps and ongoing petroleum production.
- The initial estimated NSZD rate for the test site should be reduced by, at minimum, an order of magnitude.

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References

1) D.M. Filler et al., *Polar Rec.* **2006**, *42*(221), 111-120; Van Stempvoort et al., *Cold Reg. Sci. Technol.*, **2008**, *53*, 16-41; M. Naseri et al., *Environ. Sci. Pollut. Res.* **2014**, *21*, 11250-11265.
2) D.M. Filler, D.R. Van Stempvoort & M.B. Leigh, Remediation of Frozen Ground Contaminated with Petroleum Hydrocarbons: Feasibility and Limits *in* Chapter 19 of Permafrost Soils, Soil Biology 16, R. Margesin, ed.; Springer-Verlag, Berlin, **2009**.