Empirical Data to Evaluate the Occurrence of Sub-slab O₂ Depletion “Shadow” at Petroleum Hydrocarbon-Impacted Vapor Intrusion Sites

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Outline

– Motivation
– Sub-slab soil vapor data
– Preliminary hypothesis for general lack of oxygen depletion shadow
– Conclusions
Widespread aerobic biodegradation enables vertical screening distance approach to prioritize PVI investigations (EPA 2013, Lahvis et al 2013)

- Oxygen replenishment under the slab is a critical control on PVI
  - Supply = \( f(\text{soil type, surface cover, barometric effects, wind effects, slab construction, slab footprint ??, building use}) \)
  - Demand = \( f(\text{type and strength of vapor source, source proximity}) \)

Today’s focus
Potential for Sub-slab O$_2$ Depletion (O$_2 < 4\%$ v/v)

- 3D numerical simulations (EPA 2012)
  - suggest oxygen depletion and accumulation of petroleum vapors below slab for certain source conditions

- Slab at former refinery site (Patterson and Davis, 2009)
  - Kerosene LNAPL at 10 ft bgs
  - 2700 ft$^2$ building with 10 ft wide thick concrete apron
  - Observed oxygen depletion (<1\% v/v) and high TPH (2 x 10$^7$ µg/m$^3$) below slab

- Uncertainty about the PVI decisions using near-slab soil vapor data
- Empirically evaluate occurrence of oxygen depletion
Definition of Source Types (GW vs. VZ)

Vadose Zone Source

Groundwater Source

<30 ft
Sub-slab Soil Vapor Data Compilation

- 260 sub-slab soil vapor samples at 50 UST sites (gasoline)

- 197 samples at 35 UST sites - acceptable data quality
  - Conventional sub-slab probe construction
  - Summa canister sampling
  - Oxygen data available
  - Appropriate leak detection (He, DFA, IPA)

- 89 samples at 20 UST sites – vapor source under the slab
  - 24 samples at 7 sites (GW source – LNAPL or dissolved)
  - 65 samples at 13 sites (vadose zone source – dirty soil or LNAPL under slab)
Sub-slab Oxygen vs. Distance from the Edge of Slab

Oxygen depletion:
- not related to distance of sample location from edge of the slab
- seen only for vadose zone sources (soil/LNAPL)
- not observed for GW sources (LNAPL/dissolved)

*Draft PVI guidance in Australia (Wright 2013)
Minimum Sub-slab Oxygen vs. Building Footprint

Oxygen depletion:
- not related to building footprint
- seen only for vadose zone sources (soil/LNAPL)
- not observed for GW sources (LNAPL/dissolved)
Sub-slab Oxygen vs. Depth to GW Source

- 24 samples (7 sites)
- No oxygen depletion seen for vapors from GW sources
  - Even LNAPL at water table as shallow as 10 ft
- Note that this dataset does not have LNAPL sources shallower than 10 ft
Sub-slab Oxygen vs. TPHg

- 83 samples (13 sites)
- Soil vapor likely from zone straddling aerobic biodegradation zone
- Spatial variability in the distribution of LNAPL source below slab
- Oxygen depletion seen only for vadose zone (soil/LNAPL) sources and not for GW sources
111 samples (20 sites)

Soil vapor likely from zone straddling aerobic biodegradation zone

5 of 111 samples (~5%) have benzene > 100 µg/m³ and oxygen depletion, all for vadose zone sources
Sub-slab Oxygen vs. Methane

- 98 samples (19 sites)
- Methane detections indicative of anaerobic biodegradation of hydrocarbons
- Methane > 0.5% v/v sourced only from vadose zone sources and LNAPL under slab
- No significant methane detected from GW sources
3D Numerical Simulations

- Airflow assumed only through perimeter crack (0.2 L/min)
- Oxygen depletion ‘shadow’ and hydrocarbon vapors below slab

- Airflow through perimeter crack and backfill (ca 50 L/min)
- Sub-slab is oxygenated and no hydrocarbon vapor accumulate below slab
Summary

- Sub-slab oxygen depletion shadow not observed for GW sources
- Limited instances of sub-slab oxygen depletion linked to:
  - Vadose zone sources below slab \(\rightarrow\) High source strength
  - LNAPL source right beneath the slab \(\rightarrow\) Source proximity
- Sub-slab oxygen depletion not dependent on:
  - Building footprint
  - Distance from the edge of the slab
- Generic 3D simulations:
  - Likely underestimate the actual air flow under slabs
References

- EPA 530-R-10-003, February 2012. Conceptual Model Scenarios for the Vapor Intrusion Pathway.