

Vapor Intrusion to Indoor Air at a Site with Polycyclic Aromatic Hydrocarbons in Shallow Soil

**T Taras¹, A LaPierre², M Wade¹, P Wong-Yim¹, B Davis¹,
M Dalrymple¹, J Polisini¹**

¹ Department of Toxic Substances Control
California Environmental Protection Agency, Sacramento, CA

² Iris Environmental, Oakland, CA

Society of Toxicology

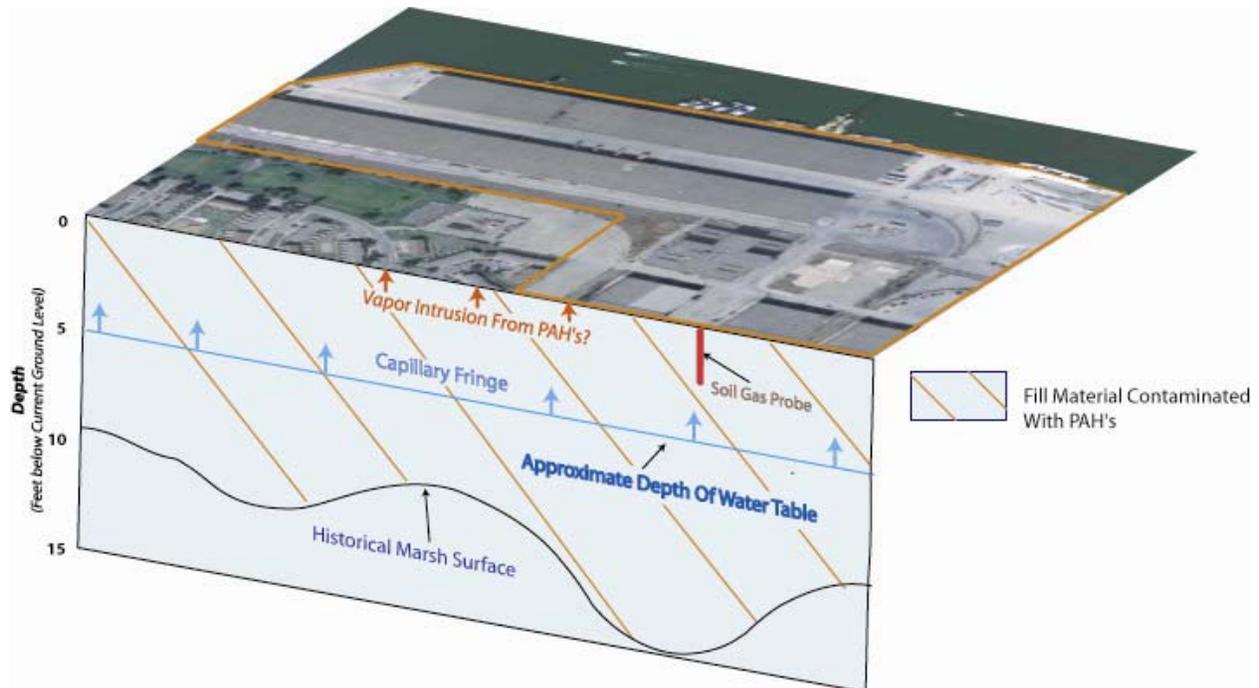
March 2008

ABSTRACT

Site A is a coastal site with polycyclic aromatic hydrocarbons (PAHs) in soil due to deposition from historical operations and subsequent use of contaminated soil as fill. Other contaminants such as benzene are also present. USEPA and CalEPA have identified several PAHs as chemicals to consider for the vapor intrusion to indoor air pathway (e.g. naphthalene which CalEPA treats as a carcinogen). This paper presents the approach used to evaluate the indoor air pathway for PAHs at Site A given challenges such as shallow groundwater, contamination in shallow soil, and complexities in soil gas sample collection and analyses for PAHs. Shallow soil gas samples were analyzed for naphthalene by three EPA methods (TO-15, TO-17, and 8260B). Six other PAHs (e.g. chrysene) not commonly analyzed for in soil gas but identified in vapor intrusion guidance were analyzed by TO-13 and TO-17 which use sorbent technology. None of these six PAHs was detected. While naphthalene is present in soil at levels exceeding risk-based concentrations for the soil ingestion and ambient air pathways, and the levels in soil indicated a potential concern for vapor intrusion, it was detected in soil gas at only one location. Although detection limits were less than the risk-based concentration, only TO-15 and TO-17 detected naphthalene. Naphthalene concentrations measured by TO-15 and TO-17 ranged roughly two-fold indicating either method would have been acceptable at this site. Johnson and Ettinger (J&E) modeling with DTSC default parameters estimated indoor air risk from naphthalene at $4E-6$ and $1E-6$ for residential and industrial receptors. J&E modeling using site-specific soil data estimated risks approximately one order of magnitude less. Overall, while naphthalene was a risk driver based on maximum projected cumulative cancer risk, soil gas investigation identified only one location where it posed a potential indoor air risk.

DESCRIPTION OF SITE A

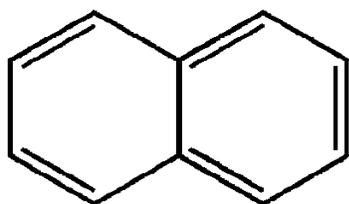
- Coastal site in California
- Site history included an oil refinery, an asphalt pipe manufacturing plant, and other manufacturing operations
- Shallow groundwater approximately 5 to 7 feet below ground surface (bgs)
- Use of dredged material contaminated by historical industrial operations as fill on top of the historical marsh surface resulted in heterogeneous shallow soil contamination with compounds such as PAHs
- Limited detections of PAHs in available groundwater data
- Other contaminants such as benzene and inorganics also present (this presentation focuses on PAHs only)



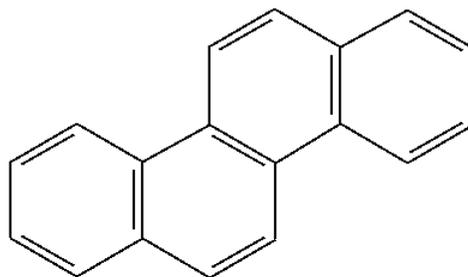
CHALLENGES FOR INVESTIGATING THE POTENTIAL FOR VAPOR INTRUSION TO INDOOR AIR AT SITE A

1. Known contamination in shallow soil necessitates sampling shallow soil gas.
2. Shallow groundwater limits the band in which soil gas can be sampled.
3. Atmospheric breakthrough and barometric pumping can confound sampling.
4. Soil gas sample collection and analyses for PAHs are complex.
 - Seven PAHs of potential concern (Cal/EPA 2005). Naphthalene is the focus of most studies.
 - Partitioning equations, volatility, and toxicity indicated potential vapor intrusion of PAHs to indoor air at Site A.
 - Adsorption onto surfaces (e.g. plastic syringes and tubing) can result in incomplete recovery of PAHs during sample collection and analysis.
 - PAHs other than naphthalene are not detected by standard analytical methods commonly used for soil gas (e.g. USEPA Method 8260B or TO-15).

COMPARISON OF PHYSICAL AND CHEMICAL PROPERTIES



Naphthalene



Chrysene

Chemical	Molecular Weight (g/mol)	Henry's Law Constant, unitless	Vapor Pressure (mm Hg)	Organic Carbon Partition Coefficient (K _{oc} , cm ³ /g)
Naphthalene	128	0.0198	0.087 ¹	2,000
Chrysene	228	0.00387	6.3 x 10 ⁻⁷ ¹	398,000
Benzene ²	78	0.227	75 ³	59

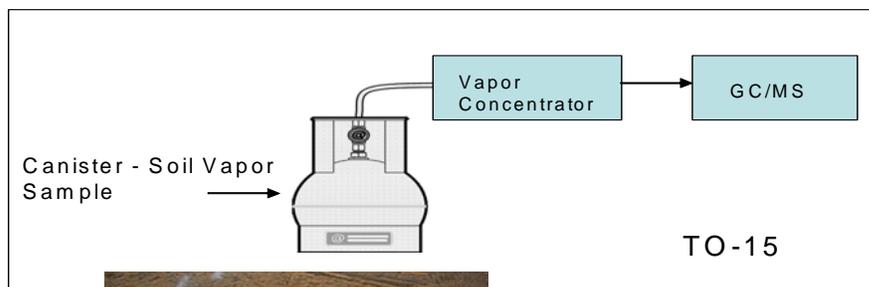
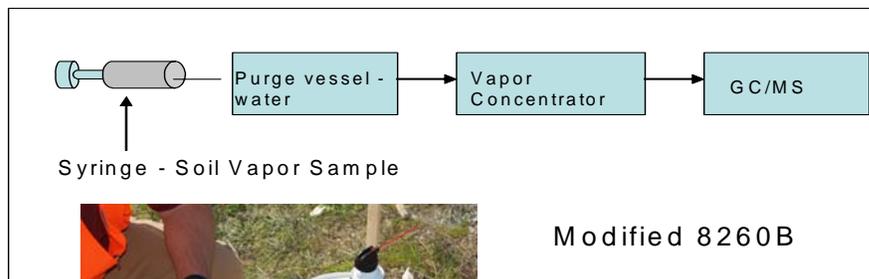
¹ At 25°C

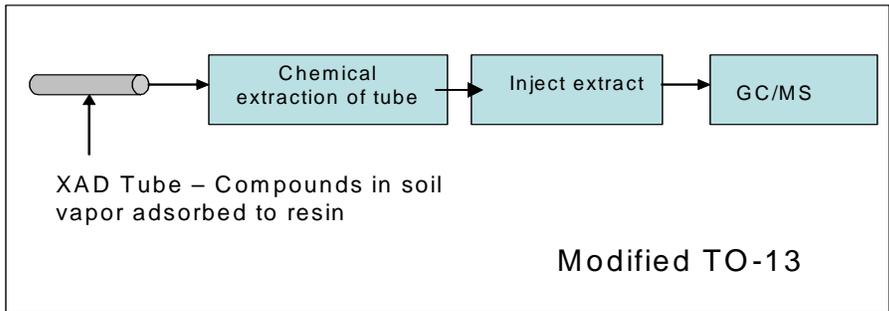
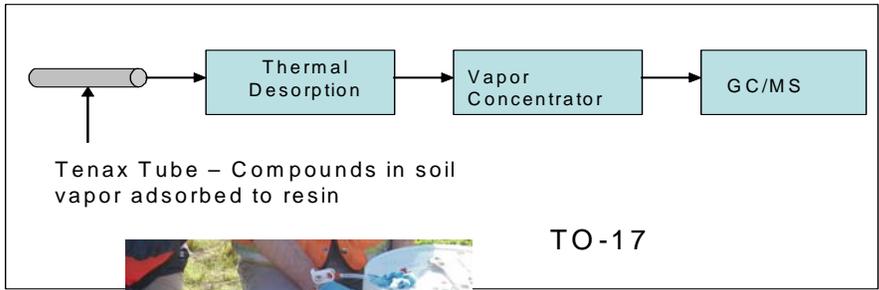
² Included for reference

³ At 20°C

INVESTIGATION APPROACH AT SITE A

- Soil gas data collected for modeling vapor intrusion into indoor air
- Attention to breakthrough issues
- Soil gas probes installed and sampled generally at locations where the highest concentrations of PAHs have been detected in media such as soil and/or groundwater
- Multiple sampling rounds and soil gas samples collected from multiple depths at a subset of the locations
- Use of Teflon® tubing (rather than polyethylene tubing which has been reported to exhibit artifacts and poor performance for naphthalene) (Hayes 2006)
- Use of multiple analytical methods for naphthalene
 - USEPA Method TO-17 (Detection limit 25 ug/m³)
 - USEPA Method TO-15 (Detection limit 20 ug/m³)
 - USEPA Method 8260B (Detection limit 70 ug/m³)
- Use of USEPA Methods TO-17 and TO-13 for other PAHs





(Sampling looks similar to TO-17)

*** Figures provided by Air Toxics, Ltd.**

RESULTS

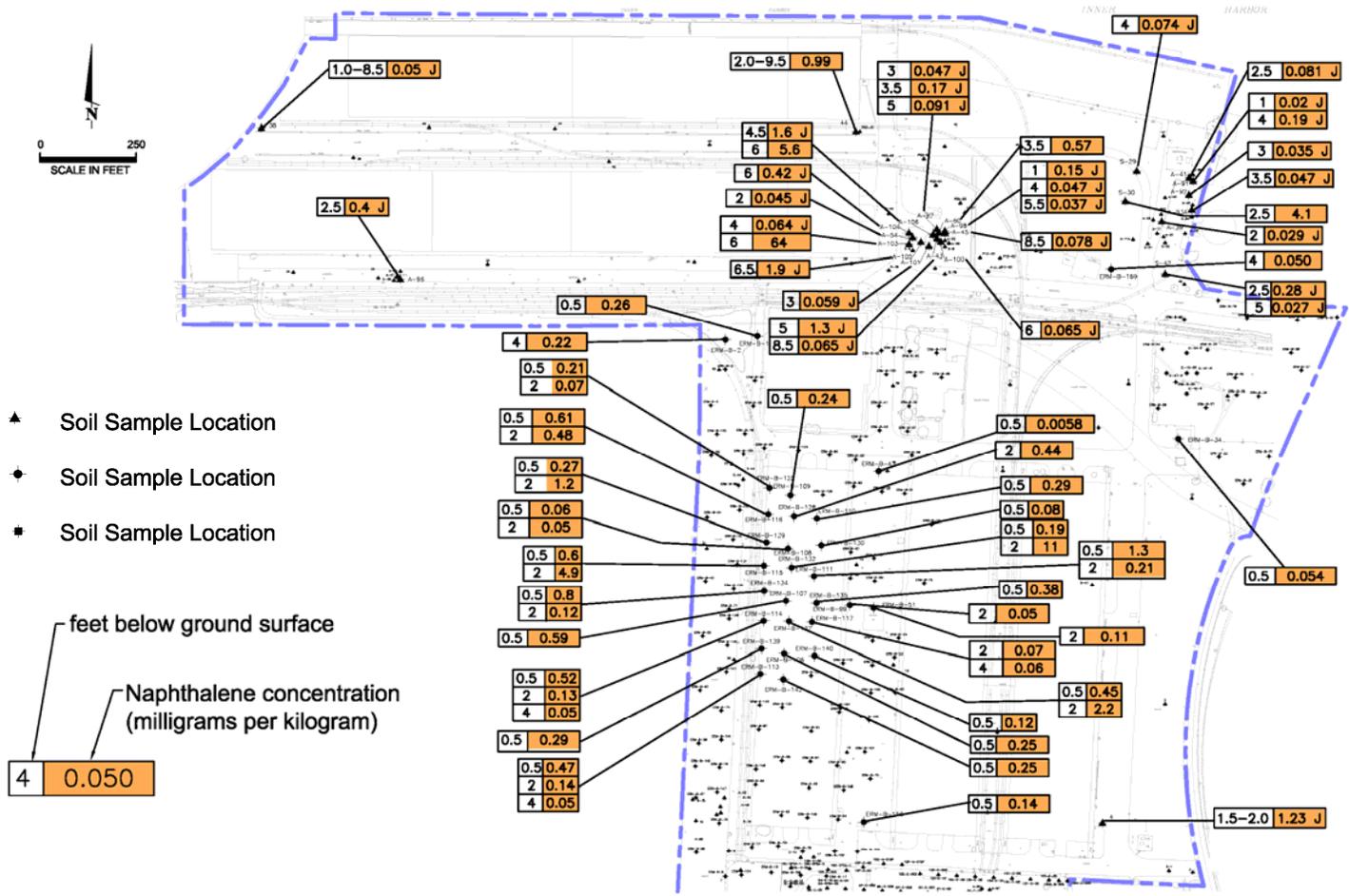
- PAHs other than naphthalene. No other PAH was detected in soil gas.
- Naphthalene.
 - Naphthalene is present in soil at levels exceeding screening-level risk-based concentrations, and the levels in soil indicated a potential concern for vapor intrusion.
 - Despite the presence of naphthalene in soil across the site, it was detected in soil gas at only a single location.
 - Johnson and Ettinger (J&E) modeling with DTSC default parameters estimated indoor air risk from naphthalene at that location to be 4E-6 and 1E-6 for residential and industrial receptors (Cal/EPA 2005). The use of site-specific soil parameters reduced the risk estimates about one order of magnitude.
 - Although all detection limits were less than the risk-based soil gas concentration, only TO-15 and TO-17 detected naphthalene. Naphthalene concentrations measured by TO-15 and TO-17 differed by roughly two-fold, indicating either method would have been acceptable at this particular site.

Comparison of Naphthalene Detections in Soil Gas

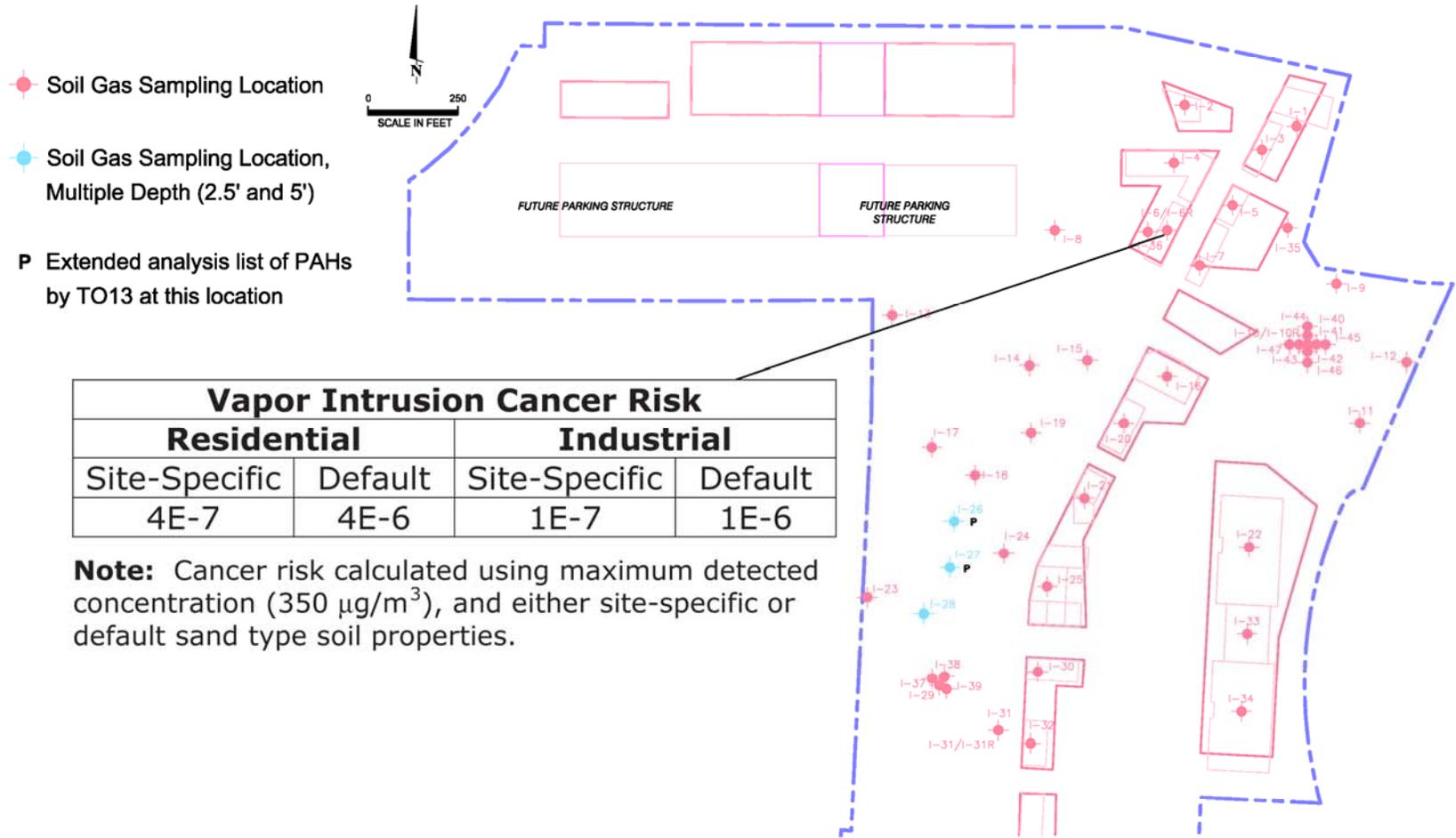
Sample Date	Depth (ft bgs)	Naphthalene (ug/m ³)		
		Method 8260B	TO-17	TO-15
3/2/07	7.0	ND, <70	350	--
4/2/07	7.5	--	68 (56)	140 (160)

- ug/m³ - micrograms per cubic meter
 ND - not detected
 < - not detected at the value shown (detection limit)
 -- - not analyzed
 () - results of duplicate sample

Naphthalene Contamination in Soil is Present Across the Site



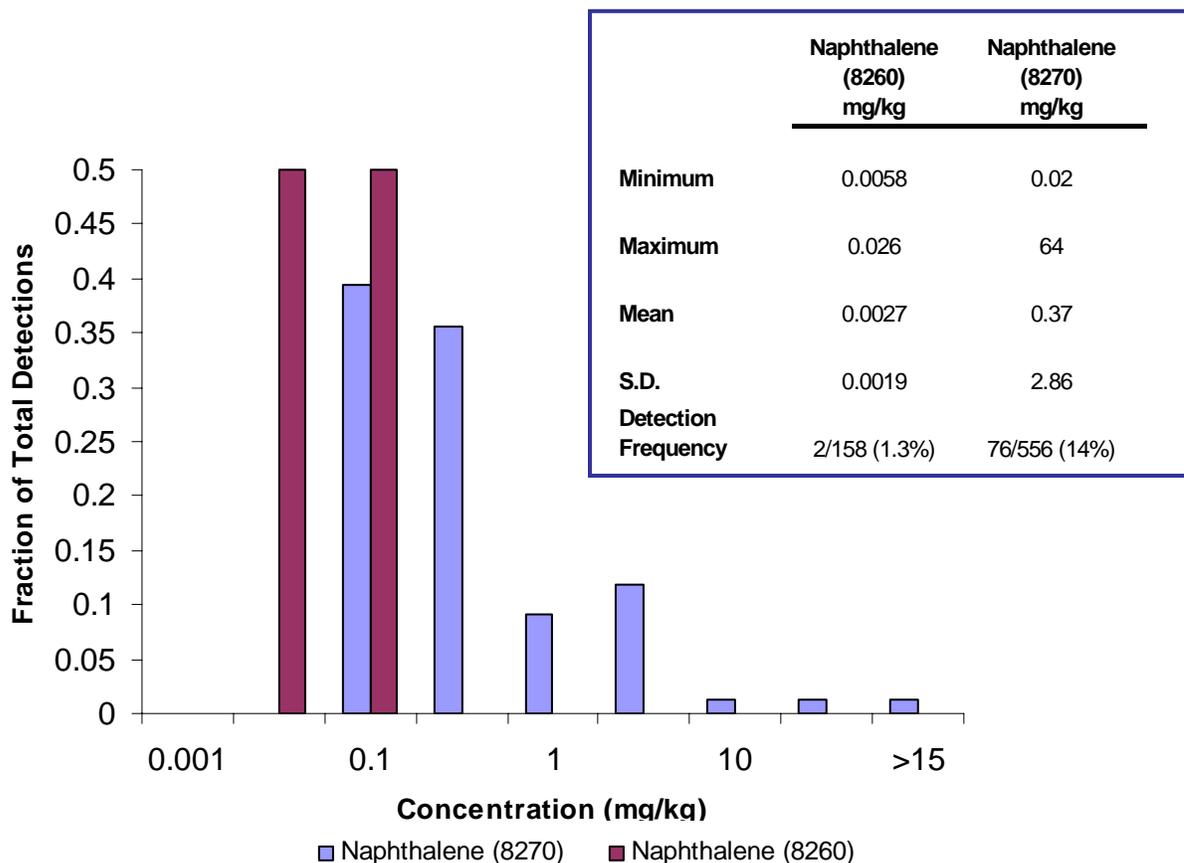
Naphthalene in Soil Gas and Risk from Vapor Intrusion



DISCUSSION

Potential reasons why naphthalene (although widespread in soil) was found in soil gas at only a single sampling location may be related to the following site-specific conditions:

- PAHs in soil at Site A were deposited in the early 1900's. Over time, this mixture of PAHs and soil has likely undergone physical and chemical changes (or aging).
- A reduction in the extractability of naphthalene has been reported over the aging processes (Ncibi et al., 2007). Volatilization of naphthalene may also be reduced as a result of aging.
- Naphthalene was found in soil at Site A as part of a mixture of heavy-end PAHs. The presence of other PAHs may act as an organic carbon source that increases naphthalene's affinity for sorption thereby decreasing potential volatilization.
- The potential for naphthalene at Site A to be bound tightly to the solid matrix is demonstrated in the following figure. The concentrations and frequency of detection for soil samples analyzed using solvent extraction (USEPA Method 8270) were higher than those analyzed using purge and trap (USEPA Method 8260).



CONCLUSIONS

- While naphthalene was present across the site in soil (with limited detections in the available groundwater data), this soil gas investigation identified only one location where it was present in soil gas.
- The use of multiple soil gas sampling and analysis methods at this site greatly reduced uncertainty about the presence of naphthalene and other PAHs in soil gas.
- Naphthalene was a risk driver based on maximum projected cumulative cancer risk due to its presence in soil and groundwater. The one location where naphthalene was detected in soil gas presents a potential indoor air risk.
- Site-specific conditions such as aging may be important factors in partitioning of naphthalene.
- Because of site-specific conditions, the findings of this paper may not be applicable to other sites.

REFERENCES

California Environmental Protection Agency, Department of Toxic Substances Control 2005. Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air – Interim Final. December 15, 2004 (Revised February 7, 2005).

Hayes HC, Benton DJ, Khan N 2006. Impact of sampling media on soil gas measurements. A&WMA “Vapor Intrusion – The Next Great Environmental Challenge – An Update”, September 13-15, 2006, Los Angeles, California.

Ncibi MC, Mahjoub B, Gourdon R 2007. Effects of aging on the extractability of naphthalene and phenanthrene from Mediterranean soils. J of Hazardous Materials 146: 378-384.

DISCLAIMER

The opinions and findings in this paper are those of the authors. They do not represent guidance or policy of the California Department of Toxic Substances Control or California Environmental Protection Agency.