USE OF MULTIPLE LINES OF EVIDENCE FOR EVALUATING A VAPOR INTRUSION SCENARIO – CASE STUDIES

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ABSTRACT

A multifaceted approach was used to evaluate vapor intrusion scenarios at two distinct sites (A and B). Site A is an oil refinery, with elevated levels of methane and gasoline vapors beneath adjacent residential and commercial properties. Site B is a former chemical manufacturing facility with a plume of chlorinated volatile organic compounds (VOCs) extending from beneath a commercial building (located on Site B) to offsite areas immediately adjacent to residential properties.

Preliminary review of subsurface data suggested that residents/workers in these buildings may be exposed to VOCs emanating from the subsurface. A step-wise approach was taken to determine if mitigation measures were warranted to prevent indoor air exposures:

(1) Shallow soil vapor data from residential and commercial buildings were compared to health-based screening criteria to identify, for further study, candidate buildings with the potential for subsurface vapor intrusion.

(2) Indoor and outdoor air monitoring and/or sub-slab soil vapor data were collected from these candidate commercial and residential buildings.

(3) Potential for other sources of organic vapors (e.g., household products, building materials, background ambient air) as confounding variable(s) were assessed using multiple data analysis techniques.

Based on the multiple lines of evidence from these analyses, it was determined that subsurface vapor intrusion did not have a significant effect on indoor air quality in the residential and commercial buildings at Site A. At Site B, soil gas, sub-slab vapor, and indoor/ambient air data indicated that VOCs had migrated from the subsurface into two of the offices and a break room in the commercial building, but not into the warehouse area. Vapor intrusion into residences located immediately adjacent to Site B could not be properly evaluated due to restrictions on subsurface data collection and accessibility issues.

INTRODUCTION

Migration of volatile compounds from the subsurface (soil, groundwater) into overlying indoor air spaces is known as vapor intrusion. In recent years, regulatory agencies have required evaluation of the vapor intrusion pathway at sites contaminated with volatile organic compound (VOCs), where buildings are present or may exist in the future. Unlike other pathways of exposure (direct contact with contaminated soils, groundwater etc.,), evaluating cancer risks and non-cancer hazards for a vapor intrusion scenario are complicated by various factors. For example, indoor air data alone are not good indicators of the extent of vapor intrusion because of the common presence of other sources of VOCs within buildings.

Mathematical modeling can be used to predict indoor air concentrations, when subsurface data (soil gas, groundwater) are available. However, these models are often limited by unique characteristics of the site such as soil type, depth to contamination, building parameters, properties of the chemicals, and changing atmospheric conditions (such as wind, pressure, precipitation). As a result, USEPA and other state agencies recommend using a tiered approach and multiple lines of evidence when evaluating the vapor intrusion pathway (USEPA 2002, DTSC 2005). This includes using modeling techniques together with direct measurement of VOCs in the subsurface and/or indoor air.

The current poster presents two case studies where California EPA's 11-step process (Figure 1) was utilized to evaluate vapor intrusion at two distinct sites. A side-by-side comparison of the individual steps in this process illustrates similarities and differences between the two cases. Emphasis on multi-faceted approaches for data evaluation based on site-specific considerations, lead to different conclusions regarding the significance of subsurface vapor intrusion at the two sites.

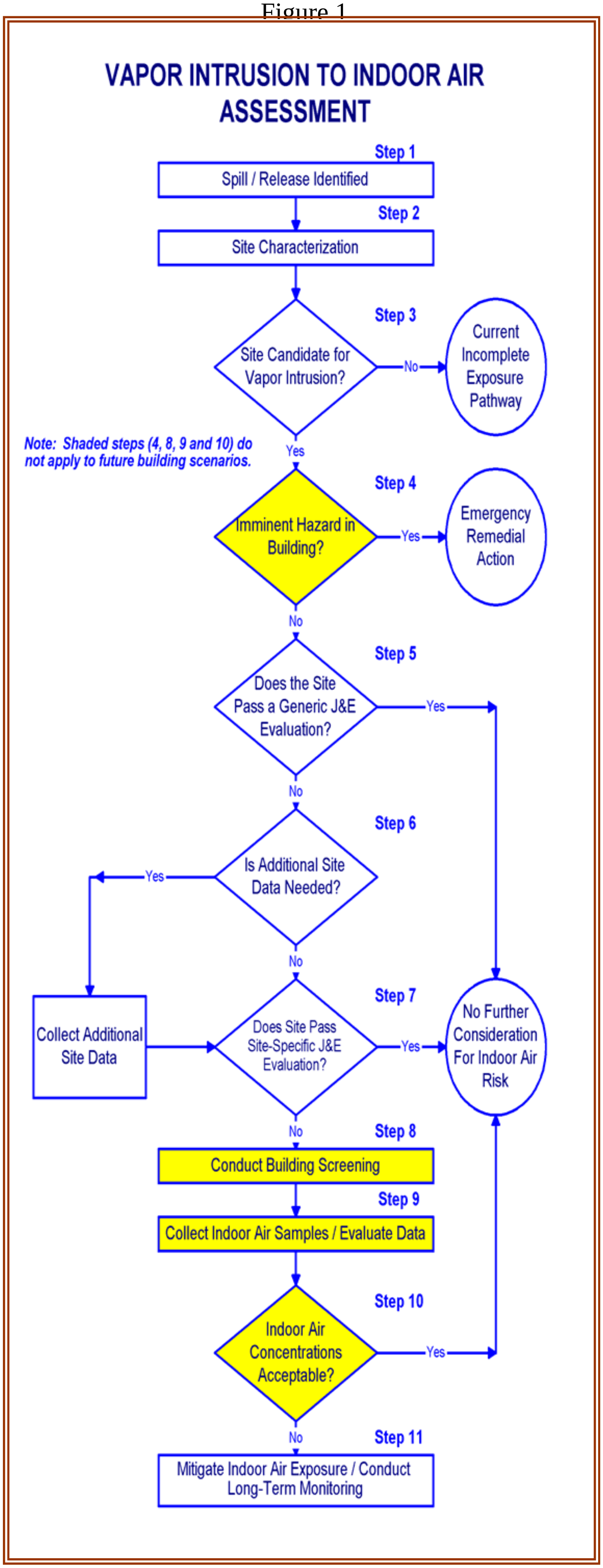
METHODS

Sampling strategy: Site investigations were conducted according to general guidelines provided in DTSC's vapor intrusion guidance document (DTSC, 2005). Soil gas and indoor air sampling was conducted according to protocols outlined in the *Active Soil Gas Advisory* (DTSC/LARWQCB, 2003). Soil gas samples were collected and analyzed using USEPA's 8260B methodology. Confirmatory soil gas samples were taken from 10% of the locations and analyzed using USEPA's TO-15 methodology in some cases. Indoor air and sub-slab samples collected using USEPA's TO-15 methodology.

Modeling: USEPA's Johnson & Ettinger (J&E) model (USEPA, 2004) was used to estimate vapor intrusion from subsurface into indoor air spaces. Generic and, when appropriate, site-specific soil and building parameters were used as model inputs.

Risk Assessment: Cancer risks and non-cancer hazards were estimated using USEPA (USEPA, 1989) and California EPA Office of Environmental Health Hazard Assessment (OEHHA, 2004) guidelines.

Figure 1



SITE A: OIL REFINERY

HISTORY (SITE A)

- An oil refinery located in a mixed residential/commercial neighborhood in southern California.
- Over time, refinery activities have resulted in contamination of soils and groundwater.
- Since the mid-1980s, the refinery has been investigating and remediating soil and groundwater contamination.

APPROACH FOR DATA COLLECTION AND ANALYSIS (SITE A)

Step 1: **Spill/Release identified** - Complaint regarding a strong odor in a residential garage; residents were temporarily relocated.

Step 2: **Site characterization** – Soil, groundwater, and soil vapor sampling was conducted in surrounding areas to determine the presence and source of vapors. More than 200 soil gas probes were installed.

Step 3: **Is the site a candidate for vapor intrusion?** Yes; methane and gasoline-type vapors, including benzene, present in the subsurface.

Step 4: **Imminent hazard in building?** No; clearance for occupancy following immediate response from local fire departments.

Step 5: **Does the site pass a generic J&E evaluation?** No; comparison with California Human Health Screening Levels (CHHSL) indicated the need for additional investigation (OEHHA, 2005).

Table A-1: Soil Vapor Monitoring Results

Chemical	Soil Gas Concentration*	Residential CHHSL	Commercial CHHSL
Methane (ppmv)	ND – 500,000	5,000**	5,000**
Benzene (ppbv)	ND – 160,000	10	44
Ethylbenzene (ppbv)	ND – 6,200	98	330
Toluene (ppbv)	ND – 9,700	36,000	100,000
m/p-Xylene (ppbv)	ND – 4,700	73,000	200,000

ND – Nondetect; * taken from 5 and 15 feet bgs; **10% of methane LEL

Step 6: **Is additional data needed?** Yes - indoor air sampling in residences.

Step 7: **Does the site pass a site-specific J&E evaluation?** NA (go to Step 8 directly).

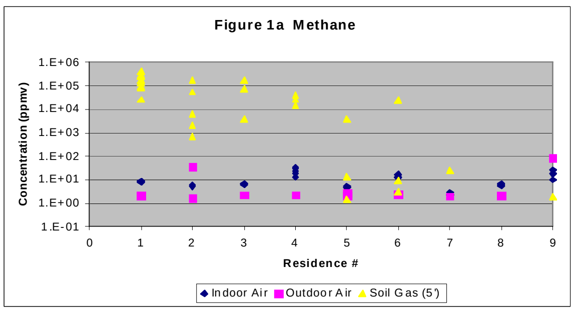
Step 8: **Conduct building screening.** 24 to 48 hours prior to indoor air testing following the Cal/EPA guidance (DTSC, 2005).

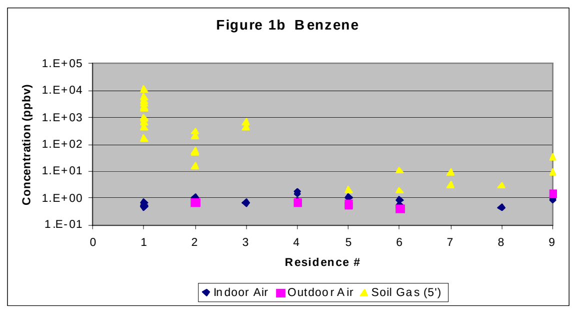
Step 9: **Collect indoor air samples/evaluate data.** Two rounds of indoor and ambient air samples were collected from nine homes located closest to the affected area. Evaluation of data using the following techniques indicates that subsurface vapor intrusion does not have a significant effect on indoor air quality in these homes:

a) Comparison with outdoor (ambient) air concentrations shows similar indoor and outdoor air quality.

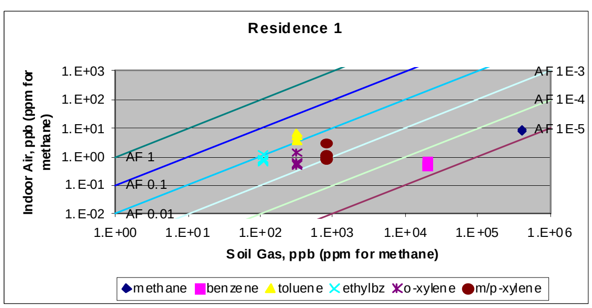
Table A-2: Indoor and Ambient Air Sampling Results			
Chemical	**Indoor Air Concentration**	**Ambient Air Concentration**	**Residential CHHSL**
Methane (ppmv)	ND – 32	ND - 87	500*
Benzene (ppbv)	ND – 1.8	ND – 1.5	0.03
Ethylbenzene (ppbv)	ND – 2.2	ND – 1.7	0.22
Toluene (ppbv)	1.4 – 13	0.97 – 2.9	81.8
m/p-Xylene (ppbv)	ND – 4.2	ND – 3.1	166
ND – Nondetect;	*1% of methane LEL (a CHHSL value is not available for methane)		

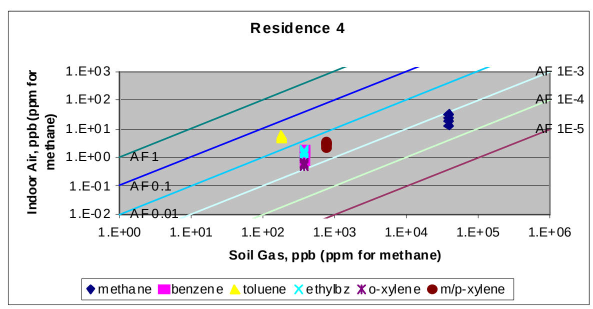
b) Spatial analysis of the data (Residence 1 is at the center of the plume and Residence 9 is at the edge of the plume) indicate no correlation between indoor air and soil gas data.





c) Attenuation factors (AF, defined as the ratio of indoor air to subsurface vapor concentrations) among chemicals vary 2-3 orders of magnitude in the same home, in contrast to ratios predicted by the J&E model for these chemicals.

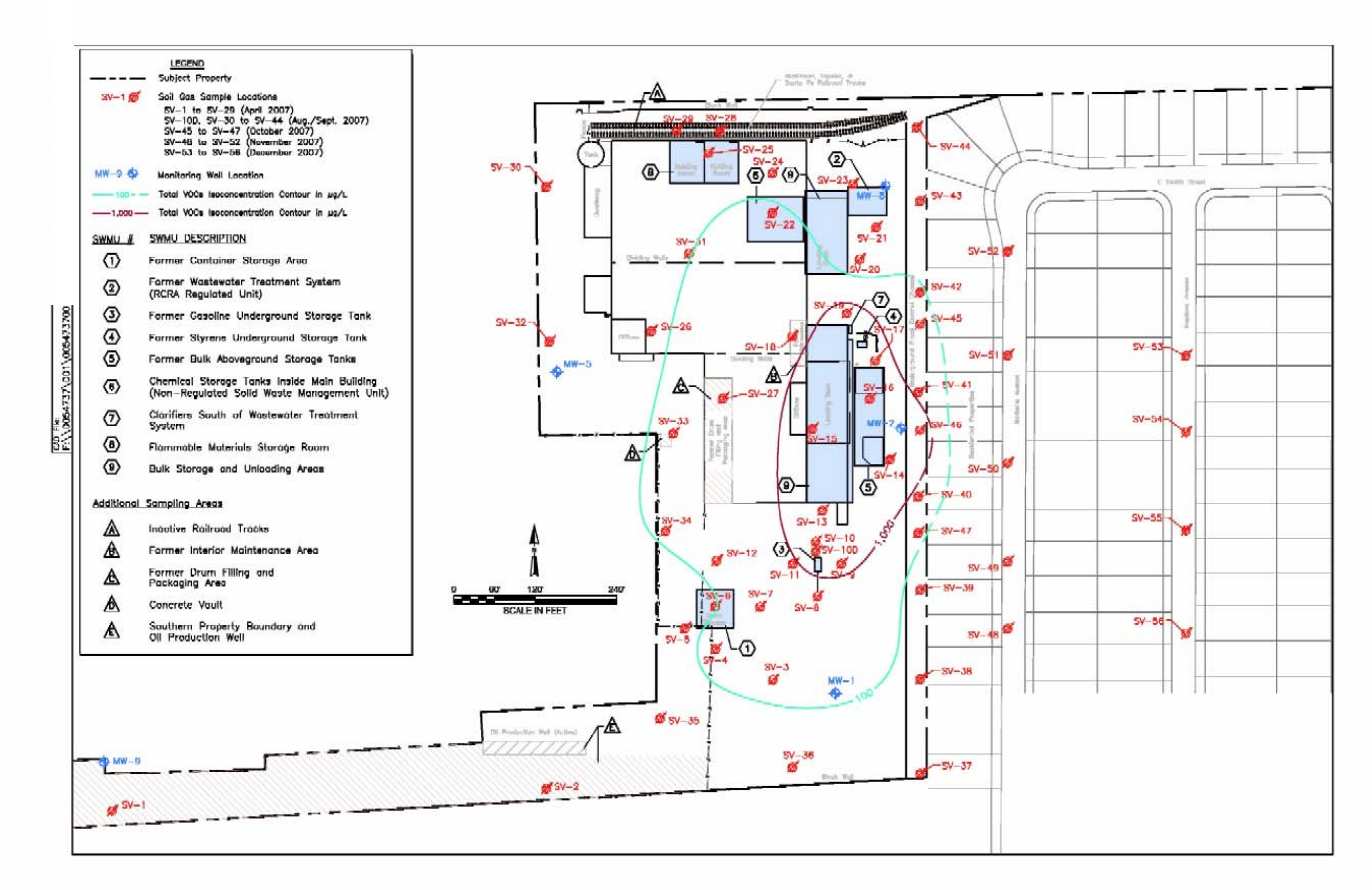




Step 10: **Indoor air concentrations acceptable?** Yes; indoor air quality comparable to ambient (outdoor) air quality.

Step 11: **Mitigate indoor air exposures. Conduct long term monitoring.** Quarterly soil vapor and groundwater monitoring.

SITE B: CHEMICAL MANUFACTURING FACILITY



HISTORY (Site B)

- Manufactured chemicals for commercial floor finishers, metal cleaners and paint strippers from 1960 to 1989.
- Several underground storage tanks and waste water processing areas were located onsite.
- Site is currently used as a warehouse facility with various offices located inside the building(s).
- Residences located immediately adjacent to eastern edge of property.

APPROACH FOR DATA COLLECTION AND ANALYSIS (SITE B)

Step 1: **Spill/Release identified** – Identified solvent spills into public drains. Groundwater contaminated with VOCs.

Step 2: **Site characterization** - Subsequent soil gas investigations indicated that areas of greatest contamination were located in chemical storage areas, and solvent loading and unloading areas on the western part of the property, adjacent to residences.

Step 3: **Is the site a candidate for vapor intrusion?** Yes. Johnson and Ettinger modeling with soilgas and groundwater data..

Step 4: **Imminent hazard in building?** No reports of odors or health problems in buildings located on the property.

Step 5: **Does the site pass a generic J&E evaluation?** No.

Step 6: **Is additional data needed?** Yes. A phased approach was used to delineate the nature and extent of subsurface VOC contamination. Thirty-six soil gas samples onsite (5 and 15 feet bgs), eleven soil gas samples from channel area (5, 15, 25, 45 and 60 feet bgs) and nine off-site soil gas samples on the two streets (5 and 15 feet bgs) were collected.

Step 7: **Does the site pass a site-specific J&E evaluation?** No. J&E modeling with site-specific soil and building parameters indicated that cancer risks were above 10^{-5} in several locations (SV-15 to SV-19, SV-27 - Table B-1). Soil gas data (collected from channel area) indicated that off-site residents may be exposed to elevated risks/hazards (Table B-2). Subsequent sampling in two adjacent streets indicated that the plume did not extend beyond the first row of houses. However, higher benzene concentrations were found in some of these locations.

Table B-1: Soil Gas Concentrations

	Onsite-commercial building (SV-13 to SV-31)		**Off-site channel area** (SV-37 to SV-46)	
Chemical	**Soil gas (µg/L)***	**Cancer Risk****	**Soil gas (µg/L)***	**Cancer Risk****
Tetrachloroethylene (PCE)	1.4 - 3700	5×10^{-3}	0.6 to 760	2×10^{-3}
Trichloroethylene (TCE)	0.1 - 1800	9×10^{-4}	ND to 73	6×10^{-5}
Vinyl chloride (VC)	ND – 2.4	5×10^{-5}	ND to 0.1	4×10^{-6}
Benzene	ND – 0.8	6×10^{-6}	ND to 0.4	5×10^{-6}

ND – Non-detect; **NA** – Not applicable;
***detected at 5 feet bgs; ** estimated for maximum detected VOC concentration using J&E model

Step 8: **Conduct building screening.** Indoor sources of VOCs in on-site commercial building included (1) packaging material with vinyl chloride labeling and (2) vehicle storage area.

Step 9: **Collect indoor air samples/evaluate data.** Nine indoor air samples were collected from onsite warehouse and offices (eight sub-slab samples were also taken from these areas concurrently).

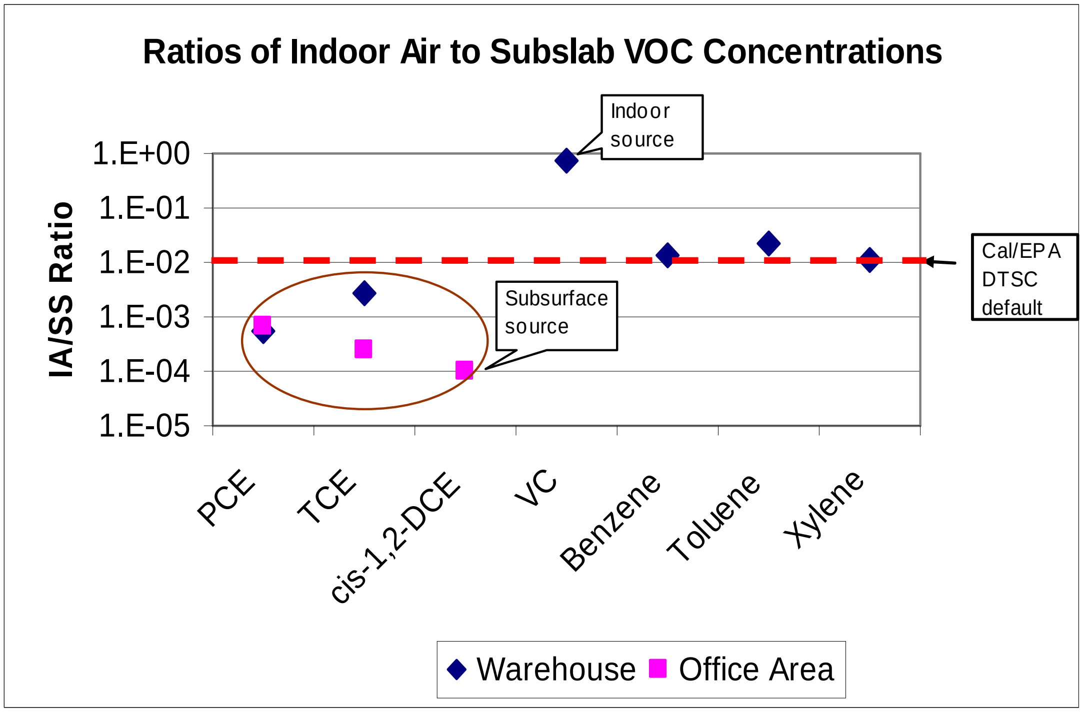
Step 10: **Indoor Air concentrations acceptable?** No. Tetrachloroethylene (PCE) concentrations were above acceptable levels in office areas and drainage location.

Table B-2: Sub-slab and Indoor air concentrations in on-site commercial building

Chemical	**Sub-Slab (µg/m^3)**	**Indoor Air (µg/m^3)**	**Cancer Risk (Indoor Air)***
Trichloroethene	100 to 98000	ND to 5.9	3×10^{-6}
Tetrachloroethene	220 to 260000	ND to 100	1×10^{-4}
Benzene	ND to 300	ND to 1.7	**
Vinyl Chloride	ND to 100	ND to 75	***

*Maximum concentration;
** Indoor air concentrations were same as outdoor ambient air levels;
***Polymer beads in warehouse were likely source of VOC

Step 11: **Mitigate indoor air exposures. Conduct long term monitoring.** Ventilation rates were increased inside office buildings and the drainage area (where high concentrations of PCE were detected) was sealed off. The source of vinyl chloride was removed from the warehouse facility. A soil vapor extraction (SVE) system was installed on the eastern portion of the property to begin extracting VOCs from the subsurface.



Comparison of attenuation factors (indoor air to sub slab data) indicated that tetrachloroethylene (PCE) and trichloroethylene (TCE) originated from the subsurface (AF in the 0.0001 range) while VC, benzene, toluene and xylene had other indoor air sources (AF in the 0.01 range)

CONCLUSIONS

- California EPA Vapor Intrusion Guidance was used as the common process for evaluating the significance of vapor intrusion to indoor air.
- A side-by-side comparison of the individual steps in this process reveal similarities and differences in the approach taken when evaluating vapor intrusion scenarios for the two cases.
- Multi-faceted approaches for data collection and evaluation are primarily based on site-specific considerations.
- Multiple lines of evidence from site data analyses lead to different conclusions regarding the significance of subsurface vapor intrusion at the two sites.
- For Site A, two rounds of monitoring activities showed that indoor air quality at residential homes are comparable to ambient (outdoor) air quality. Spatial data plots and comparison of attenuation factors among chemicals indicate that subsurface vapor intrusion is not significant at residential homes.
- For Site B, soil gas, sub-slab and indoor air data demonstrated that PCE migrated from the sub-surface into on-site indoor air spaces. Site specific attenuation factors support the conclusion that vinyl chloride in indoor air (onsite) originated from polymer beads stored in warehouse, while benzene, toluene and xylenes might be related to sources within the building (such as the vehicle storage area)

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