Urban Infrastructure and the Challenges Posed for Assessing and Mitigating Vapor Intrusion Adjacent to a Former Dry Cleaner: a Case Study

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1. Abstract

Assessment and mitigation of the subsurface vapor intrusion-to-indoor air pathway near a former dry cleaner in a densely settled urban site in Massachusetts generated interesting information regarding the influence of urban infrastructure on tetrachloroethene (PCE) migration and management. A case study will be discussed in which developing a conceptual site model (CSM) was integral to planning and executing a targeted investigation and optimizing the mitigation system design.

Initial site investigations identified a leaky sewer lateral as a likely pathway for PCE releases. Shallow groundwater flow and PCE migration were influenced by utilities, historic fill and a marine clay layer that inhibited downward migration. Sub-slab ventilation (SSV) systems were installed in multi-unit residential structures across the street from the former Dry Cleaner, which reduced PCE concentrations in indoor air; however, persistent PCE in the indoor air of one building required an innovative solution. The extent of the PCE plume was only partially defined because of constraints imposed by the existing building, so a targeted groundwater investigation adjacent to and through the basement slab was used to refine the CSM. Based on the update CSM, the SSV system was modified to include horizontal extraction wells beneath the foundation slab. Subsequent monitoring showed reduced indoor air PCE concentrations and SSV vacuum propagation throughout the building footprint overlying the PCE plume, after which regulators concurred with the effectiveness of the mitigation system and agreed to reduce indoor air monitoring frequency from monthly to annually. Based on the understanding of system performance, the SSV blower was optimized to reduce electrical consumption while maintaining mitigation effectiveness. Monitoring systems were configured to nearly eliminate the need for remediation workers to enter occupied spaces, which dramatically reduced operating costs and minimized public relations concerns. Understanding the influence of urban infrastructure was critical for effective and efficient management of vapor intrusion risks.

2. Problem

1. PCE measured in indoor air exceeded regulatory criteria persistently despite an operating SSV system;
2. The SSV system imposed only a very small differential pressure across the slab (<5 Pascals or 0.02 inches of water, where the ASTM standard for radon mitigation systems is 6-9 Pascals); and
3. The distribution of PCE in groundwater beneath the structure, the presumed source of PCE to indoor air, was unknown.

3. Refining the Conceptual Site Model

• Former dry cleaner off the figure to the right; subject structure on the left.

• PCE condensate leaked through cracks in sewer lateral causing >10,000 μg/L in groundwater over right half of Figure 1.

• The SSV system induced a differential of 1 to 3 Pa across the foundation slab nearest the plume.

• Prior to study the distribution of PCE in groundwater under the apartment building was presumed to extend westward under the slab.

• Following installation of groundwater monitoring wells through the slab and near the footer, a clearer picture emerged and a targeted modification of the SSV system was planned.

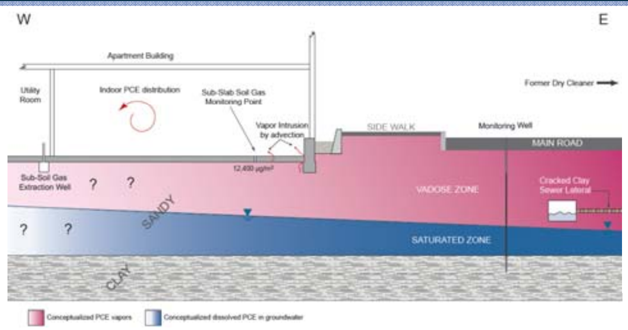


Figure 1. Pre Investigation Schematic: Subsurface infrastructure, stratigraphy and groundwater monitoring location. Groundwater flow is out of the page. Cracks in a ~100 year-old, 6" clay sewer lateral were the suspected conduits for discharge of PCE condensate to the subsurface. The former dry cleaner was located off the figure to the right. The distribution of PCE in groundwater most relevant to vapor intrusion (i.e., beneath the foundation slab) was unknown.

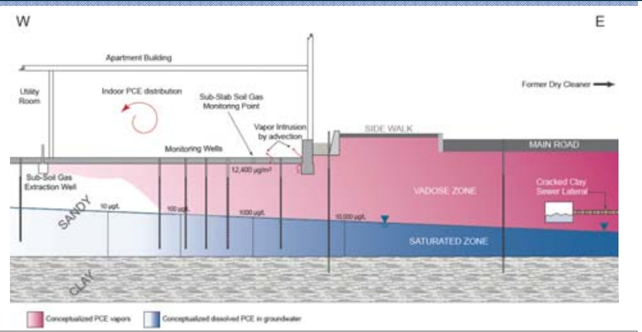


Figure 2. Post Investigation Schematic: PCE impacts to groundwater were clarified, and a modification to the SSV system was planned to (1) improve protectiveness for occupants and (2) focus SSV system operation where it was needed until groundwater remediation was completed. The locations of new sub-slab groundwater monitoring wells are indicated on Figure 5. These wells served a dual purpose of characterization and implementation of bioremediation for groundwater and ultimately for vapor intrusion.

4. Sub-slab Ventilation System Modification

The original SSV system used two vertically-installed extraction points, but due to limited access, the nearest extraction point was not installed on the plume-facing side of the building. The modified system included two horizontal trenches installed directly over the footprint of the PCE plume in groundwater, and connected to the original system's blower via overhead vacuum lines installed above the drop ceiling.

Figure 3 (Right). SSV System Modification Layout: In this figure, east is up, towards the former dry cleaner and PCE impacts to groundwater. Groundwater flow is to the right. The modified system could be configured to use any combination of new or existing extraction points.

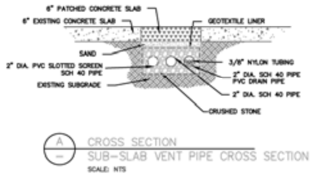


Figure 4 (Above Left). SSV Modification Trench Detail: After removing the carpet and cutting a trench through the slab, 2 lengths of slotted PVC were installed in a crushed stone backfill, covered with a geotextile and sand, and then the floor was re-cemented. Prior to re-carpeting, the joint between the floor and the footer was sealed.

5. Sub-slab Ventilation System Testing

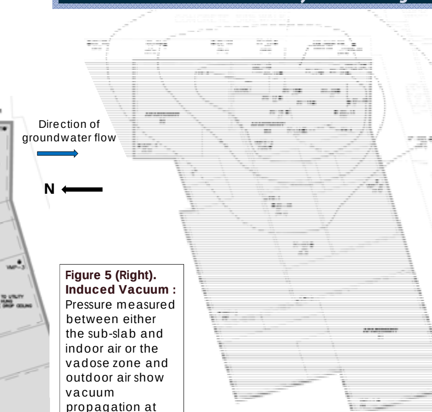


Figure 5 (Right). Induced Vacuum : Pressure measured between either the sub-slab and indoor air or the vadose zone and outdoor air show vacuum propagation at more than 10 Pascals beyond the footprint of the PCE plume, including outside the building footer.

Modifications to the SSV system resulted in several noteworthy improvements:

1. Improved and targeted vacuum propagation (Figure 5)
- Improved from ~1-3Pa to >100Pa along eastern wall facing the PCE plume in groundwater.

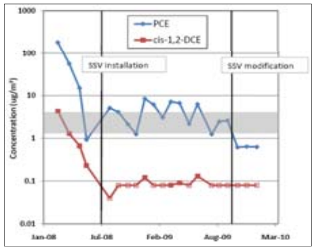
2. Reduced PCE concentrations in indoor air (Figure 6)
- PCE showed almost 100x reduction after SSV system startup (July 2008) and another almost 10x reduction after modification.
- PCE has been non-detect in indoor air since system modification (August 2009).

3. Reduced monitoring frequency
- Shifted indoor air sampling to annual instead of monthly.

4. Reduced impact to occupants
- Teflon® tubing installed in overhead pipe chase allows for annual indoor air sampling remotely from a central utility room, avoiding tenant disturbance.

5. Reduced costs to operate
- Successfully argued that maintaining pressure differential, measured monthly, demonstrated system functionality without frequent indoor air sampling.

Figure 6 (Right). PCE and cis-1,2-DCE in Indoor Air vs. Time: Indoor air samples were collected with Summa canisters equipped with 8-hour flow controllers from the apartment where SSV system modifications were completed. The gray band indicates the 50th to 90th percentiles for PCE in Typical Indoor Air in residences in Massachusetts. The cis-1,2-DCE history indicates that VOCs in indoor air were derived from groundwater.



ND values indicated with an open symbol.

Summary and Next Steps

- Constructing a CSM and performing a data gap analysis facilitated significant and targeted improvements to the mitigation system.
- Cost and intangible savings were realized through reductions in laboratory analytical needs, consulting labor for sampling and occupant disturbance.
- The modified extraction lines used the same blower and off-gas treatment system as the original SSV system.
- The existing blower will be replaced with a smaller one to reduce electrical costs by an estimated $2000 to $3000 per year while maintaining adequate vacuum propagation and other associated benefits.
- PCE in the saturated zone is being treated with in situ bioaugmentation, which is anticipated to reduce the time frame over which the SSV system must operate.