Technical Guide For Addressing Petroleum Vapor Intrusion At Leaking Underground Storage Tank Sites

United States Environmental Protection Agency

This document provides technical information to regulatory personnel from the U.S. Environmental Protection Agency (EPA) and state, tribal, and local agencies for investigating and assessing petroleum vapor intrusion (PVI) at sites where petroleum hydrocarbons (PHCs) have been released from underground storage tanks (USTs). **This document is comprised of two parts: (**1) Recommendations, which provides a description of EPA's recommended approach for addressing PVI; and (2) Supporting Technical Information, which provides detailed technical information supporting the recommendations. http://www.epa.gov/oust/cat/pvi/index.htm

Overview Of Petroleum Vapor Intrusion

Vapor intrusion is the general term given to migration of volatile organic chemicals (VOCs) from any subsurface contaminant source, such as contaminated soil or groundwater, through the soil and into an overlying building. There are two general classes of VOCs that account for a large number of soil and groundwater contamination sites in the United States:

- Petroleum hydrocarbons (PHCs) and non-PHC fuel additives
- Chlorinated solvents (e.g., the dry cleaning chemical tetrachloroethylene, also known as perchloroethylene, (PCE), and the degreasing solvents trichloroethylene (TCE), 1,1,1trichloroethane (TCA)).

In this guide, petroleum vapor intrusion (PVI) is defined as the intrusion of vapors from subsurface PHCs and non-PHC fuel additives into overlying or nearby buildings or structures.

Vapors emanating from petroleum-contaminated soil or groundwater that enter buildings may result in indoor air concentrations that pose a risk to building occupants. PVI may pose both immediate threats to safety (e.g., fire or explosion potential from petroleum vapors or methane) and possible adverse health effects from inhalation of toxic chemicals (e.g., exposure to benzene from gasoline). PVI may be associated with three groups of volatile chemicals:

- PHCs found in gasoline, diesel, and jet fuel (e.g., benzene, trimethylbenzenes (TMBs), naphthalene)
- Volatile chemicals other than PHCs that may be found in petroleum fuels, such as ethers, alcohols, and other fuel additives (e.g., methyl tertiary-butyl ether (MTBE), tertiary-butyl alcohol (TBA), ethylene dibromide (EDB), and 1,2-dichloroethane (1,2DCA))
- Methane, which is generated from anaerobic biodegradation of PHCs and other constituents of petroleum fuels (especially ethanol), and organic matter in soil

In contrast to chlorinated solvents, PHCs generally biodegrade rapidly under aerobic conditions and if biodegradation is complete, produce only water and carbon dioxide. If biodegradation is incomplete a variety of intermediate degradation products may be formed, but these are usually less toxic than the parent PHCs. If chlorinated solvents biodegrade it is usually under anaerobic conditions, which is slower and may produce intermediate degradation products that are more toxic than the parent compounds.

The aerobic biodegradability of PHCs typically reduces the potential for PVI and justifies a different approach for addressing PVI than for vapor intrusion from chlorinated solvents and other non-aerobically biodegradable VOCs.

Scope And Applicability

This PVI guide focuses on releases of petroleum-based fuels (e.g., gasoline, diesel), including both PHCs and non-PHC fuel additives, from underground storage tanks (USTs) regulated under Subtitle I of the Solid Waste Disposal Act of 1984, which are typically located at gas stations. **This guide applies to new and existing releases of PHCs and non-PHC fuel additives from leaking USTs and to previously closed sites where the implementing agency has reason to suspect that there may be a potential for PVI.** Although EPA developed the PVI guide based on data from typical UST sites, this technical guide may also be helpful when addressing petroleum contamination at comparable non-UST sites. Petroleum contamination at sites that are not comparable to UST sites (such as refineries, petrochemical plants, terminals, aboveground storage tank farms, pipelines, and large scale fueling and storage operations at federal facilities), or sites with releases of non-petroleum chemicals including comingled plumes of petroleum and chlorinated solvents regardless of the source, should be addressed under OSWER's more general vapor intrusion guide.
http://www.epa.gov/oswer/vaporintrusion/

This PVI guide does not impose legally binding requirements on implementing agencies or the regulated community. Decision-makers retain the discretion to adopt or approve approaches on a case-by-case basis that differ from this technical guide.

Recommended Actions For Addressing PVI

Addressing the potential for PVI is an integral part of the normal response to a suspected or confirmed release from any Subtitle I regulated UST system. At any leaking UST site, it is important to have a thorough understanding of the release (i.e., source, composition, and magnitude) and other factors that may influence the distribution and transport of contaminants that impact human safety and health. Until it is clear that human health and the environment are adequately protected from adverse impacts caused by the release, appropriate site characterization, risk assessment, and corrective action activities should continue.

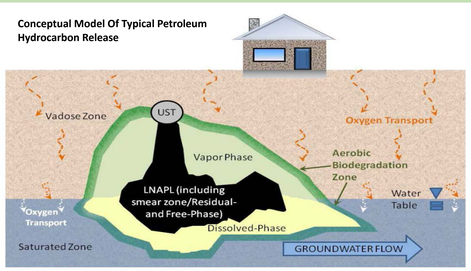


Table 1. Recommended Actions for Addressing PVI at Leaking Underground Storage Tank Sites

Recommended Actions	Purpose And Objectives	Procedures
Assess and mitigate immediate threats to safety (see Section 1, p.11)	Identify potential threat of explosion or fire due to petroleum vapors or methane. Threat may be indicated by: • LNAPL visible in building, possibly as sheen in sump • Noticeable petroleum odor; headache, dizziness, or nausea • Atypical, unusual, or disagreeable taste or smell in the water supply NOTE: Methane cannot be detected on the basis of odor, taste, or visible signs	• Investigate all reports of petroleum odors and other indicators within buildings • Detection of the presence of methane; requires specialized devices • Alert first responders so that they can, if necessary, evacuate building occupants as necessary until the potential for fire or explosion has been assessed and mitigated as needed
Conduct a site characterization and develop a conceptual site model (CSM) (see Section 3, p.39)	Characterize the physical, biological and chemical systems at the site, with emphasis on determining the spatial and temporal relationship between receptors and sources of contamination by: • Determining the full extent and location of contamination and its nature • Assessing the potential for biodegradation of PHCs • Defining the hydrologic and geologic characteristics of the site • Identifying potential receptors in the vicinity • Identifying whether preferential transport pathways are present and connect PHC vapor sources with potential receptors. Preferential transport pathways include both natural (i.e., geologic) and man-made (i.e., underground utilities, excavations) features.	• Collect sufficient site data and information to construct CSM • Identify data gaps • Update CSM as new data become available • Where preferential transport pathways connect PHC vapor sources to receptors (e.g., buildings), indoor air sampling paired with sub-slab vapor sampling is recommended
Delineate a lateral inclusion zone (see Section 4, p.44)	Screen out buildings that are not likely to be impacted by PVI to narrow the investigation to only those buildings that have a greater potential for PVI and for which further investigation should be conducted. The lateral inclusion zone is site-specific and: • Based on the extent of contamination and distance between clean monitoring points • Decreases in extent as additional data are collected to reduce uncertainty in the CSM	• Construct lateral inclusion zone based on distance between clean monitoring points (includes consideration of the presence of preferential transport pathways)

Determine vertical separation distances (see Section 5, p.48)	Further screen out buildings that are not likely to be impacted by PVI to focus the investigation on potential receptors that overlie contamination in the dissolved, vapor, and/or LNAPL phase. The vertical separation distance is:
	• The thickness of clean, biologically-active soil (see **Section 9**, p.75) separating contamination from overlying buildings or other potential receptors
	• Determined by site-specific sampling to determine the depth at which contamination is present
		• For each building within the lateral inclusion zone, collect additional soil gas, soil, and groundwater samples as necessary to determine the vertical separation distance. Additional investigation is generally unnecessary if the distance to contamination is greater than:
		  • 6 feet for dissolved contamination beneath buildings of any size, or
		  • 15 feet for LNAPL if the overlying building has at least one side shorter than 66 feet in length
		• If the distance to contamination is less than those indicated above, then additional investigation is recommended.

Evaluate vapor source and attenuation of PHC vapors (see Section 5, p.48, Section 8, p.66, Section 9, p.75, Section 10, p.81, Section 12, p.100, and Section 13, p.106)	Carefully evaluate the potential for PVI into those buildings identified as being the most likely to be impacted by PVI. This is a building-by-building evaluation based on sampling conducted within close proximity to the building or inside the building as necessary.	If contamination is in direct contact with building basement, foundation, or slab, then collect indoor air samples. Otherwise choose either option (1) or (2) below: 1. Collect near-slab soil gas samples coupled with deep (source) soil gas samples. If a potential threat of PVI is indicated, then proceed to option 2. If not, PVI is not likely to be a concern. 2. Collect indoor air samples paired with sub-slab soil gas samples. If these results indicate a potential threat of PVI, mitigate PVI as appropriate.
Mitigate PVI as appropriate (see Section 1, p.11)	Interrupt the pathway between the source of contamination and potential receptors. • Numerous approaches depending on building characteristics	• Select a remedial design that is appropriate for building and site • Remediate source of contamination, including recovery of LNAPL (if present) to the maximum extent practicable • Establish institutional controls to limit or prohibit access to affected areas of building, as necessary

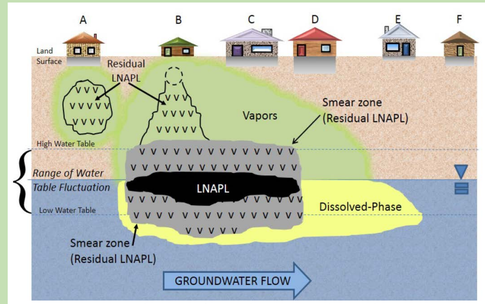
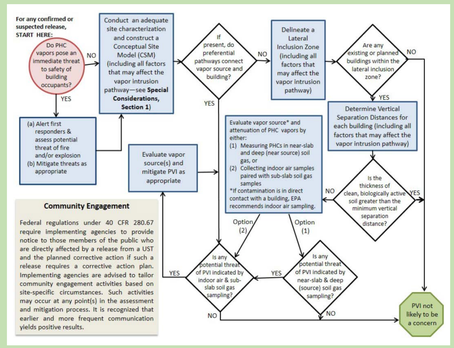


Figure 4. Typical Scenarios of Potential PVI Sources and Potential Receptors

Table 2. Summary of Characteristics of Typical Scenarios of Petroleum Vapor Sources and Potential Receptors

Scenario (as illustrated in Figure 4)	Contamination Beneath Building? (building is within lateral inclusion zone)	Potential For PVI	Near-Slab* Soil Gas Sampling Recommended?
A	Yes; shallow residual LNAPL in the vadose zone	High	Yes, if vertical separation distance is less than 15 feet from the top of residual LNAPL, otherwise No
B	Yes; residual including smear zone, LNAPL, dissolved in groundwater	High	Yes, if vertical separation distance is less than 15 feet from the top of the smear zone, otherwise No
C	Yes; smear zone, LNAPL, dissolved in groundwater	Medium	Yes, if vertical separation distance is less than 15 feet from the top of the smear zone, otherwise No
D	Yes; dissolved in groundwater	Low	Yes, if vertical separation distance is less than 6 feet from the historical high water table elevation, otherwise No
E	Maybe; plume may be diving beneath water table	Low – None	Yes, if vertical separation distance is less than 6 feet from the historical high water table elevation, otherwise No
F	No	None	No

*Near-slab soil gas samples should be collected from each side of the potentially impacted building and as close to the building as possible. These samples should be paired with deep (near source) soil gas samples. If these samples do not clearly demonstrate that biodegradation is sufficient to mitigate the threat of PVI into the building, EPA recommends collection of indoor air samples paired with sub-slab soil gas samples.



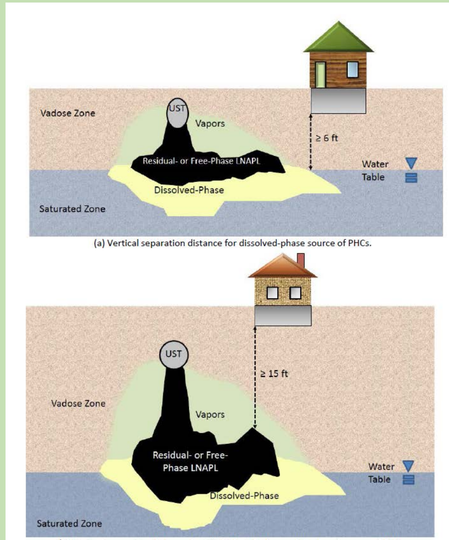


Figure 6. Vertical Separation Distances Between Source Of PHC Contaminants And Hypothetical Receptor: (a) Dissolved Source, (b) LNAPL Source.

Table 3. Recommended Vertical Separation Distance Between Contamination And Building Basement Floor, Foundation, Or Crawlspace Surface.

Media	Benzene	TPH	Vertical Separation Distance (feet)*
Soil (mg/Kg)	≤10	≤ 100 (unweathered gasoline), or ≤ 250 (weathered gasoline, diesel)	6
	>10 (LNAPL)	> 100 (unweathered gasoline) >250 (weathered gasoline, diesel)	15
Groundwater (mg/L)	≤5	≤30	6
	>5 (LNAPL)	>30 (LNAPL)	15

The thresholds for LNAPL indicated in this table are indirect evidence of the presence of LNAPL. These thresholds may vary depending on site-specific conditions (e.g., soil type, LNAPL source). The value of 5 mg/L benzene is from EPA (2013a, p.31). A study by Peargin and Kolhatkar (2011) suggests that a dissolved source with benzene greater than 1 mg/L may behave like a LNAPL source in terms of vapor-generating capability. Decision-makers may have different experiences with LNAPL indicators and may use them as appropriate. For more information, see **Section 6** (p.57) and **Figure 7** in particular.

Bulk soil samples should be analyzed for Total Petroleum Hydrocarbon (TPH) and BTEX (plus any other potential contaminants). The objective of measuring TPH is to quantify the total vapor phase concentration of PHCs. TPH may be analyzed by methods appropriate for the type of fuel released. These methods may be designated as TPH-gasoline (or sometimes gasoline range organics or GRO), TPH-diesel (or sometimes diesel range organics or DRO). Method TO-15 (see http://www.epa.gov/ttn/amtic/files/ambient/airtox/to-15r.pdf) by itself only measures a small fraction of PHCs that may be present in the vapor-phase. TO-15 analyses require a correction factor to estimate bulk TPH. An extended TO-15 analysis can provide such an estimate. For more information on TPH in vapor intrusion studies, see Brewer et al. (2013).

*The vertical separation distance represents the thickness of clean, biologically active soil between the source of PHC vapors (LNAPL, residual LNAPL, or dissolved PHCs) and the lowest (deepest) point of a receptor (building basement floor, foundation, or crawlspace surface).

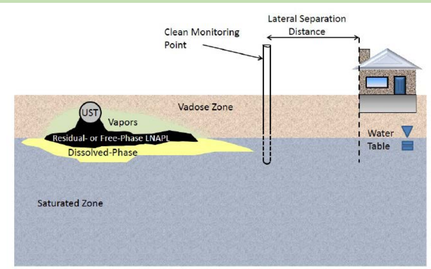
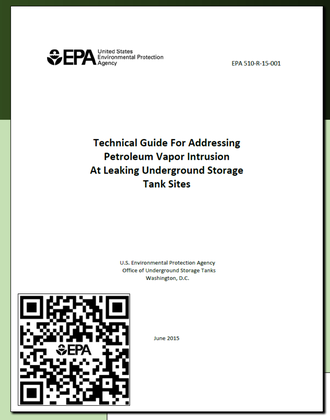


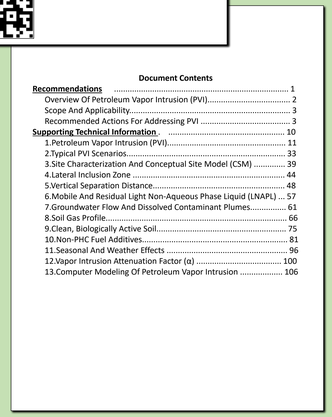
Figure 5. Lateral Separation Distance Between Source Of PHC Contamination And Hypothetical Receptor

Recommendation

Delineation of a lateral inclusion zone is site-specific. EPA recently published An Approach for Developing Site-Specific Lateral and Vertical Inclusion Zones within which Structures Should be Evaluated for Petroleum Vapor Intrusion due to Releases of Motor Fuel from Underground Storage Tanks (EPA, 2013b). This Issue Paper describes a procedure for constructing a lateral inclusion zone that decision makers may find useful. EPA recommends that all buildings within the lateral inclusion zone be further assessed to determine if they are separated from vapor sources by an adequate vertical separation distance. Further assessment may be unnecessary for those buildings outside the lateral inclusion zone unless:

- Preferential transport pathways are present that connect PHC vapor sources to receptors
- Impermeable surface cover (e.g., concrete, asphalt, ice, very large buildings) is so extensive that there is concern whether there is sufficient oxygen in the subsurface to support biodegradation
- Soil conditions are inhospitable to microorganisms (e.g., dry soils with less than 2 percent soil moisture by dry weight) such that biodegradation is insufficient to mitigate the threat of PVI





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