
Guidance Document for the Volatilization to the Indoor Air Pathway (VIAP)

Volume 4: Investigative approach for petroleum VIAP

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EXECUTIVE SUMMARY

Petroleum vapor intrusion (PVI) is a unique subdivision of the volatilization to indoor air pathway (VIAP) distinguished by the influence of aerobic biodegradation in degrading volatile petroleum hydrocarbon (PHC) vapors over short distances. Occurrence of this mechanism supports that risk evaluation associated with PVI should focus on contaminated groundwater at the surface (i.e., top) of the zone of saturation and areas where the non-aqueous phase liquid (NAPL) body is located above the saturation zone or where mobile NAPL intersects an underground conduit that may transport vapors to a structure. For PVI, risk evaluation can often be accomplished through application of nationally supported separation distances and strategic placement of representative soil gas samples around the NAPL body and contaminated groundwater.

1. INTRODUCTION

PVI and the direct volatilization of a petroleum hydrocarbon into a structure is a subdivision of the VIAP and is the process by which PHCs volatilize into vapors and migrate into a structure with the potential to pose an unacceptable exposure risk to human health.

This document uses a scientifically based approach that has been supported by empirical data and is based on the ITRC Petroleum Vapor Intrusion – Fundamentals of Screening, Investigation, and Management (PVI -1) (ITRC 2014) so that decisions can be made to confidently screen out any area, place, parcel or parcels of a property, or portion of a parcel of a property and focus limited resources on the small fraction of petroleum-contaminated properties that warrant further evaluation, vapor control, or an additional response activity to prevent unacceptable exposure risks. This document is drafted to specifically address only PVI and is consistent with Part 201. However, the approaches found in this document are applicable and can be used under Part 213 though the terminology will be different due to the use of a Risk-Based Corrective Action program consistent with ASTM International E1739.

NOTE: The use of the information in this volume requires that the data collected be representative of the actual conditions and for the purpose that it is intended. It is the user's responsibility to understand the strengths and weakness of the sampling methodology prior to utilizing and that the resulting data is what the decision is based on.

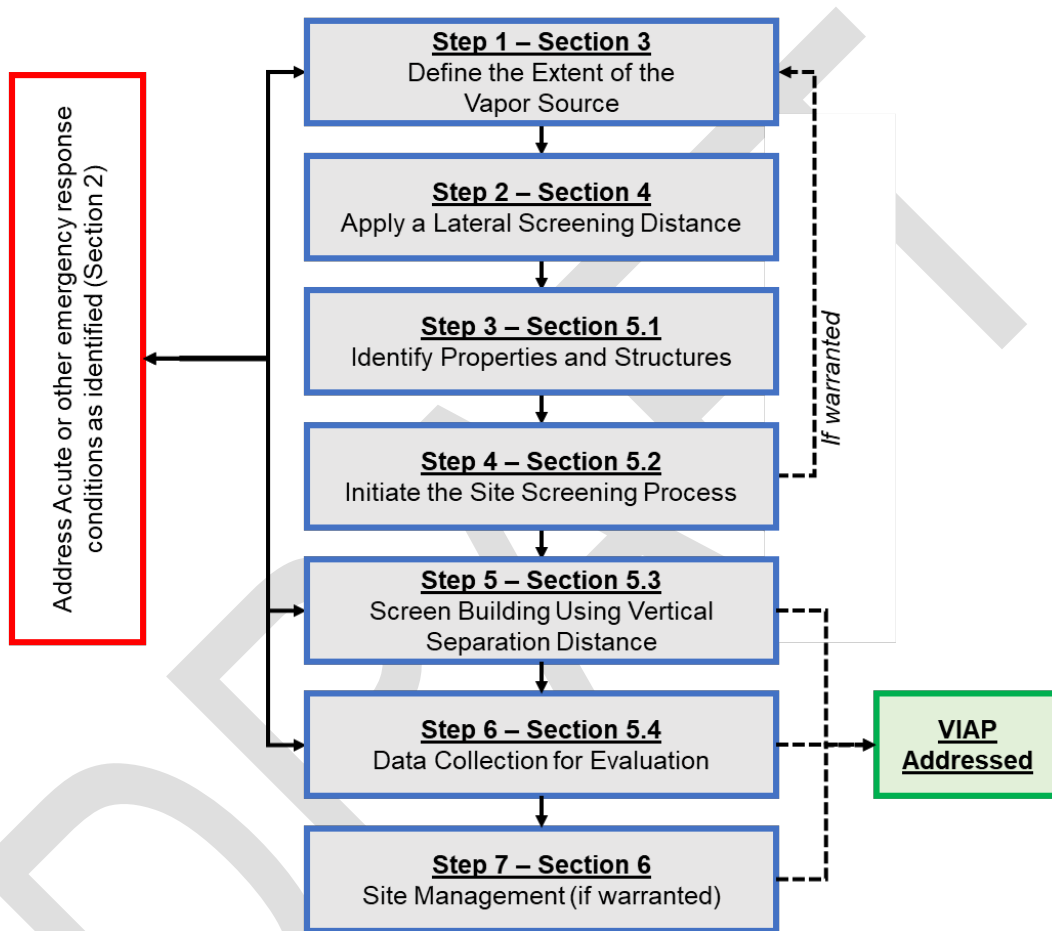
1.1. About this Volume

This volume is intended for petroleum releases that are sufficiently characterized to identify and evaluate vapor sources that rapidly biodegrade in the presence of O₂ relative to receptor locations. It does not address chlorinated volatile organic compounds (CVOCs) or other aerobically recalcitrant non-petroleum hydrocarbons compounds above the VIAC. The screening method described in this document is applicable whether the release occurred from an underground storage tank (UST); aboveground storage tank (AST); manufactured

gas plant (MGP); petroleum industrial terminal, refinery, pipeline; or other type of petroleum release. The screening and evaluation is applicable to petroleum releases in general and is not limited to the use of a property.

The VIAP assessment strategy is based upon the following stepwise approach shown on Figure 1-1.

Figure 1-1
Generalized Approach to the VIAP for Aerobically Degradable Hazardous Substances



1.2. PVI and Vapor Intrusion (VI)

The defining feature of PVI that distinguishes it as a unique subdivision of VI is the rapid rate of attenuation of PHCs because of aerobic biodegradation. With PVI, vapor concentrations generally decrease with increasing distance from a subsurface vapor source due to aerobic biodegradation, and eventually at some distance, the concentrations become negligible (USEPA 2015a and 2015b). The extent and rate to which this natural biodegradation process occurs is strongly influenced by several factors cited by Lahvis and Baehr (1996), Suarez and Rifai (1999) and USEPA (2015a) and include: the concentration of the vapor source, the distance the vapors must travel to potential receptors, and the presence of oxygen (O₂). Petroleum vapors are not expected to migrate more than 15 feet (ft) with most vapors being degraded within inches to a few feet.

Studies have documented the subsurface biodegradation of PHC vapors (McAlary et al. 2007; Ririe et al. 2002; Hers et al. 2000; Ostendorf et al. 2000). Recent evaluations of empirical soil gas data have demonstrated that biodegradation can limit the migration of PHC vapors from a subsurface vapor source (USEPA 2013; Lahvis et al. 2013; Davis 2009). These studies show that the potential for PVI is reduced because biodegradation minimizes the flux of PHC vapors in soil gas from a vapor source to overlying buildings.

General differences is discussed in Table 2-1 ITRC (2014) which is based on USEPA (2012a) and summarizes the differences between PVI and VI for PHCs and CVOCs. These differences form the basis for the PVI-specific facility screening approach discussed and detailed in this volume.

1.3. Biodegradation

Aerobic biodegradation is the most important fate and transport mechanisms for understanding PVI and is the basis for the screening strategy presented in **Sections 4** and **5**.

The processes of partitioning, diffusion, advection, and mixing are the same for PHCs and other compounds, including CVOCs. Further details on these processes, its uniqueness to PVI and the biogeochemical behavior of PHCs is discussed in Appendix C - Chemistry of Petroleum and Appendix M - Fate and Transport of Petroleum Vapors in ITRC (2014). A summary of the processes of the biodegradation is provided below.

The Process of Biodegradation

PHC-degrading bacteria are found in biologically active soil in most environments (USEPA 2015a) in Michigan. PHC-degrading bacteria can consume hydrocarbons rapidly in the presence of O₂. This process limits the transport of PHC vapors. Although PHCs can be biodegraded in the absence of O₂, the most rapid rates of biodegradation typically occur under aerobic conditions. The vadose zone above an area contaminated by a petroleum NAPL is normally an aerobic environment in which O₂ can be readily replenished from the atmosphere. USEPA (2013 and 2015b) identified a total petroleum hydrocarbon (TPH) concentration of 250,000 micrograms per kilogram (µg/kg) as a metric for clean, biologically active soil absent of NAPL. This aligns with EGLE's lines of evidence for indicators of when NAPL is present (see EGLE's Non-Aqueous Phase Liquid – Petroleum Releases Characterization, Remediation, and Management Guidance dated June 2023) and identifies where the aerobic environment will be outside of the NAPL body. The rates of petroleum vapor biodegradation typically exceed the rates of petroleum vapor transport via diffusion; therefore, petroleum vapors are often fully attenuated by aerobic biodegradation processes in the vadose zone. This process is fundamental in understanding why unsaturated soil that does not contain NAPL does not pose a risk to the VIAP and use of the screening distances for the maximum distances the petroleum vapors are likely to migrate before degradation.

Environmental Effects on Biodegradation

While there is the general reliability of aerobic biodegradation in reducing PVI, there are some environmental factors that can hinder this process, such as arid climates that lack of soil moisture (USEPA 2015a), which are not common in Michigan. The most significant factor in biodegradation is the availability of O₂, which is a necessary electron acceptor and enzyme reactant in the aerobic biodegradation of PHCs. Roggemans et al. (2001) showed O₂ concentrations of 2% by volume to be supportive of aerobic biodegradation. Factors that can limit the biodegradation are described in ITRC (2014). In Michigan, these factors can often be identified by the lack of O₂ present in the subsurface.

1.4. PVI Conceptual Site Model (CSM)

A CSM provides an iterative representation of the site data and information collected from the property or properties and guides the decision-making process. The CSM should be refined throughout the life of the project as new information is acquired. Because of the importance of biodegradation to PVI, the VIAP portion of the CSM for any petroleum release should incorporate biodegradation. Information to construct the CSM is acquired from historical research, facility characterization (e.g., sample collection), and an understanding of contaminant behavior, among other sources.

Vapor Source for a Petroleum Release

CSMs assist in defining and depicting the nature and extent of the vapor source and identifying where a potentially unacceptable risk for the VIAP may occur to guide further evaluation or response actions. The vapor source is key to understanding and identifying where potentially unacceptable risks for the VIAP may occur.

For the VIAP, the vapor source is represented by concentrations in exceedance of applicable unrestricted residential soil and groundwater VIAC. As discussed above, aerobic biodegradation is an important factor to PVI because it rapidly degrades PHC vapors over relatively short distances (ITRC 2014). Site data shows that when petroleum is most likely to pose a risk to the VIAP are limited to NAPL being close to structures (e.g., less than 15 feet); dissolved phase PHCs or NAPL in direct contact with or entry into building foundations (e.g., basements, elevator pits, etc.); and dissolved phase PHCs or NAPL entering into subsurface utilities (McHugh et al. 2010). Therefore, petroleum-contaminated soil in exceedance of applicable unrestricted residential soil VIAC that has been determined through multiple lines of evidence to be without NAPL will not be utilized in PVI risk evaluations.

Specifically, for PVI, the NAPL and contaminated groundwater in exceedance of applicable unrestricted residential VIAC are the primary areas of the vapor source where risk evaluation and characterization is warranted. In these areas, it is important to identify utilities that may allow the direct entry of contaminated groundwater or mobile NAPL to a current (or future) building or enter into a conduit that can transmit vapors to a current or future building.

Volume 6 – Volatilization to the Indoor Air Criteria provides a detailed description of the equations, inputs, and assumptions used in the development of applicable risk based VIAC with EGLE’s VIAP-SL’s calculator.

NOTE: If an evaluation is made in accordance with **Rule 299.14(5)** and **Rule 299.24(5)** using more representative data such as soil gas, it may be possible to show that the NAPL or petroleum-contaminated groundwater above applicable VIAC does not represent a VIAP risk for the current structure. The need for land or resource use restrictions will be highly dependent on-site conditions, how or where the soil gas samples were collected in relation to the vapor source, and if future land uses can be evaluated with representative soil gas samples. See **Section 6** for more details.

2. ADDRESSING ACUTE VAPOR RISKS

Unacceptable risks for VIAP may pose both immediate threats to safety (e.g., fire or explosion potential from petroleum vapors or methane) and possible short-term adverse health effects (acute) from inhalation of toxic chemicals. The potential for these to occur should be evaluated throughout the investigative process for structures within the LIZ.

NOTE: If strong petroleum odors are detected or combustible, explosive, or O₂-deficient conditions are found to exist inside a building, then first responders should be contacted immediately.

Additional Information is provided in **Attachment A** on the acute vapor risks associated with petroleum.

3. DEFINE EXTENT OF THE VAPOR SOURCE - STEP 1

Delineation of the vapor source for a petroleum release is necessary to identify which buildings and properties are within the LIZ (**Section 4**) and if there is sufficient vertical separation distance to screen out buildings (**Section 5**).

Applicable unrestricted residential soil and groundwater VIAC is used to define the vapor source during the investigative process to better understand the full extent of a person’s obligations that exist under **Part 201**. For a criterion to be applicable, all assumptions in the calculation of the criterion need to fit the conditions present at the facility. See **Volume 6 – Volatilization to the Indoor Air Criteria** for more information. For facilities that only need to consider their due care obligations under **Sec. 20107a** the applicable unrestricted residential VIAC identifies where a notice of migration is required if contamination migrates off-site.

Additional information on vapor source delineation can be found in **Attachment B**.

NOTE: Structures and properties outside of the LIZ require no further evaluation. Utilities outside of the LIZ only require evaluation if they are found to be transporting vapors.

4. APPLY A LATERAL SCREENING DISTANCE - STEP 2

Once the delineation of the vapor source has been established to applicable unrestricted residential groundwater VIAC and the NAPL body, a LIZ can be applied.

The LIZ is used to decide whether a structure or a property is close enough to a vapor source to be considered a potential risk to the VIAP. For petroleum, the LIZ includes the extent of the groundwater and/or NAPL vapor source as well as the applicable screening distances beyond the delineated extent of the petroleum vapor source. The lateral inclusion distances and vertical screening distances should be the same because the physical processes acting on PHC vapor sources (mass flux from the source, oxygen demand, and biodegradation) are the same in the vertical and horizontal directions (ITRC 2014). The vertical screening distances are expected to apply laterally in the absence of preferential pathways (natural or man-made). Structures, properties, and utilities located within the distance established by the LIZ (including those structures above a vapor source) require further evaluation as discussed in **Section 5**.

The LIZ should be based on the delineation of the groundwater in exceedance of applicable unrestricted residential VIAC and/or the NAPL vapor source. For a well characterized vapor source, the following distances may be applied:

- 15-feet from NAPL beginning at a location where NAPL is not located
- 5-feet for groundwater contamination (i.e., dissolved-phase sources), can be drawn from the edge of the delineated groundwater plume

For a petroleum facility, a 30-foot LIZ may be applied for a facility that is not well characterized when there are physical features or obstructions (e.g., a road) that require that the spacing of the borings is a long distance and the extent of contamination is interpolated. If warranted, the use of statistical methods, such as Kriging, can provide a means for justification of interpolated extent. EGLE recommends that soil and groundwater samples should be collected to complete the characterization to use the smallest LIZ rather than apply the 30-foot LIZ distance.

In some cases, a person may wish to reduce the LIZ distance further than the distances identified above. It may be possible for petroleum to reduce the LIZ to the extent of groundwater and/or NAPL vapor source with supporting data. This can be done through a representative soil gas investigation that shows PHC vapors are not migrating past the sampling location. Alternatively, a demonstration that includes a site-specific evaluation of O₂ in soil gas at the extent of the LIZ can be conducted. If the O₂ in the soil gas is greater than 2%, then there is sufficient O₂ to support rapid aerobic degradation and a reduction in the lateral inclusion may be established. However, the LIZ cannot be less than the extent of the vapor source, which is the NAPL body and the dissolved phase groundwater contamination in exceedance of applicable unrestricted residential VIAC.

