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# Starting Soon: Petroleum Vapor Intrusion

Poll Question

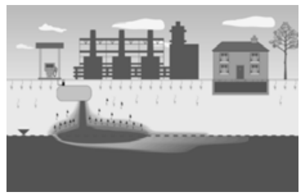
- Petroleum Vapor Intrusion (PVI) Technical and Regulatory Guidance Web-Based Document (PVI-1) www.itrcweb.org/PetroleumVI-Guidance
- Download PowerPoint file
  - Clu-in training page at http://www.clu-in.org/conf/itrc/PVI/
  - Under "Download Training Materials"
- Download flowcharts for reference during the training class
  - http://www.cluin.org/conf/itrc/PVI/ITRC-PVI-FlowCharts.pdf
- Using Adobe Connect
  - Related Links (on right)
    - Select name of link
    - Click "Browse To"
  - Full Screen button near top of page

No associated notes.

2

# Welcome – Thanks for joining this ITRC Training Class

## Petroleum Vapor Intrusion: Fundamentals of Screening, Investigation, and Management



Petroleum Vapor Intrusion (PVI) Technical and Regulatory Guidance Web-Based Document (PVI-1)
www.itrcweb.org/PetroleumVI-Guidance

Sponsored by: Interstate Technology and Regulatory Council (www.itrcweb.org)
Hosted by: US EPA Clean Up Information Network (www.cluin.org)

Chemical contaminants in soil and groundwater can volatilize into soil gas and migrate through unsaturated soils of the vadose zone. Vapor intrusion (VI) occurs when these vapors migrate upward into overlying buildings through cracks and gaps in the building floors, foundations, and utility conduits, and contaminate indoor air. If present at sufficiently high concentrations, these vapors may present a threat to the health and safety of building occupants. Petroleum vapor intrusion (PVI) is a subset of VI and is the process by which volatile petroleum hydrocarbons (PHCs) released as vapors from light nonaqueous phase liquids (LNAPL), petroleum-contaminated soils, or petroleum-contaminated groundwater migrate through the vadose zone and into overlying buildings. Fortunately, in the case of PHC vapors, this migration is often limited by microorganisms that are normally present in soil. The organisms consume these chemicals, reducing them to nontoxic end products through the process of biodegradation. The extent and rate to which this natural biodegradation process occurs is strongly influenced by the concentration of the vapor source, the distance the vapors must travel through soil from the source to potential receptors, and the presence of oxygen ($O_2$) in the subsurface environment between the source and potential receptors.

The ITRC Technical and Regulatory Guidance Web-Based Document, Petroleum Vapor Intrusion: Fundamentals of Screening, Investigation, and Management (PVI-1, 2014) and this associated Internet-based training provides regulators and practitioners with consensus information based on empirical data and recent research to support PVI decision making under different regulatory frameworks. The PVI assessment strategy described in this guidance document enables confident decision making that protects human health for various types of petroleum sites and multiple PHC compounds. This guidance provides a comprehensive methodology for screening, investigating, and managing potential PVI sites and is intended to promote the efficient use of resources and increase confidence in decision making when evaluating the potential for vapor intrusion at petroleum-contaminated sites. By using the ITRC guidance document, the vapor intrusion pathway can be eliminated from further investigation at many sites where soil or groundwater is contaminated with petroleum hydrocarbons or where LNAPL is present.

After attending this ITRC Internet-based training, participants should be able to:

Determine when and how to use the ITRC PVI document at their sites

Describe the important role of biodegradation impacts on the PVI pathway (in contrast to chlorinated solvent contaminated sites)

Value a PVI conceptual site model (CSM) and list its key components

Apply the ITRC PVI 8 step decision process to screen sites for the PVI pathway and determine actions to take if a site does not initially screen out (e.g., site investigation, modeling, and vapor control and site management)

Access fact sheets to support community engagement activities at each step in the process

For reference during the training class, participants should have a copy of the flowcharts, Figures 1-2, 3-2, and 4-1 from the ITRC Technical and Regulatory Guidance Web-Based Document , Petroleum Vapor Intrusion: Fundamentals of Screening, Investigation, and Management (PVI-1, 2014) and are available as a 3-page PDF at http://www.cluin.org/conf/itrc/PVI/ITRC-PVI-FlowCharts.pdf

Starting in late 2015, ITRC will offer a 2-day PVI focused classroom training at locations across the US. The classroom training will provide participants the opportunity to learn more in-depth information about the PVI pathway and practice applying the ITRC PVI guidance document with a diverse group of environmental professionals. Email training@itrcweb.org if you would like us to email you when additional information is available.

ITRC (Interstate Technology and Regulatory Council) www.itrcweb.org

Training Co-Sponsored by: US EPA Technology Innovation and Field Services Division (TIFSD) (www.clu-in.org)

ITRC Training Program: training@itrcweb.org; Phone: 402-201-2419

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- Course time is 2¼ hours
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- Questions and feedback
  - **Throughout training:** type in the "Q & A" box
  - **At Q&A breaks:** unmute your phone with #6 to ask out loud
  - **At end of class:** Feedback form available from last slide
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Although I'm sure that some of you are familiar with these rules from previous CLU-IN events, let's run through them quickly for our new participants.

We have started the seminar with all phone lines muted to prevent background noise. Please keep your phone lines muted during the seminar to minimize disruption and background noise. During the question and answer break, press #6 to unmute your lines to ask a question (note: *6 to mute again). Also, please do NOT put this call on hold as this may bring unwanted background music over the lines and interrupt the seminar.

Use the "Q&A" box to ask questions, make comments, or report technical problems any time. For questions and comments provided out loud, please hold until the designated Q&A breaks.

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# ITRC (www.itrcweb.org) – Shaping the Future of Regulatory Acceptance

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The Interstate Technology and Regulatory Council (ITRC) is a state-led coalition of regulators, industry experts, citizen stakeholders, academia and federal partners that work to achieve regulatory acceptance of environmental technologies and innovative approaches. ITRC consists of all 50 states (and Puerto Rico and the District of Columbia) that work to break down barriers and reduce compliance costs, making it easier to use new technologies and helping states maximize resources. ITRC brings together a diverse mix of environmental experts and stakeholders from both the public and private sectors to broaden and deepen technical knowledge and advance the regulatory acceptance of environmental technologies. Together, we're building the environmental community's ability to expedite quality decision making while protecting human health and the environment. With our network of organizations and individuals throughout the environmental community, ITRC is a unique catalyst for dialogue between regulators and the regulated community.

For a state to be a member of ITRC their environmental agency must designate a State Point of Contact. To find out who your State POC is check out the "contacts" section at www.itrcweb.org. Also, click on "membership" to learn how you can become a member of an ITRC Technical Team.

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# Meet the ITRC Trainers

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**Matthew Williams** is the Vapor Intrusion Specialist for the development and implementation of methods used to investigate and assess vapor intrusion issues for the Remediation and Redevelopment Division of the Michigan Department of Environmental Quality. He is a Geologist that has 18 years of experience in both the public and private sectors working on a wide variety of projects across the United States. He has drafted several guidance documents and standard operating procedures for the MDEQ and has conducted numerous training and talks on soil gas methods and vapor intrusion for stakeholder groups and consultants. He co-leads ITRC 2-day classroom training on Petroleum Vapor Intrusion and is a trainer in both the 2-day classroom and Internet-based training. Matt earned a Bachelor of Science degree in Geology from Central Michigan University in Mt Pleasant, Michigan in 1993.

**Ben Martich** is a Senior Scientist with Geosyntec Consultants in Anchorage, Alaska. Since 1996, he has worked in site characterization, risk assessment, and remediation. His disciplinary focus since 2004 has been characterization and risk associated with the vapor intrusion (VI) pathway. He has worked with the Alaska Department of Environmental Conservation and Montana Department of Environmental Quality in developing strategy for assessment and control of the vapor intrusion pathway, including research projects and guidance development. He has engaged in cold regions research of the vapor intrusion pathway with staff from the University of Alaska Fairbanks. He has been a member of ITRC's Petroleum Vapor Intrusion Team since its inception. Ben earned a bachelor's degree in analytical mathematics and statistics from Furman University in Greenville, South Carolina in 1996. He is a Qualified Environmental Professional (QEP) by the Institute of Professional Environmental Practice.

**Ian Hers** is a Senior Associate Engineer with Golder Associates located in Vancouver, British Columbia and has worked for Golder since 1988. He has 20 years professional experience in environmental site assessment, human health risk assessment and remediation of contaminated lands. Ian is a technical specialist in the area of LNAPL and DNAPL source characterization, monitored natural attenuation and source zone depletion, vapour intrusion, and vapour-phase *in situ* remediation technologies, and directs or advices on projects for Golder at petroleum-impacted sites throughout North America. He has developed guidance on LNAPL assessment and mobility for the BC Science Advisory Board for Contaminated Sites (SABCS) and the BC Ministry of Environment. Ian joined the ITRC LNAPL team in March 2008. Ian earned a bachelor's degree in 1986 and master's degree in 1988 in Civil Engineering from the University of British Columbia in Vancouver, BC. He then completed a doctoral degree in Civil Engineering from University of British Columbia in 2004. He is on the Board of Directors of the SABCS, is a Contaminated Sites Approved Professional in BC, and is a sessional lecturer at the University of British Columbia.

**Loren Lund** is a Principal Technologist for CH2M Hill in Shelley, Idaho. He has worked at CH2M HILL since 2008 and in environmental risk analysis and vapor intrusion since 1990. Loren is CH2M HILL's Vapor Intrusion Practice Leader, responsible for overseeing/training staff and insuring vapor intrusion best practices are applied. He is responsible for the company's compendium of best practices, standard operating procedures, quality assurance procedures, and VI website. Loren is an organizing committee member, classroom instructor, session chair, and presenter for the Air and Waste Management Association (AWMA) VI specialty conferences. He is a member of the Interstate Technology Regulatory Council (ITRC) Petroleum VI team, where he was the co-team leader responsible for authoring one of the chapters. Loren co-chairs the Navy VI Focus Group, was a co-author of the Navy 2011 Background Indoor Air Guidance for VI, and the senior technical leader for the Web-based Navy VI Tool and the current Navy Environmental Sustainability Development to Integration (NESDI) VI Decision Framework database project. He has reviewed multiple national VI guidance documents, authored over a dozen papers, and has been a session chair or featured speaker at more than a dozen VI conferences or sessions since 2004. Loren has presented over a dozen webinar training sessions on VI assessment and mitigation in the last five years. He earned a bachelor's degree in chemistry, a Ph.D. in biochemistry, and was a post-doctorate and adjunct professor in toxicology at the University of Texas in Austin.

**David Folkes** is a Principal with Geosyntec Consultants, Inc. in Denver, Colorado. Dave has worked on over 100 vapor intrusion (VI) projects across North America and overseas since 1998, including sites in Europe, South America, Australia, and Southeast Asia. He is Project Director of the Redfield Site, one of the largest VI sites in the US, and has served as an expert witness on several major VI cases, including class action lawsuits. Dave has been extensively involved with development of VI practice and guidance in the US, including training of regulators and consultants on use of the 2002 draft EPA VI guidance; and assistance with VI guidance development and training in many states over the past decade. As a member of the Interstate Technology and Regulatory Council (ITRC) VI Team, Dave helped develop its 2007 guidance and served as an instructor for VI training classes over the next four years. Dave earned his bachelor's degree in Geological Engineering in 1977 and his master's degree in Civil Engineering in 1980, both from the University of Toronto, Canada. He is a registered professional engineer in Colorado.

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# Today's Road Map

- Introduction
- PVI Pathway
- Site Screening
- Participant Questions
- Investigation & Modeling
- Vapor Control & Site Management
- Participants Taking Action
- Participant Questions

Community Engagement

No associated notes.

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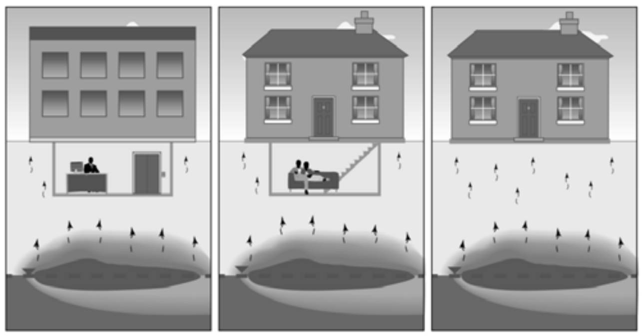
# What is Vapor Intrusion (VI)? What is Petroleum Vapor Intrusion (PVI)?

- Vapor Intrusion (VI) is the process by which volatile vapors partition from contaminated groundwater or other subsurface sources and migrate upward through vadose zone soils and into overlying buildings
- Petroleum vapor intrusion (PVI) is a subset of VI that deals exclusively with petroleum hydrocarbon (PHC) contaminants



No associated notes.

8

## Aerobic Biodegradation - Key to Limiting PVI

- Defining feature of PVI
  - Distinguishes it from Chlorinated Vapor Intrusion (CVI)
- Breakdown of chemicals by microorganisms in vadose zone soils
- PHC-degrading bacteria found in all environments
  - Consumes hydrocarbons in the presence of $O_2$
- Limits transport and effects of PHC vapors
- Previous guidance based on CVI which doesn't address biodegradation and therefore is overly conservative.

No associated notes.

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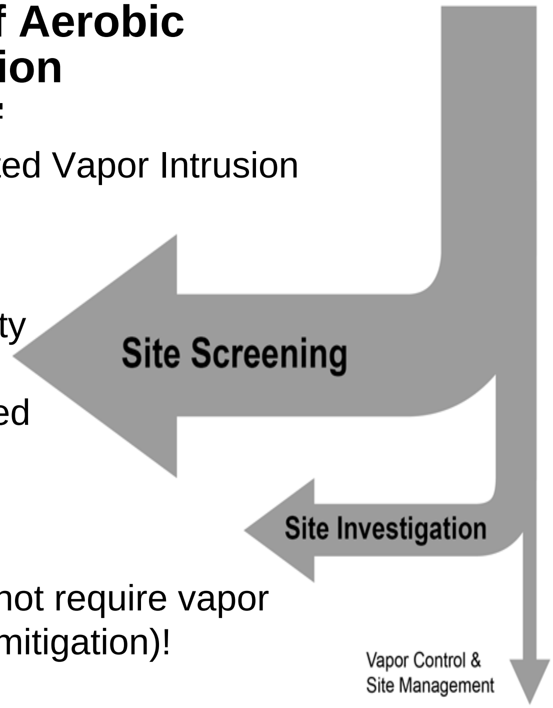
# The Effect of Aerobic Biodegradation

Unlike Chlorinated Vapor Intrusion (CVI),

the vast majority of PVI sites can be screened out . . .




. . . and not require vapor control (mitigation)!

No associated notes.

## PVI – What is the Big Deal?

- **Lack of guidance and training** to support confident decision making
- **Experience with chlorinated compound vapor intrusion** (CVI) inappropriately heightens concern for PVI
- **Limited resources** identified a need for a prioritization process to focus on sites with greatest potential for PVI
- **Financial impacts** (e.g., delays in construction or property transactions)
- **Potential adverse health effects of building occupants** when vapors are present at sufficiently high concentrations

No associated notes.

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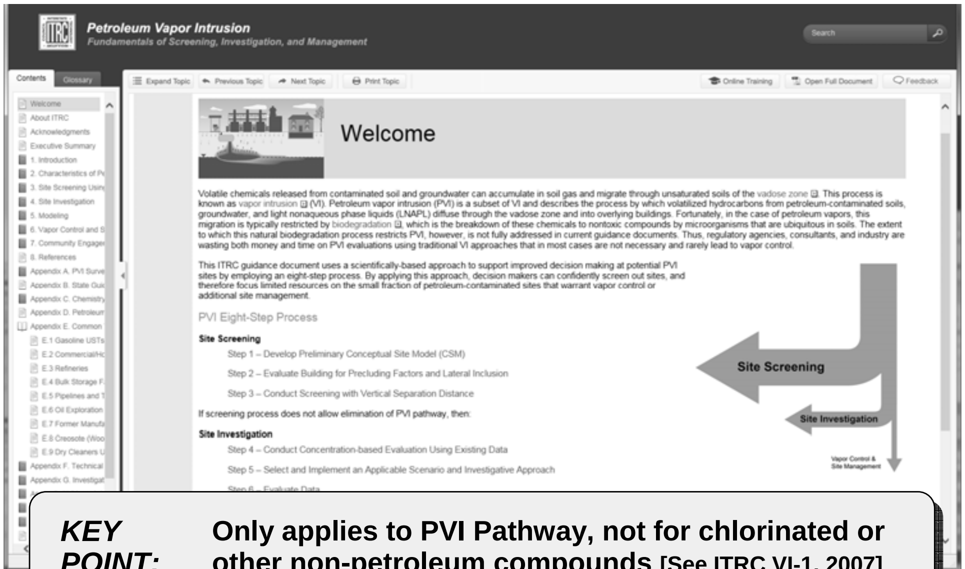
# The ITRC Solution - Guidance

***Petroleum Vapor Intrusion (PVI): Fundamentals of Screening, Investigation, and Management***




***KEY POINT:*** **Only applies to PVI Pathway, not for chlorinated or other non-petroleum compounds [See ITRC VI-1, 2007]**

No associated notes.

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## How ITRC's PVI Guidance Relates to Other Documents

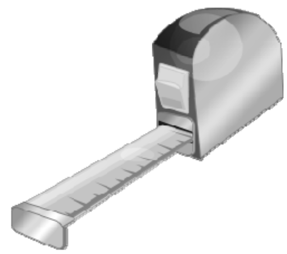
- Builds on the existing ITRC Vapor Intrusion (VI) guidance (VI-1, 2007) which focused primarily on chlorinated compounds vapor intrusion (CVI)
  - Can be a companion to the ITRC VI 2007 guidance or stand alone
- Complements the currently drafted USEPA Office of Underground Storage Tank (OUST) PVI guidance document
  - Limited to USTs in comparison to ITRC PVI document applicability to various types of petroleum sites

No associated notes.

13

## Intent of Using PVI Screening Method Based on Vertical Screening Distance

- Produce consistent and confident decisions that are protective of human health
- Minimize investigative efforts at sites where there is little risk of a complete PVI pathway
- Prioritize resources for sites with the highest risk for a complete PVI pathway



No associated notes.

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## ITRC's PVI Guidance – What It Can Do for YOU!

- Comprehensive strategy for screening, investigating and managing potential PVI sites
- Consistent approach for regulators and practitioners
- Brings credibility - nationally developed, consensus-based decision making strategy
- Scientifically based on latest research
- Applicable for a variety of petroleum site types from underground storage tanks (USTs) to larger petroleum sites (e.g., refineries and pipelines)

***KEY POINT:*** **Developed by over 100 team members across environmental sectors (including 28 state agencies)**

No associated notes.

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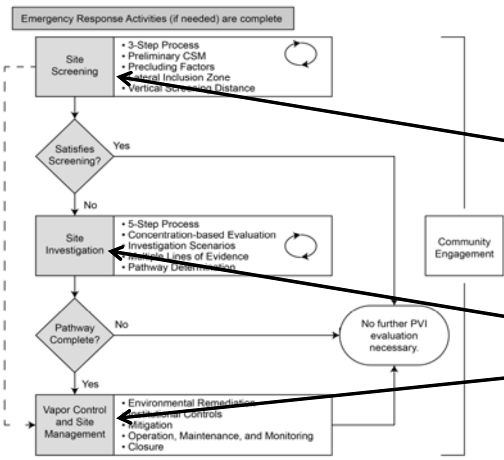
# ITRC's PVI Assessment Strategy

*Handout provided*

- Assumes any emergency response activities are complete

**Figure 1-2. PVI strategy flowchart**





- **Strategy includes:**
  - **Site screening using Vertical screening distance**
  - **Site investigation**
  - **Vapor Control and Site Management**

ITRC PVI-1, 2014: Figure 1-2

No associated notes.

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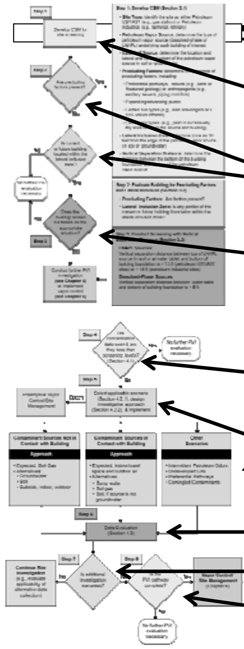
# Users Follows Step-Wise Approach

*Handout provided*



**Site Screening:**

**Step 1:** Develop preliminary conceptual site model (CSM)

**Step 2:** Evaluate site for precluding factors and lateral inclusion

**Step 3:** Screen building using vertical separation distance

**Site Investigation** (if necessary):

**Step 4:** Conduct concentration-based evaluation using existing data

**Step 5:** Select and implement applicable scenario and investigative approach

**Step 6:** Evaluate data

**Step 7:** Decide if additional investigation warranted?

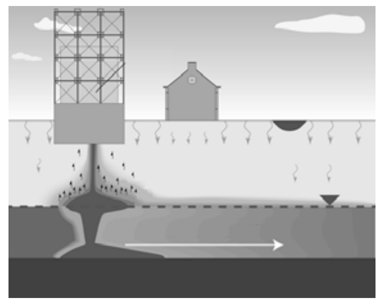
**Step 8:** Decide if the PVI pathway complete?

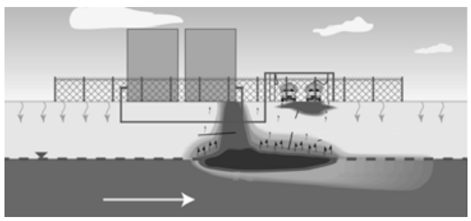
No associated notes.

# ITRC PVI Guidance Applicability Beyond Gas Stations…….

Poll Results

- Gasoline and diesel USTs
- Commercial/home heating oil UST
- Refineries
- Bulk storage facilities
- Pipeline/transportation
- Oil exploration/production sites
- Former Manufactured Gas Plants
- Creosote facilities
- Dry cleaners using petroleum solvents





ITRC PVI-1, 2014: Appendix E

No associated notes.

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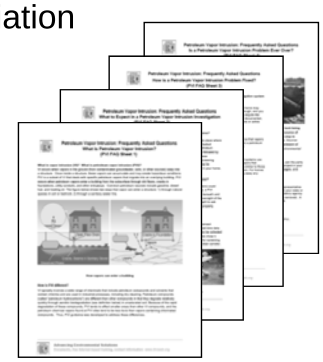
# Community Engagement
# Be Prepared!

Community Engagement

- PVI investigation can be disconcerting and intrusive to the public
- Be prepared to address PVI-specific concerns and questions that are likely to arise during any phase of investigation, mitigation, or remediation
- Community Engagement FAQs (Appendix K)
  - What is PVI?
  - What to Expect in a PVI Investigation
  - How is a PVI Problem Fixed?
  - Is a PVI Problem Ever Over?



ITRC PVI-1, 2014: Appendix K – Frequently Asked Questions Fact Sheets

No associated notes.

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## After Today's Training You Should Know:

- When and how to use ITRC's PVI document
- Important role of biodegradation in the PVI pathway (in contrast to chlorinated solvent contaminated sites)
- Value of a PVI conceptual site model (CSM) and list its key components
- How to apply the ITRC PVI 8 step decision process to:
  - Screen sites for the PVI pathway
  - Take action if your site does not initially screen out
    - Investigation and Modeling
    - Vapor Control and Site Management
- When and how to engage with stakeholders

No associated notes.

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# Today’s Road Map

PVI Pathway

Introduction

→ **PVI Pathway**

Site Screening

Participant Questions

Investigation & Modeling

Vapor Control & Site Management

Participants Taking Action
Participant Questions

Community Engagement

No associated notes.

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# PVI Pathway
# Learning Objectives

PVI Pathway

- Important role of biodegradation in the PVI pathway (in contrast to chlorinated solvent contaminated sites)
  - Factors that influence aerobic biodegradation of petroleum vapors
- Value of a PVI conceptual site model (CSM)

Biodegradation

3 factors: distance, concentration, oxygen (O2)

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# PVI Pathway
# Characteristics of PVI

PVI Pathway

- Vapor intrusion and vapor flow basics
- Differences between PVI and CVI (chlorinated vapor intrusion)
- Biodegradation – and why we can rely on it
  - Evidence for biodegradation
  - The importance of $O_2$
- Case studies/interactions demonstrating biodegradation
- PVI conceptual site model (CSM)

ITRC PVI-1, 2014: Chapter 1 and Chapter 2

No associated notes.

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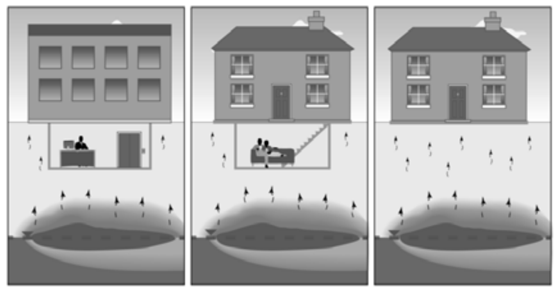
# Vapor Intrusion – Vapor Flow Limited By:

PVI Pathway

- Buildings (air exchange, positive pressure, background)
- Building foundations (intact, no cracks or unsealed penetrations)
- Vadose zone
  - High soil moisture or clay (no vapor migration)
  - Aerobic biodegradation
  - Lateral offset
- Source and groundwater
  - Clean water lens over source, clay layers
  - Finite source mass, saturated vapor limits



***KEY POINT:*** **Presence of subsurface source does not always result in observed vapor intrusion.**

CSM

4 compartments or components:

Building, foundation, soil layer (separating), vapor source

Vapors need to get from 'source' to enclosure to be a risk.

In many instances petroleum vapors can't (don't) make it from the source to the enclosure.

For any one or more of the listed reasons

We focus on aerobic biodegradation, because it is significant and nearly ubiquitous.

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# Vapor Impacts to Indoor Air, NOT Related to VI Pathway

PVI Pathway

Other potential issues:

- Ambient outdoor air quality
- Vapors off-gassing from tap water
- Impacted water or product inside a building
- Household or commercial products stored or used in a building
- Building materials containing volatile compounds
- Household activities

There are other conceptual models for vapor intrusion.

Not covered here.

There's also other potential risk 'impacts' at sites (groundwater ingestion, soil contact, etc.), again, not covered here.

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## Poll Question

Poll Question

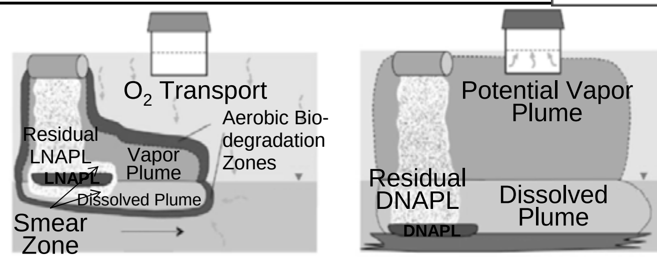
- What is your level of experience with addressing chlorinated compound vapor intrusion (CVI) sites?
  - No experience
  - Very limited experience (just a couple of sites)
  - Some experience (somewhere in between)
  - Extensive experience (more than 15 sites)

No associated notes.

# Differences Between PVI and CVI

PVI Pathway

Figure: Petroleum Hydrocarbons And Chlorinated Solvents Differ In Their Potential For Vapor Intrusion (PDF). EPA. *March 2012*.




| Variable | PVI | CVI |
|---|---|---|
| Type of chemical | non-chlorinated hydrocarbon | chlorinated hydrocarbon |
| Example | Benzene | perchloroethylene (PCE) |
| Source Type | LNAPL | DNAPL |
| Aerobic biodegradation | **Consistently very rapid** | Consistently very limited |
| Vapor intrusion potential | low | High |
| Degradation products | $CO_2$, $H_2O$ | intermediates |

***KEY POINT:*** **Soil vapor clouds for CVI are bigger than for PVI. Why? Answer: Aerobic Biodegradation**

Graphic is from an EPA publication (as noted)

Petroleum Hydrocarbons And Chlorinated Solvents Differ In Their Potential For Vapor Intrusion (PDF). EPA. March 2012.

http://www.epa.gov/oust/cat/pvi/index.htm

Key: different chemicals behave differently

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## Petroleum Vapors Biodegrade Rapidly

PVI Pathway

- Petroleum biodegradation
  - Occurs reliably
    - Microorganisms are ubiquitous
  - Starts rapidly
    - Short acclimation time
  - Occurs rapidly
    - Where oxygen is present

***KEY POINT:*** **Microbial communities can start consuming PHCs within hours or days of the introduction of PHCs into the subsurface.**

No associated notes.

## Biodegradation is Widely Recognized

PVI Pathway

- US EPA. 2002. Draft Guidance . EPA/530/D-02/004
- US EPA. 2005. EPA/600/R-05/106
- ITRC, 2007. Vapor intrusion: A practical guideline
- US EPA, 2012. Hydrocarbons and Chlorinated Solvents Differ in their potential for vapor intrusion
- USEPA, 2013. Draft - OSWER – Assessing Mitigating VI
- USEPA, 2013, Draft – OUST - Guide for PVI at USTs
- Others …

  many hundreds of peer-reviewed publications.

***KEY POINT:*** **Aerobic petroleum biodegradation is significant. We can use this in practical evaluation of PVI.**

Biodegradation gets mentioned in regulatory guides (as listed).

Also there are many hundreds (if not near thousands) of publications referring to petroleum chemical biodegradation.

Refs [for information]:

US EPA. 2002. Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance). EPA/530/D-02/004, U.S. Environmental Protection Agency Office of Research and Development, Washington, DC, Washington, D.C., November, 2002: pp. 52.

Tillman, F.D., and J.W. Weaver. 2005. Review of recent research on vapor intrusion. EPA/600/R-05/106, U. S. Environmental Protection Agency Office of Research and Development, Washington, DC, September, 2005: pp. 41.

ITRC. 2007. Vapor intrusion: A practical guideline. Interstate Technology & Regulatory Council, Washington, D.C., January, 2007: pp. 74.

US EPA. 2011. Petroleum Hydrocarbons And Chlorinated Hydrocarbons Differ In Their Potential For Vapor Intrusion. United States Environmental Protection Agency, Washington, D.C., September, 2011: pp. 13.

USEPA: OSWER FINAL GUIDANCE FOR ASSESSING AND MITIGATING THE VAPOR INTRUSION PATHWAY FROM SUBSURFACE SOURCES TO INDOOR AIR (EXTERNAL REVIEW DRAFT), April 2013. U.S. Environmental Protection Agency Office of Solid Waste and Emergency Response.

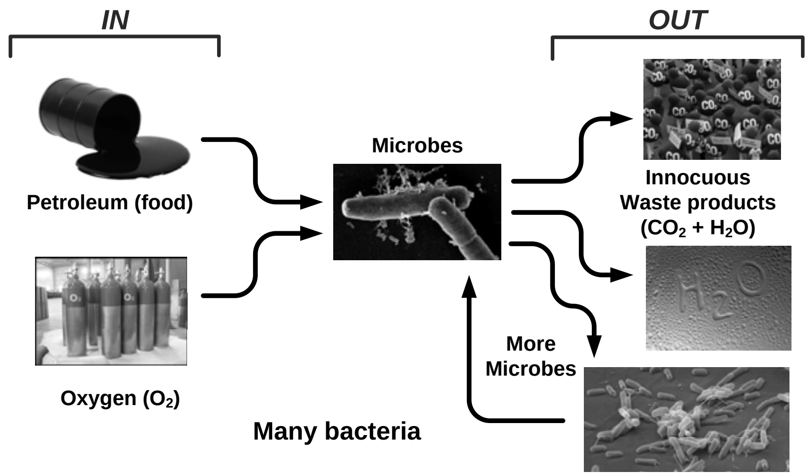
USEPA: Guidance For Addressing Petroleum Vapor Intrusion At Leaking Underground Storage Tank Sites, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Office of Underground Storage Tanks

Washington, D.C. April 2013.

29

# Aerobic Biodegradation Basics

PVI Pathway




***KEY POINT:*** **PHC degrading bacteria are found in all environments and can consume hydrocarbons rapidly in presence of $O_2$, limiting transport of petroleum vapors.**

No associated notes.

30

# Influences on Extent and Rate of Biodegradation

PVI Pathway

Key factors:

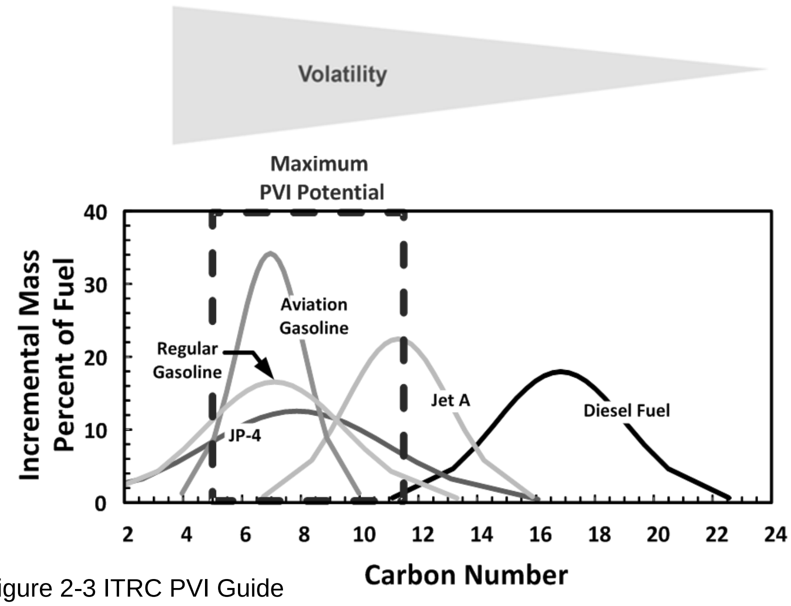
- Concentration of vapor source
- Distance vapors need to travel to potential receptors
- Presence of $O_2$ between source and potential receptors

No associated notes.

31

# Vapor Source

PVI Pathway



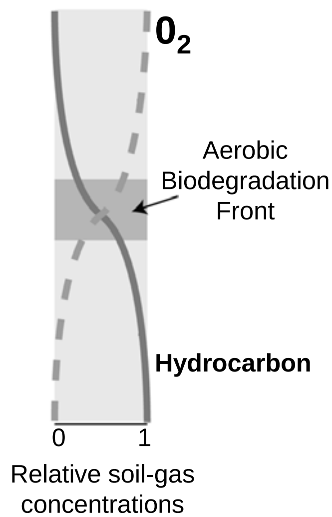

See Figure 2-3 ITRC PVI Guide

No associated notes.

32

# Observed Petroleum Soil Gas Profiles

PVI Pathway




| **Lower Concentration Source** | **Higher Concentration Source** |
|---|---|
| **Dissolved Groundwater** Source | **LNAPL** Source |
| **Clean** Soil Model | **Dirty** Soil Model |
| **Deeper** 'reaction zone' | **Shallower** 'reaction zone' |
| **Lower** VOC surface flux | **Higher** VOC surface flux |
| **Lower** Oxygen Demand | **Higher** Oxygen Demand |

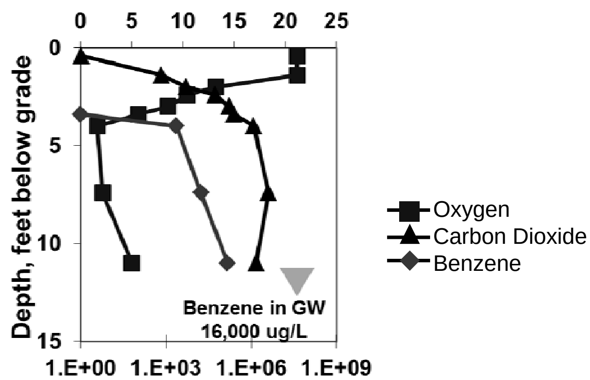
This shows a 'slice' of the conceptual model: The soil compartment

33

# Evidence for Aerobic Biodegradation

PVI Pathway

- Inverse relationship of oxygen and petroleum vapors
- Inverse relationship of oxygen and carbon dioxide



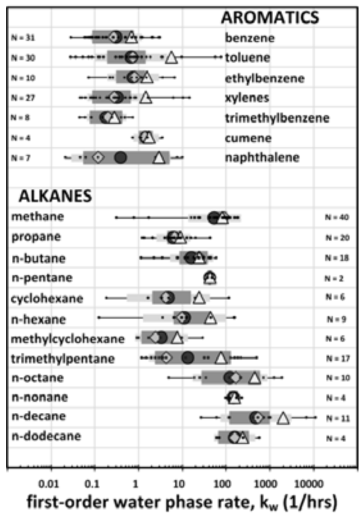

*Beaufort, SC NJ-VW2 (Lahvis,et al., 1999)*

This shows a 'slice' of the conceptual model: The soil compartment

34

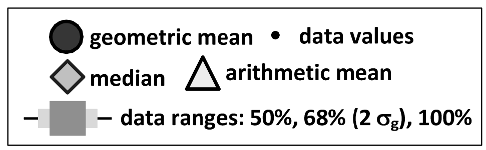
# Aerobic Petroleum Biodegradation Rates in Soil: Compiled Data

PVI Pathway




ITRC PVI-1, 2014: Figure I-1

- Empirical data
  - From field measurements, columns, microcosms.
  - First-order. Normalized by ‘water-phase’ concentration
- Applicability
  - Scenario-specific
  - For aerobic, air connected vadose-zone soils
  - Don’t mix rates (not interchangeable with ground- water or source-zone attenuation rates)




From the soil gas profiles data on the prior slide, as well as a lot of other field and laboratory data, we can estimate degradation rates.

Aerobic data.

For air-connected vadose zone soils.

This is from the ITRC PVI guide if you want more detail.

Overall, these rates are fast (compared to soil diffusion); but not infinite.

Final note that these rates are specific to the scenario (vadose zone soils).

They are normalized to ‘water phase’ concentrations; since the biodegradation occurs in the water phase and at rates proportional to water-phase concentration.

Other rates (groundwater, LNAPL source depletion) are different; don’t mix them up.

35

# Aerobic Petroleum Biodegradation Rates in Soil

PVI Pathway

- With these rates
  - In aerobic soils, petroleum chemicals attenuate over relatively short distances
  - 50% decrease in 5 to 50 cm
    - Approximate range
    - Depending on soil conditions

***KEY POINTS:*** **Rates are fast – compared with diffusion; geometric decrease in concentration over distance**

No associated notes.

36

# How much oxygen is needed?

PVI Pathway

- Aerobic Biodegradation
  - Hydrocarbon to Oxygen use ratio: 1 : 3 (kg/kg)
  - Atmospheric air (21% Oxygen; 275 $g/m^3$ oxygen)

***ISSUE:*** **Can oxygen get into the subsurface ?**

***KEY POINT:*** **Oxygen in air provides the capacity to degrade 92 $g/m^3$ hydrocarbon vapors (92,000,000 $ug/m^3$)**

No associated notes.

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# Environmental Effects on Biodegradation

PVI Pathway

- Despite general reliability of aerobic biodegradation in reducing PVI, it can be limited by availability of $O_2$
  - Oxygen into subsurface
    - Under building foundations
  - Limited soil diffusion
    - Soils with high moisture
    - Soils with low permeability
  - Oxygen demand
    - Presence of high PHC concentrations (e.g., near LNAPL source)
    - Soils with high organic content

While occurs reliably, can be limited

Depends on O2 into soil

Factors such as foundations, soils, distance (in soil) can limit oxygen in the subsurface.

Also oxygen demand from other petroleum chemicals, or from organic matter in soil (such as very peaty soils) will have high oxygen demand.

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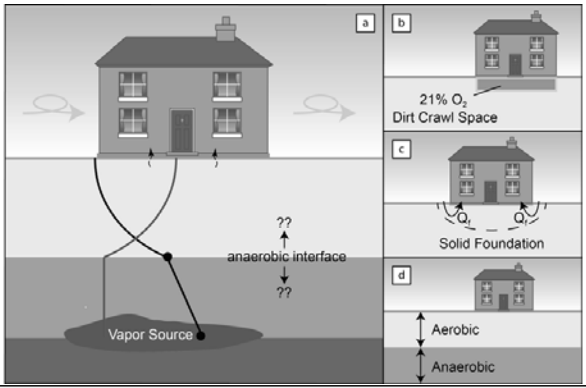
## Common Question: Is there enough $O_2$ under buildings to support biodegradation?

PVI Pathway

- Answer: Generally, **Yes**, even modest $O_2$ transport yields sufficient aerobic biodegradation in most cases




***KEY POINT:*** **Two key factors – both needed – to run out of oxygen:**
- Limited oxygen transport below the foundation
- High oxygen demand

Question:

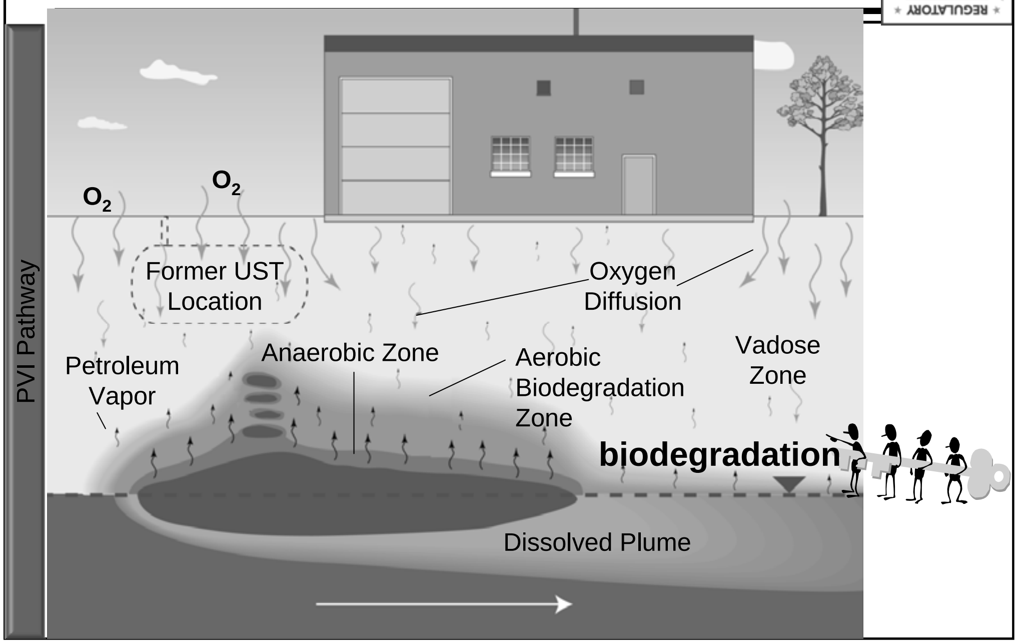
Does $O_2$ get into soils?

Answer:

Generally yes.

It is hard to keep 21% $O_2$ in ambient air out of unsaturated soils.

# PVI – General Conceptual Site Model (CSM)

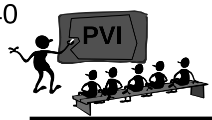



Showing a figure for a – revisited – conceptual model.

Shows both petroleum vapors and $O_2$

Degradation zone within the soil layer

Separation between the vapor 'source' and the building foundation.




# Community Engagement
# What is PVI?

Community Engagement

- What is VI? What is PVI?
- What is aerobic biodegradation
- What is the most common cause of PVI?
- Where is PVI most likely to occur
- What are the health effects caused by PVI?
- What do I do if I suspect that PVI is occurring?
- Where can I find more information about PVI?


Petroleum Vapor Intrusion: Frequently Asked Questions
What is Petroleum Vapor Intrusion?
(PVI FAQ Sheet 1)

Advancing Environmental Solutions

ITRC PVI-1, 2014: Appendix K – Frequently Asked Questions Fact Sheets

No associated notes.

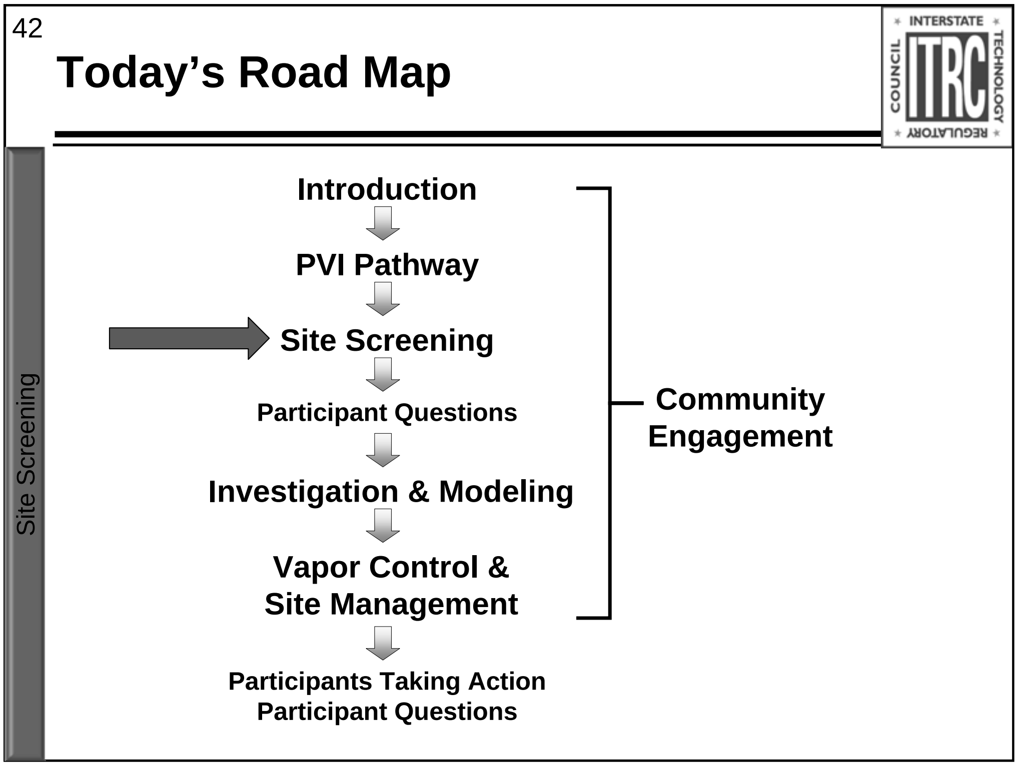
41

## PVI Pathway Summary

PVI Pathway

- Value of a PVI conceptual site model (CSM)
  - Source, Soil Layer, Foundation, Building (& Oxygen)
- Petroleum biodegradation
  - Evidence
  - Rates
- Oxygen in the subsurface
  - Lots of oxygen in air
  - It does not take much in the subsurface for significant biodegradation
- Be prepared for community engagement

No associated notes.




No associated notes.

43

Site Screening

# Site Screening<br>Outline and Learning Objectives

- Outline
  - Describe the conceptual site model
  - Summarize the empirical basis for screening
  - Describe the step-wise approach
  - Provide case study example
- Learning Objectives
  - Understand basis for site screening and how to implement the step-wise approach
  - Apply the screening approach at potential PVI site using a case study

No associated notes.

44

# Site Screening Definition and Rationale

Site Screening

- New method for PVI screening
- Based on the ***vertical screening distance***
  - Minimum soil thickness between a petroleum vapor source and building foundation necessary to effectively biodegrade hydrocarbons below a level of concern for PVI
- Based on empirical data analysis and modeling studies
- Approach expected to improve PVI screening and reduce unnecessary data collection

No associated notes.

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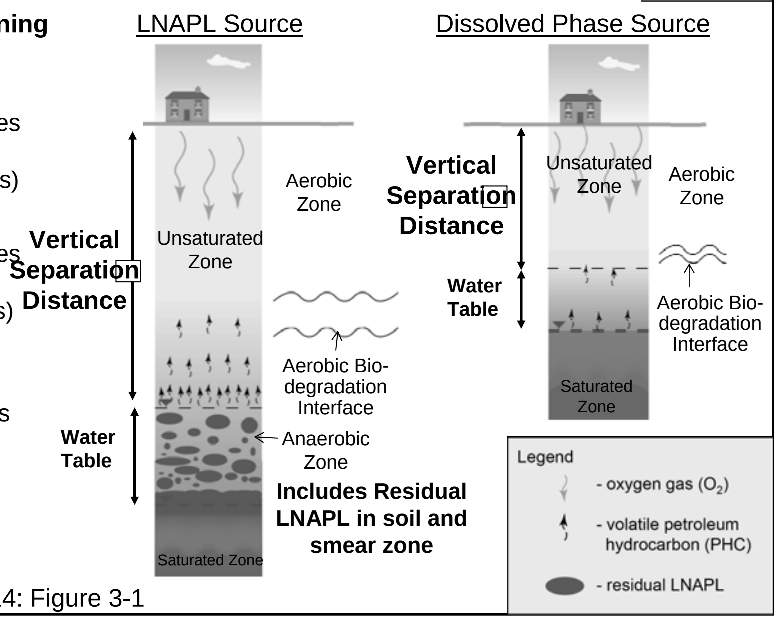
# Conceptual Model of Vertical Screening Distances

Site Screening

**Vertical screening distances**

- 15 feet – LNAPL sources (petroleum UST/AST sites)
- 18 feet – LNAPL sources (petroleum industrial sites)
- 5 feet – dissolved-phase sources




ITRC PVI-1, 2014: Figure 3-1

UST – underground storage tanks

AST – above ground storage tanks

## Basis for Site Screening

Site Screening

- Large body of empirical data (1995-2011)
- Compilation of paired measurements
  - concurrent contaminant source strength and associated vapor data
- Data from hundreds of petroleum release sites
  - Wide range of geographical, environmental and site conditions
- Analysis shows significant biodegradation and attenuation of petroleum vapors within short, predictable distances
- Mostly gasoline station sites
- Analysis conducted for three site and source types:
  1) Dissolved-phase sites
  2) LNAPL UST/AST sites
  3) LNAPL Petroleum industrial sites

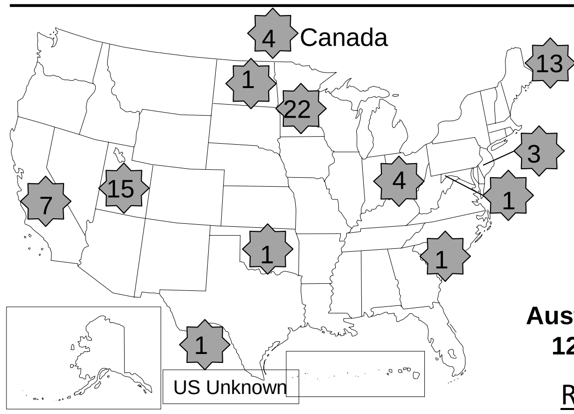
**ITRC PVI-1, 2014: see Appendix F for details**

No associated notes.

47

# USEPA Database – Number of Sites

Site Screening





**Australian data analyzed separately**
**124 sites, >1000 measurements**

**74 Sites**
**893 benzene vapor measurements**


REFERENCES

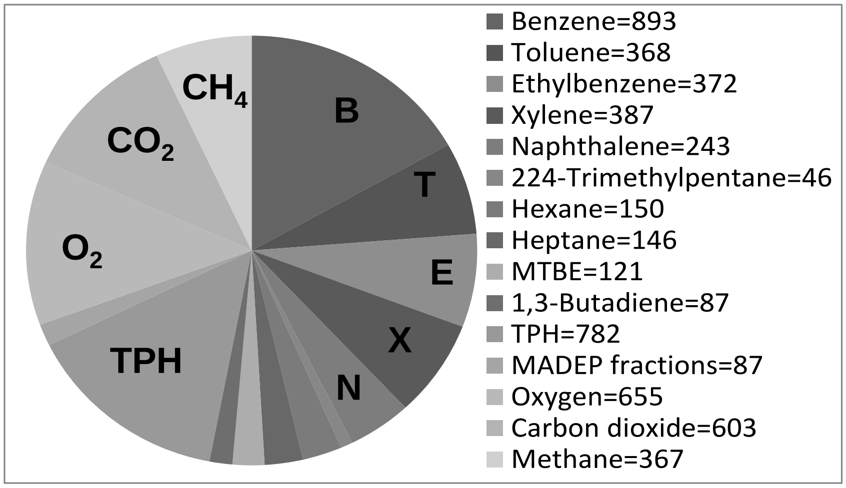
Davis, R.V., 2009-2011
McHugh et al, 2010
Peargin and Kolhatkar, 2011
Wright, J., 2011, 2013 (Australian da
Lahvis et al, 2013
EPA Jan 2013, 510-R-13-001


No associated notes.

48

# USEPA Database Number of Soil Vapor Analyses

Site Screening



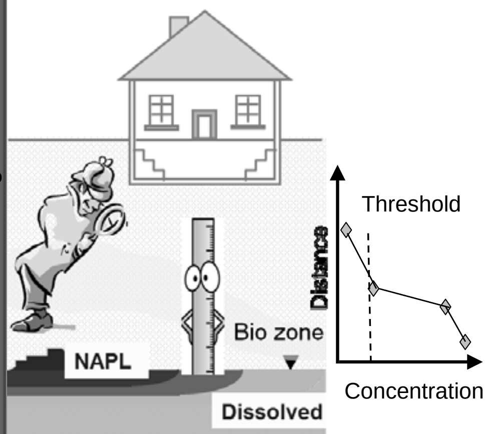

**893 benzene vapor measurements**
**Analysis conducted for 10 compounds plus TPH fractions!**

No associated notes.

49

# Empirical Data Analysis

Site Screening



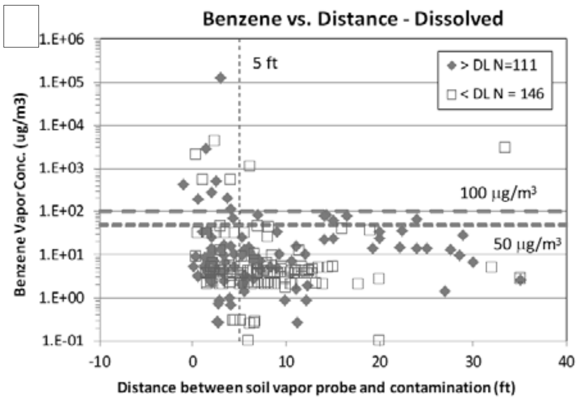

- Probability-based *method:* soil vapor concentrations compared to risk-based threshold vapor concentrations for varying vertical distances
- Vertical distance of vapor attenuation based on distance between vapor probes required to attenuate benzene to 50-100 µg/m$^3$; consideration of 100-fold (0.01) attenuation from subsurface to indoor air.
- Non-detects addressed through robust substitution, Kaplan-Meier method

No associated notes.

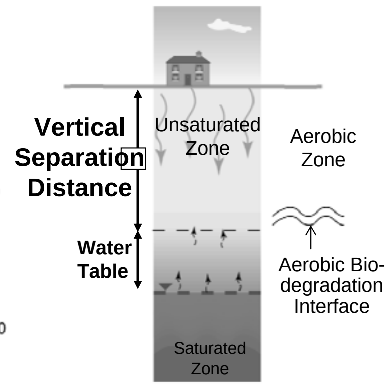
50

# USEPA Vertical Distance Method Dissolved Source

Site Screening




Dissolved Phase Source




***KEY POINTS***

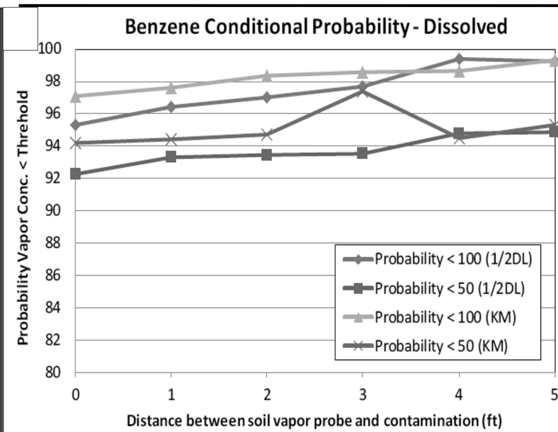
- **Vertical screening distance = 5 feet for dissolved-phase**
- **Benzene requires the greatest distance to attenuate**

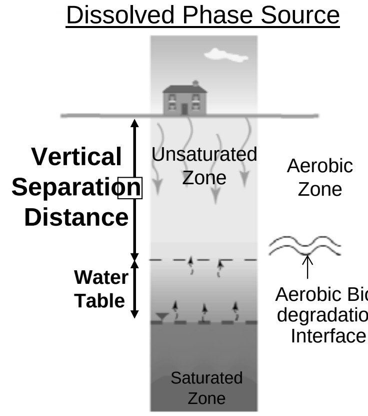
No associated notes.

51

# USEPA Vertical Distance Method Dissolved Source

Site Screening




| | |
|---|---|
| ***KEY POINTS*** | • **High probability and confidence of vertical screening distance for dissolved sites** |

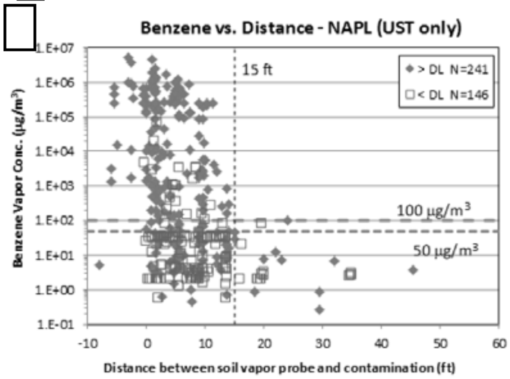
Note: Probability is expressed as percentage

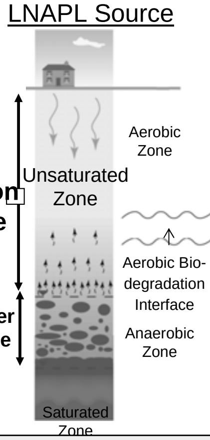
No associated notes.

52

# USEPA Vertical Distance Method LNAPL Source UST/AST Sites

Site Screening




***KEY POINTS***

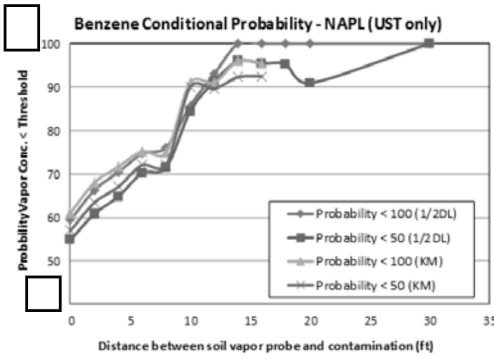
- **Vertical screening distance = 15 feet for LNAPL UST/AST sites (18 feet industrial sites)**
- **Benzene requires the greatest distance to attenuate**

No associated notes.

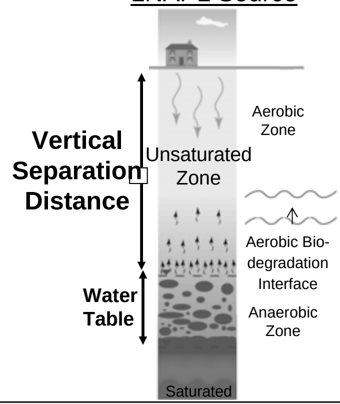
53

# USEPA Vertical Distance Method LNAPL Source UST/AST Sites

Site Screening




LNAPL Source




*KEY POINTS*

- **High probability and confidence of vertical screening distance for small UST/AST sites**
- **Slightly less confidence in industrial sites due to small data set**

No associated notes.

54

# The Effect of Soil Gas Screening Level on Screening Distance

**What if my agency recommends lower soil gas screening levels than those used in the empirical studies?**

| Benzene soil gas screening level (µg/m$^3$) | LNAPL screening distance (feet) | Dissolved-phase screening distance (feet) |
|---|---|---|
| 100 < | 13.2 | 0.3 |
| 50 < | 13.6 | 0.91 |
| 30 < | 14.0 | 1.5 |
| 20 < | 14.3 | 2.0 |
| 10 < | 14.8 | 3.0 |
| 5 < | 15.4 | 4.1 |

**Distances are relatively insensitive to the soil gas screening level**

***KEY POINT:*** **The vertical screening distances are protective to very low soil gas screening levels.**

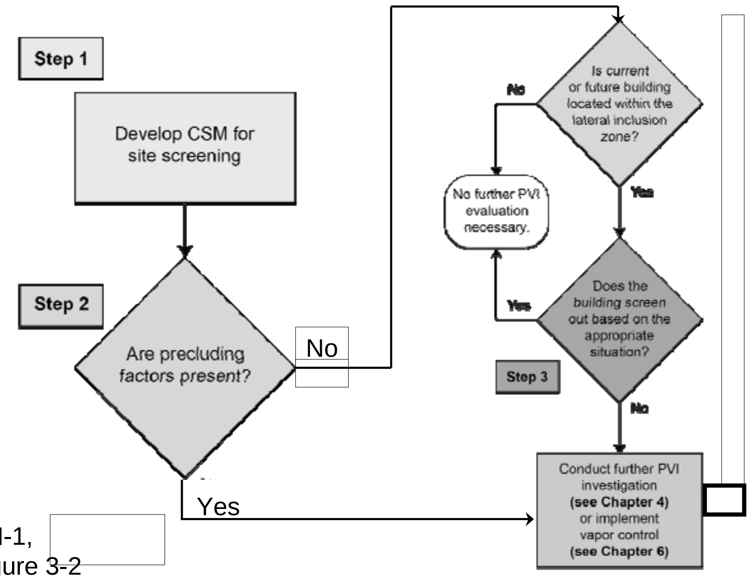
Table from Appendix F

55

# Using the Site Screening Process

*Handout provided*

Site Screening




ITRC PVI-1, 2014: Figure 3-2

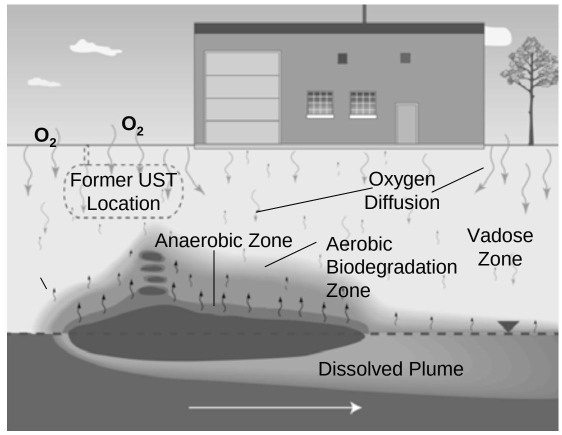
No associated notes.

56

# Step 1: Develop Conceptual Site Model (CSM)

Site Screening

- Preliminary CSM using soil and groundwater data collected as part of routine initial site investigation
- Visualization of site conditions, allows for evaluation of contaminant sources and impacted media, migration pathways, and potential receptors
- For PVI CSM
  1. Site type
  2. Petroleum vapor source
  3. Extent of source
  4. Precluding factors
  5. Lateral inclusion zone
  6. Vertical separation distance




No associated notes.

# Step 1: Develop CSM
# Site Type

Site Screening

- Site type
  - Petroleum UST/AST sites
    - e.g., service stations or similar
  - Petroleum industrial sites
    - e.g., terminals, refineries, pipelines

**_KEY POINT:_** Differences in the vertical screening distances according to site type may relate to the volume of the LNAPL release or extent of the LNAPL plume.

No associated notes.

58

## Step 1: Develop CSM Petroleum Vapor Source

Site Screening

- Petroleum vapor source (Table 3-1)
  - LNAPL vs dissolved-phase source
  - Multiple lines of evidence approach
    - Direct indicators (LNAPL, sheen)
    - Indirect indicators (concentrations, PID readings, etc.)
  - LNAPL source includes sites with free-phase or residual LNAPL (which may be difficult to detect)

No associated notes.

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# Step 1: Develop CSM Petroleum Vapor Source

Site Screening

Table 3-1. General LNAPL indicators for PVI screening

| Indicator | Comments |
|---|---|
| **Groundwater** | |
| • Benzene: > 1 - 5 mg/L<br>• $TPH_{(gasoline)}$: > 30 mg/L<br>• BTEX: > 20 mg/L<br>• Current or historical presence of LNAPL (including sheens) | There is not a specific PHC concentration in groundwater that defines LNAPL because of varying product types and degrees of weathering. |
| **Soil** | |
| • Current or historical presence of LNAPL (including sheens, staining)<br>• Benzene > 10 mg/kg<br>• $TPH_{(gasoline)}$ > 250 - 500 mg/kg<br>• Ultraviolet fluorescence (UV) or laser induced fluorescence (LIF) fluorescence response in LNAPL range<br>• PID or FID readings > 500 ppm | • The use of TPH soil concentration data as LNAPL indicators should be exercised with caution.<br>• TPH soil concentrations can be affected by the presence of soil organic matter.<br>• TPH soil concentrations are not well correlated with TPH or $O_2$ soil gas concentrations (Lahvis and Hers 2013b). |
| **Location relative to UST/AST** | |
| • Adjacent (e.g., within 20 feet of) a known or suspected LNAPL release area or petroleum equipment | The probability of encountering LNAPL increases closer |

Notes:

1 One or more of these indicators may be used to define LNAPL.

2 Value used in the derivation of screening distances by USEPA (2013a) and Lahvis and Hers (2013b).

3 Value used in the derivation of screening distances by Peargin and Kolhatkar (2011).

4 Value used in the derivation of screening distances by USEPA (2013a).

5 Value recommended by Lahvis and Hers (2013b).

6 Value is from ASTM E2531-06.

7 Value recommended by USEPA (2013a) and Lahvis and Hers (2013b).

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# Step 1: Develop CSM
# Extent of Source

Site Screening

- Extent of source – delineation is essential
  - Top of LNAPL in groundwater, soil, and smear zone – soil sampling at sufficient frequency with field screening and lab analysis
  - Dissolved plume – edge of plume using MCLs, detection limits or other criteria

No associated notes.

61

# Step 1: Develop CSM Precluding Factors

Site Screening

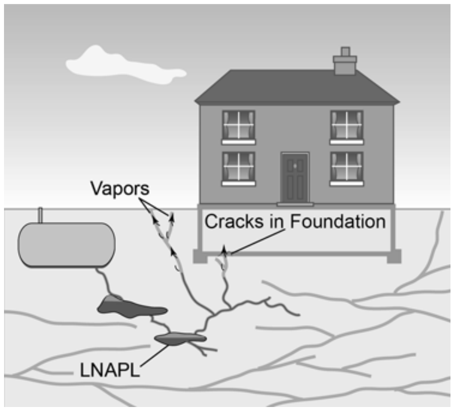
- Precluding factors
  - Preferential pathways
    - Natural: karst or fractured geology
    - Anthropogenic: poorly-sealed utility line (e.g sewer, water)
  - Expanding/advancing plume
    - See also ITRC’s Evaluating LNAPL Remedial Technologies for Achieving Project Goals (LNAPL-2, 2009)
  - Certain fuel type (e.g., lead scavengers or > 10% vol/vol ethanol)
    - See also ITRC's Biofuels: Release Prevention, Environmental Behavior, and Remediation (Biofuels-1, 2011)
  - Certain soil types (e.g., peat [foc>4%] or very dry soils [<2% by vol.])

No associated notes.

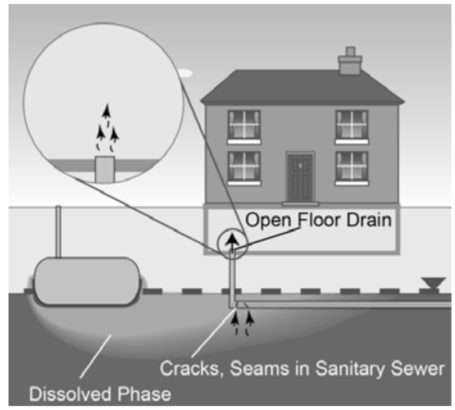
62

# Precluding Factors – Preferential Pathways

Site Screening




Precluding factor: fractured or karst geology




Precluding factor: conduit intersecting source and entering building

ITRC PVI-1, 2014: Figure 3-3, 3-4

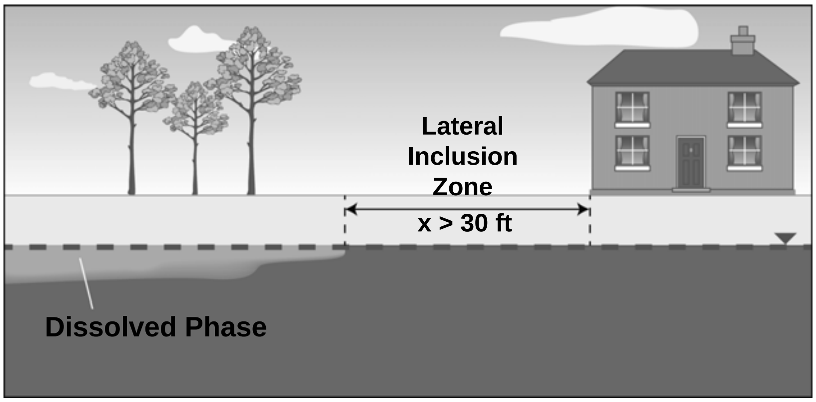
No associated notes.

63

# Step 1: Develop CSM Lateral Inclusion Zone

Site Screening

- Lateral inclusion zone
  - 30’ from leading edge of contamination to building
  - Leading edge defined by regulatory level



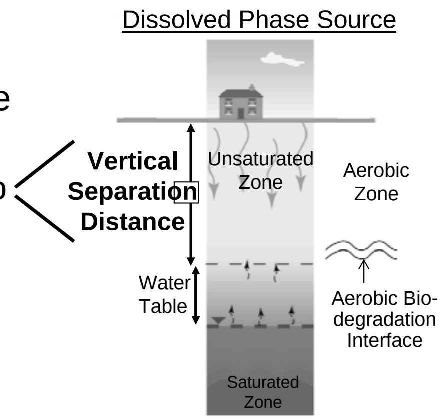

No associated notes.

64

# Step 1: Develop CSM
# Vertical Separation Distance

Site Screening

- Vertical separation distance
  - Measured from top of the petroleum vapor source to the bottom of the building foundation
    - Consider water table fluctuations




No associated notes.

65

## Step 2: Evaluate Building for Precluding Factors and Lateral Inclusion

Site Screening

- Are precluding factors present? (from previous slides)
- If no precluding factors, determine if edge of building foundation is within lateral inclusion zone (30 feet from the edge of the petroleum vapor source).

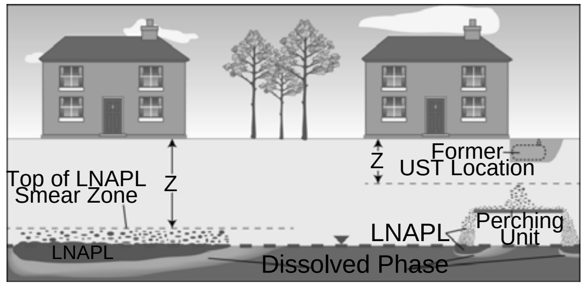
No associated notes.

66

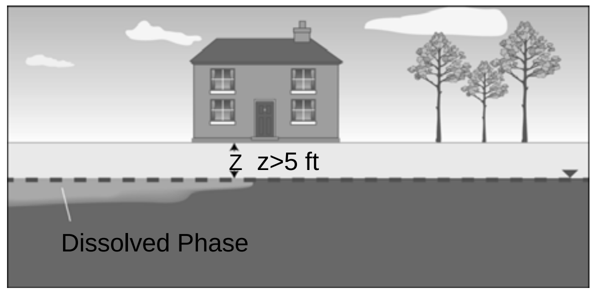
# Step 3: Conduct Screening with Vertical Separation Distance

Site Screening

- ▶ LNAPL
  - Petroleum UST/AST = 15 ft
  - Industrial = 18 ft




- ▶ Dissolved Phase Source
  - All petroleum site types = 5 ft



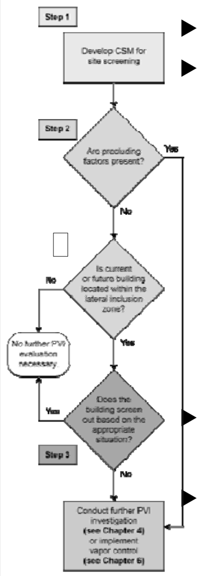

ITRC PVI-1, 2014:
Figure 3-5, 3-6

No associated notes.

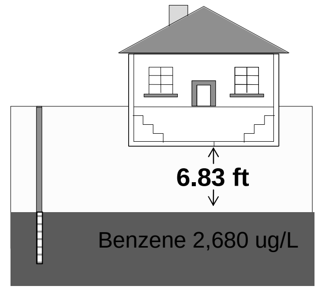
67

# Case Study Using Vertical Screening: Santa Clara, Utah

Case Study




- Step 1: Develop CSM
- Step 2:
  - Precluding Factors?
    - No preferential pathways
    - Plume stable/shrinking
    - No lead scavengers and <10% ethanol
  - Within Lateral Inclusion Distance?
    - Yes (building <30 ft from dissolved source)
- Step 3: Sufficient Vertical Separation?
  - Yes (Dissolved source 6.83 ft below basement slab)
- Further PVI Investigation?
  - UDEQ determined PVI pathway not complete




Courtesy Robin Davis UTDEQ

No associated notes.

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# Today's Road Map

Introduction

PVI Pathway

Site Screening

Participant Questions

Investigation & Modeling

Vapor Control & Site Management

Participants Taking Action

Participant Questions

Community Engagement

No associated notes.

# Today's Road Map

Site Investigation

- Introduction
- PVI Pathway
- Site Screening
- Participant Questions
- ➡ Investigation & Modeling
- Vapor Control & Site Management
- Participants Taking Action
- Participant Questions

Community Engagement (Introduction through Vapor Control & Site Management)

No associated notes.

# Site Investigation Overview

Site Investigation

- Site Screening (Chapter 3) did not eliminate PVI from further consideration due to:
  - Insufficient vertical separation distance
  - Precluding factors
  - Regulatory requirements
- What now?

- Site Investigation (Chapter 4) and Investigation Methods and Analysis Toolbox (Appendix G)

No associated notes.

71

## Site Investigation Learning Objectives

Site Investigation

**You will learn:**

- To apply the 5-step process outlined in the Chapter 4 decision flow chart using a multiple lines of evidence approach
- About additional information available in Appendix G “Toolbox” to help you select the investigative strategy that is right for your site.
  - Includes list of approaches with pro/cons, methods, videos, considerations and more….

***Key Point:*** **Focus the investigation only on data and lines of evidence needed to assess PVI**

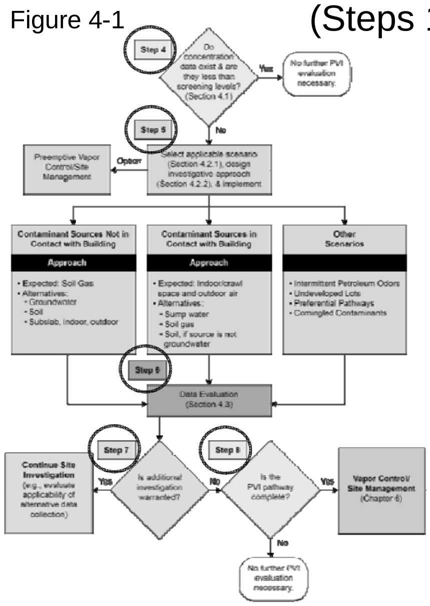
No associated notes.

72

# Site Investigation Process and Flow Chart

Site Investigation

Figure 4-1




(Steps 1-3 in Chapter 3, Site Screening)

Step 4: Concentration-Based Evaluation

Step 5: Select Scenario and Design Investigation Approach

Step 6: Evaluate Data

Step 7: Determine Need for Additional Investigation

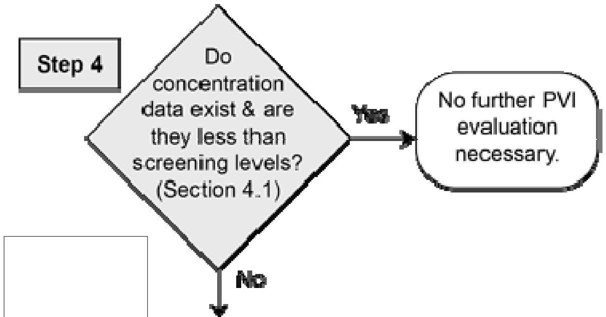
Step 8: Determine if PVI Pathway Complete

No associated notes.

73

# Step 4: Concentration-Based Evaluation

Site Investigation



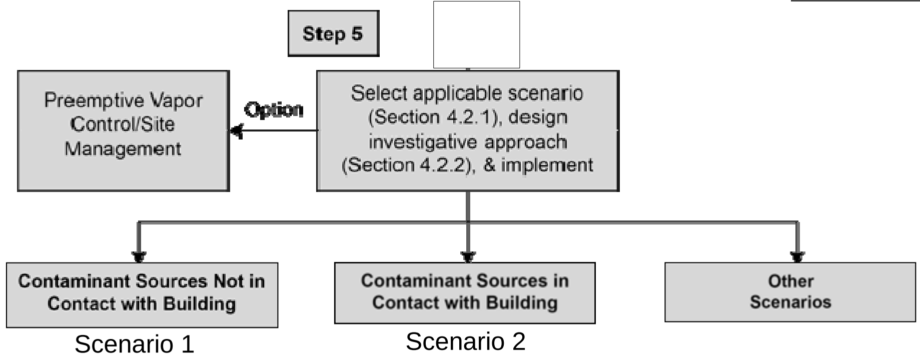

- Compare existing concentrations with screening criteria
  - Criteria often vary by state/region
- **NOTE:** Concentration-Based Evaluation is separate from vertical distance screen in Chapter 3

No associated notes.

74

# Step 5: Select Scenario and Design Investigation Approach

Site Investigation




- Consider scenarios when selecting investigation strategy and methods

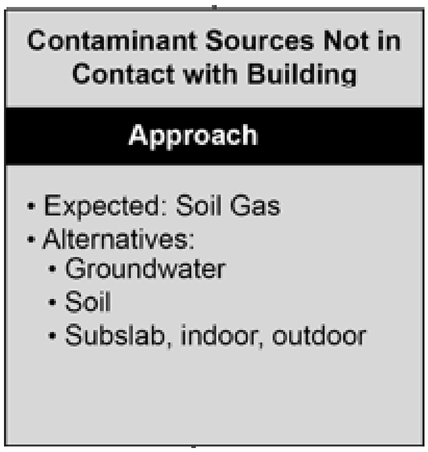
***Key Point:*** **Understanding applicable regulatory requirements is part of designing a successful investigation.**

No associated notes.

75

# Step 5: Scenario 1 - Contamination NOT in Contact with Building

Site Investigation




- Soil gas (exterior, near-slab, or sub-slab) sampling is expected approach since:
  - Reflects partitioning, sorption, and biodegradation in vadose zone between source and building
- Alternative approaches may be considered
  - Examples - groundwater, soil, subslab soil gas, or indoor air and outdoor air data
  - Phased or concurrent sampling

No associated notes.

76

# Step 5: Scenario 2 - Contamination in Contact with Building

Site Investigation

| Contaminant Sources in Contact with Building |
|---|
| **Approach** |
| • Expected: Indoor/crawl space and outdoor air<br>• Alternatives:<br>• Sump water<br>• Soil gas<br>• Soil, if source is not groundwater |

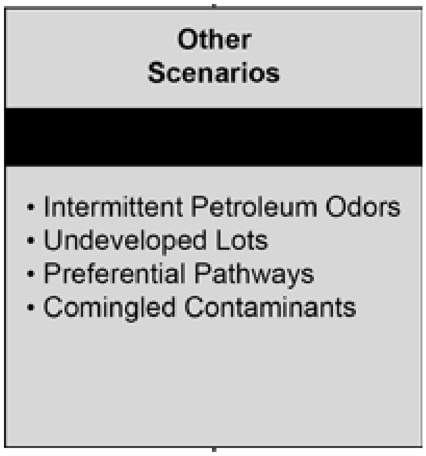
- Indoor or crawlspace and outdoor air sampling is expected approach since:
  - Sub-slab soil gas sampling may not be possible
- **CAUTION:** Interpretation of indoor results often confounded by indoor or outdoor sources of PHCs

No associated notes.

77

## Step 5: Other Scenarios - Special Cases or Exceptions

Site Investigation




- Intermittent petroleum odors
  - Walk-through
  - Verification sampling
  - Further investigation
- Undeveloped lots
  - Soil gas
  - Groundwater sampling
- Preferential pathways
  - Indoor air sampling
- Comingled contaminants
  - Refer to ITRC Vapor Intrusion Pathway: A Practical Guideline V-1 (2007)

No associated notes.

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# Investigation Methods and Analysis Toolbox – Appendix G

Site Investigation

The Tool Box is a tremendous resource and answers many questions about the What, Hows, and Whys

- What samples can be collected?
  - Table G-6. Pros and Cons of Various Investigative Strategies
- How do I ensure sample integrity during soil gas collection?
  - G.5 Active Soil Gas Methods
- Why should I do a pre-building survey?
  - G 11.1 Pre-Sampling Building Surveys

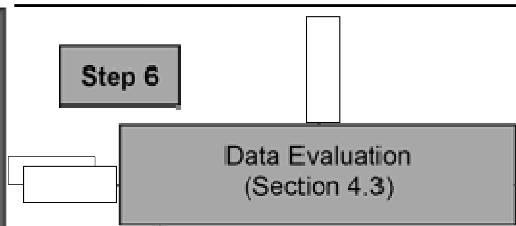
***Key Point:*** **Includes videos, step-by-step instructions, list of analysis methods and more………**

No associated notes.

# Step 6: Evaluate Data

**To assess completeness and significance of the PVI pathway**

Site Investigation




***KEY POINT:*** Data evaluation methods vary; check with regulatory agency

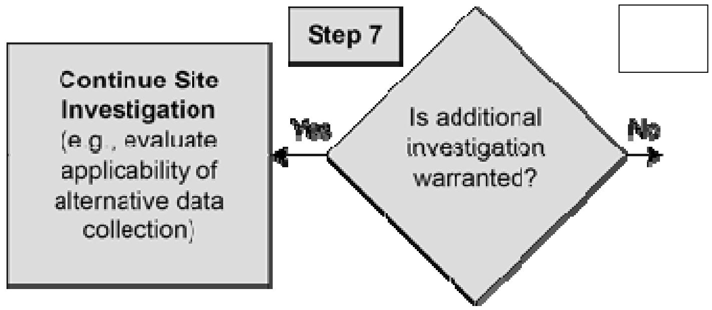
- Data quality considerations
  - Detection limits; false positives/negatives, and sampling errors
- Multiple-lines-of-evidence evaluation (ITRC VI-1 (2007))
  - Compare with screening levels
    - Default, empirical, or modeled attenuation
  - Compare ratios within or between sample types
  - Account for potential bias from background sources
  - Consider individual/cumulative strength of evidence

No associated notes.

80

# Step 7: Determine Need for Additional Investigation

Site Investigation




- This step reflects iterative nature of PVI investigations
- Considerations
  - Delineation of pVOCs adequate?
  - All potentially affected buildings considered?
  - Evidence sufficiently strong to support decision?
  - Vapor controls can be considered at any step

No associated notes.

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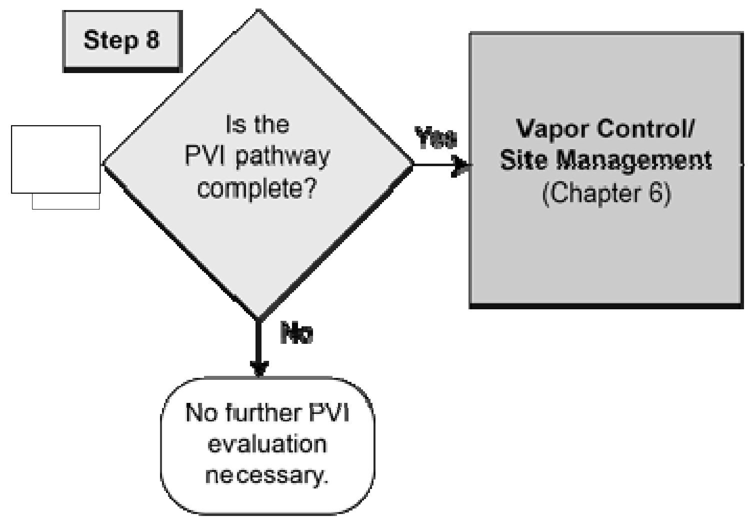
# Step 8: Determine if PVI Pathway is Complete

Site Investigation




No associated notes.

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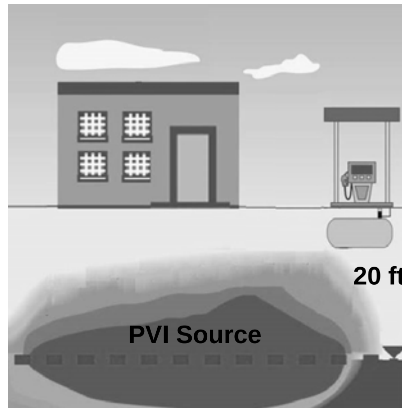
# Case Study – Background

**Case Study**

Case Study

- Gasoline/Diesel Station in Salina, UT
- Operated since 1971
- Black top /concrete surface
- Silty/sand interbedded with fine-grained sand
- Groundwater at 20 ft bgs
- Petroleum releases from dispensers, product lines, and USTs




Courtesy Robin Davis UTDEQ

No associated notes.

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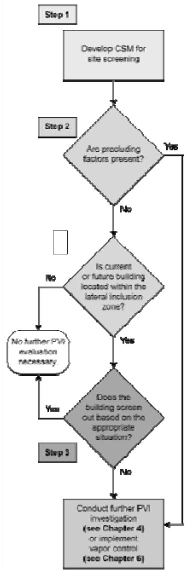
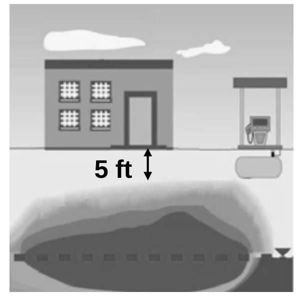
# Case Study – PVI Screening

**Case Study**

Case Study




- Step 1: Develop CSM
- Step 2:
  - Precluding Factors?
    - No preferential pathways
    - Plume stable/shrinking
    - No lead scavengers and <10% ethanol
  - Within Lateral Inclusion Distance?
    - Yes (building <30 ft from dissolved/LNAPL sources)
- Step 3: Sufficient Vertical Separation?
  - No (top of LNAPL 5 ft below slab)
- Further PVI Investigation?
  - Yes




No associated notes.

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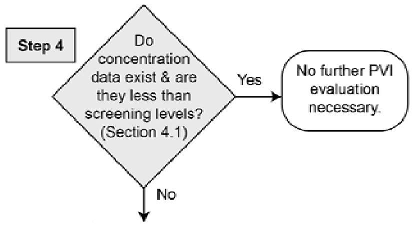
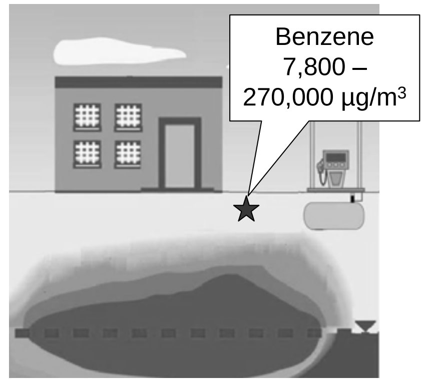
# Case Study – Site Investigation
## Concentration Based Evaluation
### Case Study

Case Study




Step 4: Concentrations
< Screening Levels?

- Benzene near-slab (1.5 ft bgs) soil gas: 7,800 – 270,000 µg/$m^3$
- Vapor intrusion screening level (VISL) = 50-100 µg/$m^3$ (example only)

**No, concentrations are not below screening levels, go to step 5**

No associated notes.

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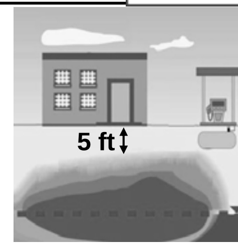
# Case Study – Site Investigation
## Investigation Scenario

Case Study

**Step 5**

Select applicable scenario (Section 4.2.1), design investigative approach (Section 4.2.2), & implement

**Option** → Preemptive Vapor Control/Site Management




| Contaminant Sources Not in Contact with Building | Contaminant Sources in Contact with Building | Other Scenarios |
|---|---|---|
| **Approach** | **Approach** | |
| • Expected: Soil Gas<br>• Alternatives:<br>  • Groundwater<br>  • Soil<br>  • Subslab, indoor, outdoor | Expected: Indoor/crawl space and outdoor air<br>Alternatives:<br>• Sump water<br>• Soil gas<br>• Soil, if source is not groundwater | • Intermittent Petroleum Odors<br>• Undeveloped Lots<br>• Preferential Pathways<br>• Comingled Contaminants |

No associated notes.

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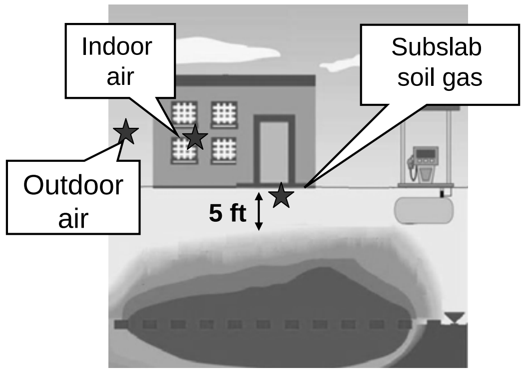
# Case Study – Site Investigation
## Investigation Scenario and Strategy

Case Study

**Contaminant Sources Not in Contact with Building**

**Approach**

- Expected: Soil Gas
- Alternatives:
  - Groundwater
  - Soil
  - Subslab, indoor, outdoor




Case Study

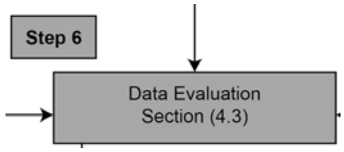
Step 5: Select Scenario and Investigation Strategy

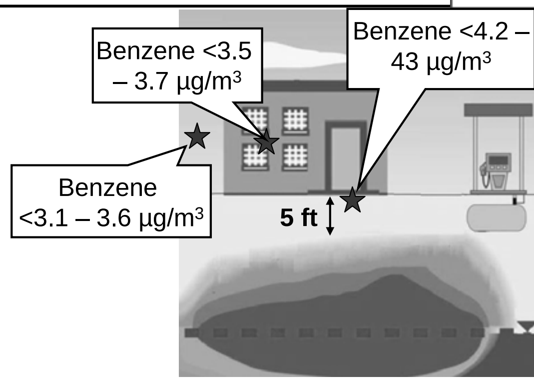
- ▶ Contamination NOT in Contact with Building
- ▶ Concurrent subslab soil gas, indoor, and outdoor air sampling (2 events)
  - See Appendix G for investigative methods

No associated notes.

# Case Study – Site Investigation
## Data Evaluation
### Case Study

Case Study




Step 6: Evaluate Data

- Indoor/outdoor air reporting
limits >1E-06, but similar to 1E-05 risk-based VISLs
- Subslab concentrations < VISLs (50-100 µg/$m^3$ – example only)
- Indoor levels similar to 1E-05 risk-based VISL, non-detect, or similar to outdoor air concentrations

VISL = Vapor Intrusion Screening Level

No associated notes.

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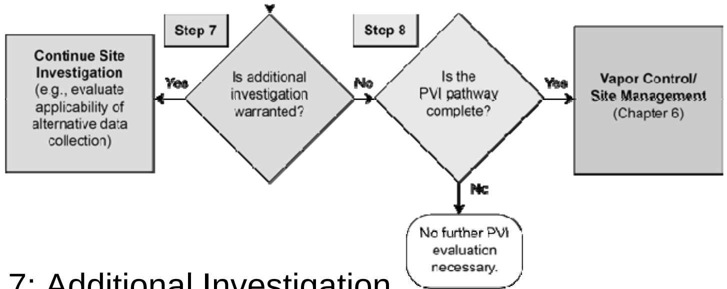
# Case Study – Site Investigation
## Additional Investigation/Pathway Complete?
Case Study

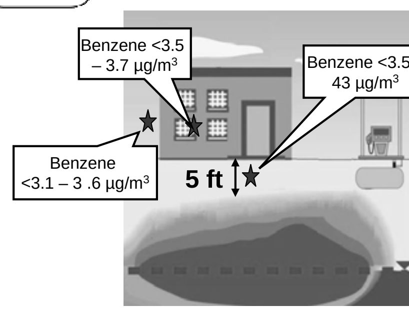



Step 7: Additional Investigation Warranted?

- No (sufficient data were available)

Step 8: PVI Pathway Complete?

- No, since indoor levels similar to 1E-05 risk-based VISL, non-detect, or similar to outdoor air concentrations




Case Study

No associated notes.

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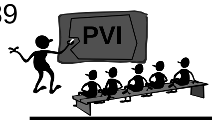


# Community Engagement

## What to expect in a Petroleum Vapor Intrusion Investigation

Community Engagement

- What will happen if a petroleum release happens in my neighborhood or in my local area?
- What will happen if I am asked to allow a PVI investigation to be conducted in my house?
- What happens during a PVI investigation?
- Where can I find more information about PVI investigations?

ITRC PVI-1, 2014: Appendix K – Frequently Asked Questions Fact Sheets

No associated notes.

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## Site Investigation Summary

Site Investigation

- Know the applicable regulatory requirements for PVI investigations
- Take multiple lines of evidence approach
- Apply 5-step process outlined in decision flow chart
  - Concentration-based evaluations can be performed at various points in process
  - Consider CSM scenario when selecting investigation strategy and methods
    - Contamination in contact, not in contact, or other
  - Consider feasibility of soil gas sampling as it reflects partitioning, sorption, and biodegradation
- Use Appendix G "Toolbox" as guide to expected and alternative investigation methods
- Communicate with stakeholders

No associated notes.

# Today's Road Map

Modeling

- Introduction
- PVI Pathway
- Site Screening
- Participant Questions
- Investigation & Modeling ←
- Vapor Control & Site Management
- Participants Taking Action
- Participant Questions

Community Engagement (Introduction through Vapor Control & Site Management)

No associated notes.

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# Modeling
# Overview and Learning Objectives

Modeling

- ▶ Overview
  - Why use models and the process to follow when conducting a PVI modeling study
  - Describe the BioVapor model
  - Provide case studies where BioVapor model was used
- ▶ Learning Objectives
  - Determine if modeling is applicable for evaluating the PVI pathway at your sites
  - Understand why the BioVapor model is often an appropriate choice for evaluating the PVI pathway
  - Ask appropriate questions about model inputs and results

ITRC PVI-1, 2014: Chapter 5 and Appendix H and Appendix I

No associated notes.

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Modeling

# Why Use Models to Evaluate PVI?

- Predict health risk when fail screening process
- Derive clean-up goals (based on acceptable risk)
- Better understand biodegradation processes and key factors – conduct “what-if” analyses
- Support remedial design – how much oxygen do I need?
- Support vertical screening distances

***KEY POINT:*** Vapor-transport modeling can be used to evaluate the fate and transport of contaminant vapors from a subsurface source, through the vadose zone, and potentially into indoor air.

No associated notes.

94

# 3 Model Types Used to Evaluate PVI

Modeling

- **Empirical** - use predictions based on observations from other sites (such as bioattenuation factors)
  - Example: vertical screening distance
- **Analytical** - mathematical equations based on a simplification of site conditions
  - Example: Johnson & Ettinger (J&E), **BioVapor**
- **Numerical** - allow for simulation of multi-dimensional transport and provide for more realistic representation of site conditions
  - Due to level of data and effort (increased costs), rarely used

ITRC PVI-1, 2014: Appendix H

No associated notes.

95

## Acceptability of Models for Evaluating PVI Pathway

Modeling

- Use of models in regulatory program vary
  - Continues to evolve as rules and regulations are revised
- From MA DEP (2010), in states where VI modeling may be applied
  - May be used as the sole basis for eliminating consideration of the VI pathway (11 states)
  - It may be applied as a line of evidence in the investigation (7 states)
  - If applied, it may require confirmatory sampling (8 states)

No associated notes.

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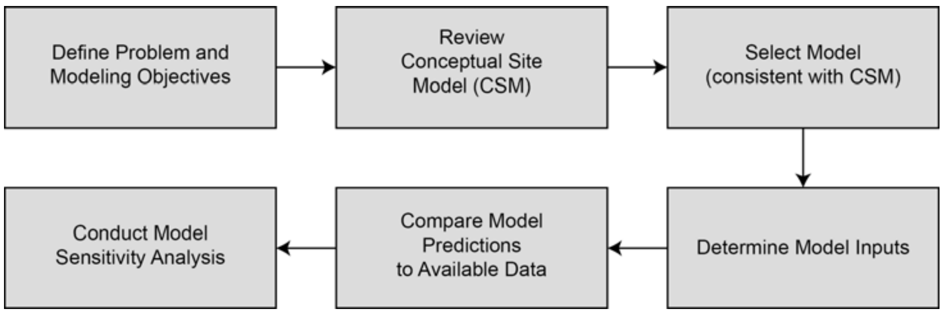
# Framework for Using Models for PVI Pathway Assessment

Modeling




ITRC PVI-1, 2014: Figure 5-2

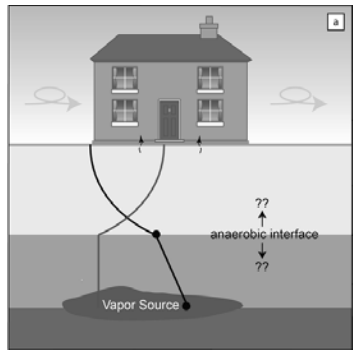
No associated notes.

# Overview of BioVapor Model

**API: Download at: http://www.api.org**

Modeling

- Why use
  - Quantify the contribution of aerobic biodegradation
  - Relatively easy to use, available, built-in parameter database
  - Reviewed and accepted by EPA, basis for EPA PVIScreen
- Model characteristics
  - Same conceptual framework as J&E but includes ‘$O_2$-limited aerobic bio’
  - Similar caveats on model applicability and use
  - Key biodegradation inputs:
    - ***Oxygen boundary conditions***
    - ***First-order decay constant***
    - ***Baseline respiration rate***
  - Source concentrations also important




ITRC PVI-1, 2014: Table 5-1

No associated notes.

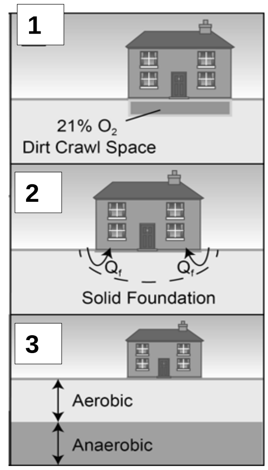
98

# Oxygen in the BioVapor Model

Modeling

**Three Options:**

1. Specify $O_2$ concentration below foundation
   - Measure oxygen
2. Let the model balance hydrocarbon flux & oxygen consumption
   - Specify airflow under foundation ("Qf ") – determines $O_2$ mass transfer
3. Specify aerobic depth
   - Measure vapor profile




***Key Point:*** **Pick one method; the others are related (and predicted)**
**Methodology relatively unique to BioVapor (particularly #2)**

No associated notes.

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# Source Concentrations in the BioVapor Model

Modeling

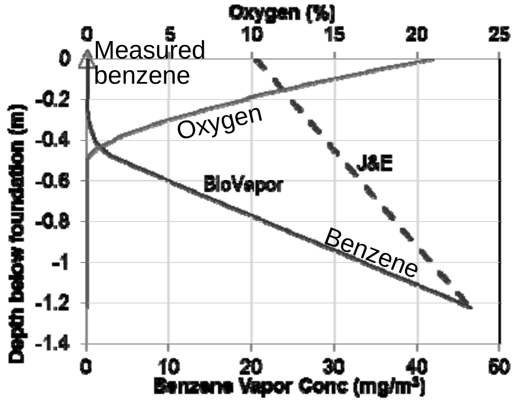
- Vapors at fuel-impacted sites are primarily aliphatic hydrocarbons; aromatics represent small percentage (typically <10%)
- BioVapor allows you to input full petroleum vapor composition
- Chemical analysis and inputs should reflect oxygen demand, e.g., through "TPH" vapor analysis or aliphatic and aromatic hydrocarbon fractions

***Key Point:*** **Source hydrocarbon concentrations input should address total oxygen demand including methane**

No associated notes.

# BioVapor Case Study –
## Salt Lake City, UT – Dissolved Source

Case Study




| GW Conc (mg/L) | | Vapor Conc (mg/m³) | | |
|---|---|---|---|---|
| | Measured Source | Predicted Source | Measured Subslab | Predicted Subslab |
| TPH | 12 | 22,600 | 0.14 | 10.9 |
| Benzene | 4 | 46.3 | <0.005 | 0.006 |

- Shallow dissolved hydrocarbon source below townhouses (source – building separation 4ft (1.2 m))
- Source GW concentrations
  - TPH = 12 mg/L
  - Benzene 4 mg/L
- Measured subslab < predicted concentrations (model conservative)
- Modeling added line of evidence for no concern with respect to indoor air

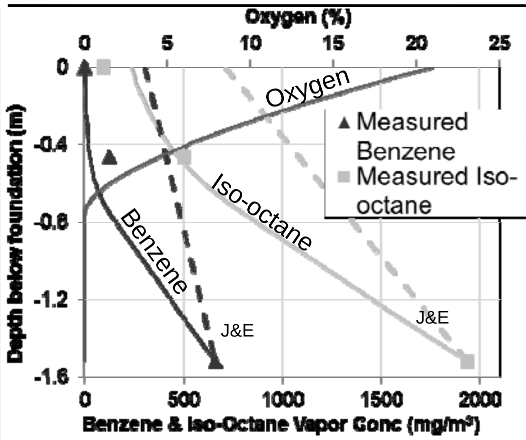
For details see Hers & Jourabchi 2014 "*Comprehensive Evaluation of the BioVapor* …", AWMA VI Conf., Sept 10-11,'14

No associated notes.

101

# BioVapor Case Study – Stafford, NJ – LNAPL Site

Case Study




| Source Vapor Conc. (mg/m³) | | Indoor Air Conc. (mg/m³) Predicted | Measured |
|---|---|---|---|
| Benzene | 660 | 0.017 | <0.0025 |
| Hexane | 6,150 | 0.39 | <0.0025 |
| Iso-octane | 1,930 | 0.91 | 0.70 |
| MTBE | 5,940 | 4.8 | 0.24 |

- Shallow LNAPL source below houses (source – building separation = 5ft (1.52 m))
- Source SV concentrations
  - Benzene = 660 mg/m3
  - TPH = 200,000 mg/m3
- Measured indoor air & subslab < predicted concentrations (model conservative)
- Modeling added line of evidence for evaluating background, predicts aromatics & aliphatics behavior well

No associated notes.

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# Modeling Summary

Modeling

- Determine if modeling is applicable for evaluating the PVI pathway at your sites
- Identify appropriate model(s) for evaluating the PVI pathway
- BioVapor model is often an appropriate choice for evaluating the PVI pathway
- Ask appropriate questions about model results

No associated notes.

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# Today's Road Map

Vapor Control and Site Management

**Introduction**

**PVI Pathway**

**Site Screening**

**Participant Questions**

**Investigation & Modeling**

**Vapor Control & Site Management**

**Participants Taking Action**
**Participant Questions**

**Community Engagement**

No associated notes.

# Vapor Control & Site Management Learning Objectives and Overview

Vapor Control and Site Management

- How **factors unique to PVI mitigation** may affect your remedy decisions
- **Types of vapor control strategies** to manage PVI when indoor air exceed mitigation action levels, or are likely to exceed screening levels in future buildings
- Where to find **more detailed information** on
  - Design, operations and maintenance (O&M) and closure of mitigation systems
  - Community engagement

*Handout provided*

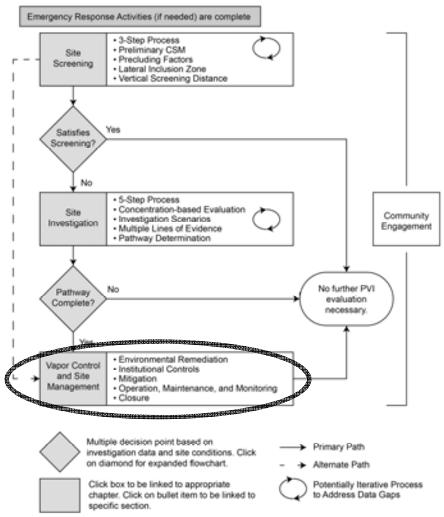


Figure 1-2. PVI strategy flowchart

ITRC PVI-1, 2014: Chapter 6

No associated notes.

105

## Factors Unique to PVI Mitigation

Vapor Control and Site Management

- Petroleum soil/groundwater impacts typically less extensive and easier to remediate than chlorinated solvent impacts
- Vertical migration of petroleum vapors limited by bioattenuation
- Introduction of oxygen below building may reduce or eliminate impacts
- High concentrations potentially explosive

***KEY POINT:*** **The unique properties of petroleum VOCs may affect the appropriate response action**

No associated notes.

106

# Vapor Control Strategies for Petroleum Hydrocarbons

Vapor Control and Site Management

- Environmental remediation
- Mitigation
- Institutional controls

or any combination of these approaches

Figure 6-1. Small-scale soil vapor extraction (SVE) system designed to address the source of vapors. Photo Source: Vapor Mitigation Sciences, LLC.

Figure J-4. Passive sump mitigation system. Photo Source: Kansas Dept. of Health and Environment

***KEY POINT:*** **Both short-term and long-term risks should be considered to determine the appropriate response action**

No associated notes.

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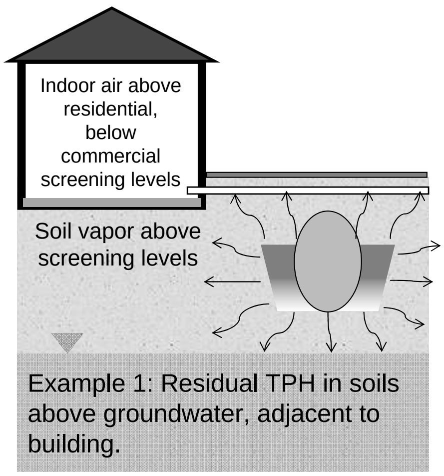
# Example 1 – Vapor Control Strategies

**Residual TPH in soils above groundwater, adjacent to building**

Poll Question




- Evacuate
- Remediation
  - Excavate & remove source
  - Soil vapor extraction
  - Utility trench dam
- Mitigation
  - Sub-slab depressurization
  - Building positive pressure
  - Sealing cracks (only)
- Institutional Controls
  - Restrict residential use
  - Require testing/mitigation if occupied
  - Require continued O&M of mitigation

Which vapor control strategy is likely to be most suitable for Example 1? Select up to 3 options.

Evacuate

Remediation: Excavate & remove source

Remediation: Soil vapor extraction

Remediation: Utility trench dam

Mitigation: Sub-slab depressurization

Mitigation: Building positive pressure

Mitigation: Sealing cracks (only)

Institutional Controls: Restrict residential use

Institutional Controls: Require testing/mitigation if occupied

Institutional Controls: Require continued O&M of mitigation

Discuss what doesn’t make sense in this situation, pro’s and con’s of the remaining options, what might be unique to PVI etc.

In this case, building mitigation would typically not make sense. Even though indoor air is above the residential SL (presumably background has been addressed or acknowledged), the concentrations are below commercial SLs, so they’re not too high (also meaning that evacuation would not be warranted). Since excavation and/or SVE could likely be accomplished fairly quickly, even residential risk might be acceptable (considering the short duration of exposure). Although the source is fairly close to the building, vapor migration along the utility line is likely the main pathway, suggesting that a trench dam should be considered. ICs should not be needed in this case, assuming that active remediation is the selected approach. SVE in the source zone would likely prevent lateral movement of vapors toward the building.

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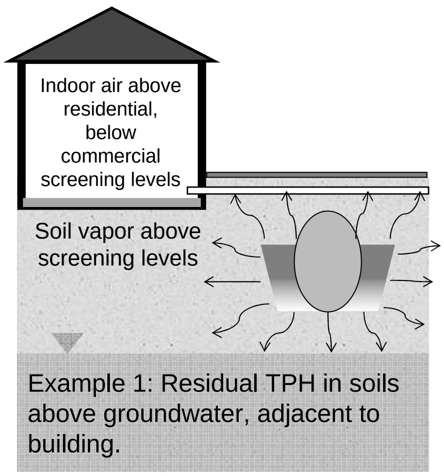
## Example 1 – Suggested Approaches

**Residual TPH in soils above groundwater, adjacent to building**




- Evacuate
  - Not an emergency!
- Remediation
  - Excavate & remove source
  - Soil vapor extraction
  - Utility trench dam
- Mitigation
  - Likely not warranted
  - Indoor air screening levels > Residential, < Commercial
- Institutional Controls
  - Restricting residential use an option if applicable

Which vapor control strategy is likely to be most suitable for Example 1? Select up to 3 options.

Evacuate

Remediation: Excavate & remove source

Remediation: Soil vapor extraction

Remediation: Utility trench dam

Mitigation: Sub-slab depressurization

Mitigation: Building positive pressure

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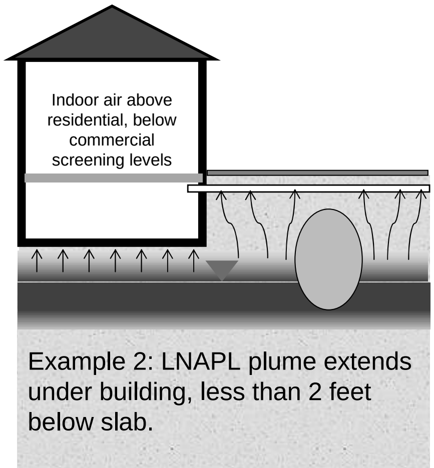
109 **Example 2 – Vapor Control Strategies**

**LNAPL plume extends under building, less than 2 feet below slab**

Poll Question




- Evacuate
- Remediation
  - Excavate & remove source
  - Source remediation (MPE, bio, etc.)
  - Utility trench dam
- Mitigation
  - Sub-slab depressurization
  - Building positive pressure
  - Sealing cracks (only)
- Institutional Controls
  - Restrict residential use
  - Require testing/mitigation if occupied
  - Require continued O&M of mitigation

Which control strategy is likely to be most suitable for Example 2? Select up to 3 options.

Evacuate

Remediation: Excavate & remove source

Remediation: Source remediation (MPE, bio, etc.)

Remediation: Utility trench dam

Mitigation: Sub-slab depressurization

Mitigation: Building positive pressure

Mitigation: Sealing cracks (only)

Institutional Controls: Restrict residential use

Institutional Controls: Require testing/mitigation if occupied

Institutional Controls: Require continued O&M of mitigation

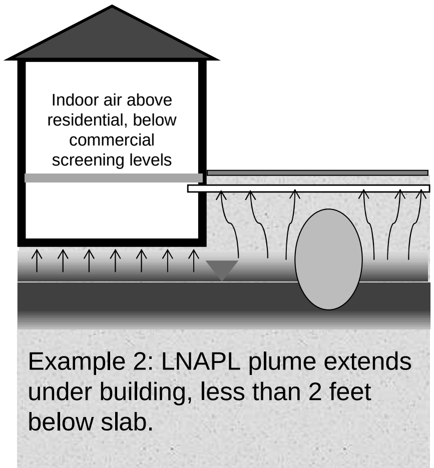
Discuss what doesn't make sense in this situation, then pro's and con's of the remaining options.

In this case, the contamination is extensive and below the building, so excavation and/or remediation, while likely required in any case, might not control vapors quickly enough. Not an emergency situation given the concentrations, but mitigation with a requirement to continue mitigation O&M until source cleanup is achieved would be reasonable. Building positive pressure is not typically a good approach for residential buildings (a commercial building would not require mitigation). Sealing cracks is seldom sufficient. Source remediation should also consider the potential for generating more vapors (e.g., sparging).

110

## Example 2 – Suggested Approaches

**LNAPL plume extends under building, less than 2 feet below slab**




- Evacuate
  - Not an emergency situation!
- Remediation
  - Source under structure
  - Unlikely to address VI in reasonable time frame
- Mitigation
  - Likely best option, or….
- Institutional Controls
  - May be an option in commercial settings

Which control strategy is likely to be most suitable for Example 2? Select up to 3 options.

Evacuate
Remediation: Excavate & remove source
Remediation: Source remediation (MPE, bio, etc.)
Remediation: Utility trench dam
Mitigation: Sub-slab depressurization
Mitigation: Building positive pressure
Mitigation: Sealing cracks (only)
Institutional Controls: Restrict residential use
Institutional Controls: Require testing/mitigation if occupied
Institutional Controls: Require continued O&M of mitigation

Discuss what doesn’t make sense in this situation, then pro’s and con’s of the remaining options.

In this case, the contamination is extensive and below the building, so excavation and/or remediation, while likely required in any case, might not control vapors quickly enough. Not an emergency situation given the concentrations, but mitigation with a requirement to continue mitigation O&M until source cleanup is achieved would be reasonable. Building positive pressure is not typically a good approach for residential buildings (a commercial building would not require mitigation). Sealing cracks is seldom sufficient. Source remediation should also consider the potential for generating more vapors (e.g., sparging).

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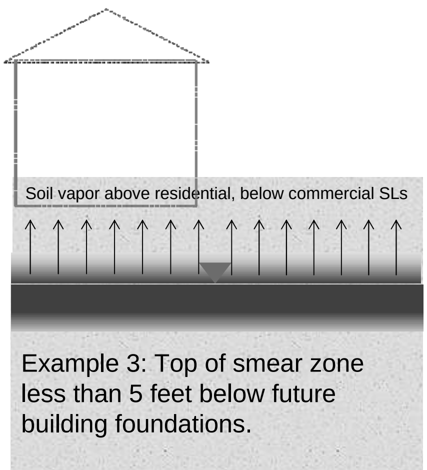
# Example 3 – Vapor Control Strategies

**Top of smear zone less than 5 feet below future building foundations**

Poll Question




- Evacuate
- Remediation
  - Excavate & remove source
  - Source remediation (MPE, bio, etc.)
  - Replace/clean top 5 feet of soil
- Mitigation
  - Sub-slab depressurization
  - Building positive pressure
  - Sealing cracks (only)
- Institutional Controls
  - Restrict residential use
  - Require testing/mitigation if occupied
  - Require intrinsically safe building design

Note, choices slightly different for this scenario.

Which control strategy is likely to be most suitable for Example 3? Select up to 3 options.

Evacuate
Remediation: Excavate & remove source
Remediation: Source remediation (MPE, bio, etc.)
Remediation: Replace/clean top 5 feet of soil
Mitigation: Sub-slab depressurization
Mitigation: Building positive pressure
Mitigation: Sealing cracks (only)
Institutional Controls: Restrict residential use
Institutional Controls: Require testing/mitigation if occupied
Institutional Controls: Require intrinsically safe building design

In this case, remediation might be feasible before development. Alternatively, cleaning up the upper 5 feet might be sufficient to allow development without VI concerns (while long term remediation including MNA continues). Ics requiring evaluation and/or mitigation at the time of development might be required.

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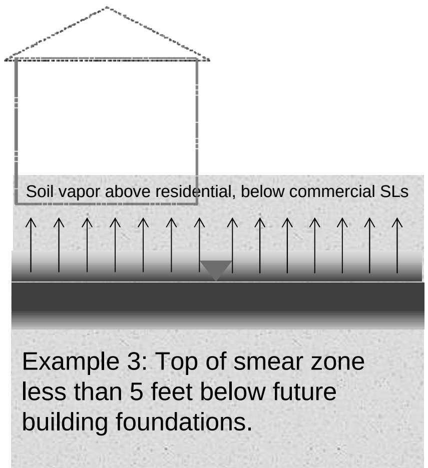
# Example 3 – Suggested Approaches

**Top of smear zone less than 5 feet below future building foundations**




- Evacuate
  - No one is there!
- Remediation
  - Can it occur before development?
  - Create bioattenuation zone with 5+ feet clean soil?
- Mitigation
  - If remediation not complete
  - More options with new construction
- Institutional Controls
  - If remediation not complete

Note, choices slightly different for this scenario.

Which control strategy is likely to be most suitable for Example 3? Select up to 3 options.

Evacuate

Remediation: Excavate & remove source

Remediation: Source remediation (MPE, bio, etc.)

Remediation: Replace/clean top 5 feet of soil

Mitigation: Sub-slab depressurization

Mitigation: Building positive pressure

Mitigation: Sealing cracks (only)

Institutional Controls: Restrict residential use

Institutional Controls: Require testing/mitigation if occupied

Institutional Controls: Require intrinsically safe building design

In this case, remediation might be feasible before development. Alternatively, cleaning up the upper 5 feet might be sufficient to allow development without VI concerns (while long term remediation including MNA continues). Ics requiring evaluation and/or mitigation at the time of development might be required.

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# PVI Mitigation Resources

Vapor Control and Site Management

- Chapter 6 (Vapor Control and Site Management)
  - Overview of strategies
  - Factors unique to PVI mitigation
- Appendix J (Vapor Intrusion Control)
  - Detailed information on methods, selection factors, design, O&M, closure strategies
  - Table J-1 – Summary of Mitigation Methods
    - Technology
    - Typical applications
    - Challenges
    - Range of installation costs

| System | Technology | Typical Applications | Challenges | Range of Installation Costs (per ft²)[b] |
|---|---|---|---|---|
| Active System | Subslab Depressurization (SSD) | Most structures; sumps, drain tiles, aerated floors, and block wall foundations may also be depressurized if present. | Low permeability and wet soils may limit performance; otherwise, highly effective systems; may require a discharge permit | \$2-\$10/ft²; residential systems typically in the \$2-4/ft² range |
| | Sub-Slab Ventilation (SSV) or Crawlspace Venting | New and existing structures relies more on influencing air flow over depressurization. | Low permeability and wet soils may limit performance; otherwise, highly effective systems; may require a discharge permit | \$2-\$10/ft²; residential systems typically in the \$2-4/ft² range |
| | Sub-Membrane Depressurization (SMD) | Existing structures, crawl spaces | Sealing to foundation wall, pipe penetrations; membranes may be damaged by occupants or trades people accessing crawl space. | \$1-\$6/ft²; residential systems typically in the \$1.50-2/ft² range |
| | Sub-Slab Pressurization (SSP) | Same as SSD; most applicable to highly permeable soils | Higher energy costs (not included) and less effective than SSD; potential for short-circuiting through cracks | \$1-\$5/ft² |
| | Building Pressurization | Commercial structures that are specifically designed., | Requires regular air balancing and maintenance; may not | \$1-\$15/ft²; heavily dependent on size and complexity of structure |

ITRC PVI-1, 2014: Chapter 6 and Appendix J

No associated notes.

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# Community Engagement

## How is a PVI Problem Fixed? Will it Ever be Over?

Community Engagement

- What are some commonly used vapor control methods?
- How do I operate a vapor control system?
- How long will it take to get rid of the petroleum vapor intrusion problem?
- So, I may have a vapor control system in my home for years?
- How will I know how long it will take for clean-up and vapor control?


Petroleum Vapor Intrusion: Frequently Asked Questions
How is a Petroleum Vapor Intrusion Problem Fixed?
(PVI FAQ Sheet 3)


Petroleum Vapor Intrusion: Frequently Asked Questions
Is a Petroleum Vapor Intrusion Problem Ever Over?
(PVI FAQ Sheet 4)

ITRC PVI-1, 2014: Appendix K – Frequently Asked Questions Fact Sheets

No associated notes.

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## Vapor Control and Site Management Summary

Vapor Control and Site Management

- Unique PVI factors may affect mitigation approach
  - Remediation may be more appropriate than building mitigation
  - Consider remediation/mitigation technologies that increase oxygen levels below building
  - Combine remediation and mitigation technologies
  - Consider explosion potential
  - Think outside the box
- The ITRC PVI guidance provides useful information and references for mitigation

No associated notes.

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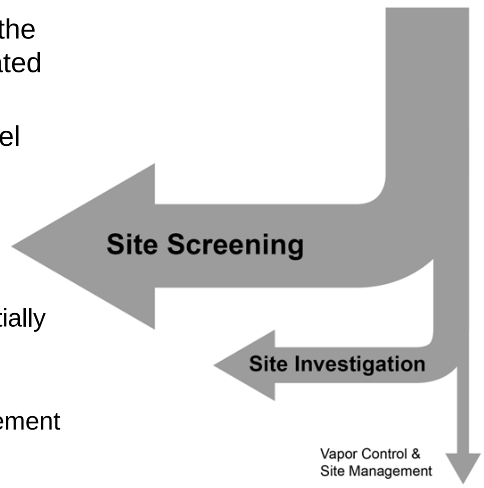
# After Today's Training You Should Know:

- When and how to use ITRC's PVI document
- Important role of biodegradation in the PVI pathway (in contrast to chlorinated solvent contaminated sites)
- Value of a PVI conceptual site model (CSM) and list its key components
- How to apply the ITRC PVI 8 step decision process to:
  - Screen sites for the PVI pathway
  - Take action if your site does not initially screen out
    - Investigation and Modeling
    - Vapor Control and Site Management
- When and how to engage with stakeholders




No associated notes.

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## ITRC PVI 2-Day Classroom Training

- Content
  - More in-depth information about the PVI pathway
  - Practice applying the ITRC PVI guidance document
  - Participate with a diverse group of environmental professionals
- Locations (starting in Fall 2015)
  - Email training@itrcweb.org if you would like us to email you when additional information is available

No associated notes.

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## Thank You for Participating

- **2nd question and answer break**
- **Links to additional resources**
  - http://www.clu-in.org/conf/itrc/PVI/resource.cfm
- **Feedback form – *please* complete**
  - http://www.clu-in.org/conf/itrc/PVI/feedback.cfm


Need confirmation of your participation today?

Fill out the feedback form and check box for confirmation email.

Links to additional resources:
http://www.clu-in.org/conf/itrc/PVI/resource.cfm

Your feedback is important – please fill out the form at:
http://www.clu-in.org/conf/itrc/PVI

**The benefits that ITRC offers to state regulators and technology developers, vendors, and consultants include:**

✓Helping regulators build their knowledge base and raise their confidence about new environmental technologies

✓Helping regulators save time and money when evaluating environmental technologies

✓Guiding technology developers in the collection of performance data to satisfy the requirements of multiple states

✓Helping technology vendors avoid the time and expense of conducting duplicative and costly demonstrations

✓Providing a reliable network among members of the environmental community to focus on innovative environmental technologies

**How you can get involved with ITRC:**

✓Join an ITRC Team – with just 10% of your time you can have a positive impact on the regulatory process and acceptance of innovative technologies and approaches

✓Sponsor ITRC's technical team and other activities

✓Use ITRC products and attend training courses

✓Submit proposals for new technical teams and projects