Site Investigation

Key topics

- Data quality
- Identifying pitfalls
- Data collection processes
- Analytical methods

Petroleum VI Screening

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Investigative Approach

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Data Evaluation

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Vapor Control and Site Management

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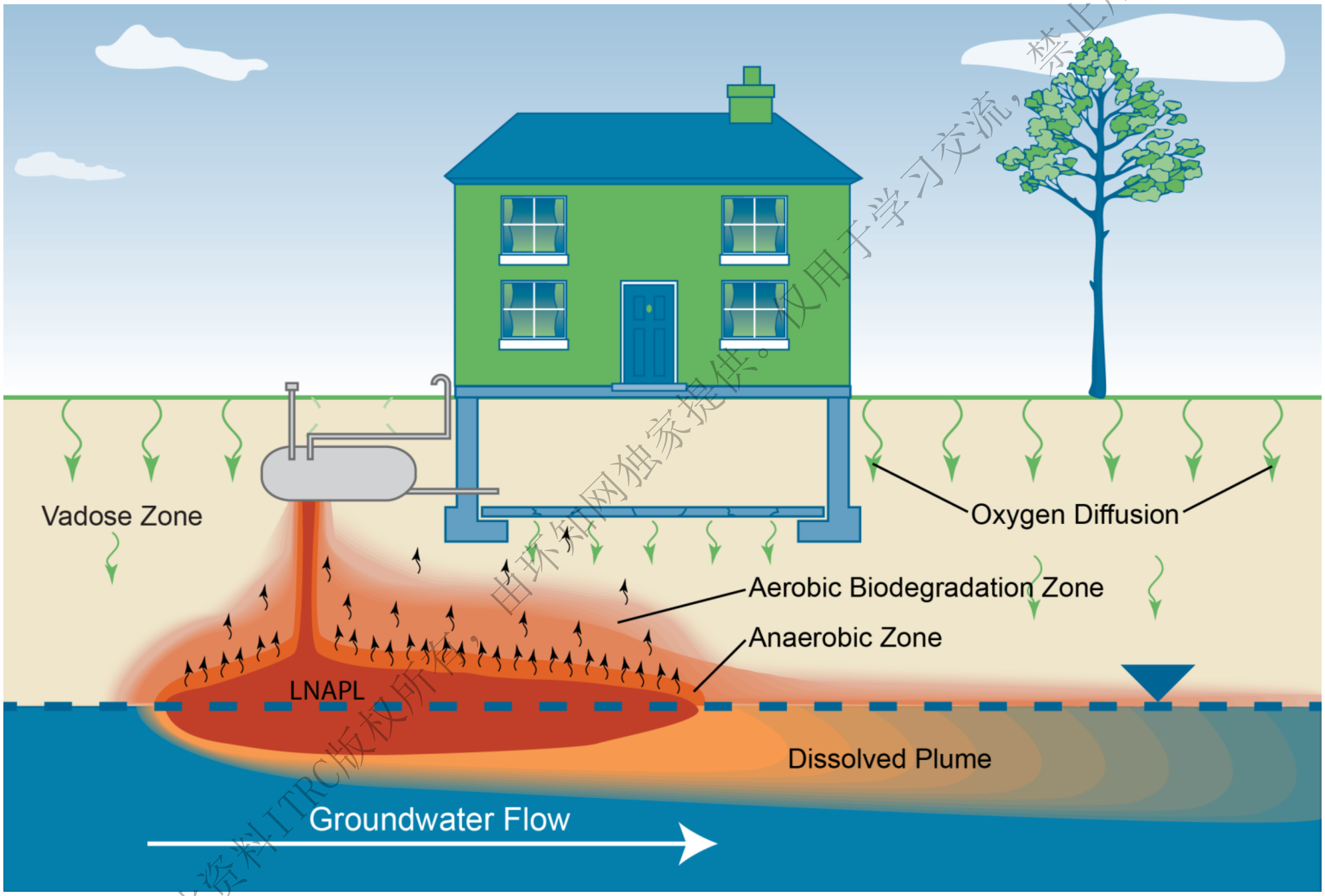
General Remediation

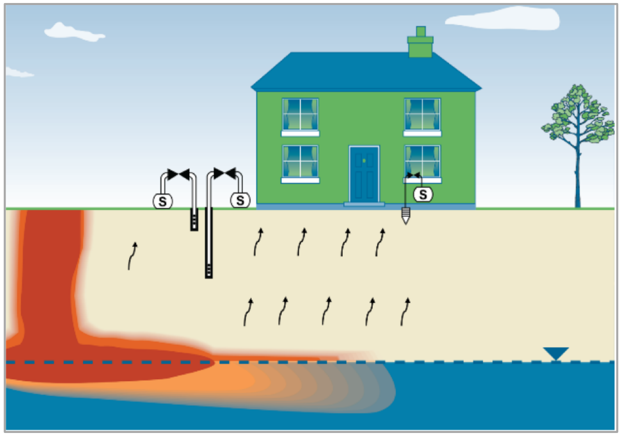
Scenario 1 – Contamination NOT in Contact with Building



ITRC PVI-1, Figure E-2

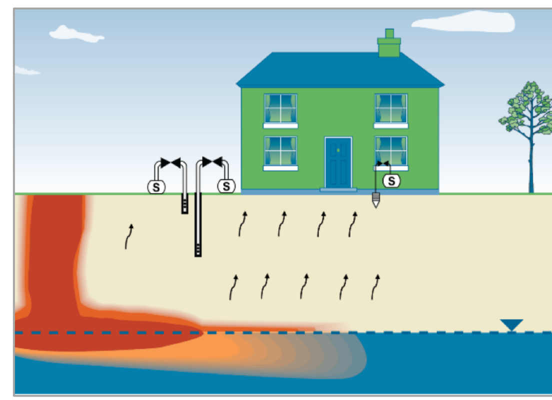
Scenario 1 – Investigative Approach

- Soil gas sampling is expected (i.e., default) approach since:
  - Reflects partitioning, sorption, and biodegradation in vadose zone between source and building
- Focus effort on evaluating aerobic biodegradation in vadose zone
  - Exterior, near slab
  - Vertical profile



Scenario 1
Primary Tool – Soil Gas Sampling

- Considerations
  - Spatial variability
  - Temporal variability
  - Screening levels
    - Typically higher screening levels than indoor air
  - Not direct measure of exposure (i.e., pathway-based evaluation, not receptor)

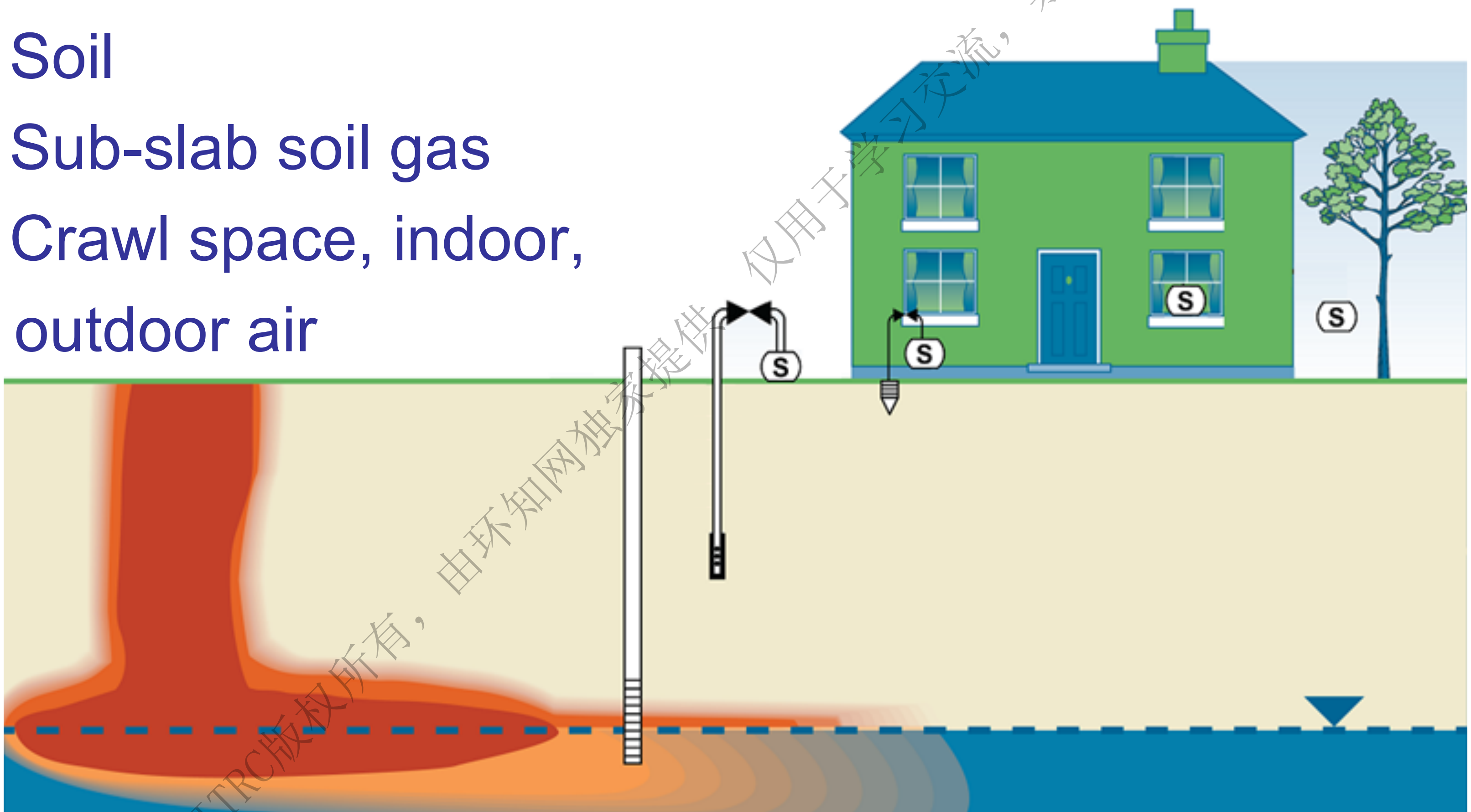


Key Point: **Decision-making based on data outside of buildings.**

If enough attenuation demonstrated within vadose zone, then won't need to sample individual buildings.

Scenario 1: Alternative Approaches

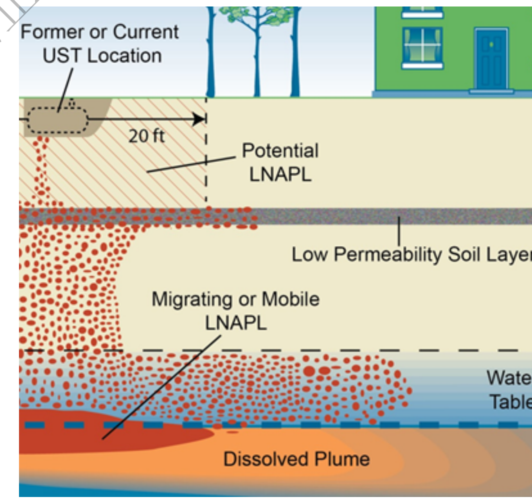
- Groundwater
- Soil
- Sub-slab soil gas
- Crawl space, indoor, outdoor air



Key Point: **Different tools are available, depending on site needs and agency requirements**

Alternatives – Groundwater Sampling

- To increase confidence in plume characterization
  - Well density within plume; Delineation wells/ GW flow/direction; perched vs true GW
  - Changes in water table depth
- Considerations
  - GW samples not collected from soil-water interface are not appropriate for VI evaluation
  - Screen length
  - Not a direct measurement of soil gas concentrations
  - Potential for long-term monitoring



Source: W. McKercher, MS DEQ

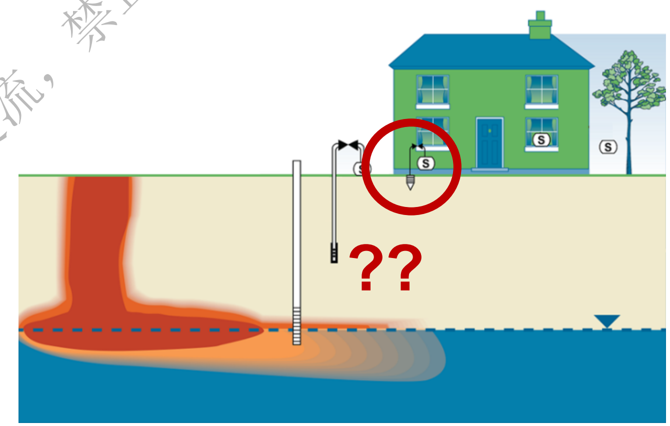
Alternatives – Soil Data

- To increase confidence in CSM, source characterization
  - Existing data can be used to screen in sites
  - Additional soil data may be needed to understand 1) top of impacted zone (separation distance), or 2) show "clean" soil in a vertical profile
- Considerations – hard to use data to estimate vapors
  - 10X to 1000X losses of VOCs (EPA/600/SR-93/140)
  - Method 5035 to minimize VOC loss, but may result in elevated reporting limits (methanol extraction)
  - Partitioning equations tend to overestimate soil gas concentrations

Source: W. McKercher, MS DEQ

Alternatives – Sub-slab Soil Gas Sampling

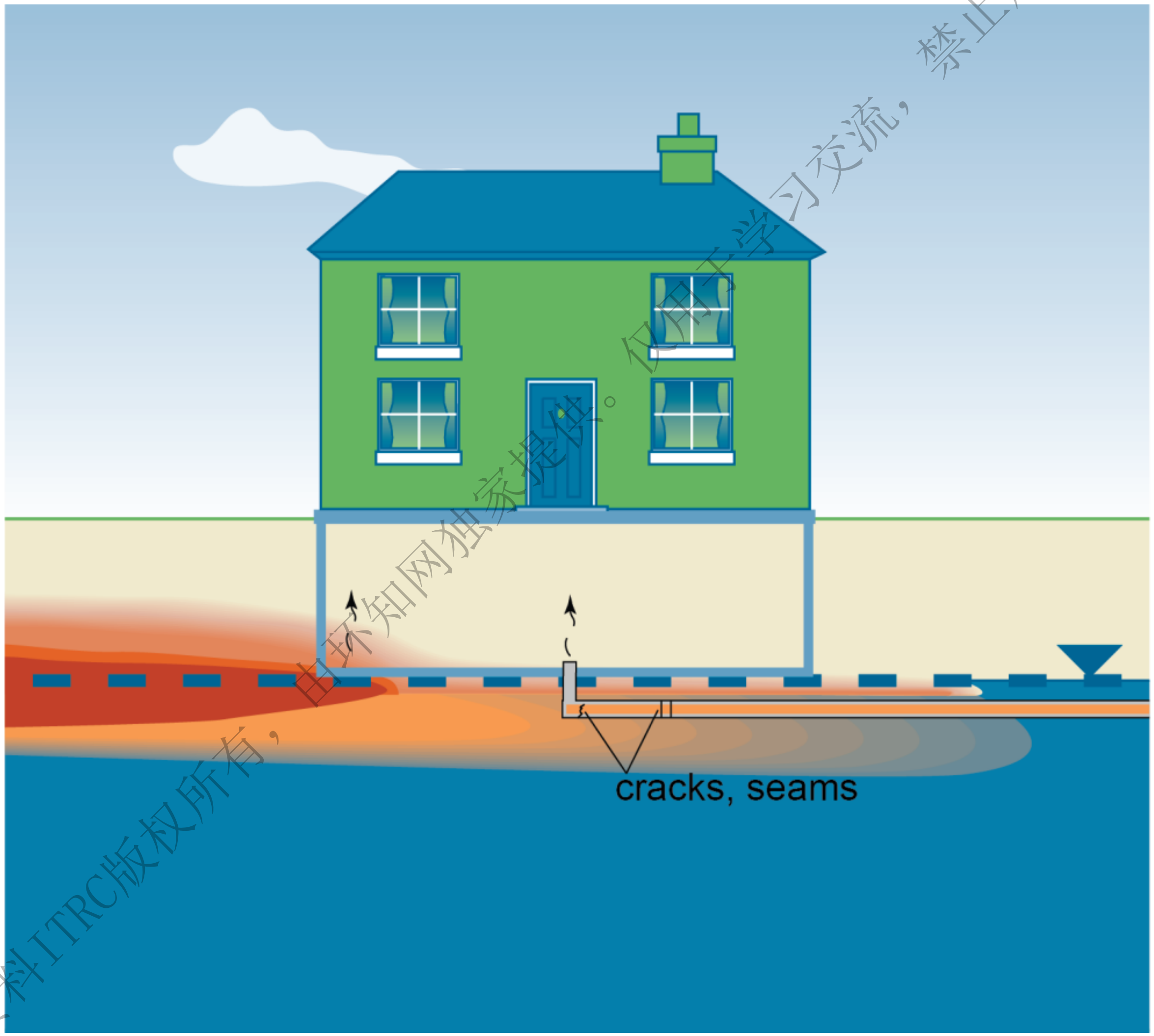
- Can be part of pathway evaluation
  - May be required by state guidance
- Considerations
  - Sample immediately below structure
    - Intrusive
  - Spatial and temporal variability
  - Can be impacted by indoor VOC sources!
    - So, consider collecting sub-slab – indoor – outdoor concurrently



Source: Kansas DHE

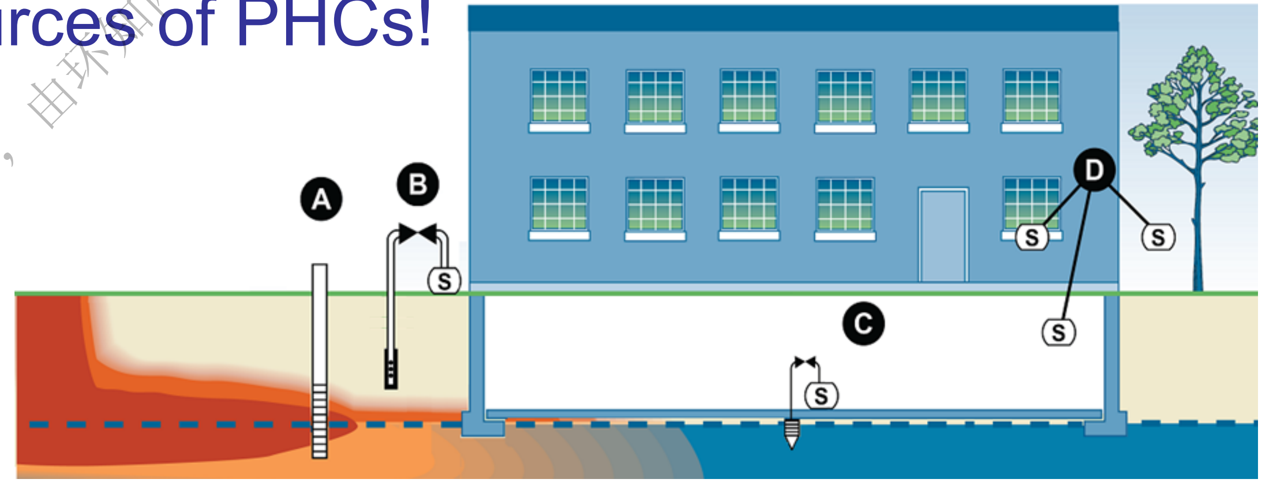
ITRC PVI-1, Appendix G.8.4

Scenario 2 – Contamination in Contact with Building



Scenario 2 – Investigative Approach

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



Scenario 2: Primary Tools – Indoor Air / Crawl Space Sampling

- Actual concentration, no modeling required
- No drilling or heavy equipment
- Less spatial variability than soil vapor
  - One sample often adequate for typical basements
- Considerations
  - Intrusive
  - Potential for background sources, addressed by:
    - Survey of building materials and activities
    - Supplemental tools
    - Concurrent outdoor air, sub-slab sampling
  - No control (sample left unattended for 8-24 hours)
  - Typically more temporal variability than soil vapor
    - Up to one order of magnitude common for indoor air

Summa Canister for Indoor Air Sampling

Passive Sampling device

Source: W. McKercher, MS DEQ

Primary Tools – Outdoor Air Sampling

Every time you collect an indoor air or crawl space sample, **ALWAYS** collect a concurrent outdoor (ambient) air sample!

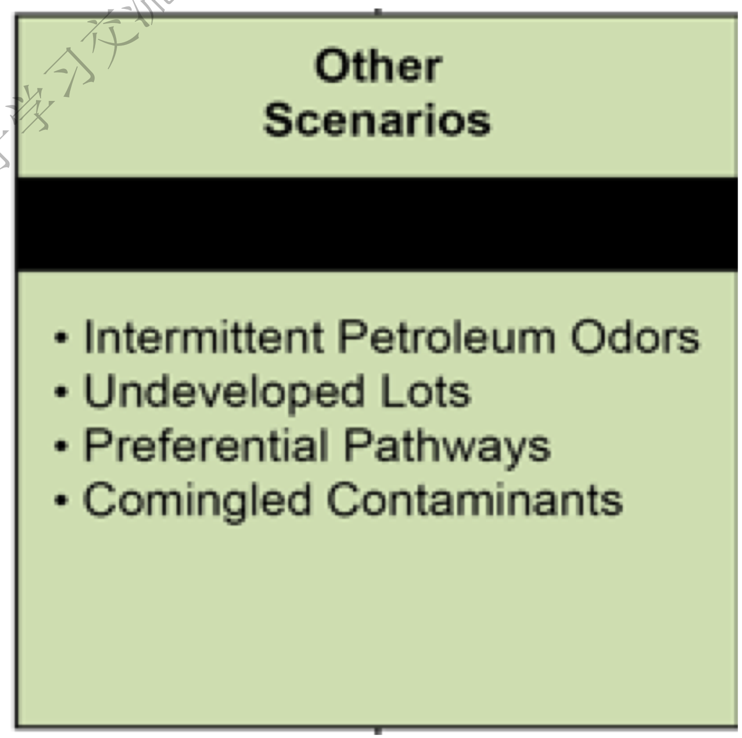
Outdoor Air Sample with Tubing to Reach Required Sampling Height

Source: GSI Environmental

Source: W. McKercher, MS DEQ

Other Scenarios – Special Cases or Exceptions

- Intermittent petroleum odors
  - Walk-through
  - Verification sampling
  - Further investigation
- Undeveloped lots
  - Soil gas
  - Groundwater sampling
- Preferential pathways
  - Indoor air sampling
- Comingled contaminants
  - Refer to USEPA OSWER Guide (2015) or ITRC Vapor Intrusion Pathway: A Practical Guideline V-1 (2007)



Important Considerations Required
Screening or Target Levels

- ▶ Sources
  - Federal
    - EPA Regional Screening Levels (RSLs)
  - State specific
- ▶ Screening levels – common errors
  - Comparing to the wrong screening levels
  - Not calculating correct levels

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

EPA Regional Screening Levels (RSLs)

Resident Ambient Air Table – May 2016

Key: I = IRIS; P = PPRTV; A = ATSDR; C = Cal EPA; X = APPENDIX PPRTV SCREEN (See FAQ #27); H = HEAST; J = New Jersey; O = EPA Office of Water; F = See FAQ; E = Environmental Criteria and Assessment Office; S = see user guide Section 5; L = see user guide on lead; M = mutagen; V = volatile; R = RBA applied (See User Guide for Arsenic notice) ; c = cancer; * = where: n SL < 100X c SL; ** = where n SL < 10X c SL; n = noncancer; m = Concentration may exceed ceiling limit (See User Guide); s = Concentration may exceed Csat (See User Guide); SSL values are based on DAF=1

Toxicity and Chemical-specific Information						Contaminant		Carcinogenic Target Risk (TR) = 1E-06	Noncancer Hazard Index (HI) = 1
IUR $(ug/m^3)^{-1}$	key	RfC_i (mg/m^3)	key	voc	mutagen	Analyte	CAS No.	Carcinogenic SL TR=1.0E-6 (ug/m^3)	Noncarcinogenic SL HI=1 $(\mu g/m^3)$
5.1E-06	C					ALAR	1596-84-5	5.5E-01	
						Acephate	30560-19-1		
2.2E-06	I	9.0E-03	I	V		Acetaldehyde	75-07-0	1.3E+00	9.4E+00
						Acetochlor	34256-82-1		
		3.1E+01	A	V		Acetone	67-64-1		3.2E+04
		2.0E-03	X	V		Acetone Cyanohydrin	75-86-5		2.1E+00
		6.0E-02	I	V		Acetonitrile	75-05-8		6.3E+01
				V		Acetophenone	98-86-2		
1.3E-03	C					Acetylaminofluorene, 2-	53-96-3	2.2E-03	
		2.0E-05	I	V		Acrolein	107-02-8		2.1E-02
1.0E-04	I	6.0E-03	I		M	Acrylamide	79-06-1	1.0E-02	6.3E+00
		1.0E-03	I			Acrylic Acid	79-10-7		1.0E+00
6.8E-05	I	2.0E-03	I	V		Acrylonitrile	107-13-1	4.1E-02	2.1E+00
		6.0E-03	P			Adiponitrile	111-69-3		6.3E+00
						Alachlor	15972-60-8		

http://www.epa.gov/region9/superfund/prg/ *Note: check for semi-annual updates*

Attenuation Factor – Determining your Soil Gas Goals

- Alpha (or α) = Attenuation Factor
  $\alpha = Concentration_{indoor}/Concentration_{soil\ gas}$
- Which means
  - If you know "allowable" indoor air value, you can estimate the concentration of soil gas that may pose a risk
    - $C_{indoor} / \alpha_{soil\ gas} = C_{soil\ gas}$

OR

  - If you know the soil gas you can estimate the expected indoor air concentration
    - $C_{soil\ gas} * \alpha_{soil\ gas} = C_{indoor}$

Supermarket of Screening Levels: EPA VISL Calculator

OSWER Vapor Intrusion Screening Level Calculator (VISL)
https://epa-visl.ornl.gov/cgi-bin/visl_search

OSWER VAPOR INTRUSION ASSESSMENT
Vapor Intrusion Screening Level (VISL) Calculator Version 3.4, November 2015 RSLs

The primary objective of risk-based screening is to identify sites or buildings unlikely to pose a health concern through the vapor intrusion pathway. Generally, at properties where subsurface concentrations of vapor-forming chemicals (e.g., groundwater or "near source" soil gas concentrations) fall below screening levels (i.e., VISLs), no further action or study is warranted, so long as the exposure assumptions match those taken into account by the calculations and the site fulfills the conditions and assumptions of the generic conceptual model underlying the screening levels. In a similar fashion, the results of risk-based screening can help the data review team identify areas, buildings, and/or chemicals that can be eliminated from further assessment. The generic conceptual model underlying these screening levels is described in OSWER Publication 9200.2-154 (OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway From Subsurface Vapor Sources to Indoor Air) (EPA 2015; Section 6.5)

Parameter	Symbol	Value	Instructions
Exposure Scenario	Scenario	Residential	Select residential or commer
Target Risk for Carcinogens	TCR	1.00E-06	Enter target risk for carcinoge
Target Hazard Quotient for Non-Carcinogens	THQ	1	Enter target hazard quotient f
Average Groundwater Temperature (°C)	Tgw	25	Enter average of the stabilize

View All Chemicals

View Checked Chem

CAS	Chemical Name	Does the chemical meet ...	Does chemical have ...	Is Chemical Sufficiently Volatile ...	Is Chemical Sufficiently Volatile and Toxic to Pose ...		
83-32-9	Acenaphthene						
x 30560-19-1	Acephate						
75-07-0	Acetaldehyde						
34256-82-1	Acetochlor	No	No	No (not volatile)	No (not volatile)		
67-64-1	Acetone	Yes	Yes	Yes	Yes	3.2E+04	NC
75-86-5	Acetone Cyanohydrin	No	Yes	No (not volatile)	No (not volatile)		
75-05-8	Acetonitrile	Yes	Yes	Yes	Yes	6.3E+01	NC
98-86-2	Acetophenone	Yes	No	No Inhal. Tox. Info	No Inhal. Tox. Info		
53-96-3	Acetylaminofluorene, 2-	No	Yes	No (not volatile)	No (not volatile)		
107-02-8	Acrolein	Yes	Yes	Yes	Yes	2.1E-02	NC
79-06-1	Acrylamide	No	Yes	No (not volatile)	No (not volatile)		
79-10-7	Acrylic Acid	Yes	Yes	Yes	Yes	1.0E+00	NC
107-13-1	Acrylonitrile	Yes	Yes	Yes	Yes	4.1E-02	C
111-69-3	Adiponitrile	No	Yes	No (not volatile)	No (not volatile)		

Benzene

Target Indoor Air @ TCR= 1E-06
0.36 µg/m³

Target SS/ SG @ TCR= 1E-06
12 µg/m³

Target Groundwater @ TCR= 1E-06
1.6 µg/L

Sampling Plan Development
Project Goals/Data Quality Objectives

Project Planning

- Define/identify
  - Type of Site
  - Contaminants of concern
  - Regulatory screening levels
  - Study goals
- Choose/establish
  - Type of samples
  - Number of samples
  - Sampling and analytical method
  - Reporting limits
  - Validation procedures

Source: Mississippi Energy Institute

Source: W. McKercher, MS DEQ

Sampling Plan Development
Project Goals/Data Quality Objectives

- If indoor air sampling, then also complete
  - Pre-sampling building survey
    - Interior survey
    - Site screening
  - Outdoor air sample
- Collect
  - Samples
  - QA/QC samples

Source: W. McKercher, MS DEQ

Some Key VI Assessment Issues

- Experience of the collector/consultant
  - Have they done this before?
  - Do they understand RBSLs (risk-based screening levels?
  - Quality/experience of field staff? Senior or Junior?
- Has enough data been collected near/ around/under?
- Were the pre-existing data collected in a manner appropriate for a VI Investigation?
  - Groundwater Data

Investigation Methods and Analysis Toolbox – Appendix G

The Tool Box is a tremendous resource, answering 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

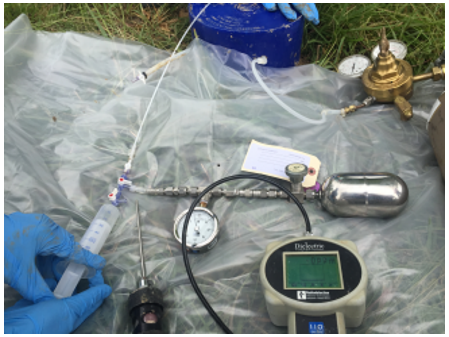
Key Point: **The Toolbox includes videos, step-by-step instructions, list of analysis methods and more…**

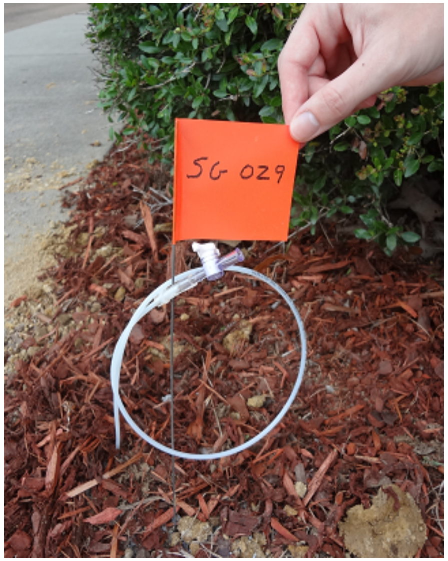
Where to Find the Information in the ITRC PVI Guidance & Appendix G

- Groundwater sampling [4.2.2.1; G.2]
- Soil sampling [4.2.2.6, G.3]
- Soil Gas sampling [4.2.2.2; G.8-G.11]
- Crawl space sampling [4.2.2.5, G.4]
- Indoor air sampling [4.2.2.3, G.5]
- Ambient air sampling [4.2.2.4, G.6]
- Difference in sampling between petroleum and chlorinated
- Supplemental Tools and Data Useful for VI Investigations [G.7]
- Analysis Methods [G.12]

Soil Gas Sampling

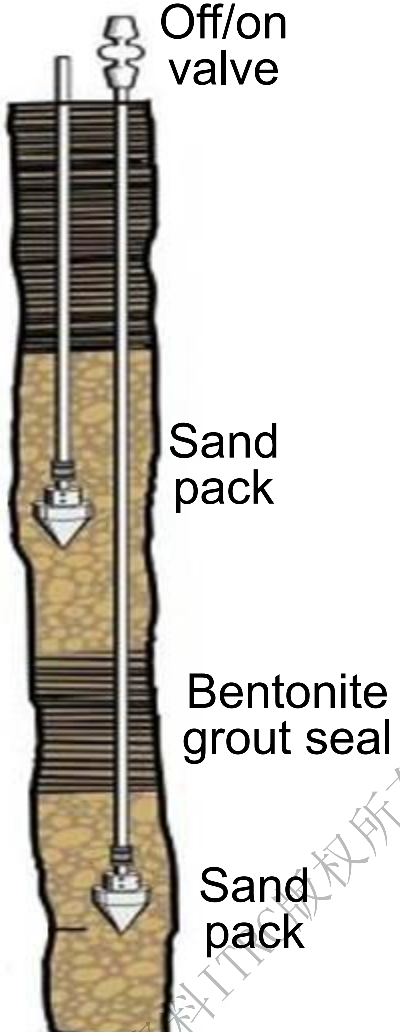
- Soil Gas - vapor in the space between soil particles
  - Above the water table
  - Can sample actively or passively
- Active Soil Gas Sampling (most common)
  - Installation
  - Equipment
  - Vacuum and leak tests
  - Purge, flow rate



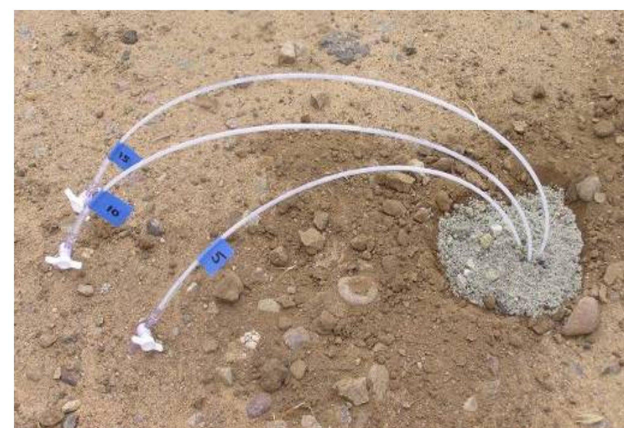


Source: W. McKercher, MS DEQ

Active Soil Gas Sampling Options:
Single vs. Multi-Depth Nested Well



Alternating layers of glass bead or sand with bentonite layers which isolate each independent zone



Source: W. McKercher, MS DEQ

Active Soil Gas Sampling:
Soil Gas Sampling Setup

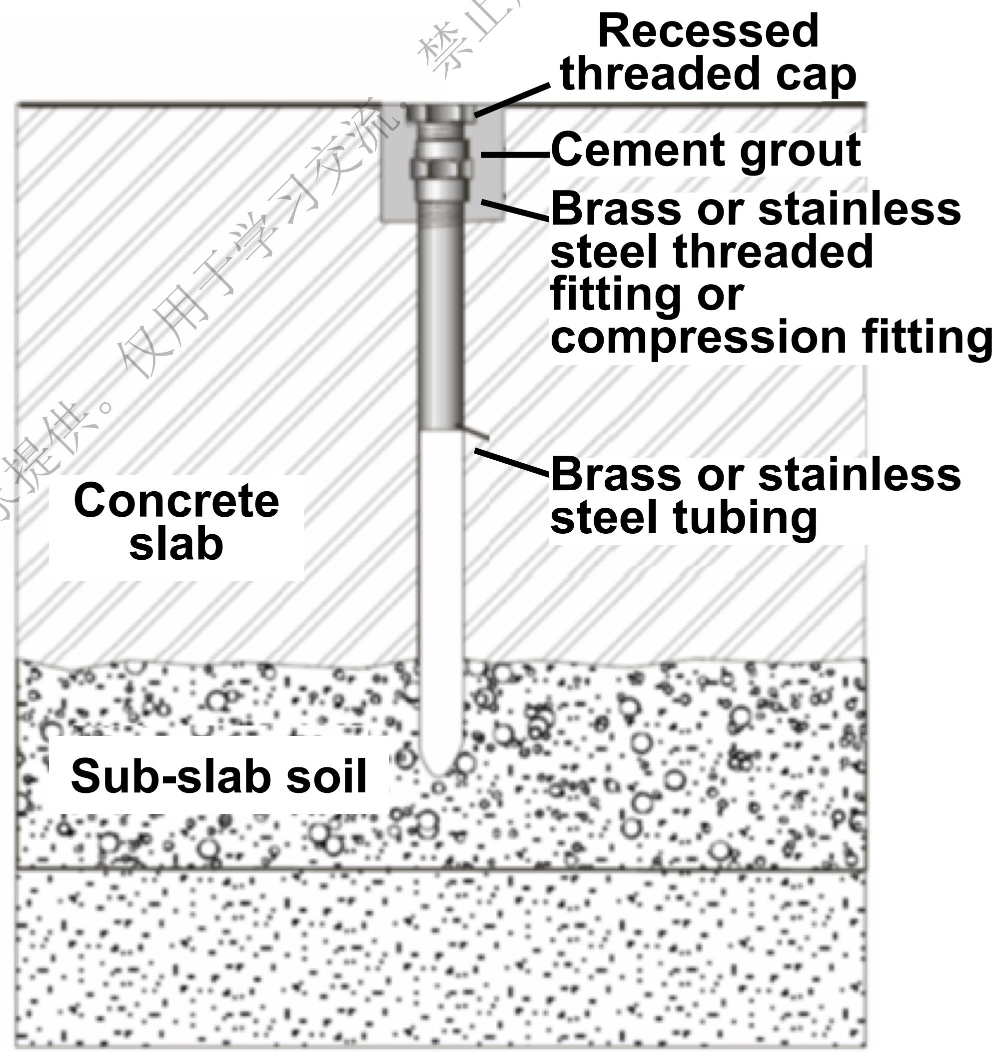
Source: W. McKercher, MS DEQ

Active Soil Gas Sampling:
Issues with Rainfall Events

Source: W. McKercher

Key Point: **Monitor weather events prior to field sampling activities**

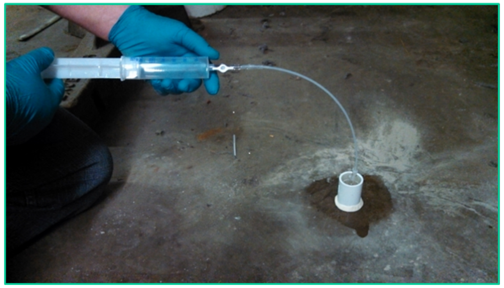
Active Soil Gas Sampling:
Sub-slab Soil Gas Sampler Installation



Source: USEPA 2006

More Quality Assurance Steps:
Leak Tracer Methods

- Liquid (e.g., Isopropanol) – Less common
  - Pros - Fast & easy; Can cover multiple locations quickly
  - Cons - Qualitative; No results in real-time without on-site lab; Can raise det. limits in VOC analysis
- Gas (e.g., Helium) - More common approach
  - Pros - Quantitative; Real-time results with portable meters
  - Cons - Can be complicated; Increases costs; Harder to cover multiple locations
- Water Dam – for use with sub-slab soil gas
  - Pros – Easy process, no meters required
  - Cons – Failure will load your sampling point with water



Source: W. McKercher, MS DEQ

Sample Container Issues

Mini- vs. Large Canisters

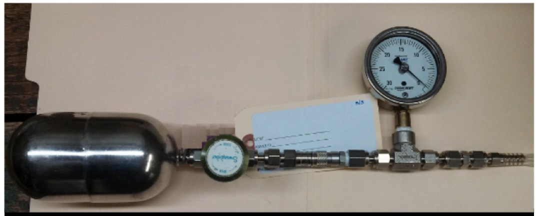
Source: H&P Mobile Geochemistry, Inc.

Filling Tedlar bag with syringe

Key Point: **Coordinate with lab for equipment needs – Canister size (detection limit), flow controller.**

Some Active Soil Gas Issues

- Individually certified clean canisters
  - Not needed if Detection Limit > 5 µg/m^3
- Sample Collection Process
  - Purge
  - Dedicated flow controllers
    - Many states require sample collection rate of 200 mL/min, but grab samples OK
    - Calibrated orifice typically can be reused
  - Residual vacuum in canisters
    - Not critical for soil gas samples (but may be required by state)



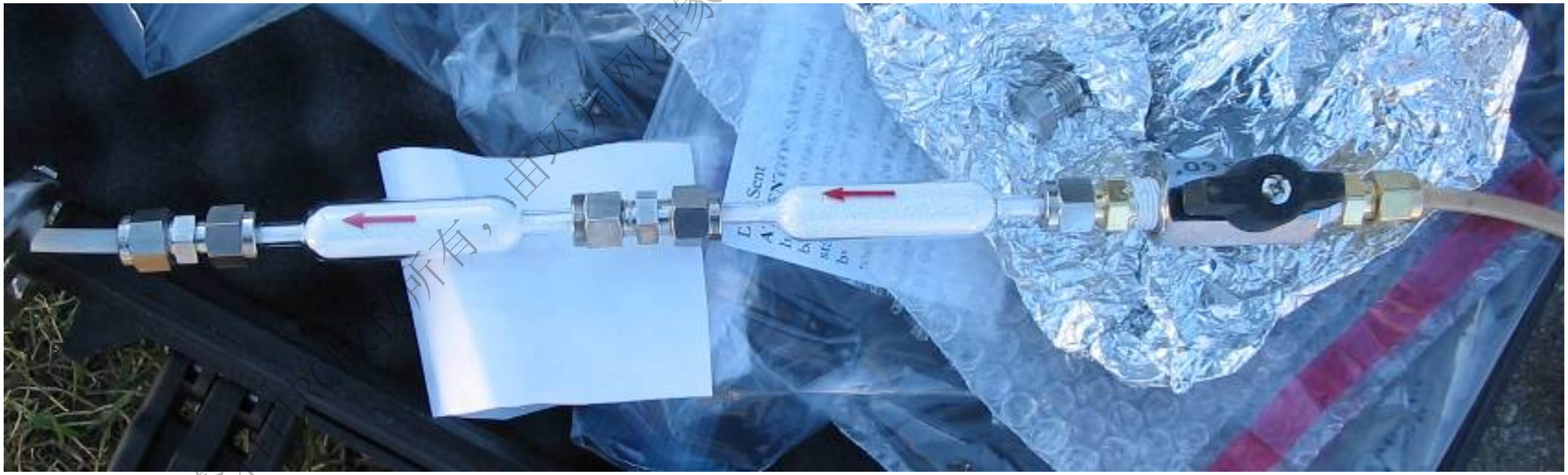
Summa Canister, Flow Controller, Vacuum Gauge

Source: W. McKercher, MS DEQ

Stay tuned: **More considerations for sampling with Summa canisters to be discussed later…**

Investigation Methods and Analysis
Sampling onto Adsorbents

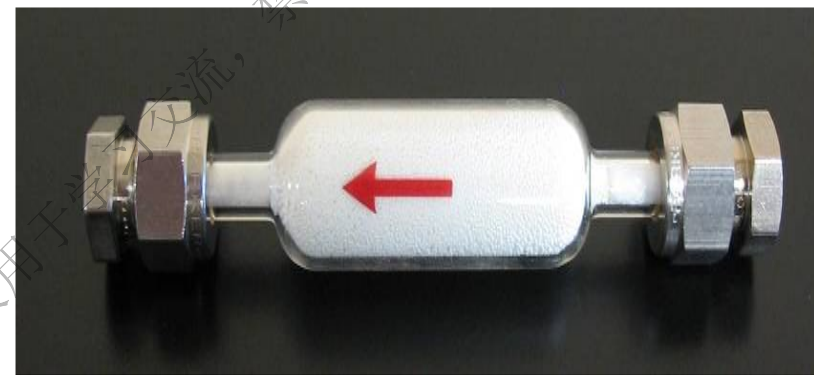
Utilizes an air sampling pump to draw a fixed volume of air across adsorbent material – allows for quantifiable concentration data



Source: H&P Mobile Geochemistry, Inc.

Sorbent Concentration Calculation

$$C = \frac{m}{Qt} \times 1{,}000{,}000$$

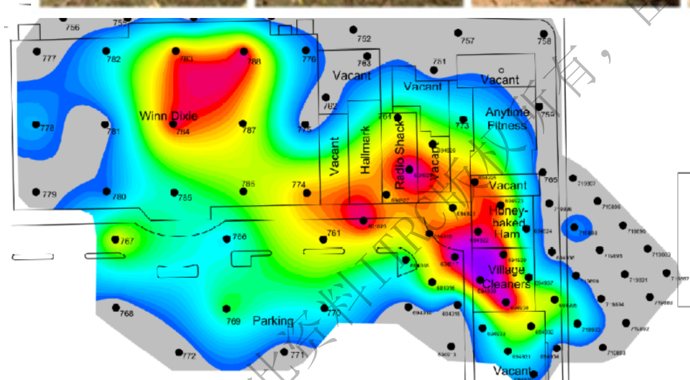


Source: H&P Mobile Geochemistry, Inc.

- C = concentration in µg/m^3
- m = mass of analyte in µg
- t = exposure time in minutes
- Q = experimentally measured sampling rate (ml/min)
  (varies by chemical; listed on manufacturer-supplied data sheet)

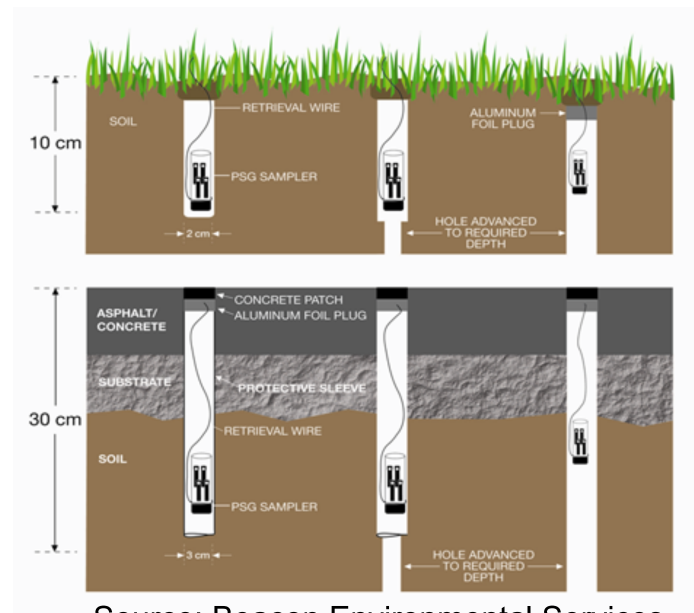
Another Option for Soil Gas
Passive Soil Gas

- Currently considered as a screening tool
- Pros
  - Easy to deploy
  - Can find contamination zones
  - Low permeability soils
- Cons
  - Typ. does not give concentration
  - No less expensive (depending on analysis)



Source: W. McKercher, MS DEQ

Source: Amplified Geochemical Imaging, LLC



Source: Beacon Environmental Services, Inc.

Investigation Methods and Analysis
Indoor Air Sampling

INTERSTATE TECHNOLOGY REGULATORY COUNCIL ITRC

SUMMA Canister

Evacuation Chamber

Air Sampling Pump with Sorbent Tubes

Tedlar Gas Sampling Bag

Glass Sampling Bulb

Source: NJDEP

Assembled 6-L SUMMA canister, vacuum gauge, flow controller, cane

Source: W. McKercher, MS DEQ

Indoor Air – Residential Locations

- Canister placement in homes
  - Basement (if present)
  - First floor
  - Ambient (outdoor) air
- Central living areas preferred
- Away from windows, vents, and doors
- Where they won't be disturbed
- Avoid
  - Bathrooms
  - Utility/storage rooms
  - Laundry rooms
  - Hobby areas

Source: W. McKercher, MS DEQ

More Supplemental Tools and Data

- **Portable Field Analyzers (G.12.2)**
- **Real-Time and Continuous Analyzers (G.7.5)**
- Flux Chambers (G.7.1)
- Determination of Sub-slab Specific Attenuation Factors Using Tracers (G.7.2)
- Determination of Room Ventilation Rates using Tracers (G.7.3)
- Forensic Data Collection (G.7.6)
- Meteorological Data (G.7.7)
- Pneumatic testing (G.7.8)

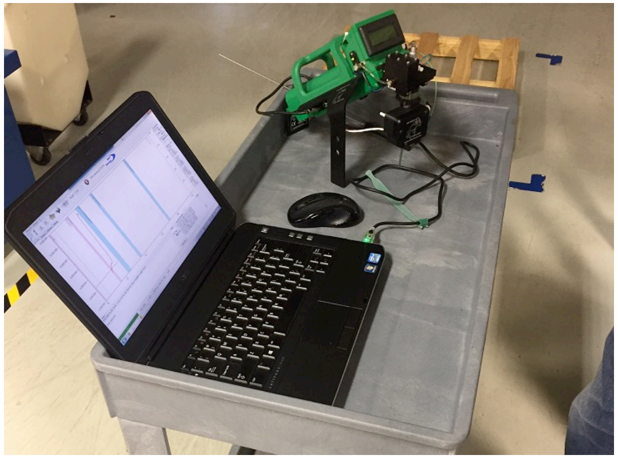
Key Point: **Refer to Appendix G**

Portable Field Analyzers

- VOCs
  - Hand-held PIDs – 1 to 10 ppmv
  - ppbRae – 50 to 100 ppbv
  - GC/MS – ppt range
- Hydrocarbons
  - Portable Flame Ionization Detectors (FID) (Foxboro, Photovac)
- Oxygen, Carbon Dioxide, Methane
  - LandTech GEM 5000 or similar
- Methane
- Helium (leak check)

Portable GC/MS

Source: GSI Environmental



Source: W. McKercher, MS DEQ

Pros & Cons – Portable Field Analyzers (PIDs)

- PIDs – most common
  - Pros
    - Identifies location and relative strength of background sources of VOCs in indoor air
    - Most are effective at "screening in" sites
  - Cons
    - Generally in the parts-per-million range
    - Most are not effective at "screening out"
    - Sensitive to environmental conditions
    - Most are not compound-specific

Source: W. McKercher, MS DEQ

Real-Time and Continuous Analyzers

- GC (TO-14) and GC/MS (TO-15)
- Can reach ultra-low levels (1-10 μg/m^3) for subset of compounds
- Can analyze 4 to 15 times per hour
- Up to 16 sampling ports
- Instant feedback – can provide data through an internet connection in real time

More Typical for CVI than PVI investigations

GC-ECD

Source: Hartman Environmental Services

Laboratory Analytical Methods

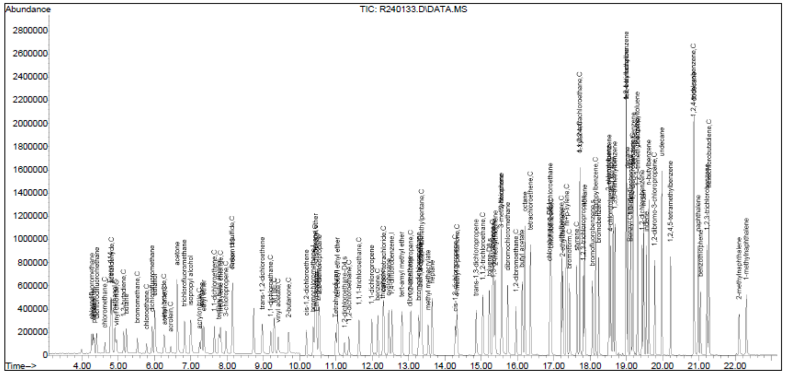
- Common methods used for PVI

Method	Reporting Limit	Soil Gas	Crawl Space/Indoor/ Outdoor
Common GC/MS Methods for VOCs			
8260	50 – 100 ug/m³	**Yes**	**No**
TO-15 (Summa)	Scan: 1 – 3 ug/m³ SIM: 0.011–0.5 ug/m³	**Yes**	**Yes**
Other Methods			
Fixed Gases (ASTM D1946 or EPA Method 3C)	0.5 – 1%	**Yes**	**No** (special cases may apply)

Key Point: **Method selection is driven by target site chemicals and DQOs. Other methods available (see Toolbox).**

Analytical Methods for TPH

- Most VI investigations consider specific target compounds, but some states require analysis for TPH ranges
  - Aliphatics (for example, C_5-C_8 & C_9-C_{12})
  - Aromatics (for example, C_9-C_{10})
- FID based methods
  - e.g., TO-3, 8015
  - Can't distinguish non-HCs from HCs
  - Will over-report



- **Best to Use a GC/MS Method - 8260, TO-15, TO-17**
  - Subtract out non-HCs

Acceptability of Models for Evaluating PVI Pathway

- Regulatory programs vary on use of models
  - Evolving as regulations are updated
  - Most states place limits on inputs and modifications

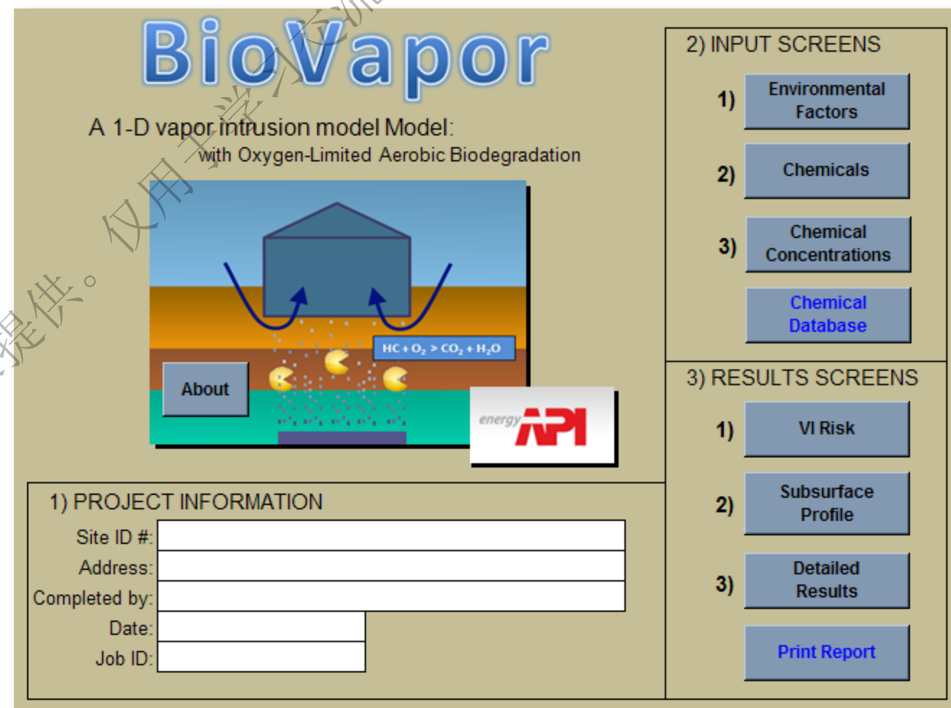
- In states where VI modeling may be applied:
  - Some may use as "sole basis" for eliminating pathway (e.g., model indicates low risk, no confirmatory indoor sampling)
  - Some may use as one of several lines of evidence
  - Some require indoor air sampling to validate results

Use of Models

- Johnson-Ettinger
  - GW, soil, soil gas spreadsheets
    - Used to develop GW-2 standards
- EPA Vapor Intrusion Screening Level Calculator (VISL)
- ***Models incorporating biodegradation***
  - Biovapor (API)
  - EPA PVIScreen – coming soon
  - PVI2D – just out (Yao et al) – www.PVITools.net

BioVapor

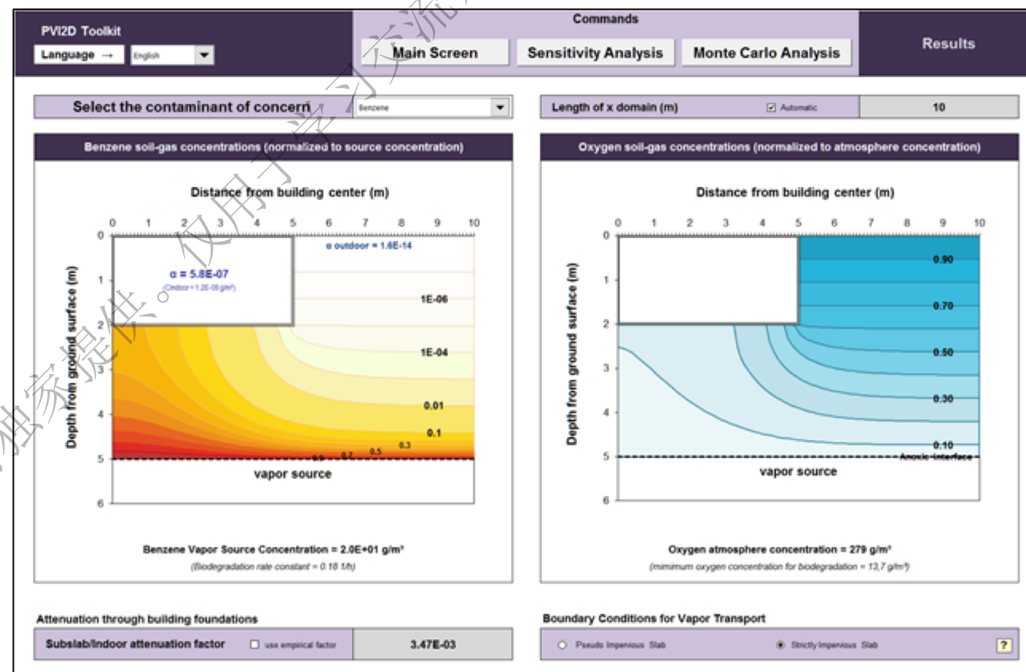
- One-dimensional model
- Accounts for aerobic biodegradation
- Easy to use
- Like J&E model, with biodegradation
- US EPA is developing a similar model (PVIScreen)



Download BioVapor at
http://www.api.org

Other PVI Models

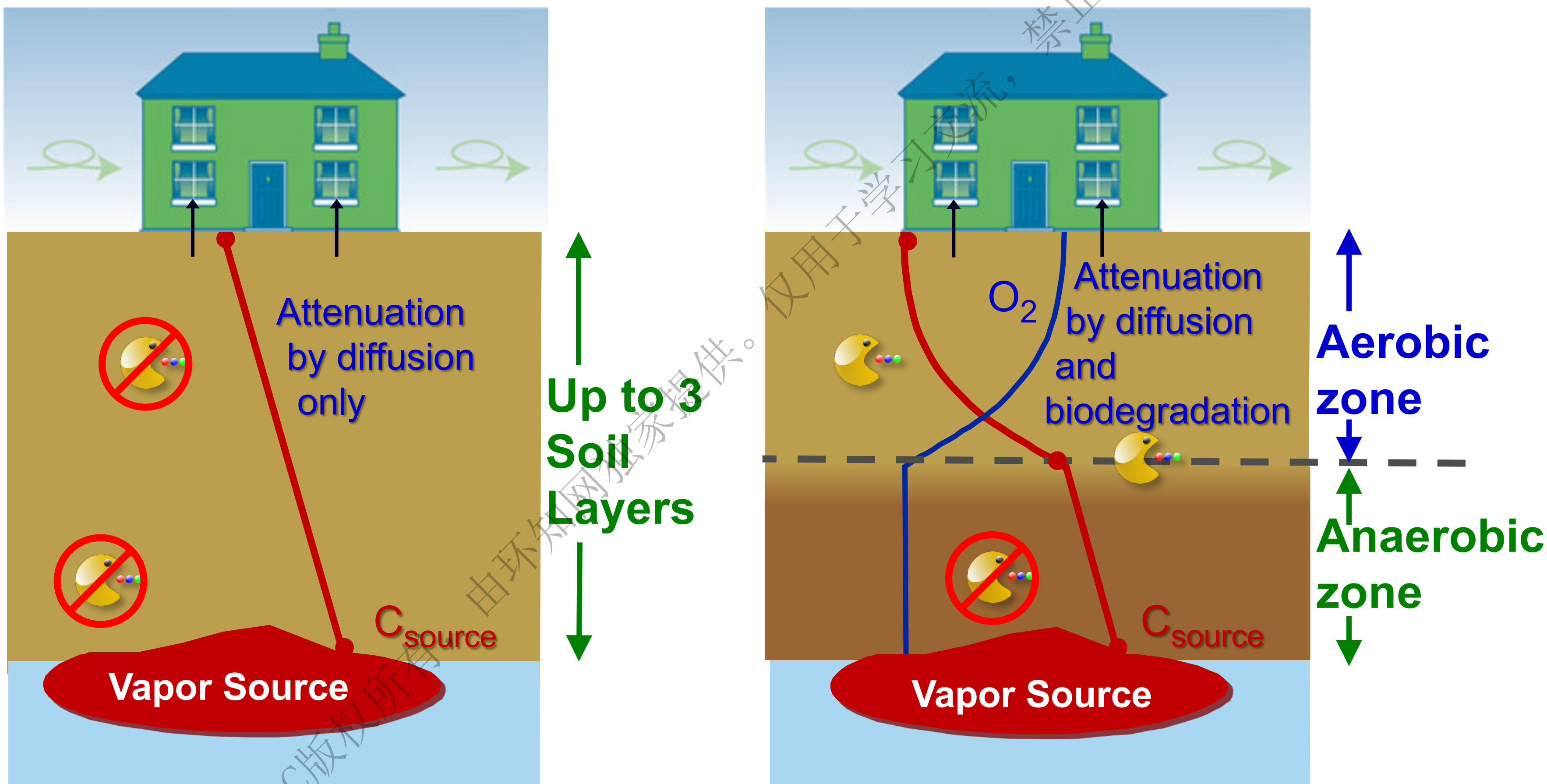
- US EPA PVIScreen
  - Currently in beta
  - One-dimensional
  - Statistical parameter estimator (Monte Carlo)



- PVI Tools
  - 2D, good for understanding oxygen shadow under buildings
  - http://www.pvitools.net/

Source: PVItools

Johnson & Ettinger and BioVapor Models Compared



J&E

BioVapor
and future EPA PVIScreen

PVI Specific Site Investigation:
Summary

If additional investigation (i.e., sampling) is needed

- Pathway-based evaluation vs. receptor-based evaluation
- Select scenario and choose approach based on data quality objectives
- May be adaptive, iterative