This presentation is an excerpt from the vapor intrusion training that Dr. Blayne Hartman has been presenting to Federal & State regulatory agencies, DOD facilities, consulting groups, and stakeholders around the country.

Lecture notes are at the bottom of each slide so that if played out as a hard-copy, the presentation can be a useful reference document.
This presentation will focus specifically on soil gas sampling and analysis since it is currently the most preferred approach around the country and, if you have a vapor intrusion problem, the chances are high you will be required to oversee or work with soil gas data. If time allows, it also will cover sampling strategies, how to assess bioattenuation, and a description of some other assessment tools to supplement soil gas data.
Ingredients for Effective VI Assessments

- Investigatory Approach
- Determine Correct Screening Levels
- Sample & Analyze Properly
- Know & Use Supplemental Tools
- Demonstrating Bioattenuation

The keys to effective vapor intrusion assessments are the proper approach, determine the correct screening level, sample & analyze correctly and efficiently, know when and how to use supplemental assessment tools, and to know how to demonstrate bioattenuation if petroleum hydrocarbons.
Approach Generalizations

- Indoor Air
  - Always find something
  - Multiple sampling rounds: extra time & $
- Groundwater Data
  - Typically over-predicts risk
- Soil Phase Data
  - Typically not allowed; over-predicts risk
- Soil Gas Data
  - Transfer rate unknown
  - Sub-slab intrusive

Each investigatory approach has pros and cons that must be considered before choosing the one to use at a site.
Some Key VI Issues

- **Experience of the Collector/Consultant**
  - Have they done this before?
  - Do they understand vapor intrusion?
  - Quality/experience of field staff? Sr or Jr?

- **Spatial & Temporal Variability**
  - GW, Indoor Air, Soil Gas

- **Ultra Low Screening Levels**
  - Increases chances for false positives

The most important ingredient for cost effective and efficient VI investigations is the experience of the person/firm doing the collection. Is the collection being done by a firm that has prior experience? Is it a routine part of their services or an occasional part? Do they put experienced people in the field who can think or junior staff who aren’t well versed? This applies to the consultant and their subcontractors.

Spatial and temporal variations exist in all types of data, especially soil gas. So you need enough data to give decent coverage near, around, or under the receptor. Simpler collection systems with small volumes are advantageous as there is less to go wrong and enable higher production per day (20+ samples per day). Less expensive analytical methods (8021, 8260) enable more analyses for reasonable cost. Real-time data can be extremely helpful to track soil gas contamination laterally and vertically.

Legal considerations often dictate what additional work needs to be done at what standards.

All of these issues affect the investigation progress and hence the cost you end up paying (the ultimate bottom line).
Soil Gas Measurement

• Pros:
  – Representative of Subsurface Processes
  – Higher Screening Levels
  – Relatively Inexpensive
  – Can Give Real-time Results

• Cons:
  – Transfer Rate Unknown
  – Conservative Default Criteria
  – Multiple Sampling Protocols

Currently Most Preferred Approach

Measurement of soil gas is by far the most preferred approach around the country. Actual soil gas data are reflective of subsurface properties, are less expensive than indoor air measurements, and allow real-time results. The screening levels are also higher so there is less chance to be chasing blanks.

There are some drawbacks, including the lack of knowledge of the transfer rate, very restrictive screening levels for sub-slab data, and debate over how & where to collect samples.
Which Soil Gas Method?

- Active?
- Passive? (qualitative)
- Flux Chambers? (limited use)

**Active method most often employed for VI**

There are three types of soil gas methods..

The active method is the one most applicable to risk assessments.
Passive Soil Gas

• Pros:
  – Easy to Deploy
  – Can Find Contamination Zones
  – Low Permeability soils

• Cons:
  – Does not Give Concentration
  – No Less Expensive

Considered as Screening Tool

Passive soil gas methods consist of the burial of an adsorbant into the group for a period of time (typically 5 to 10 days) and the subsequent retrieval of the adsorbant for measurement. The contaminants “passively” diffuse and adsorb onto the collector over time. The method is easy to deploy and is proven to find contamination zones. However, the method does not yield concentration values and thus can’t be used for risk-based applications. Ongoing efforts to “calibrate” the method to give concentration data are inconclusive.

As a result, this method is considered by most regulatory agencies, including EPA, to be a screening method. It can be used to locate contamination zones on larger parcels where the contamination is not already defined.
Passive Soil Gas Samplers

Examples of passive collectors.
Direct Flux Measurement  
(Flux Chambers)

• Pros:
  – Direct Measurement of Intrusion

• Cons:
  – Proper Location?
  – Protocols Debated
  – How to Use Data?
  – Unsophisticated Audience
  – Regulatory Acceptance Limited

Surface flux chambers are attractive because they give a direct measurement of the flux into the structure or out of the soil. This eliminates the need to know the effective diffusivity and the uncertainty inherent in the models. The biggest drawback with chambers is whether they can be placed in the proper locations in an existing structure. Also, few regulators, consultants, or vendors have used them, so they are unfamiliar of the protocols to use and how to interpret the data. As a result, regulatory acceptance is limited. In slab-on-grade structures or undeveloped lots or crawl spaces, surface flux chambers may be the best method to use. Chambers will also prove useful to support the presence of bioattenuation.
Static Flux Chamber

Photo of a static flux chamber equipped with a LandTech GEM 2000 real-time oxygen, carbon dioxide, and methane analyzer used to collect data continuously.
Soil gas sampling is typically done either outside the building or inside the building. Exterior sampling is less intrusive allowing more coverage and easier access. But are the data representative of what is underneath the structure? Internal sampling gives the levels immediately under the structure, but the drawbacks are many.

### Internal vs. External Samples

- **Exterior Sampling**
  - Is the pathway incomplete?
  - Less intrusive; more coverage
  - Use to locate receptors for internal sampling

- **Internal Sampling (sub-slab)**
  - Access agreements (attorneys)
  - More intrusive
  - Scheduling
  - Some agencies prefer
VI Requires Much Lower DLs

- Typical Soil Gas Concentrations
  - MTBE & Benzene near gasoline soil: >100 ug/L
  - PCE under dry cleaner: >100 ug/L

- Soil Gas Levels a Threat to GW:
  - MTBE: >10 ug/L
  - BTEX/PCE: >100 ug/L

- Soil Gas Levels “Failing” EPA VI Criteria
  - Subslab: Benzene: 0.003 ug/L, PCE: 0.008 ug/L
  - At 5’: Benzene: 0.15 ug/L, PCE: 0.400 ug/L

The biggest difference between sampling soil gas for site assessments and for vapor intrusion is that we are measuring at concentration levels 1,000 to 10,000 times lower. So, the protocols require much greater care. At such low levels, the chances for false positives from equipment blanks are much greater.
Get Enough Data

- Soil Gas Not Homogeneous
- Spatial & Vertical Variations Exist
- Don’t Chase 1 pt Anomalies
- Get Enough Data Near/Around/Under
- On-site Analysis Enables Real-Time Decisions

Soil gas, like soil, is not homogenous in most cases. So you need enough data to give decent coverage near, around, or under the receptor. Simpler collection systems with small volumes are advantageous as there is less to go wrong and enable higher production per day (20+ samples per day). Less expensive analytical methods (8021, 8260) enable more analyses for reasonable cost. Real-time data can be extremely helpful to track soil gas contamination laterally and vertically.
Probe Installation Methods

- Driven Probe/Rod Methods
  - Hand Equipment, Direct-Push
  - Collect sample while probe in ground

- Vapor Mini-Wells/Implants
  - Inexpensive & easy to install/remove
  - Allow repeated sampling
  - Near surface & deep (down auger flights)
  - Can “nest” in same bore hole

There are two common ways to collect active soil gas samples: collection through a probe or rod driven into the ground or collection through a vapor well buried into the ground. Both methods give reliable data.

The vapor wells consist of small diameter, inert tubing and offer advantages when vertical profiles are desired or when repeated sampling events are likely. Multiple tubes can be “nested” in the same borehole.
Collection through the probe rod is advantageous if only one sampling round is required. Seals at the base of the probe are advisable, especially if depths are shallow and larger volume samples (>1 liter) are collected.
Picture of the post-run tubing (PRT) connector used by most direct-push rigs. Fitting can leak if threads not sealed properly. There is no way to tell for sure since the operator can not see the connection.
Soil vapor implants nested in same borehole at three different depths. This method is advantageous if repeated sampling is anticipated.
Multi-Depth Nested Well

Soil Vapor Nested Well

Our vapor implants are inexpensive, unintrusive and offer repeated analysis at multiple depths.

1/8" or 1/4" Tubing

Wire Wrap

Gas Inlet Perforations

Soil Gas Implant Probe

1/8" or 1/4" Tubing

Second Soil Vapor Implant

Bentonite Grout Seal

First Soil Vapor Implant

Sand Pack

Off/On Valve

A schematic of a multi-depth nested vapor well.
Probe Considerations

• Tubing Type
  – Rigid wall tubing ok (nylon, teflon, SS)
  – Flexible tubing not (tygon, hardware store)
  – Small diameter best (1/8” or ¼”)

• Probe Tip
  – Beware metal tips (may have cutting oils)

• Equilibration Time
  – Effects by air knife, rotary, air percussion, sonic

• Equipment Blanks
  – Need to collect blank through collection system

Some of the issues that need to be considered when installing probes include:

Tubing Type: Small diameter tubing offers advantages over large PVC pipe. Flexible tubing tends to leak.

Probe tip: Metal tips may have blanks due to the cutting process.

Equilibration time: How long to wait, especially if air knives are used to clear holes or larger drill rigs are used.

Equipment blanks: need to collect blank through the collection system. Trip blanks not enough.
A test of the influence of tubing type was performed in February 2008 at the Lemoore NAS research site. Six different tubings were nested together in the same borehole. Soil gas concentrations were measured on 2 occasions two days apart. The sampling order was reversed from day 1 to day 2 to eliminate any purge volume effects.
This is a chromatogram of the air from inside polyethylene tubing off of a direct-push rig.
Soil Gas Sampling Issues

• Sample Size
  – Greater the volume, greater the uncertainty
  – Smaller volumes faster & easier to collect

• Containers
  – Canisters: More blank potential. Higher cost
  – Tedlars: Good for ~2 days. Easier to collect

• Flow Rate
  – Really not imp. But most agencies < 200 ml/min

• Tracer/Leak Compound
  – Crucial for sub-slab & larger sample volumes
  – Gases (He, SF6, Propane) & Liquids (IPA)

Lower detection levels requires more careful protocols. Important sampling considerations include sample volume, container type, flow rate, and leak testing to ensure valid samples are collected.

Smaller volumes require less complicated sampling systems and minimize the chances for leakage from the surface and desorption off soil. Recent studies have shown no difference in soil gas values regardless of whether small (0.5 L) or large (100 L) volumes are collected.

Sample containers must be inert, clean, and handled properly (no cooling or heat). Canisters have longer holding times, but have the potential for blanks (carry-over from previous samples), cost more, and can be trickier to fill. Tedlar bags are good for ~2 days, are less expensive, and suitable for concentrations of 1 ppbv or higher.

Sample flow rate is of concern to many agencies, but recent data are showing it not to be a factor.

Tracer/leak compounds are generally required to ensure sample integrity because small leaks can create significant effects at such low concentrations. The larger the volume extracted and the more complicated the sampling system, the greater the potential for leaks.
A 6-liter Summa can is about the size of a basketball. A 400 cc mini-can is about the size of a baseball.

Lower volumes give more control on sample location, require less time to collect, and minimize chances of breakthrough from the surface or other sampling zones in nested wells.

For soil gas samples, most labs only require 100 cc of sample, so small canisters (<1 liter) are sufficient volume.
EPA-ORD funded a program that looked at variation in soil gas concentration with sample flow rate. In general, there was a very modest increase, less than a factor of two, in measured TCE concentrations with increasing purge rate over the range of 100 ml/min to 5,000 ml/min.
This slide shows soil gas results for different collection volumes ranging from 500 cc to 100 liters collected by EPA-ORD at a test site. There is no significant variation in concentration.

Slide courtesy of Dr. Dominic DiGuilio, EPA-ORD
Calibration standards made up in tedlar bags showed very good stability in two tests. Results are shown here for TCE & PCE, but similar results seen for TCA and 1,2 cis DCE and 1,2 tr DCE. The 25 ppbv standard made in NY was shipped by airplane to CA.

<table>
<thead>
<tr>
<th></th>
<th>TCE</th>
<th>PCE</th>
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<tbody>
<tr>
<td>Test #1 (25 ppbv)</td>
<td></td>
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<tr>
<td>2/11/08 - NY</td>
<td>25.0</td>
<td>25.0</td>
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<tr>
<td>2/15/08 - NY</td>
<td>25.2</td>
<td>22.6</td>
</tr>
<tr>
<td>2/21/08 - CA</td>
<td>25.3</td>
<td>25.1</td>
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<tr>
<td>Test #2 (50 ppbv)</td>
<td></td>
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<tr>
<td>2/19/08 - CA</td>
<td>44.2</td>
<td>43.4</td>
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<tr>
<td>2/29/08 - CA</td>
<td>43.7</td>
<td>54.9</td>
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</table>
The use of tedlar bags for soil gas samples has many advantages and will lead to better quality data if allowed in the updated DTSC guidance.
Liquid Tracer Method

• Pros
  – Fast & easy
  – Can cover multiple spots easy
  – Very conservative (100 ug/L = 0.1% leak)

• Cons
  – Typically qualitative
  – Don’t know results in real-time without lab
  – Small leak can raise DLs of VOC analysis

OK Method if Lab On-site

Pros & cons of the liquid tracer method.
Gas Tracer Method

- **Pros**
  - Quantitative
  - Real-time results with portable meters

- **Cons**
  - More complicated and slower. Increases costs
  - Harder to cover multiple locations, esp with DP

Best Method if No Lab On-site

Pros and cons of using gases as leak/tracers.
Liquid Method

In this method, a liquid is applied to a rag or paper towel and the towels emplaced at various points along the probe and sampling train. This method is qualitative.
Gas Method

In this method, a shroud is filled with a tracer gas and the gas concentration measured in the shroud and in the sample. Typical gases utilized are helium, carbon dioxide, propane, isobutylene, or sulfur hexafluoride. This method is quantitative.
If covering the entire sampling train is desired, a tent shroud can be used. The tracer, either a liquid or gas, is emplaced in the shroud. The concentration can be measured in the tent and in the sample with a hand-held meter or on-site lab.
A simple and fast procedure to purge soil vapor probes is to use a disposable gas-tight syringe. Volumes can be carefully measured, the collector can get a feel for the permeability of the sampling zone from the syringe resistance, low vacuums and flow are applied, and no bulky hardware or power is required.
Sample Collection

Collection of a soil vapor sample in a mini-Summas (400 cc). Leak/tracer is typically applied prior to sample collection.
Sample Collection

Collection of a soil vapor sample in a tedlar using a syringe. No power required, no complicated fittings. Leak/tracer can be applied prior to sample collection.
Sample Transfer

Soil vapor samples can be easily transferred from a tedlar bag into an evacuated canister in the field for longer holding times or for more security during sample shipping.
Beware of the Hardware

The tackle box on the left shows the required hardware to collect soil gas samples in Summas.

The syringe to the right is the only collection device required for on-site analysis of soil gas.
A soil gas sample collection system used by a consulting firm. Extremely complex, lots of dead-volume for cross contamination, and numerous fittings for potential leaks. Cleaning the system between samples to avoid false positives is much more involved.
Sampling for SVOCs can require a lot hardware which increases the potential for leaks.
Some Final Sampling Issues

• Certified Clean Canisters
  – Not needed if DL > 5 ug/m³

• Residual Vacuum in Canisters
  – Not critical for soil gas samples

• Dedicated Flow Restrictors
  – Not necessary if cleaned between samples

A few additional sampling considerations.
Common Soil Gas Analyses

- VOCs
  - Soil & Water Methods: 8021, 8260
  - Air Methods: TO-14, TO-15, TO-17
- Hydrocarbons
  - 8015 m, TO-3
- Oxygen, Carbon Dioxide
  - ASTM 1945-96
- SVOCs: TO-4, TO-10, TO-13 (8270?)

This slide gives a summary of the most common analytical methods used for soil gas samples. More discussion on these methods follows.
A variety of portable field analyzers exist for analyzing soil gas samples. For vapor intrusion applications, required detection levels of VOCs are lower than the field analyzers can reach, but they still are useful for screening sites or for sites with high concentrations. These meters give a total concentration only, so they are limited at sites with more than one compound.

Portable hydrocarbon detectors have higher detection limits (~5 ppmv) and do not give compound resolution.

Oxygen, carbon dioxide, and methane can be reliably measured with field meters to required detection levels.
Soil Gas Analysis Issues
(TO-14/15 or 8260 or 8021)

- All Methods Give Reliable Results
- Some States Require TO-15
- Detection Level Discriminator:
  - TO Methods: <1 to 1 ug/m³
  - 8021: 2-5 ug/m³
  - 8260: 10-100 ug/m³
- On-Site Analysis:
  - Extremely Helpful for VI
  - Minimizes False Positives

A variety of analytical methods are available to measure soil gas samples, but no federal guidance document exists specifying any one. Methods 8021 and 8260 are soil & water methods but give accurate results for soil gas samples at detection levels above 10 ug/m³. The toxic organic methods (TO) are designed for ambient air samples, so they give accurate results for soil gas samples at much lower detection levels. The TO methods require extensive hardware and are far more expensive.

The criteria for selection should be which method(s) reach the required detection limits.

On-site data are extremely useful to ensure that the samples do not have tracer/leak levels above acceptable levels, provide real-time data for decision making, and to validate detections seen in the off-site data. If measured values are high, then the on-site methods (8021, 8260) are more appropriate to use than the ultra-sensitive TO methods. If on-site values are low or below detection, then the samples can be measured off-site by the TO methods.
This slide shows a comparison of on-site analysis of TCE by 8021 out of a Tedlar vs. off-site analysis by TO-15 out of a Summa canister. Correlation is excellent down to values as low as 2 ug/m3.

Slide courtesy of Dr. Dominic DiGuilio, EPA-ORD
<table>
<thead>
<tr>
<th>High SG Concentrations Create Headaches</th>
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<tbody>
<tr>
<td>• Typical Soil Gas Concentrations</td>
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<tr>
<td>– Benzene near gasoline soil: &gt;100,000 ug/m3</td>
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<tr>
<td>– TPH vapor: &gt;1,000,000 ug/m3</td>
</tr>
<tr>
<td>– PCE under dry cleaner: &gt;100,000 ug/m3</td>
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<tr>
<td>• TO-15 Maximum Conc: 2,000 ug/m3</td>
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<tr>
<td>– Must do large dilutions, DL goes up</td>
</tr>
<tr>
<td>– False positives from hot samples</td>
</tr>
<tr>
<td>• Canister &amp; Hardware &amp; Instrument Blanks</td>
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Typical soil gas concentrations at leaky UST, dry cleaner, and industrial solvent sites are in the 100,000s to 1,000,000 of ug/m3. But, for 1 in 1 million risk, the risk-based screening levels are less than 10 to 100 ug/m3. This large concentration range creates a number of analytical headaches.

The TO-methods and hardware (canisters, flow chokes) are not designed for such high concentrations. System carryover, large dilutions, and contaminated canisters increase the potential for false positives, raises reporting levels, and gives air labs logistical fits which limits the utility of these methods.

The 8260 and 8021 methods can’t get lower than 10 to 100 ug/m3 so they may not reach required DLs.

In practice, a combination of these methods is the best approach. If expected values are high, then the 8021 & 8260 are advantageous to use than the ultra-sensitive TO methods. If expected values are low, then the TO methods offer advantages.
New Advance: 
On-Site TO-15 Scan/SIM

- Simultaneous Scan/SIM mode enables
  <10 ug/m3 for All VOCs &
  ~2 ug/m3 for subset of compounds.
- Only 2cc of Sample. Eliminates Hardware
- Real-time Analysis in Structures: Control!

New equipment allows on-site TO-15 analyses. New GC/MS equipment enables simultaneous Scan/SIM mode meaning you can measure for all VOCs (>60 compounds) at DLs < 10 ug/m3 while simultaneously measuring for a subset of compounds at lower detection levels (<2 ug/m3). Only 2 cc of sample are required for analysis, so much of the sampling hardware can be eliminated, reducing chances of false positives.

This capability enables real-time analysis in structures. This might eliminate need for unsupervised time-integrated sampling.
Soil Gas Sampling Strategies

- Where to Collect Samples
- Exterior vs. Interior (sub-slab)
- How Often to Sample
- Documenting Bioattenuation

In this part of the presentation, we will discuss soil gas sampling strategies.
Where to Sample Spatially

- **Source Not Immediately Below**
  - Collect on side towards source
  - Collect on other sides of structure
  - Preferential pathways at edges & conduits

- **Source Below**
  - Collect around structure before sub-slab
  - Get decent coverage

- **Representativeness**
  - Need enough points.
  - What algorithm?

There is currently much debate on where to collect samples and no existing protocols or guidance. So, common sense comes into play. If the source is not directly below, collect samples between the structure and the source at a depth that is deep enough to give repeatable results. Collect in any known preferential pathways, such as utility lines.

If the source is below, it may be okay to collect around the structure before going inside the structure.

Spatial averaging allows a better representation of what’s below the structure. One approach is to collect samples on all sides of the house and use an averaging method to get a value under the structure footprint.

If real-time data exist, add additional points depending upon the results. If not, collect extra samples spatially and analyze if necessary.
Are sub-slab samples necessary to collect? This issue is highly contested around the country and has huge ramifications. Sub-slab samples are much more intrusive, require access agreements, and often attorneys get involved, especially for private residences.
Sub-Slab vs. Near-Slab

- EPA & Some States Prefer Sub-slab
  - “Ponding” effect under slab?
  - Balls don’t run uphill
- Very Intrusive
- Legal Complications
- HCs: If O₂ High, Near-slab OK
- Cl-HCs: at Source or Vertical Profiles

The draft OSWER VI guidance strongly advocates sub-slab samples and some State agencies agree. Some are fearful that the contaminants build-up under the slab (“ponding effect”). But, sub-slab sampling is intrusive and often leads to legal complications. By Fick’s law, the sub-slab concentration can be no higher than the source concentration, so if the source is below, collection of exterior soil gas samples at the source depth or at some depth closer to the source will give useful data and not create as many legal headaches.

If high oxygen levels exist all around the slab at a shallow depth, and the slab small, it is likely that bioattenuation under the slab is occurring and shallow soil gas will be representative of sub-slab soil gas.

For chlorinated solvents, data bases to date are more conflicting. Deeper soil gas might be most reflective, but it will tend to overestimate the sub-slab concentration. Vertical profiles around the receptor might be more appropriate.
Data from Endicott NY show a poor correlation between sub-slab soil gas and exterior, shallow soil gas. However, the data were not always collected at the same time and many of the exterior samples were collected far away from the slab.

Slide courtesy of Dr. William Wertz, NYDEC
Effect of Source Concentration

Results suggest that there may be source vapor concentrations that are of little concern if soil gas beneath the foundation is well-oxygenated (e.g., groundwater plume sources)

\[ \lambda = 0.18 \text{ h}^{-1} \]

\[ \alpha = 7.1 \times 10^{-5} \]

\[ \alpha = 7.2 \times 10^{-8} \]

\[ \alpha = 5.6 \times 10^{-11} \]

Recent modeling by Dr. Lilian Abreau (Geosyntec Consultants) has shown that for hydrocarbons sources in the soil vapor less than 20 mg/L, sub-slab concentrations match exterior soil gas concentrations.

Slide courtesy of Dr. Lilian Abreau, Geosyntec Consultants
How Often to Sample?

• Depth Below Surface
  – 3’ to 5’ bgs generally considered stable
  – Temporal Studies Ongoing
• Seasonal Effects – How Important?
  – Most studies show less than 5x
• Extreme Conditions?
  – Heavy rain
  – Extreme heating/cooling

The closer to the surface, the more the potential temporal variation. Depths of 3’ to 5’ below the surface are generally considered deep enough to get repeatable data and resampling is not required by most agencies.

Historical radon data around houses show variations less than a factor of 7 in cold climates. Recent VOC data from Endicott show soil gas variations less than a factor of 4 over 15 months. Larger variations may be likely in areas of extreme temperature variation (northern climates), during heavy periods of precipitation, and when the structure’s heating or ventilation systems are operative.

In general, if the soil gas concentrations are below allowed levels by a factor of 10, there should be no need to repeat sampling.

If conditions suggest that temporal variations may be significant and if the measured values are close to the fail level, then repeated sampling may be appropriate and vapor implants are a good approach.
A study funded by Chevron Corp examined the effect of meteorological parameters on soil gas concentrations at a hydrocarbon contaminated site in Wyoming. There was no clear correlation between most of the meteorological parameters and soil gas concentrations.

A similar study funded by EPA-ORD (NERL) at Vandenberg AFB in spring 2007 showed similar results.

Slide courtesy of Paul Johnson, ASU and Chevron Corp.
Recent data collected over 15 months from Endicott NY show very low variations in deep soil gas (max variation less than factor of 2) and sub-slab soil gas concentrations (max variation less than factor of 4). Hence, in most cases, it is not necessary to collect samples more than once.

Slide courtesy of Dr. William Wertz, NY-DEC
This is a plot of data recently collected for an EPA funded study by an automated instrument at Vandenberg AFB site from three probes at the same location but at different depth (3’, 8, & 17’ bgs). This plot consists of over 500 points per probe collected once per hour over a 4 week period from mid March to mid April 2007. The soil gas concentrations varied by less than 10% over these four days even for probes only 3 feet below the surface.
Bioattenuation of HCs

- Existing Data Suggest $O_2$ Effective Barrier
- Attenuation $> 10,000$ Times Over Default
- Document By Vertical Profiles of COC & $O_2$
- Recent 3-D Modeling Substantiates

A vast number of studies have been performed clearly demonstrating that the bioattenuation of hydrocarbon vapors occurs in aerobic soils. In general, the studies show that when oxygen levels are 10% or greater (a published study by NJDEP suggested oxygen levels as low as 6% are sufficient), and a couple feet of vadose zone exist between the source and receptor, that the hydrocarbons aren’t escaping into the receptor. Attenuation factors can be as high as 10,000 times ($\alpha = 0.0001$).

Documentation that this process is occurring is done by collecting vertical profiles of the soil gas for the hydrocarbons, oxygen, and carbon dioxide. If shown to occur, many agencies are conservatively allowing a factor of 10 to 100 reduction in the alpha factor.
This is the theoretical profile for hydrocarbon VOCs, CO2, and oxygen in the soil gas with depth where bioattenuation is active. Without on-site analysis, you don’t know where the depth of this zone is. Either use oxygen to find it or collect additional samples.
An analysis of hydrocarbon sites from around the country has been performed by Robin Davis of the Utah DEP. Her analysis shows that 92% of TPH contaminated sites and 98% of benzene contamination have significant (>100 times) reduction in concentration due to bioattenuation.

Slide courtesy of Robin Davis of Utah DEP
The end result of the recent modeling by Dr. Lilian Abreau (Geosyntec Consultants) is that one can now estimate the bioattenuation attenuation factor based upon depth to source and source strength. Note that for all concentrations below 10,000 ug/L, the attenuation factor is no higher than 1e-5. This is 4 orders of magnitude lower than the EPA VI guidance default value! Unless the source is within 3 feet of the receptor, the attenuation factor never exceeds 1e-3, still 2 orders of magnitude lower than the EPA default value.

Slide courtesy of Dr. Lilian Abreau, Geosyntec Consultants, and API.
There are some other inexpensive tools/data that can be applied to better evaluate some of the default model parameters and the vapor intrusion pathway. These tools/data have much more influence on the resulting risk than measurement of soil porosity and cost about the same.

Radon can be used to determine a site-specific alpha that may be 10 to 100 times lower than the default alpha allowed.

Tracers can be used to measure the room ventilation rates and may give values 2 to 10 times higher than the default value, especially for commercial sites.

For HCs, vertical profiles of the soil gas can demonstrate bioattenuation. In some States, the agencies allow for a 10 times reduction in risk if bioattenuation is demonstrated. Although the DTSC guidance recognizes bioattenuation, it currently gives no indication as to how the data will be interpreted.

Real-time analyzers can be used to locate problem houses, preferential pathways into structures, or sort out background scatter. Pressure measurements are helpful with indoor air data to possibly show a background source.
Automated Analyzers

- GC and GC/MS (TO-15)
- Can Reach Ultra-Low Levels (1-10 ug/m3) for Subset of Compounds
- Can Analyze 3 to 4 Times per Hour
- Multiple Locations
- Real-Time Feedback

Automated continuous analyzers exist that run unattended enabling analysis around the clock. They can sample from multiple rooms or probes and can send data over the internet in real time. Both gas chromatographs (GC) running 8021 and mass spectrometer (GC/MS) instruments running TO-15 are currently available.
VI Documents

• Overview of SV Methods (www.handpmg.com)
  – LustLine Part 1 - Active Soil Gas Method, 2002
  – LustLine Part 2 - Flux Chamber Method, 2003
  – LustLine Part 3 - FAQs October, 2004
  – LustLine Part 4 – Soil Gas Updates, Sept 2006

• Other
  – ITRC VI Guidance (www.itrcweb.org)
  – CA-DTSC Soil Gas Sampling Advisory, (www.DTSC.gov)

A summary of existing documents on soil gas methods can be found at these locations:
Existing Documents & Training

• Soil Gas Sampling SOPs
  – Soil Gas Sampling, Sub-slab Sampling, Vapor Monitoring Wells/Implants, Flux Chambers (www.handpmg.com)

  – EPA-ORD Sub-slab SOP–Draft, Dr. Dom DiGuilio (www.iavi.rti.org/resources)

• Other
  – API Soil Gas Document (www.api.org/bulletins)

More documents.
VI Websites & Links

- www.handpmg.com
  - Soil gas information
  - Units converter
  - Articles & presentations
- www.itrcweb.org
- www.api.org
- http://iavi.rti.org

Useful vapor intrusion websites.
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