Soil Gas Sampling & Collection Methods

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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.

Presentation Summary

- Overview of Soil Gas Methods
- Probe Installation Methods & Issues
- Sample Collection Methods & Issues
- Sample Analytical Issues

This presentation will focus primarily on active soil gas probe installation and sampling methods with a brief treatment on analytical methods and issues. The presentation is based upon over 25 years of oil gas field experience.

Which Soil Gas Method?

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

There are three types of soil gas methods. Active refers to actively withdrawing vapor out of the ground. It gives quantitative values. Passive refers to burying an adsorbent in the ground and letting the vapors passively contact and adsorb onto the collector. It does not give quantitative data and hence can not be used for risk applications, except for screening. Surface flux chambers measure the actual flux out of the ground.

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.

Direct Flux Measurement
(Flux Chambers)

- Pros:
  - Direct Measurement of Vapor Intrusion
- Cons:
  - Proper Location?
  - How to Use Data?
  - Unsophisticated Audience

Considered a Secondary Tool

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 actual transfer rate 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. In houses with dirt crawlspaces or dirt basements, or on undeveloped lots, surface flux chambers are a viable method to use. Chambers are also useful to test if vapor intrusion is occurring in situations where contaminants are found in the very shallow (<3' bgs) vadose zone.

Active Soil Gas

- Pros:
  - Representative of Subsurface Processes
  - Higher Screening Levels
  - Can Give Real-time Results
- Cons:
  - Mass Transfer Coefficient Unknown
  - Overly Restrictive Default Criteria
  - Protocols still debated

Measurement of active 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 or false positives.

There are some drawbacks, including the lack of knowledge of the vapor transfer rate into the structure, very restrictive screening levels for sub-slab data, and confusion over how & where to collect samples.

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" VI Criteria
  - Subslab: Benzene: 0.015 ug/L, PCE: 0.040 ug/L
  - At 5': Benzene: 0.15 ug/L, PCE: 0.40 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.

Probe Installation Methods

- Sample Through Rod Methods
  - Aka temporary probes
  - Collect sample while probe rod in ground
  - Less disturbance, less parts in the ground
- Vapor Mini-Wells/Tubing Method
  - Aka semipermanent or permanent probes
  - Bury tubing in the ground
  - Better for repeated sampling

There are two common ways for collecting active soil gas samples: collection through a probe or rod driven into the ground or collection through a vapor well buried into the ground.

Collection through the probe rod is advantageous if only one sampling round is required. Also, less materials are emplaced in the ground minimizing disturbance of the in-situ vapor and decreasing the potential for blanks from the materials.

Vapor wells consist of small diameter, inert tubing and offer advantages when vertical profiles are desired or when repeated sampling events are likely.

Both methods can give reliable data if done properly.

Through Rod Methods

- Hand Methods (Rotohammer, Slidehammer)
  - Better access
  - Shallower depths (<6’ bgs)
  - Internal tubing already connected
  - Smaller hole
- Direct Push Methods
  - Access more limited
  - Deeper depths
  - Post-run tubing connector can leak
  - Can smear walls in finer grained materials

Collection through the probe rod is most commonly done by one of two methods: using hand methods or with direct-push systems.

Hand methods are useful in limited access areas for shallow sampling (<6’ bgs), but also have a few technical advantages over the direct-push methods.

Direct push methods can go deeper, but can not get to tight areas. The post-run tubing can leak at the coupling point inside the rod and smearing of the borehole walls can reduce permeability in finer grained or moist soils.

For either method, seals at the base of the probe at the ground surface are advisable, especially if depths are shallow, soils are coarse grained, and larger volume samples (>1 liter) are collected.

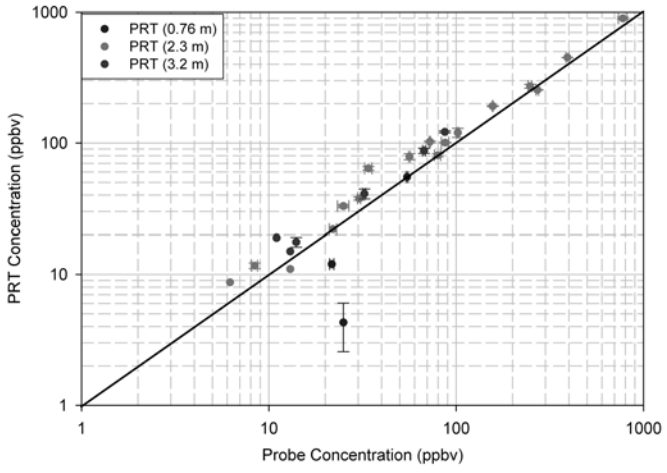
Mini-Wells/Tubing Method

- Inexpensive & easy to install/remove
- Allow repeated sampling
- Can “nest” in same bore hole
- Near surface & deep (down auger flights)
- More disturbance to in-situ soil gas
- More parts in the ground – increases blanks

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.

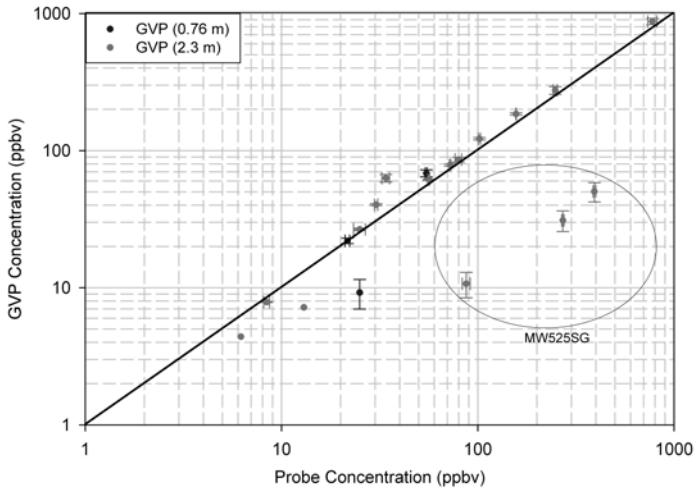
Disadvantages are that more materials are left in the ground increasing the chance for blanks and the burial of the tubes with a sand-pack causes a greater disturbance of the in-situ soil gas.

Comparison – DP to Tubes



Comparison data collected by Dom DiGiulio and others shows good agreement between the direct-push method and vapor well method.

Comparison – Hand to Tubes



Comparison data collected by Dom DiGiulio and others shows good agreement between the hand probe method and vapor well method.

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.

Soil Gas Sampling Issues

- Sample Size
  - Greater the volume, greater the uncertainty
  - Smaller volumes faster & easier to collect
  - Large purge vols require pumps & control
- Containers (Don't Chill!!)
  - Canisters: More blank potential. Higher cost.
  - Do NOT need to certify clean if > 10 ug/m3
  - Tedlars: Good for ~2 days. Easier to collect
- Flow Rate
  - Really not imp. But most agencies < 200 ml/min

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.

Larger purge volumes require pumps and flow control which requires more effort and increases chance of errors. Three dead volumes should extract 88% or original air in the system volume, but what about sand pack and surrounding formation?

A variety of sample containers can be used depending upon volume required and storage time. All must be inert, tested clean, and handled properly (no cooling or heat).

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.

Soil Gas Sampling Issues

- Tracer/Leak Compound
  - Gaseous (He) or Liquid (IPA, Freons)
  - Imp for sub-slab & larger sample volumes
- Pumps
  - Collect on upstream side. Watch vacuum applied
- Rain
  - How long to wait after a rain event?
- Time-Integrated Samples?
  - Existing data does not show large variations

Tracer/leak compounds are required to ensure sample integrity. Both gaseous (He) and liquid tracers are used. The liquid tracers are operationally simpler and can cover more locations.

If pumps are used, samples should be collected upstream of pump and the applied vacuum should be minimized to avoid leaks.

Does rain influence soil gas concentrations? Probably not for depths greater than 3' and certainly not under paved surfaces.

Are time-integrated samples required ala indoor air samples? Most data do not show large temporal variations in soil gas concentrations.

Liquid Leak 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

Liquid tracers are readily available, easy to use, and can be applied to many points along the sampling train at the same time. However, they are qualitative and don't allow real-time feedback. So, if you do not have on-site analysis, you are taking a chance that the collected sample is leak-free.

Gas Leak 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

Use of gases is quantitative and enables real-time feedback with portable meters. However, the procedure requires more hardware and time. Also, it is more difficult to cover the entire sampling train especially is sampling through a direct-push rod.

The "Key" Sampling Issues

(That Directly Affect the Bottom Line)

- Experience of the Collector/Consultant
  - Have they done this before?
  - Quality/experience of field staff? Sr or Jr?
- Good Hardware
  - Beware the Wal-Mart soil gas lab
- Get Enough Data Near/Around/Under
  - Would you close a site with only 1 boring?

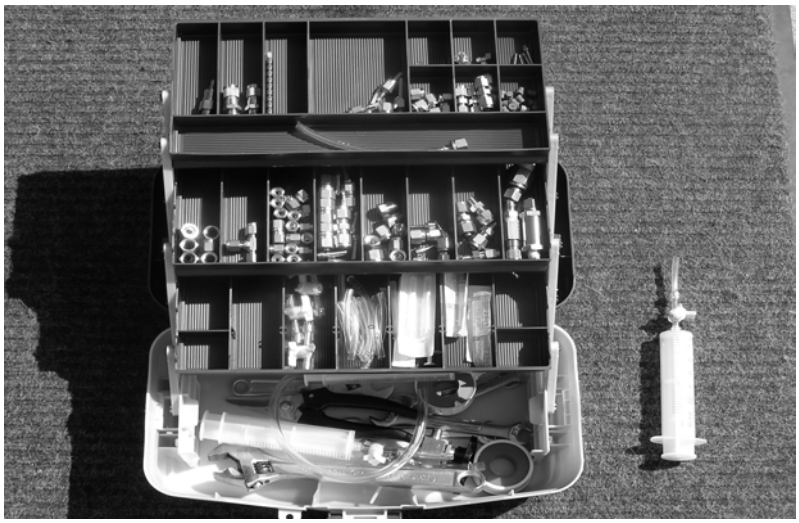
The most important ingredient for cost effective and efficient VI investigations is the experience of the person/firm doing the collection. Is the collection being done by a firm that has prior experience? Is it a routine part of their services or an occasional part? Do they put experienced people in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

The hardware used is also critical. Bottom line: bad hardware, bad data.

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.

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

Beware of the Hardware



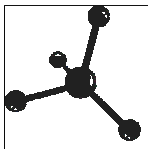
The tackle box on the left shows the required hardware to collect soil gas samples in Summas.

The syringe to the right is the only collection device required for on-site analysis of soil gas.

Additional Considerations

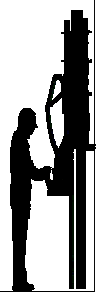
- Certified Clean Canisters
  - Not needed if DL > 5 to 10 ug/m3
- Residual Vacuum in Canisters
  - Increases chances of leaks
- Dedicated Flow Restrictors
  - Not necessary if cleaned between samples

A few additional sampling considerations.



Soil Gas Analysis Issues
(TO-14/15 or 8260 or 8021)

- All Methods Give Reliable Results
- Detection Level Discriminator:
  - TO Methods: 1 to 10 ug/m^3
  - 8260 SIM: 10 ug/m^3
  - 8260: 50 ug/m^3
- On-Site Analysis:
  - Extremely Helpful for VI
  - Minimizes False Positives



A variety of analytical methods are available to measure soil gas samples. 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.

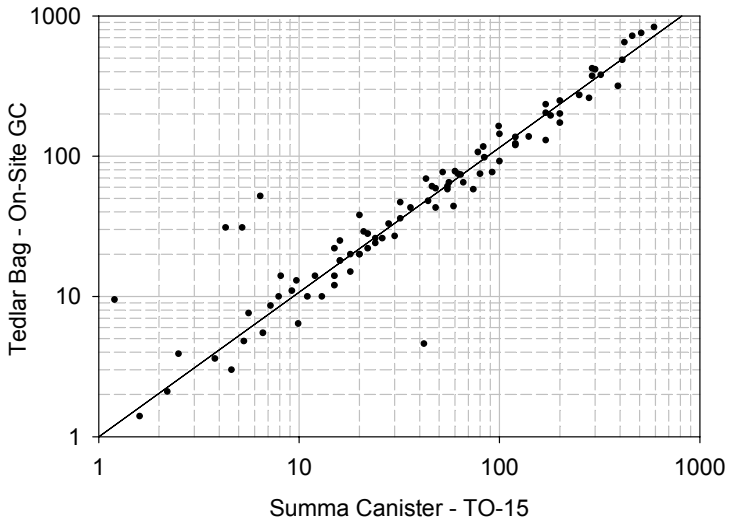
Mobile Laboratory Capabilities

- VOCs
  - 8021, 8260, Air Methods: TO-14, TO-15
- Hydrocarbons
  - 8015 m, TO-3
- Oxygen, Carbon Dioxide
  - ASTM 1945-96, Method 3
- SVOCs: NIOSH Methods, 8270?

Same QA/QC Specs as Fixed Labs

Mobile laboratories are now capable of performing many sophisticated analyses previously only possible in fixed labs. This is due primarily to advances in analytical instrument technology. Simple GC methods as well as GC/MS methods, including the TO-methods, are now possible to do in mobile labs. The QA/QC criteria are no different than those in fixed base laboratories.

On-Site 8021 Analysis vs. Off-site TO-15 Analysis



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 collected by EPA-ORD at a test site. Correlation is excellent down to values as low as 2 ppbv.

Slide courtesy of Dr. Dominic DiGuilio, EPA-ORD

High SG Concentrations Create Headaches

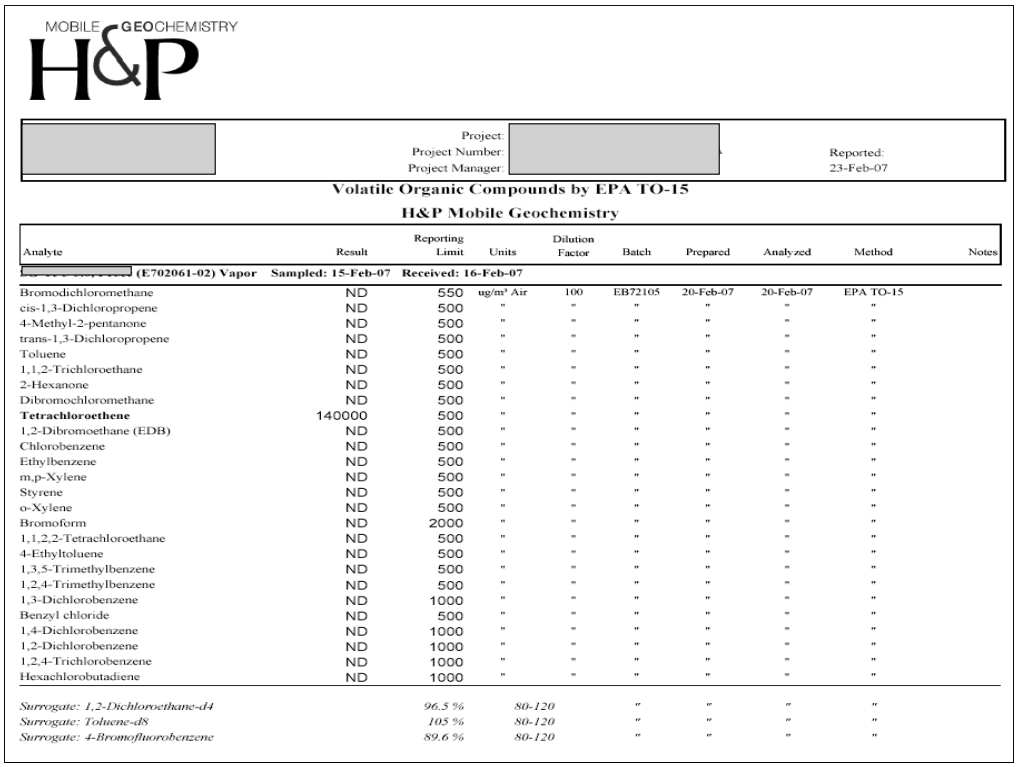
- Typical Soil Gas Concentrations:
  - Benzene near gasoline soil: >100,000 ug/m3
  - TPH vapor: >1,000,000 ug/m3
  - PCE under dry cleaner: >100,000 ug/m3
- TO-15 Maximum Conc: 2,000 ug/m3
  - Must do large dilutions, DL goes up
  - False positives from hot samples
- Canister & Hardware & Instrument Blanks

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.



MOBILE GEOCHEMISTRY
H&P

[redacted]

Project: [redacted]
Project Number:
Project Manager:

Reported:
23-Feb-07

Volatile Organic Compounds by EPA TO-15

H&P Mobile Geochemistry

Analyte	Result	Reporting Limit	Units	Dilution Factor	Batch	Prepared	Analyzed	Method	Notes
[redacted] (E702061-02) Vapor	Sampled: 15-Feb-07	Received: 16-Feb-07							
Bromodichloromethane	ND	550	ug/m³ Air	100	EB72105	20-Feb-07	20-Feb-07	EPA TO-15	
cis-1,3-Dichloropropene	ND	500	"	"	"	"	"	"	
4-Methyl-2-pentanone	ND	500	"	"	"	"	"	"	
trans-1,3-Dichloropropene	ND	500	"	"	"	"	"	"	
Toluene	ND	500	"	"	"	"	"	"	
1,1,2-Trichloroethane	ND	500	"	"	"	"	"	"	
2-Hexanone	ND	500	"	"	"	"	"	"	
Dibromochloromethane	ND	500	"	"	"	"	"	"	
Tetrachloroethene	140000	500	"	"	"	"	"	"	
1,2-Dibromoethane (EDB)	ND	500	"	"	"	"	"	"	
Chlorobenzene	ND	500	"	"	"	"	"	"	
Ethylbenzene	ND	500	"	"	"	"	"	"	
m,p-Xylene	ND	500	"	"	"	"	"	"	
Styrene	ND	500	"	"	"	"	"	"	
o-Xylene	ND	500	"	"	"	"	"	"	
Bromoform	ND	2000	"	"	"	"	"	"	
1,1,2,2-Tetrachloroethane	ND	500	"	"	"	"	"	"	
4-Ethyltoluene	ND	500	"	"	"	"	"	"	
1,3,5-Trimethylbenzene	ND	500	"	"	"	"	"	"	
1,2,4-Trimethylbenzene	ND	500	"	"	"	"	"	"	
1,3-Dichlorobenzene	ND	1000	"	"	"	"	"	"	
Benzyl chloride	ND	500	"	"	"	"	"	"	
1,4-Dichlorobenzene	ND	1000	"	"	"	"	"	"	
1,2-Dichlorobenzene	ND	1000	"	"	"	"	"	"	
1,2,4-Trichlorobenzene	ND	1000	"	"	"	"	"	"	
Hexachlorobutadiene	ND	1000	"	"	"	"	"	"	
Surrogate: 1,2-Dichloroethane-d4		*96.5 %*		*80-120*		"	"	"	
Surrogate: Toluene-d8		*105 %*		*80-120*		"	"	"	
Surrogate: 4-Bromofluorobenzene		*89.6 %*		*80-120*		"	"	"	

Here is an example of what happens to reporting limits with high concentration soil gas samples. The value for PCE is 140 ug/L (140,000 ug/m3). The TO-15 method upper limit was 100 times lower, so the sample had to be diluted 100 times. Consequently, the reporting limit for all compounds increased to levels higher than could have been reported by Method 8260. This situation is common at UST sites, dry cleaners, and commercial facilities using solvents.

How Often to Sample?

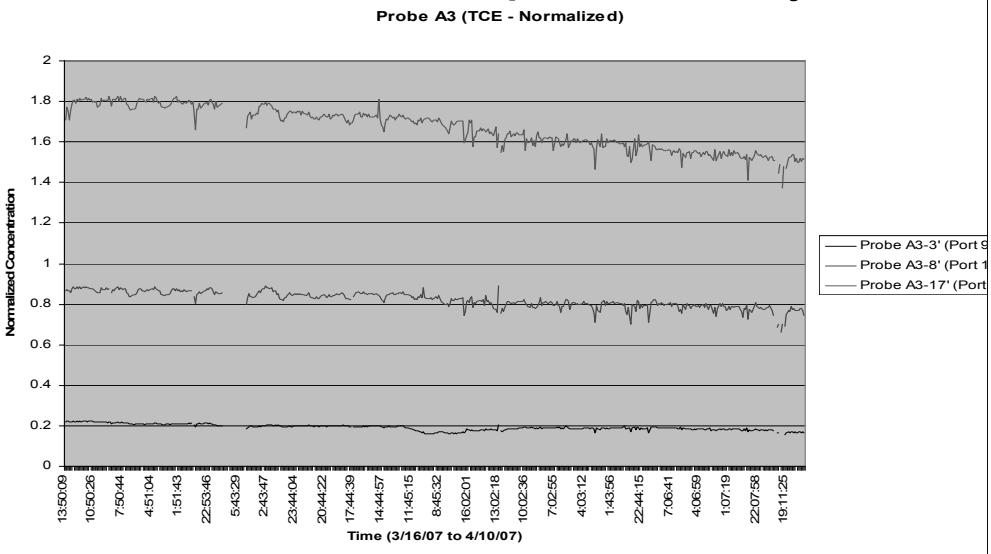
- Closer to Surface, More Variability
  - 3’ to 5’ bgs generally considered stable
  - Upper few feet likely variable
  - Recent data show repeatability at 3’ bgs
- Seasonal Effects
  - Most studies show less than 5x
  - Heating/cooling of structure more imp
  - Heavy periods of rain
  - Fluctuation groundwater

The closer to the surface, the more the potential temporal variation. Depths of 3’ to 5’ below the surface are generally considered stable and repeatable. Recent studies imply soil gas concentrations are stable at depths shallower than 5’ bgs.

Temporal variations have been shown to be less than a factor of 5 even in colder environments. Larger variations may be seen due to effects caused when heating or ventilation systems are operative, during heavy periods of precipitation, and if the groundwater levels fluctuate.

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.

Soil Gas Temporal Study



This is a plot of data recently collected by an automated instrument at aVandenberg 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. The soil gas concentrations varied by less than 10% over these four days even for probes only 3 feet below the surface.

Summary

- Both Probe Installation Methods OK
- Experience Important
- Hardware Important
- Coverage Important
- Extra Careful Procedures Important for VI

A summary of the key points in this presentation.

VI Samping Documents

- Overview of SV Methods (www.handpmg.com)
  - LustLine Part 1 - Active Soil Gas Method, 2002
  - LustLine Part 3 - FAQs October, 2004
  - LustLine Part 4 – More Q&A, Summer 2006
- Regulatory Guidance
  - ITRC toolkit (www.itrcweb.org)
  - CA-EPA Soil Gas Advisory (www.dtsc.ca.gov)
  - NY, NJ, MO Soil Gas Documents

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

VI Documents

- Soil Gas Sampling SOPs
  - Soil Gas Sampling, Sub-slab Sampling, Vapor Monitoring Wells/Implants, Flux Chambers (www.handpmg.com)
- Other
  - API Soil Gas Document (www.api.org/bulletins)

More documents.

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