This presentation gives a very brief introduction to soil gas methods for vapor intrusion applications and an introduction to active soil gas results collected in July 2006 from the Ertel test site.
ITRC Survey Results

- 39 of 43 states say vapor intrusion is a current concern being actively addressed
- VI concerns in every program (RCRA, FUDs CERCLA, brownfields, UST, dry-cleaning,
- Most preferred methods for evaluating vapor intrusion: shallow soil gas/subslab sampling followed by indoor air measurements
- 9 states allow for biodegradation of petroleum hydrocarbons

Interstate Technology Regulatory Council (ITRC) conducted a survey of all States regarding vapor intrusion in late 2004. The results showed that nearly all States are worried about this pathway in most of their programs and that soil gas measurements are preferred over indoor air measurements.
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.
Active Soil Gas

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

• Cons:
  – Mass Transfer Coefficient Unknown
  – Overly Restrictive Default Criteria
  – Protocols still debated

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 fail levels are also higher so there is less chance to be chasing blanks.

There are some drawbacks, including the lack of knowledge of the effective diffusivity, very restrictive fail levels for sub-slab data, and debate over how & where to collect samples.
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.
Sampling Through Rod

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.
Soil vapor implants nested in same borehole at three different depths. This method is advantageous if repeated sampling is anticipated.
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.

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.
The “Key” Sampling Issues
(That Directly Affect the Bottom Line)

• Get Enough Data Near/Around/Under
• Simpler Collection Systems
  – 20 to 30 samples/day ($50-$75 each)
  – Less chances for goofs & leaks
• Less Expensive, Simpler Analysis
• Experience of the Collector/Consultant
  – Have they done this before?
  – Quality/experience of field staff? Sr or Jr?

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.

The last 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.

All of these issues affect the investigation progress and hence the cost you end up paying (the ultimate bottom line).
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: 0.004 ug/L
  - At 5’: Benzene: 0.155 ug/L, PCE: 0.20 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.
Are sub-slab samples the best to collect? Regulatory guidance and current thinking is still not clear.

Slide courtesy of Dr. Paul Lundegard
What sample depth near building best estimates subslab concentration?

[ No biodegradation]

For small source-slab separation, near building soil gas collected right above the source best estimates 

For large source-slab separation, near building soil gas collected at about 5 m bgs best estimates 

Modeling efforts indicate that near-slab soil gas samples can give representative sub-slab soil gas concentrations if collected at the proper depths. For shallow sources (<10’), collect just above the source. For deeper sources (>10’), the modeling suggests that you collect ~10 feet below the bottom of the slab or foundation. These results still need to be validated with actual field data.

However, for petroleum hydrocarbons, bioattenuation is active in the upper 10’ of the vadose zone, so samples closer to the receptor are more advisable.

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

- Closer to Surface, More Variability
  - 3’ to 5’ bgs generally considered stable
  - Recent studies less than factor of 2
- Seasonal Effects
  - Most studies show less than 5x
- Larger Variations If:
  - Extreme temperature variations
  - Heating/cooling of structure
  - Heavy periods of rain

The closer to the surface, the more the potential temporal variation. Soil gas data collected at depths of 3’ to 5’ below the surface are generally considered stable and repeatable. A number of recent studies are showing that temporal variation, even over the seasons in northern climates, is less than a factor of 5.

Larger variations can be expected in areas of extreme temperature variation (northern climates), during heavy periods of precipitation, and when the structure’s heating or ventilation systems are operative.

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.
Recent data collected over 15 months from Endicott NY show very low variations in soil gas collected 10’ below the surface (max variation less than factor of 2) and shallow 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
Ertel Program Goals

• Compare a Variety of Soil Gas Methods
• Compare Sub-slab to Exterior Soil Gas
  – Depends upon Location of Source
• Map Spatial Variability Under Slab
• Measure Temporal Variability

Need to Know Zone of Contamination

The goals for the August MSRAS soil gas workshop/course at Ertel are as listed.
   To accomplish these goals, we needed to know where the zone of contamination is, both laterally and vertically.
Pre-Existing Data

- **Groundwater Data**
  - Very Limited,
  - Source Unknown (but Suggested High Conc.)

- **Passive Soil Gas**
  - 2-D only. 3-D profile desired
  - Mass not concentration

**Collect “Screening Level” Active Soil Gas Data**

We had very little previous data from the site. We knew the site was an old manufacturing facility that used solvents. Limited groundwater data suggested high levels of trichloroethylene (TCE) contamination, but the source was not clear. No soil gas data existed.

A passive soil gas survey was conducted, courtesy of Gore & Associates, to identify and delineate the zone on contamination in the soil gas. Gore passive modules were emplaced at about 25 locations adjacent to and under the building at a depth of 3’ bgs. The survey showed a large TCE contamination zone under the building in the southern portion of the building.
Approach

• Simple & Fast Collection Method
  – Small volume (50 cc) syringes (seconds/sample)
  – Some tedlars & canisters

• On-site Analysis by GC Method 8021
  – Simple, Fast (7 min), quantitative

• Real-Time Decisions to add Locations

An active soil gas survey was conducted in late July after the passive soil gas survey to allow 3-dimensional characterization and to get actual soil gas concentrations not possible from the passive soil gas program. Samples were collected from about 50 locations using 60 cc syringes and analyzed on-site with a gas chromatograph using EPA method 8021. About 60 samples were collected over 2 days.

Additional sampling locations were added based upon the real-time results.
Preliminary Tests
Soil Gas Sampling Issues

- How Much to Collect?
  - Variation with Extraction Volume?
- Containers
  - Compare Syringes, Tedlars, Summas
- Tubing Type
  - 1/8” & ¼” OD rigid wall installed
- Temporal Variation
- Onsite 8021 vs. Off-site TO-15

In addition to delineating the contamination plume, a few preliminary tests were done on different sampling issues:

Soil gas concentration variation with sample volume.
Comparison of samples collected with syringes, tedlars, and polished canisters.
Comparison of results from the on-site 8021 analysis to off-site TO-15 analysis.
Measurement of temporal variability over 2 days.
Sample Locations

Active soil gas sampling locations during the July 2006 pre-screening program.
TCE concentrations in ug/L at the sub-slab locations. Concentrations reached 300 ug/L equal to 300,000 ug/m3. Very high concentrations.
TCE concentrations in ug/L at 3 feet bgs. Concentrations were still very high, but lower than the sub-slab values indicating a surface source.
TCE concentrations in ug/L at 7 feet bgs. Concentrations were still very high, higher than the concentrations at 3 feet, but lower than the sub-slab values.
Conclusions From Active Data

- Building Contamination Source
  - 300 ug/L SS-D3, 114 ug/L P4-11’
- Mostly TCE except in NE @ 3’ bgs
- 24 hour Temporal Variation Small
  - 3% SS-D3, 20% SS-D2
- Volume Effect Small
  - <20% from 60 cc to 1400 cc

The conclusions from the July active soil gas data:

TCE concentrations were very high under the building extending to the depth of groundwater at ~ 11’ bgs.

The concentrations were higher under the slab indicating the source was originally in the building.

The variation in concentration measured at two locations was less than analytical precision.

The concentration difference between syringe samples and samples collected in tedlar bags and canisters was less than 20%.

The on-site 8021 results matched the off-site TO-15 results within 11%.

With these results in hand, decisions were made about what to attempt and accomplish for the August soil gas workshop.