Vapor Intrusion Risk Pathway: Overview, Regulatory Updates, Practical Assessment Strategies

Regenesis/LandScience Seminar
St. Louis MO

February 2011

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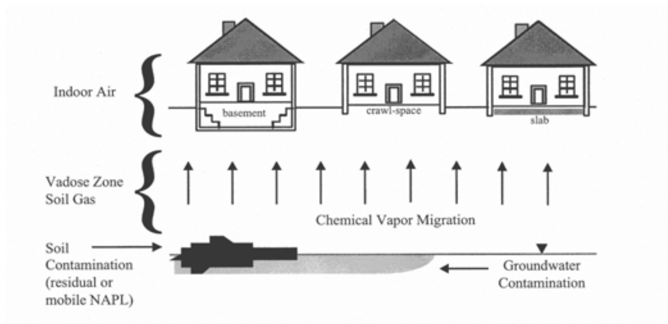
This presentation is an excerpt from the vapor intrusion training that Dr. Hartman has been presenting to Federal & State regulatory agencies, DOD facilities, consulting groups, and stakeholders around the country. As of January 2011, this training has been given to over 30 State Regulatory agencies, including ASTSWMO and the State Coalition of Dry Cleaners. Training has also been given to many PRPs such as the major oil companies, Armed Services, & EPRI.

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.

What Is Vapor Intrusion?



Key Criteria Influencing Risk Assessment:

- Risk level (1 in 10,000? 100,000? 1,000,000?)
- Toxicity of Compounds
- Exposure Factors (time, rates, ventilation)

Vapor intrusion refers to the upward migration of contaminants in the vapor phase from groundwater, soil, or soil gas contamination sources.

Key criteria to the risk determination are the risk level, the toxicity of the contaminant, and the exposure factors. These parameters are often much more important than model parameters such as soil porosity and pressure gradients.

Why Do You Care About VI?
(Risk Often More Perceived Than Real)

- Health & Safety of Occupants
- EPA, ITRC, & State Guidances
- ASTM New Phase 1 Standard
- Attorneys & Citizen Groups
- Future Liability

In some cases, there is a real threat to occupants.

But in the majority of cases, the risk to occupants is exaggerated, hence the perception is greater than the real risk. Nevertheless, you need to worry about it because the EPA has identified it as a risk pathway, numerous states have their own guidance or policies, and citizen groups and of course, attorneys are making it an issue.

When to Worry About VI?

- If VOC Contamination & Structures Exist:
  - Laterally within 100’ (EPA, MO – 25’ for HCs)
  - Vertically Within 100’ (EPA, MO-25’?)
  - NY: No Limits!!!
- Complaining Occupants
- Structures With Odors, Wet Basements
- Sites With Contamination & Future Use
- Attorneys & Communities

The EPA & many State guidances use the distance criteria listed above to screen sites needing to assess the pathway. At sites with existing contamination but no current buildings, the pathway will need to be assessed when development is proposed. Attorneys and community activist groups can expand these criteria beyond the EPA limits. In some recent cases, concern about the safety of burrowing animals, and fruits & vegetables has been the reason to assess the vapor intrusion pathway.

What Compounds?

- VOCs:
  - Hydrocarbons (benzene, aliphatics?)
  - Chlorinated HCs (TCE, TCA, PCE, VC)
  - Methane
- Semi-VOCs:
  - Naphthalene
  - PAHs
  - PCBs & Pesticides
  - Pb, Hg

The list of compounds that are in the EPA VI guidance and some State guidances include VOCs and semi-VOCs. The semi-VOCs are particularly problematic because the risk-based screening levels (RBSL) are typically very low (eg., for PCBs, the RBSL is 10 to 100 times lower than benzene).

Low RBSLs Mean More Sites
(VI Levels 10,000 Times Lower)

- Typical Water Levels:
  - Water: PCE: 5 ug/L

- PCE Levels Exceeding 1E-6 Risk:
  - Indoor Air: 0.0004 ug/L
  - Subslab soil gas: PCE: 0.004 ug/L

For the vapor intrusion risk pathway, acceptable concentration levels are 1000 to 10,000 times lower than acceptable levels for soil and water. So essentially, this increases the number of sites that have to be evaluated.

Review of VI Guidances

- EPA OSWER
- MO - DNR
- ITRC Guidance
- ASTM
- Exclusion Criteria for HC Sites?

If you are a consultant or RP, you need to know which agency has jurisdiction and what their vapor intrusion policy is in order to know what approaches are allowed and what the allowable levels are.

EPA-OSWER Draft Guidance

- Tier 1: **Primary** Screening
  - Q1: VOCs present?
  - Q2: Near buildings?
  - Q3: Immediate concern?
- Tier 2: Secondary Screening
  - Q4: Generic screening
  - Q5: Semi-site specific screening (alphas from charts & tables)
- Tier 3: Site-Specific Pathway Assessment
  - Q6: Indoor air (and/or subslab)

The current EPA draft VI guidance consists of 3 tiers, consisting of 6 questions. Tier 1 is essentially a screening survey asking basic questions such as whether volatile compound contamination exists and whether buildings exist.

Tier 2 consists of 2 questions/steps: Q4 & Q5. Question 4 is so restrictive (i.e., very low screening levels) that just about every site is sucked in, similar to a vortex or hopper. Question 5 allows more sampling options, is not as conservative, and may be the best tier/question to work within.

Tier 3, question 6, allows for only two investigatory methods, indoor air or sub-slab soil gas, and has very restrictive (i.e., very low screening levels) criteria. Once at this level, it is extremely hard to get out and requires expensive and repeated sampling.

Newest Changes (2012?)
EPA OSWER VI Guidance

- Tier 1: **Primary** Screening
  - Q1: VOCs present?
  - Q2: Near buildings?
  - Q3: Immediate concern?
- Tier 2: Source Screening
  - Generic screening using <u>near-source</u> samples
- Tier 3: Pathway (Building) Assessment
  - Multiple lines of evidence (sg & gw)
  - Sub-slab & Indoor Air Data

The changes currently being considered by the EPA would make the vapor intrusion pathway even more stringent. Few sites would screen out and indoor sampling (sub-slab or indoor air) is required in most cases.

Guidance Updates

- Fed EPA (OSWER & Superfund)
  - – Moving to sub-slab & indoor air
  - – 7 to 30 day indoor air sampling period
  - – Att factor of 0.1 for SG & 0.001 for GW
  - – Modeling no longer an exit
- EPA-OUST: Guidance for HCs by 2012
  - – Exclusion criteria by 2011?

Here are some of the proposed changes to the OSWER guidance, due out in 2012.

Meanwhile, OUST is coming out with their own guidance for petroleum hydrocarbons also in 2012.

Allowable Benzene in GW
1e-6 risk

- New OSWER Guidance:

0.31 ug/m3/0.001 = 0.31 ug/L/0.2 = 1.5 ug/L

- MO Tier 1 screening value: 621 ug/L

EPA value ~400 times lower than MO!!

Based upon the proposed new EPA OSWER guidance, allowable levels for benzene in groundwater will be ~400 times lower than MO currently allows!

VI Regulatory State Guidance

States with Regulatory VI Guidance in 2004

States with Regulatory Guidance in 2010

As of 2010, 32 states have VI guidance. They are: Alabama, Alaska, California, Colorado, Connecticut, Delaware, Hawaii, Idaho, Indiana, Kansas, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New York, North Carolina, Ohio, Oregon, Pennsylvania, Rhode Island, South Dakota, Virginia, Washington, Wisconsin, and Wyoming

MRBCA Assessment Approach (Appendix C)

- Are Receptors Within 25’ of Contamination?
- Tier 1: Soil & GW RBTLs (look-up tables)
- Tier 2-1: Develop Site Specific Levels (SSTL)
- Tier 2-2: Use Soil Gas Target Levels
- Tier 3: Use Model (RAM Group/Custom)

(Refer to Figure C-1 Flowchart)

Can Invoke Risk Management Plan at Any Time

The Missouri RBCA guidance approach for assessing the indoor inhalation pathway (vapor intrusion) is like this.

Methods for Target Level Determination

- Soil & GW: MO Table 7.1 through 7.3
- Soil Gas: Tier 2 Target Levels
- From Spreadsheet/Model (RAM Group)
- Use Custom Software (Tier 3)

In Missouri, target levels already exist in tables 7.1 through 7.3 for soil & groundwater and in Tier 2 for soil gas. A custom software package developed by the RAM group is used by MO to determine site-specific screening values. In Tier 3, you can use the RAM software with site-specific parameters or use another model if approved.

ITRC VI GUIDANCE

- Practical How-to Guide
- Stepwise Approach
- Investigatory Tools (Toolkit)
- Thorough Discussion of Mitigation
- Scenarios Document
- Three Training Dates in 2011

ITRC has recently finished it's vapor intrusion guidance document. It consists of 2 documents: A practical guideline and a separate scenarios document. A 2-day classroom training course will be held at 3 locations in the US in 2010.

The Net Widens: ASTM VI Standard

- Focus on Property Transactions
- Prescriptive Screening Distances
- No RBSLs (RBC)
- No Assessment Recommendations
- Legal Standards
- Mitigation
- Initially Released March 3, 2008
- Revised version: June 2010

ASTM convened a technical workgroup in 2005 to write a standard for vapor intrusion as it applies to property transactions. The standard was released on March 2008 & revised in June 2010.

ASTM VI Standard

Vapor Intrusion Condition (VIC) *is defined as* ***"****the presence or likely presence of any volatile chemical of concern in existing or planned structures on a property resulting from an existing release or a past release from contaminated soil or groundwater on the property or within close proximity to the property,* ***at a concentration that presents or may present a human health risk****."*

The Standard defines a new term/arconym: the Vapor Intrusion Condition.

Liability Concerns

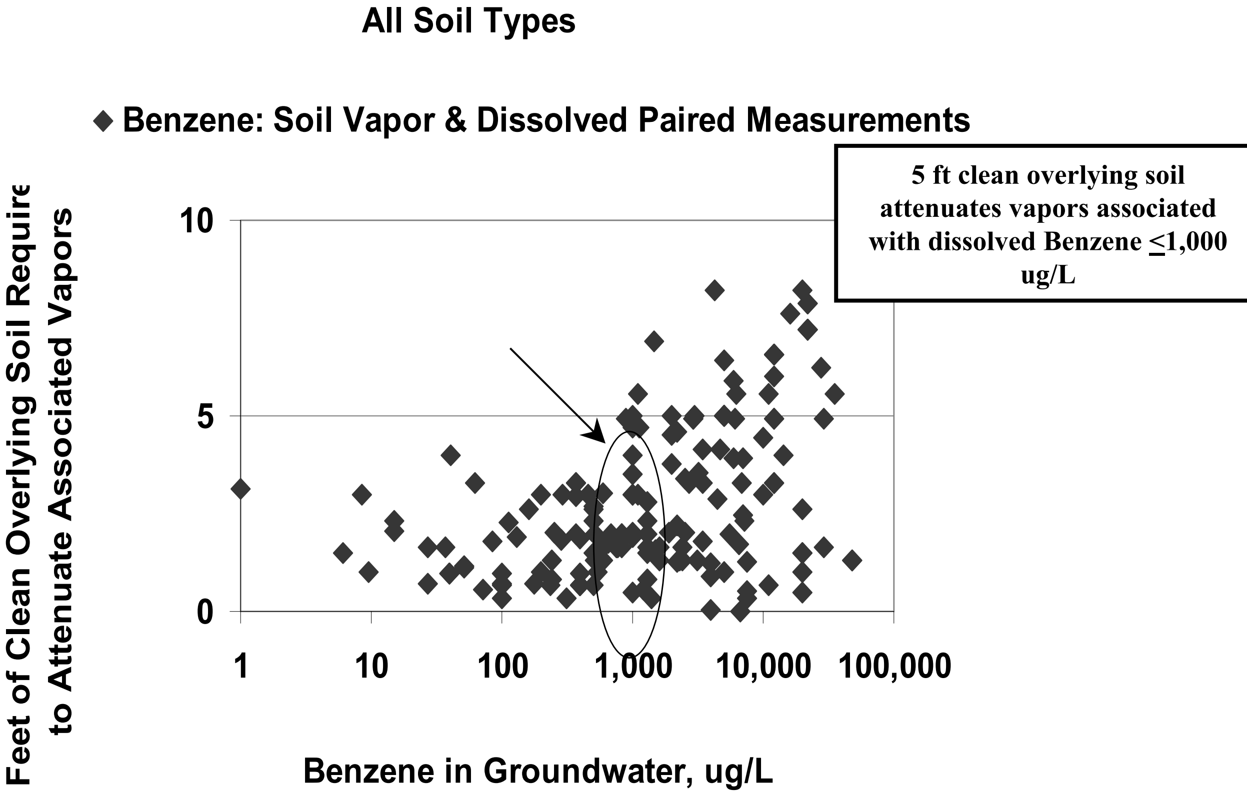
- Phase I Environmental Consultant
- Prospective/Current Property Owner
- Property Lender
- Property Insurer

Liability concerns is a big part of vapor intrusion. Those at risk include consultants, property owners (past, current & future), lenders, and insurance companies.

Exclusion Criteria for Petroleum Sites

Can we screen out HC sites from VI assessments?

Results for Dissolved Benzene



Robin Davis of the Utah DEP compiled a petroleum vapor data-base to determinethe thickness of clean overlying soil necessary to fully attenuate vapors from their respective dissolved source strengths. There are 180 paired benzene SV & GW field measurements from 48 geographic locations; 14 events beneath buildings. Conservative screening criteria emerge showing that vapors associated with dissolved benzene sources of about 1,000 ug/L or less are attenuated with 5 feet of clean overlying soil.

Slide courtesy of Robin Davis, Utah DEP

From New CA-LUFT

Based on these studies, a LUFT site is assumed to present no unacceptable risk from vapor intrusion if site conditions indicate that there is :

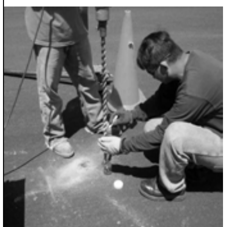
- *Dissolved* groundwater concentrations below 1000 micrograms per liter (ug/L) for benzene and 10,000 ug/L for TPH and 5' from receptor.

- Free product is 30 or more from receptor

Under these conditions, it is assumed that natural attenuation is sufficient to mitigate concentrations

CA State Water Boards are proposing to adopt the exclusion criteria in their new LUFT manual.

Methods to Assess VI



- Indoor Air Sampling
- Groundwater Sampling
- Soil Phase Sampling
- Predictive Modeling
- Measure Flux Directly
- Soil Gas Sampling
- Supplemental Tools/Data

In this part of the seminar, we will discuss the primary techniques/tools used to assess the vapor intrusion pathway, including the pros & cons of each.

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 picking the proper approach, determining the correct screening levels, sample & analyze correctly and efficiently, know when and how to use supplemental assessment tools, and to know how to demonstrate bioattenuation if petroleum hydrocarbons are the COC.

Some Key VI Assessment Issues

- Experience of the Collector/Consultant
  - Have they done this before?
  - Do they understand RBSLs?
  - Quality/experience of field staff? Sr or Jr?
- Get Enough Data Near/Around/Under
- Legal Perspective
  - How conservative to be or not be?

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.

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.

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

All of these issues affect the investigation progress.

Most Common VI Bloopers

Unit Confusion:

- Assuming ug/L equivalent to ppbv
- Assuming ug/m3 equivalent to ppbv
- Vacuum units: in Hg to inches H20

Screening Levels:

- Comparing to CHHSLs
- Not calculating correct levels

Approach Generalizations

- Indoor Air
  - Always find something
  - Multiple sampling rounds:
- Groundwater Data
  - Typically over-predicts risk
- Soil Phase Data
  - Typically not allowed; over-predicts risk for HCs
- 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.

Indoor Air Measurement

- Pros:
  - Actual Indoor Concentration
- Cons:
  - Where From?
    - Inside sources (smoke, cleaners)
    - Outside sources (exhaust, cleaners)
    - People activities – NO CONTROL!
  - Time-intensive protocols
  - Snapshot, limited data points
  - Expensive!!

Measuring indoor air might seem to be the most direct and simplest approach, but it has its share of problems. The biggest problem is background sources of contaminants. Many commonly used household products contain some of the target compounds of concern. For example, benzene from gasoline, PCE from dry cleaned clothes, TCA from degreasing cleaners. In addition, the protocols are laborious, intrusive, offer little control, and are expensive. For these reasons, the EPA and many States shy away from this method. However, this method may still be the method of choice if the contaminant of concern is not one commonly found in household products (e.g., 1,1 DCE).

Indoor Air

Consumer Products Containing PCE

Product	PCE Concentration
ARAMCO Art and Crafts Goop	Not Specified
Aleenes Patio & Garden Adhesive	70%
Gumout Brake Cleaner	50 - 90%
Liquid Wrench Lubricant w/ Teflon	65 - 80%
Plumbers Goop Adhesive	67.5%
Hagerty Silversmith Spray Polish	30.5%
Champion Spot it Gone	20 - 25%

KEY POINT: **Wide variety of consumer products still contain high concentrations of PCE.**

Contaminants in indoor air may be from household products, not vapor intrusion.

Slide courtesy of Dr. Tom McHugh, GSI, Houston, TX

Target Compounds					
4)	Chloromethane	2.002	50	4813	
7)	Chloroethane	2.561	64	3991	
8)	Trichlorofluoromethane	2.817	101	2070	
11)	Acetone	3.317	43	14416174	894
12)	Isopropyl alcohol	3.317	45	94670	~~385~~
13)	Methylene Chloride	3.680	84	6533	
16)	Diisopropyl ether*	4.264	45	1756282	~~81~~
17)	1,1-Dichloroethane	4.091	63	52909	~~2~~
18)	Ethyl-t-butyl ether*	4.710	59	501954	25
19)	2-Butanone	4.871	72	36815	~~86~~
22)	Chloroform	4.859	83	22151	
23)	Bromochloromethane	4.728	128	217	
26)	1,1-Dichloropropene	5.109	75	2475	
29)	1,2-Dichloroethane	5.151	62	1445	
30)	~~TAME* (2 methoxy 2 met...~~	~~5.347~~	~~73~~	~~5913~~	
31)	Benzene*	5.264	78	2724469	75
32)	~~Trichloroethene~~	~~5.705~~	~~95~~	~~1454~~	
33)	1,2-Dichloropropane	5.847	63	109116	~~14~~
34)	Bromodichloromethane	6.008	83	127010	~~8~~
35)	Dibromomethane	5.961	93	794	
36)	cis-1,3-Dichloropropene	6.336	75	3448	
38)	Methyl Isobutyl Ketone	6.520	43	737901	~~198~~
39)	Toluene*	6.592	92	7153783	274
40)	trans-1,3-Dichloropropene	6.651	75	14157	1

Compounds in Bloonie, a kids toy available in the US.

58)	1,1,2,2-Tetrachloroethane	8.568	83	91292	180.66 ng
59)	1,2,3-Trichloropropane	8.616	75	112180	168.59 ng
60)	n-Propylbenzene	8.616	91	8054470	1288.03 ng
62)	1,3,5-Trimethylbenzene	8.741	105	6061679m	1318.01 ng
63)	2-Chlorotoluene	8.681	91	6809750	1789.21 ng
64)	4-Chlorotoluene	8.741	91	1265341	322.07 ng
65)	tert-Butylbenzene	9.027	119	1891115	435.53 ng
66)	1,2,4-Trimethylbenzene	9.027	105	8143013m	1879.66 ng
67)	sec-Butylbenzene	9.027	105	8143968	1416.03 ng
68)	p-Isopropyltoluene	9.253	119	54681	11.06 ng
71)	n-Butylbenzene	9.562	91	27682	5.95 ng
76)	Naphthalene	11.033	128	869	0.69 ng
79)	Ethanol	2.978	45	983528	207445.35 ng
80)	t-Butanol *	3.317	59	432657	9715.81 ng

More compounds in Bloonie.

Cleaning Your Dishes?
(or Polluting Your House)

Another unsuspecting source of VOCs

Dawn VOC Analysis Results

DRAFT: Soap Head Space (E012073-01) Vapor Sampled: 10-Dec-10 Received: 13-Dec-10

2,2,4-Trimethylpentane	**54**	10	ug/m3	1	EL01310	13-Dec-10	13-Dec-10	EPA TO-
n-Heptane	**230**	5.0	"	"	"	"	"	"
Trichloroethene	ND	5.0	"	"	"	"	"	"
1,2-Dichloropropane	ND	5.0	"	"	"	"	"	"
1,4-Dioxane	**2100**	5.0	"	"	"	"	"	"
Bromodichloromethane	ND	5.0	"	"	"	"	"	"
cis-1,3-Dichloropropene	ND	5.0	"	"	"	"	"	"
4-Methyl-2-pentanone (MIBK)	ND	5.0	"	"	"	"	"	"
trans-1,3-Dichloropropene	ND	5.0	"	"	"	"	"	"
1,3-Dichloropropane	ND	10	"	"	"	"	"	"
Toluene	**120**	5.0	"	"	"	"	"	"
1,1,2-Trichloroethane	ND	5.0	"	"	"	"	"	"
2-Hexanone (MBK)	ND	10	"	"	"	"	"	"
Dibromochloromethane	ND	5.0	"	"	"	"	"	"
Tetrachloroethene	ND	5.0	"	"	"	"	"	"
1,2-Dibromoethane (EDB)	ND	5.0	"	"	"	"	"	"
1,1,1,2-Tetrachloroethane	ND	5.0	"	"	"	"	"	"
Chlorobenzene	ND	5.0	"	"	"	"	"	"
Ethylbenzene	**25**	5.0	"	"	"	"	"	"
m,p-Xylene	**27**	5.0	"	"	"	"	"	"
Styrene	ND	5.0	"	"	"	"	"	"
o-Xylene	**16**	5.0	"	"	"	"	"	"
Bromoform	ND	20	"	"	"	"	"	"
1,1,2,2-Tetrachloroethane	ND	5.0	"	"	"	"	"	"
4-Ethyltoluene	**13**	5.0	"	"	"	"	"	"
1,2,3-Trichloropropane	ND	10	"	"	"	"	"	"
Isopropylbenzene (Cumene)	ND	10	"	"	"	"	"	"
Bromobenzene	ND	10	"	"	"	"	"	"
2-Chlorotoluene	ND	10	"	"	"	"	"	"
n-Propylbenzene	ND	10	"	"	"	"	"	"
p-Isopropyltoluene	**1200**	10	ug/m3	1	EL01310	13-Dec-10	13-Dec-10	EPA TO-1
1,2-Dichlorobenzene	ND	10	"	"	"	"	"	"
n-Butylbenzene	ND	10	"	"	"	"	"	"
1,2-Dibromo-3-chloropropane	ND	20	"	"	"	"	"	"
Naphthalene	**31**	10	"	"	"	"	"	"

Dawn – No Wonder She's Smiling

DRAFT: Soap Head Space (E012073-01) Vapor Sampled: 10-Dec-10 Received: 13-Dec-10

Propene	**190**	10	ug/m3	1	EL01310	13-Dec-10	13-Dec-10	EPA TO-15	
Dichlorodifluoromethane (F12)	ND	10	"	"	"	"	"	"	
Chloromethane	**190**	5.0	"	"	"	"	"	"	
Dichlorotetrafluoroethane (F114)	ND	10	"	"	"	"	"	"	
Vinyl chloride	ND	5.0	"	"	"	"	"	"	
1,3-Butadiene	**7.2**	5.0	"	"	"	"	"	"	
Bromomethane	ND	5.0	"	"	"	"	"	"	
Chloroethane	ND	5.0	"	"	"	"	"	"	
Ethanol	**6000000**	10	"	"	"	"	"	"	E
Trichlorofluoromethane (F11)	ND	5.0	"	"	"	"	"	"	
Acetone	ND	20	"	"	"	"	"	"	
Isopropyl alcohol	ND	10	"	"	"	"	"	"	
1,1-Dichloroethene	ND	5.0	"	"	"	"	"	"	
Tertiary-butyl alcohol (TBA)	ND	20	"	"	"	"	"	"	
1,1,2-Trichlorotrifluoroethane (F113)	ND	10	"	"	"	"	"	"	
Methylene chloride (Dichloromethane)	ND	10	"	"	"	"	"	"	
Carbon disulfide	ND	5.0	"	"	"	"	"	"	
trans-1,2-Dichloroethene	ND	5.0	"	"	"	"	"	"	
Methyl tertiary butyl ether (MTBE)	ND	5.0	"	"	"	"	"	"	
Vinyl acetate	ND	10	"	"	"	"	"	"	
1,1-Dichloroethane	ND	5.0	"	"	"	"	"	"	
2-Butanone (MEK)	**100**	5.0	"	"	"	"	"	"	
n-Hexane	**110**	5.0	"	"	"	"	"	"	
cis-1,2-Dichloroethene	ND	5.0	"	"	"	"	"	"	
Diisopropyl ether (DIPE)	ND	5.0	"	"	"	"	"	"	
Ethyl acetate	ND	5.0	"	"	"	"	"	"	
Chloroform	**130**	5.0	"	"	"	"	"	"	
2,2-Dichloropropane	ND	10	"	"	"	"	"	"	
Tetrahydrofuran	ND	5.0	"	"	"	"	"	"	
Ethyl tert-butyl ether (ETBE)	ND	5.0	"	"	"	"	"	"	
1,1,1-Trichloroethane	ND	5.0	"	"	"	"	"	"	
1,2-Dichloroethane (EDC)	ND	5.0	"	"	"	"	"	"	
1,1-Dichloropropene	ND	10	"	"	"	"	"	"	
Benzene	**19**	5.0	"	"	"	"	"	"	
Carbon tetrachloride	ND	5.0	"	"	"	"	"	"	
Dibromomethane	ND	10	"	"	"	"	"	"	
Cyclohexane	ND	10	"	"	"	"	"	"	
Tertiary-amyl methyl ether (TAME)	ND	5.0	"	"	"	"	"	"	

Groundwater Data

- Preexisting Data Often Exist
  - Over proper well screen interval?
  - Coverage typically limited; interpolation
- Gather New Data
  - Well location, construction, sampling
- Likely Will Over-Predict VI Risk
- New EPA att factor (0.001) very tough!

Generally Overpredicts VI Risk

At many sites, groundwater data already exist. But, it may not be from a well screened across the interface. Plus, coverage often is limited so you have to interpolate the data.

Some States prefer groundwater data. Or if groundwater is very shallow, it may be the only option. If you are going to collect new groundwater data, be sure that the well locations and construction are correct.

But note that the new proposed EPA-OSWER guidance has a very strict default attenuation factor which lowered the allowable value.

Soil Phase Data

- Soil Data Generally Not Accepted in VI Assessment
- Existing Soil Data – Line of Evidence
  - Can "screen in" sites
  - Cannot be used alone to "screen out" sites
- Convert to Soil Gas Concentrations
  - Partitioning equations exist. Likely overestimate.

MO Does Allow

Soil phase data are generally not acceptable for VI investigations by most States. This is because equilibrium partitioning is rarely achieved so it is difficult to predict soil vapor concentrations from soil phase data, and hence in turn, the vapor intrusion risk.

- Soil data can be used to "screen in" sites, but cannot be used alone to "screen out" sites
- Soil data may have elevated reporting limits or volatilization losses, therefore non detect (ND) in soil does not mean "no potential for VI"

- One can convert soil data to soil gas concentrations using partitioning equations. This result provides an estimate of the soil gas concentration in the vadose zone.

Modeling

- Johnson-Ettinger Most Common
  - GW, soil, soil gas spreadsheets
  - Screen & advanced versions
  - EPA-OSWER: no longer an exit
- RAM Software for MO
- Biovapor
  - Includes bioattenuation
  - Agency acceptance?

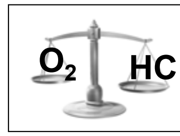
The use of models to calculate an indoor air concentration, and in turn a health risk, is commonplace. Existing models use groundwater, soil, or soil gas data and are relatively easy to use. In general, if default parameters are used, they tend to over calculate the risk for most situations.

The Johnson-Ettinger model/spreadsheet is the most commonly used model. Several versions currently exist with different default values for various parameters, so one must be careful to know what version they are using. There are many parameters that can be changed, some more easily that the others.

EPA OSWER's current position is to use the models as a screening tool, but not for closing the pathway.

Conceptual Model

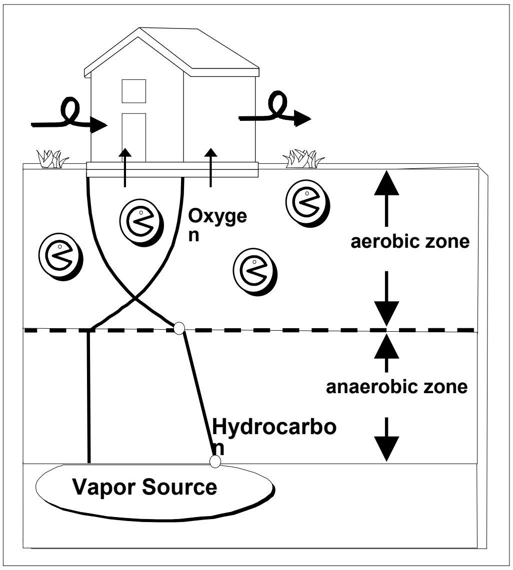
What is BioVapor?

1-D Analytical Model	**Version of Johnson & Ettinger vapor intrusion model modified to include aerobic biodegradation (DeVaull, 2007).**	$\left(\frac{c_e}{c_s}\right)=\frac{\left(\frac{1}{L_{mix}\cdot ER}\right)}{A\cdot\left(\frac{1}{L_{mix}\cdot ER}+\frac{1}{h}\right)+B\cdot\left(\frac{L_s}{D_{eff}}\right)}$ **SIMPLE MATH**
Oxygen Mass Balance	**Uses iterative calculation method to account for limited availability of oxygen in vadose zone.**	
User-Friendly	**Simple interface intended to facilitate use by wide range of environmental professionals.**	

KEY POINT:	**Free, easy-to-use vapor intrusion model that accounts for oxygen-limited aerobic vapor intrusion.**

API has developed a new spreadsheet based upon the J-E model which includes bioattenuation. The spreadsheet is now available from the API website.

BioVapor – API 1-D Steady State VI Model



3 **Advection, diffusion, and dilution through building foundation**

2 **Diffusion & 1st order biodegradation in aerobic zone**

1 **Diffusion only in anaerobic zone**

Algebra Solution for:

Oxygen demand = Oxygen Supply

Conceptual model of the API Biovapor model/spreadsheet

Which Soil Gas Method?

- Active?
- Passive? (MO considers screening tool)
- Flux Chambers? (limited use)

Active method most often employed for VI

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 were discussed previously.

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

Passive Soil Gas Samplers

Adsorbent inside tube open on one end

Adsorbent inside badge

Adsorbent inside vapor permeable, waterproof membrane

Examples of passive collectors.

Active Soil Gas

- Pros:
  - Representative of Subsurface Processes
  - Higher Screening Levels
  - Relatively Inexpensive
  - Can Give Real-time Results
- Cons:
  - Mass Transfer Coefficient Unknown
  - Spatial Variability
  - 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

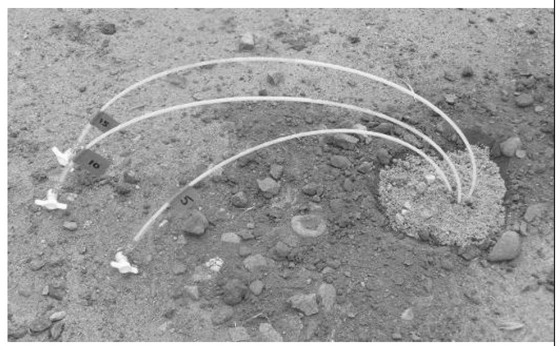
There are two common ways to collect active soil gas samples: collection through a probe or rod driven into the ground or collection through a vapor well buried into the ground. Both methods give reliable data.

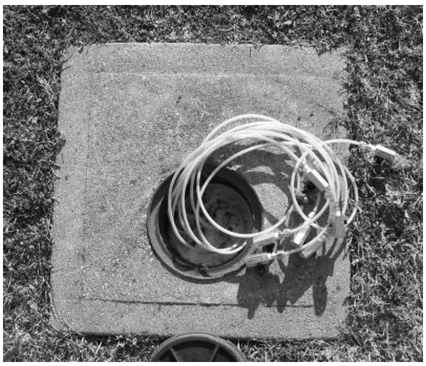
The vapor wells consist of small diameter, inert tubing and offer advantages when vertical profiles are desired or when repeated sampling events are likely. Multiple tubes can be "nested" in the same borehole.

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.

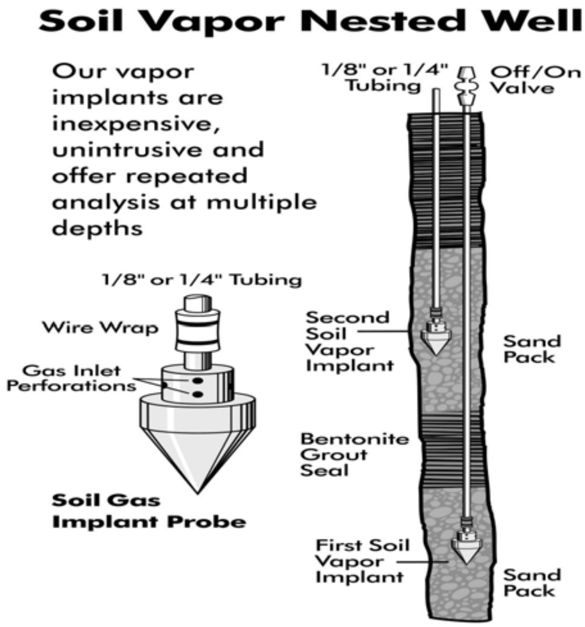
Soil Gas Implants





Soil gas implants nested in same borehole at three different depths. This method provides better seals at the intervals you wish to sample, can be removed after installation or left in place if repeated sampling is anticipated.

Multi-Depth Nested Well



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)
- Probe Tip
  - Beware metal tips (may have cutting oils)
- Materials Used to Bury Probes
  - Sand, cement
- 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.

Some Lessons Learned

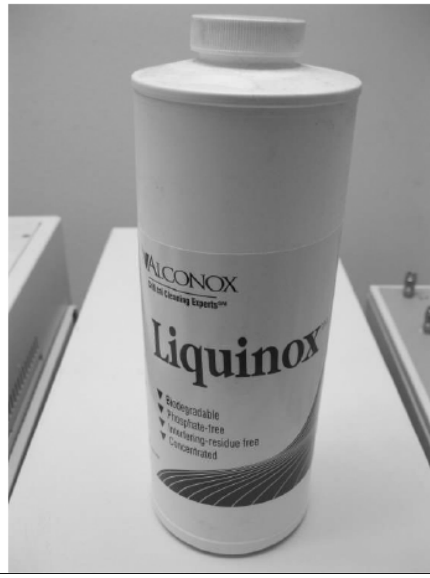
•Do not mark sample locations with spray paint: toluene

•Watch what you use to seal holes

Loaded with TCE

Loaded with TBA

Deconning or Conning?



Another unsuspecting source of VOCs

Better Be Sure to Triple Wash!

H&P Mobile Geochemistry, Inc.

DRAFT: Liquinox (E102045-02) Vapor   Sampled: 10-Feb-11   Received: 10-Feb-11

Analyte	Result	Reporting Limit	Units	Dilution Factor	Batch	Prepared	Analyzed	Method	Notes
Benzene	**1530**	16.2	ug/m3	5	EB11401	10-Feb-11	10-Feb-11	EPA TO-15	
Carbon tetrachloride	ND	31.9	"	"	"	"	"	"	
Trichloroethene	ND	27.3	"	"	"	"	"	"	
1,2-Dichloropropane	ND	46.9	"	"	"	"	"	"	
Bromodichloromethane	ND	34.0	"	"	"	"	"	"	
cis-1,3-Dichloropropene	ND	23.0	"	"	"	"	"	"	
4-Methyl-2-pentanone (MIBK)	ND	41.5	"	"	"	"	"	"	
trans-1,3-Dichloropropene	ND	23.0	"	"	"	"	"	"	
Toluene	**90.2**	19.1	"	"	"	"	"	"	
1,1,2-Trichloroethane	ND	27.6	"	"	"	"	"	"	
2-Hexanone (MBK)	ND	41.5	"	"	"	"	"	"	
Dibromochloromethane	ND	43.2	"	"	"	"	"	"	
Tetrachloroethene	ND	34.4	"	"	"	"	"	"	
1,2-Dibromoethane (EDB)	ND	39.0	"	"	"	"	"	"	
1,1,1,2-Tetrachloroethane	ND	34.8	"	"	"	"	"	"	
Chlorobenzene	ND	23.4	"	"	"	"	"	"	
Ethylbenzene	**671**	22.0	"	"	"	"	"	"	
m,p-Xylene	**1950**	44.0	"	"	"	"	"	"	
Styrene	ND	21.6	"	"	"	"	"	"	
o-Xylene	**612**	22.0	"	"	"	"	"	"	
Bromoform	ND	52.4	"	"	"	"	"	"	
1,1,2,2-Tetrachloroethane	ND	34.0	"	"	"	"	"	"	

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 (sorbent methods)
  - Air Methods: TO-4, TO-10, TO-13

This slide gives a summary of the most common analytical methods used for soil gas samples.

Don’t Forget 8021

- Can get to 1 ug/m3 for TCE, CCl4, PCE
- Can get to ~25 ug/m3 for Benz & Naphthalene
- 5 minute run time for benzene, TCE & PCE
- Cost ~ 1/5 of TO-15

Method 8021 is the forgotten method out there, but it has great sensitivity and offers many advantages over the other analytical methods if only a few target compounds exist.

Supplemental Tools/Data

- Site Specific Alpha Using Radon
  - Factor of 10 to 100. $100/sample
- Indoor Air Ventilation Rate
  - Factor of 2 to 10. <$1,000 per determination.
- Continuous analyzers
  - Real-time monitoing
- Pressure Measurements
  - Can help interpret indoor air results

Refer to ASTM E2600-08 Table X.1 for summary table

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.

Automated continuous analyzers exist that can provide large amounts of data at low cost with remote monitoring via the internet.

Pressure measurements can be helpful when interpreting indoor air data.

Got Natural Gas?

The hidden source of contamination at a site in Los Angeles

BBQ Sample Results

Analyte	BBQ	Garage	Patio	Garage #2	Closet
methane	40%	90%	100%	nd (0.1%)	nd (0.1%
	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3
n-hexane	1700	2000	10000	nd (15)	nd (15)
cy-hexane	750	5500	12000	nd (20)	21
n-heptane	460	710	3100	nd (50)	nd (50)
benzene	270	340	1900	6.5	7.9
toluene	150	110	120	44	62
xylenes	40	105	177	113	33
tri-methyl benzene	3	85	25	110	nd (10)
tri-methyl pentane	nd (200)	300	nd (200)	nd (20)	nd (20)

Natural gas contains high amounts of benzene and could be the major source for sub-slab and indoor air in neighborhoods containing natural gas service.

Practical Strategies
(Things to Do)

- Get Enough Data
- Consider Less Expensive Methods (8021, 8260)
- CL-HCs: Vertical Profiles Around Structure
- HCs: Oxygen Profiles Around Structure
- Use Radon for Slab-Specific Alpha
- Measure Ventilation Rate
- Have Competent Subs
- Check Your Units!

These are things you want to do/allow to practically and cost effectively assess this risk pathway.

Previews of the VI Future

- VI Likely to be a Concern at Your Sites
- Variable Regulatory Guidance Makes Assessment Tricky & Slow
- ASTM Standard Increase # of Sites
- New EPA OSWER Guidance to be Stricter
- Hydrocarbons to be Less of a Concern

Here are some predictions & previews of the vapor intrusion pathway for the next few years.

Want to Know More?

- ITRC 2-day VI Training 2011
  - April 18 & 19: Princeton NJ
  - July 18 & 19: Detroit
  - October (first week): Denver
- EPA VI Workshop – AEHS San Diego 3/2011
- HC VI Workshop – AEHS San Diego 3/2011
- Battelle Conf – Reno, June 2011

Upcoming vapor intrusion training.

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
  - LustLine – VI For Petroleum Hydrocarbons, Nov 2010
- Robin Davis' Articles on Bioattenuation:
  - Lustline #61 May 2009
  - LustLine #52 May 2006 (www.neiwpcc.org)

A summary of some existing documents.

Existing Documents & Training

- Soil Gas Sampling SOPs
  - Soil Gas Sampling, Sub-slab Sampling, Vapor Monitoring Wells/Implants, Flux Chambers (www.handpmg.com)
- Other
  - ITRC VI Guidance (www.itrcweb.org)
  - API Soil Gas Document (api.org)
  - ASTM E2600-08: Good Summary Table in App X

More documents.

VI Websites & Links

- www.handpmg.com
  - Soil Gas Information
  - Other Site Assessment Methods
- www.itrcweb.org
- www.api.org
- EPA-OSWER's New VI Site: http://www.epa.gov/oswer/vaporintrusion/

Useful vapor intrusion websites.

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