

Some Basics

- Units
- Fick's Law
- Contaminant Partitioning
- Attenuation (alpha) Factors
- Risk Based Screening Levels
(RBSL, RBC, CHHSLs)

The Most Common Goof

1 ug/L Benzene equals:

- a) 1 ppbv
- b) 1 ppmv
- c) 330 ppbv
- d) None of the Above

The Most Common Goof

Sent: Wednesday, November 20, 2007 11:36 AM

Subject: VI Question

Blayne,

I have a technical question for you. I'm worried that some deep soil gas data I just collected might have been compromised by ambient air leakage from the surface. The measured oxygen level was 44% much higher than we expected in deeper soil gas. The data are attached. What is your opinion?

How do Vapors Move?

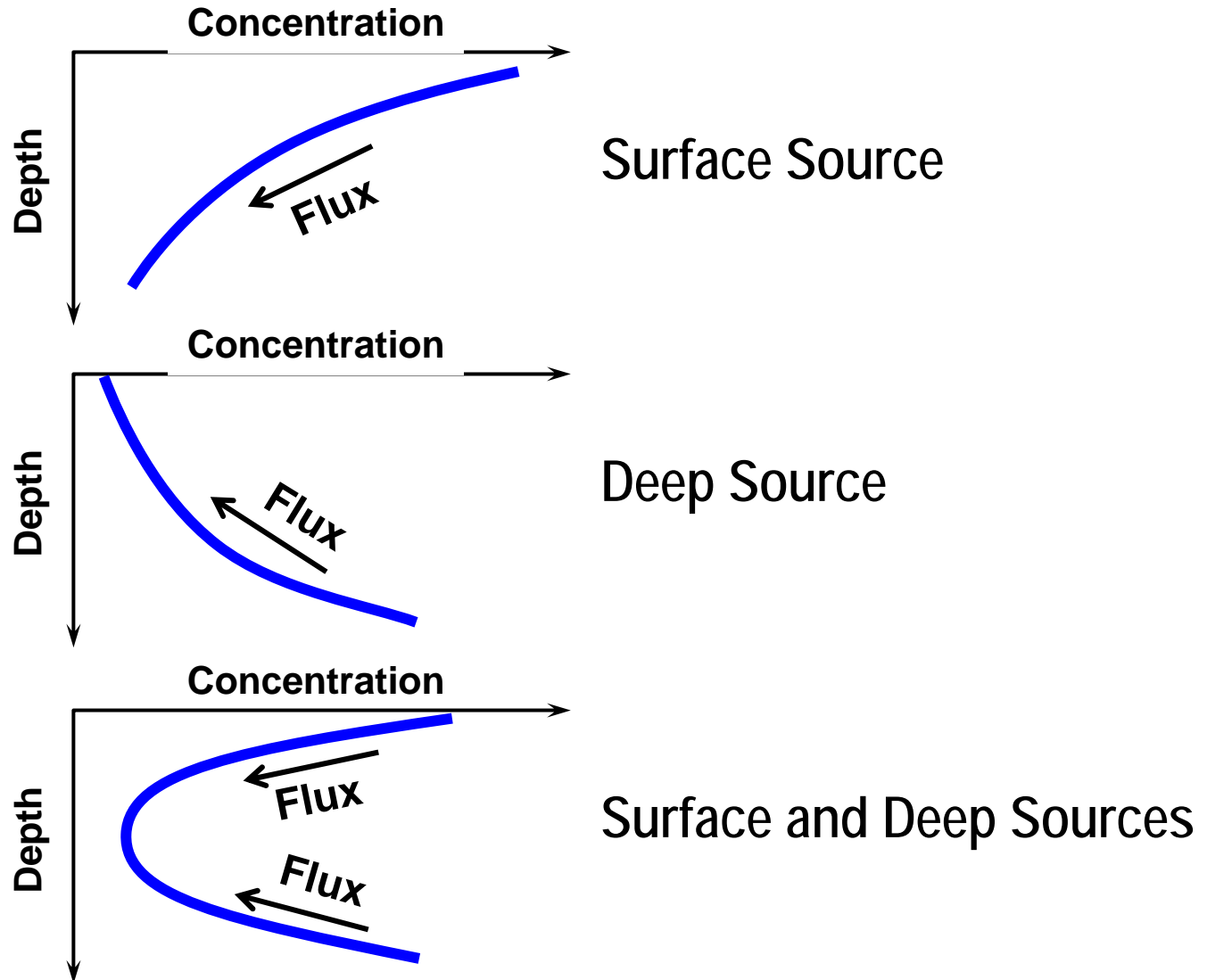
$$\text{Movement (Flux)} = K \, d\phi/dx$$

where: K is a proportionality constant
 $d\phi/dx$ is a gradient

<u>Property</u>	<u>Equation</u>	<u>Constant</u>
Momentum:	Flux = $K \, dH/dx$	hydraulic cond
Heat (Poisson's):	Flux = $\Phi \, dT/dx$	thermal cond
Mass (Fick's):	Flux = $D \, dC/dx$	diffusivity

Momentum, Heat, Mass ALL Move from High to Low

Common Vapor Profiles



How Fast do Things Move?

$$\text{Distance} = (2 * D_e * t)^{1/2}$$

where: D_e is effective diffusivity, t is time

Vapors through the Vadose Zone:

$$D_e = 0.01 \text{ cm}^2/\text{sec}$$

$$\text{Distance} = (2 * 0.01 * 31,000,000) = 800 \text{ cm/yr}$$

Vapors through Liquid (into/out of GW):

$$D_e = 0.000001 \text{ cm}^2/\text{sec}$$

$$\text{Distance} = (2 * 0.000001 * 31,000,000) = 8 \text{ cm/yr}$$

Transport in Vadose Zone 100 times faster than in GW

Contaminant Partitioning

Groundwater to Soil Gas (Henry's Constant):

$$H = C_{sg}/C_w, \text{ so, } C_{sg} = C_w * H$$

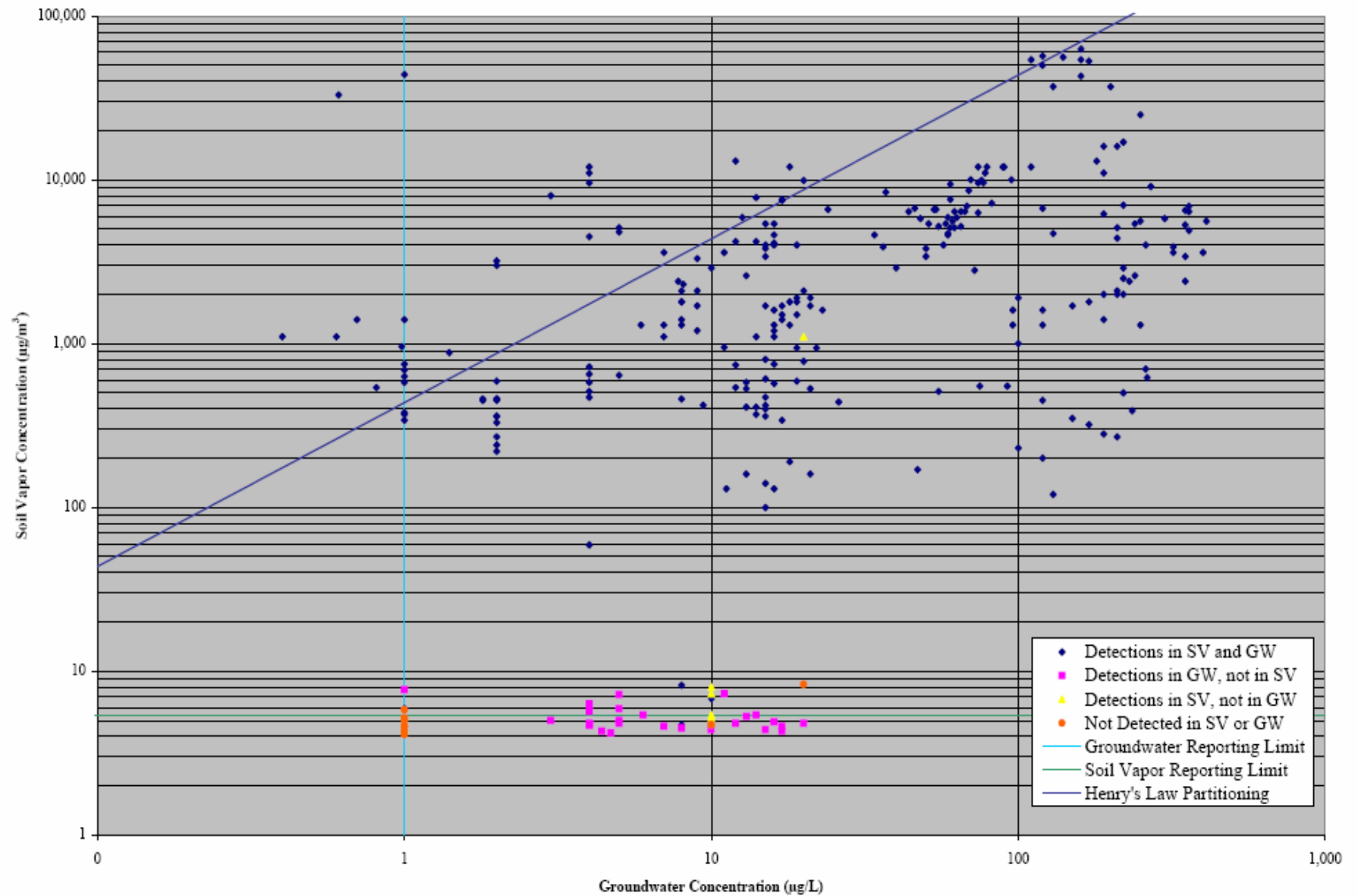
Example: $H_{\text{benzene}} = 0.25$ (dimensionless)

For GW Conc = 10 ug/L

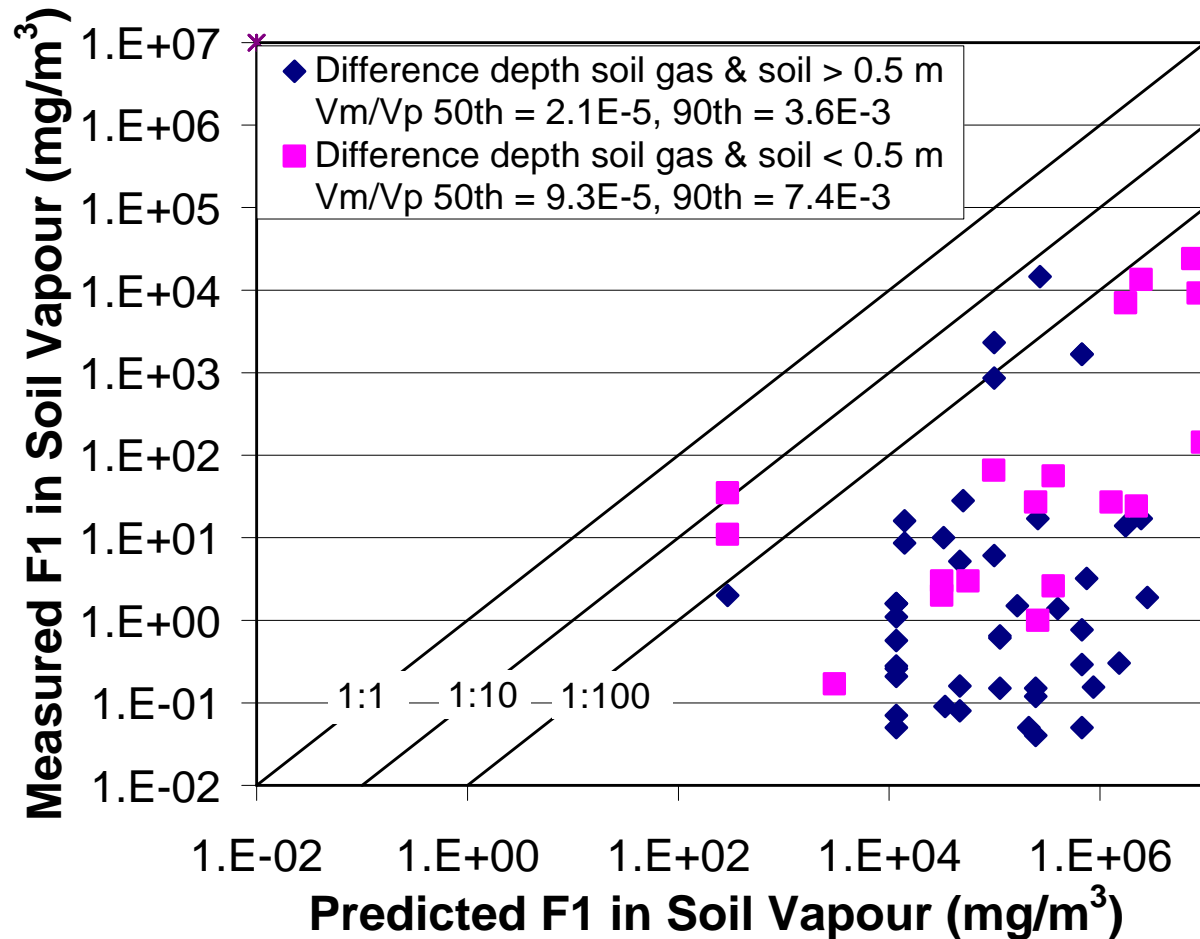
$$C_{sg} = 10 * 0.25 = 2.5 \text{ ug/L}$$

**Assumes Equilibrium. Very Rarely Achieved
(no mixers or blenders in the subsurface)**

Figure 2
TCE in Water Table Depth Soil Vapor and Groundwater
 Quarterly Report - Soil Vapor Monitoring
 Comprehensive Operations, Maintenance, & Monitoring Program
 Endicott, New York



Measured Soil Gas Data vs. Predicted from Soil Phase Data



CPPI Database

.005

**Key
point:**

Measured vapor concentrations 10 to 1000x less than predicted

Attenuation (alpha) Factors

$$\alpha_{sg} = C_{indoor}/C_{sg}$$

$$\alpha_{gw} = C_{indoor}/(C_{gw} * H)$$

- Lower alpha means higher attenuation
- Current VI guidances:
 - EPA $\alpha_{sg} = 0.002$ for 5', 0.1 for sub-slab
 - CA $\alpha_{sg} = 0.002$ for 5', 0.01 for sub-slab
 - NY State Data Shows $\alpha_{sg} < 0.01$
 - Hydrocarbon α_{sg} likely < 0.0001

Figure 3a- DRAFT
Vapor Attenuation Factors - Soil Vapor to Indoor Air Pathway
Basement Foundations

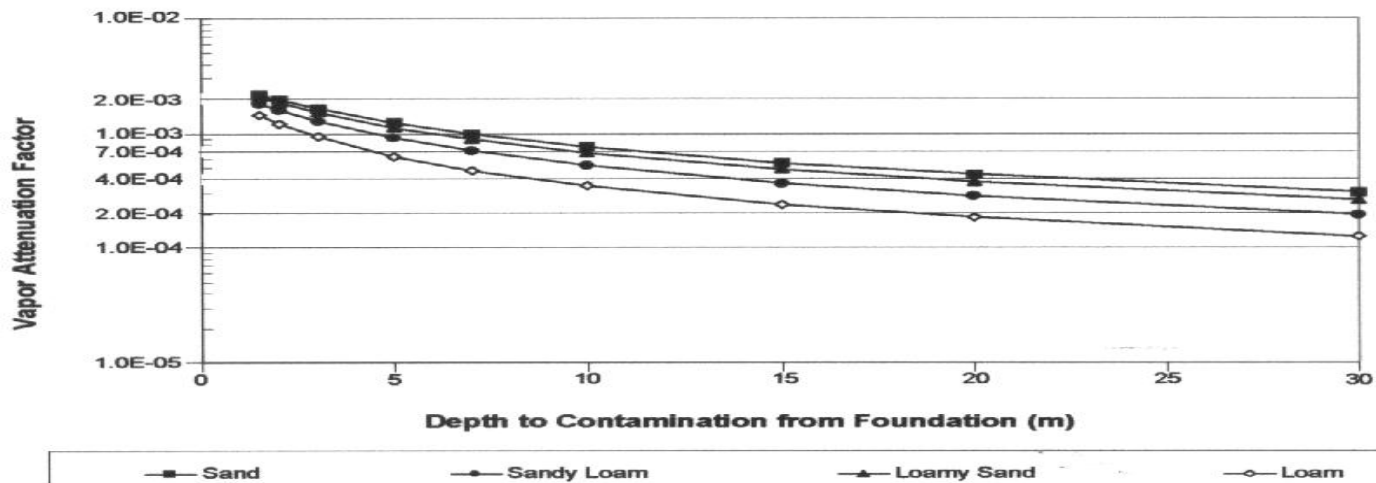
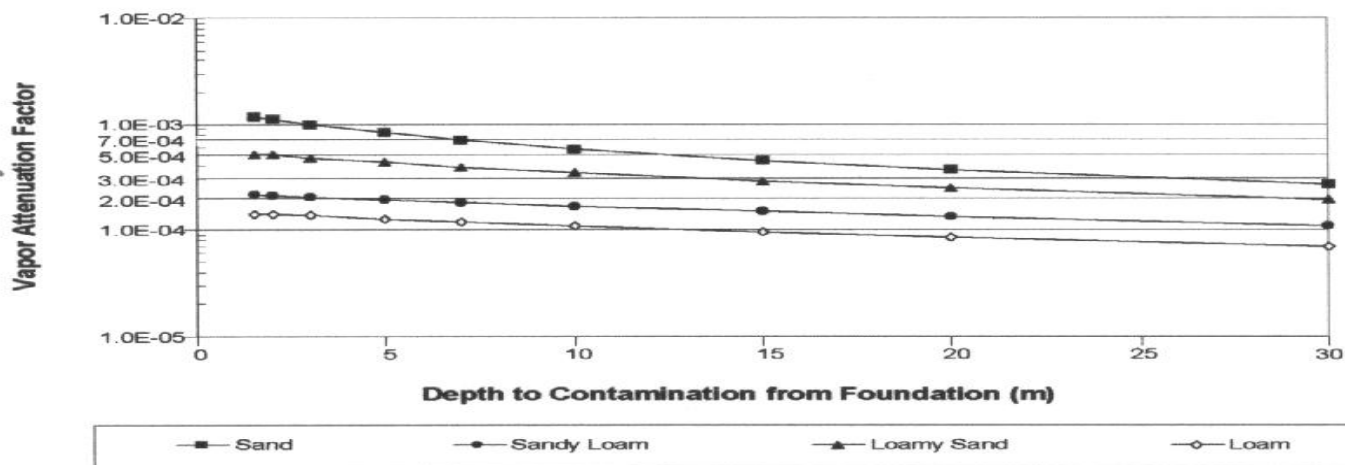


Figure 3b- DRAFT
Vapor Attenuation Factors - Ground Water to Indoor Air Pathway
Basement Foundations



Johnson and Ettinger Model

$$\alpha = \frac{C_{indoor}}{C_{vs}} = \frac{\left[\frac{D_T^{eff} A_B}{Q_B L_T} \right] \exp\left(\frac{Q_{soil} L_{crack}}{D_{crack}^{eff} \eta A_B} \right)}{\exp\left(\frac{Q_{soil} L_{crack}}{D_{crack}^{eff} \eta A_B} \right) + \left[\frac{D_T^{eff} A_B}{Q_B L_T} \right] + \left[\frac{D_T^{eff} A_B}{Q_{soil} L_T} \right] \left(\exp\left(\frac{Q_{soil} L_{crack}}{D_{crack}^{eff} \eta A_B} \right) - 1 \right)}$$

D_T^{eff} = "overall" effective diffusion coefficient [cm²/s]

D_{crack}^{eff} = effective diffusion coefficient through cracks in foundation [cm²/s]

C_{vs} = vapor concentration at the source [g/cm³]

C_{indoor} = indoor air concentration [g/cm³]

L_T = distance from source to basement [cm]

A_B = cross-sectional area of foundation available for vapor flux [cm²]

Q_{soil} = volumetric flow rate of soil gas into the building [cm³/s]

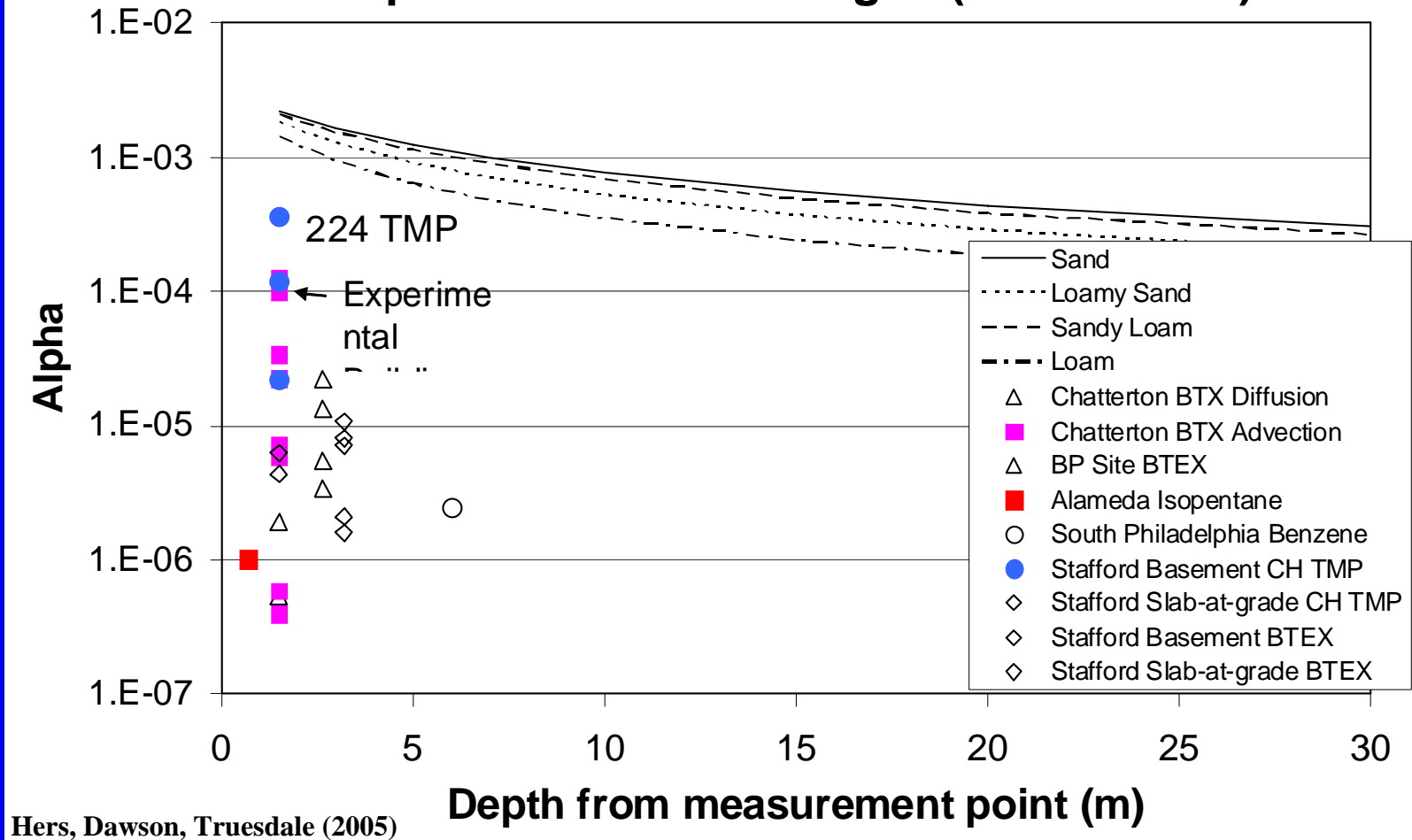
L_{crack} = thickness of the foundation [cm]

A_{crack} = area of cracks or openings through which vapors enter building [cm²]

Q_B = building ventilation rate [m³/s]

η = the "crack factor": A_{crack}/A_B so that $0 \leq \eta \leq 1$

Petroleum Hydrocarbon Site Soil Vapor Alpha Comparison to USEPA Fig. 3 (filtered data)



Measured attenuation factors for hydrocarbons can be orders of magnitude below “no-degradation” model predictions.

Using Alpha Factors to Calculate Screening Levels

For Soil Gas:

$$C_{sg} = C_{indoor} / \alpha_{sg}$$

For Groundwater:

$$C_{gw} = C_{indoor} / (H * \alpha_{gw})$$

Example: C_{in} benzene = 0.3 ug/m³

$$C_{sg} (5') = 0.3 / 0.002 = 150 \text{ ug/m}^3$$

$$C_{gw} = 0.3 / (0.20 * 0.0005) = 30 \text{ ug/L}$$

Acceptable Soil Gas Levels (Benzene 1e-6 Risk)

State	Alpha	1/Alpha	Fail Level (ug/m ³)
NH	0.002	500	150
CA-DTSC	0.002	500	42
CT	0.0013	770	192
NJ (Subslab)	0.05	200	60
EPA Q4	0.1	10	3.1
EPA Q5	0.002	500	155
EPA Q6	0.1	10	3.1

RISK 101:

Screening Levels

- RBSL: Risk Base Screening Level
- RBC (from ASTM): Risk Based Concentration
- CHHSL: CA Human Health Screening Level
- ESL (from SF RWQCB): Environmental Screening Levels

Need to Know When & How to Use

RISK 101:

Why Are Indoor Air RBSLs So Low?

- Benzene: EPA: 0.30 ug/m³
- TCE: EPA: 0.022 or 1.0 ug/m³
- PCE: EPA: 0.41 ug/m³
- Values Assume Exposure Times of:
 - 24 hr, 350 days/yr, 30 years

Ultra Conservative Assumptions Lower Allowed Levels and Bring in More Sites

Reasonable Exposure Times?

(Benzene $1e-6$ risk, 5' deep SG sample)

Agency	Residential	Workplace	Ratio
OEHHA	36	61*	1.7
DTSC	42	84	2
SF ESLs	85	145*	1.7

* Corrected for ventilation rate

Note: Ratio Should be 5

Screen Out More Sites By:

- Using Correct Risk Level
 - 1 in 1 million: Residences, Schools, Hosp
 - 1 in 100,000: Commercial Settings (cumulative)
 - 1 in 10,000: Mitigation Required
- Adopting More Realistic Exposure Times
 - Workplace: 8 hrs/day, 250 days/yr, 25 yrs (5x)
 - School: 8 hrs/day, 180 days/yr, 6 yrs (30x)
- Accounting for Bioattenuation