ADVANCEMENTS IN QUANTITATIVE PASSIVE SOIL GAS SAMPLING

Presented by

Presented by: Lowell Kessel, Co-Author: Harry O'Neill

Session F: March 24, 2022, 1PM

24th California Unified Program
Annual Training Virtual Conference
March 22, 23, 24, 29, 30, 31 - 2022

www.calcupa.org

1

Outline

- Introductions
- Passive Sampling and Indoor Air Regulatory Guidance
- Vapor Intrusion Challenges we all deal with and why Passive is Preferred
- Common challenges for soil gas sampling
  - Influence of geological and evapotranspiration conditions
  - Advection and diffusion in typical soil gas investigations
- Soil gas regulatory guidance and sampling methodology concerns
- Spatial variability during soil gas investigations
- Case studies
- Advancements in Passive Sampling

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

2

NELAP and DoD Accredited Laboratory

Beacon is a specialized laboratory focused on providing highly accurate air and soil vapor data.

PJLA
Testing
DoD ELAP

Accredited in accordance with:

ISO/IEC 17025:2017
U.S. DoD Environmental Laboratory Accreditation Program (ELAP)
National Environmental Laboratory Accreditation Program (NELAP)

Accredited Analytical Methods:

U.S. EPA Methods 8260C, TO-17, TO-15, and 325B

Beacon's Quality System ensures consistent and reliable results.

ASTM INTERNATIONAL

Lead Author in development of ASTM Standard D7758:
Passive Soil Gas Sampling in the Vadose Zone

CALIFORNIA CUPA FORUM

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

3

Field Sampling Accreditation

Beacon is a specialized laboratory that offers our services through easy-to-use test kits.

PJLA
Field Sampling & Measurement Organization

Accredited in accordance with:

THE NELAC INSTITUTE

The NELAC Institute National Environmental Field Activities Program (NEFAP) For Environmental Field Sampling of Air and Emissions

Beacon was the first company to receive NEFAP accreditation, and it is for the preparation of Sampling Kits and the collection of indoor air, ambient air, and soil gas samples using sorbent samplers

CALIFORNIA CUPA FORUM

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

4

Passive Samplers – Principles of Operation

$$J = -D\frac{dC}{dx}$$

For application of Fick's First Law to a diffusive sampler several simplifying assumptions are necessary:

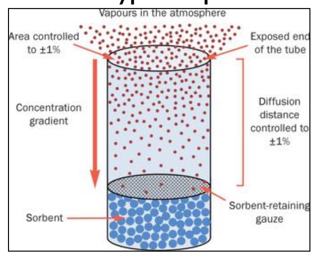
Ambient concentration of the analyte is present at the surface of the monitor (C_{amb}); it's important that the sampler does not take matter from its surrounding environment faster than it can be replenished.

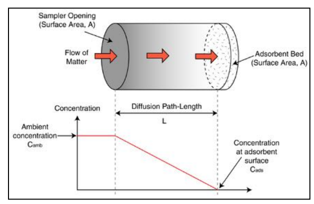
Zero concentration of the analyte at the surface of the sorbent; the adsorbent is a zero sink and therefore there is no saturation of the adsorbent ($C_{ads} = 0$)

There is a linear concentration gradient between the two.

Steady state conditions always exist.

Axial type samplers





Source: Markes International

24th California Unified Program Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

5

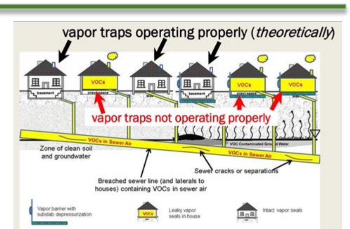
Applications of Passive Vapor Sampling

Indoor Air

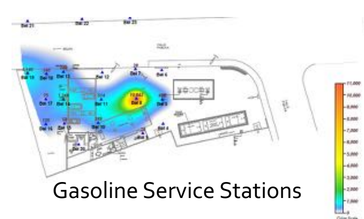
- Quantify indoor and ambient air concentrations (VI)
- Sewer line monitoring (VI and Source delineation)
- Health and Safety Compliance and Perimeter monitoring at
  - Excavation and remediation sites (reduced sampling)
  - Refineries (EPA method 325)

Soil Gas

- Sample soil gas to assess whether VI risks present (VI and CSM)
- Quantify soil gas and subslab concentrations (VI and CSM)
- High Resolution investigations (Source areas and GW plumes)
- Improve conceptual site model (reduce or fill in the data gaps)



Source: Dr. Kelly Pennell, University of KY
Considerations For Evaluating Alternative Pathways As Part Of Vapor Intrusion Assessments, AEHS 2018

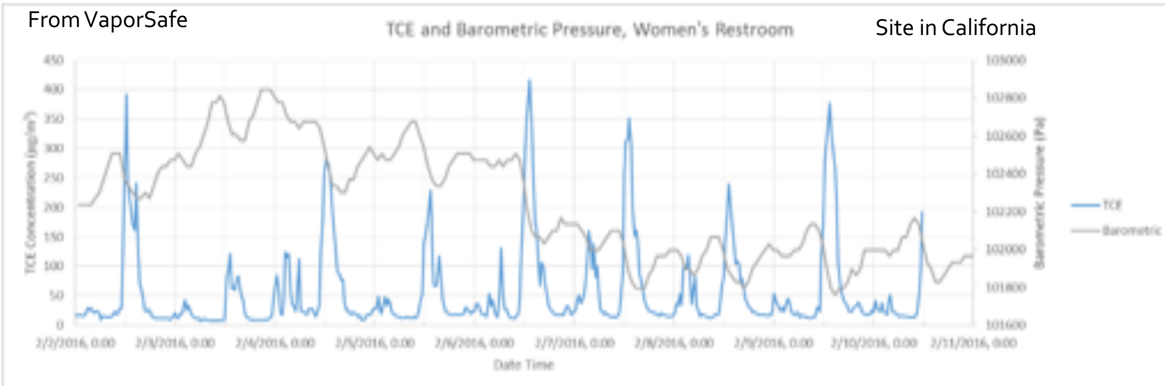


Gasoline Service Stations

24th California Unified Program Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

6

Temporal Variability Causes VI Challenges



- Pressure change: 1,000 Pascal=4 inches H2O
- Orders of magnitude change within hours randomly occurring.

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

7

Excerpts from Draft 2020 DTSC VI Guidance

3B.1 – Indoor Air: Sampling Method

Indoor air samples should be collected in accordance with the VIG (DTSC, 2011a), except where this Supplemental Guidance supersedes (e.g., locations and numbers of samples and sampling events). If the subsurface contamination is well characterized, consider limiting the analyte list to the known subsurface VFCs.

Time-integrated, rather than "grab" sampling methods are preferred for sampling indoor air to better characterize the average daily inhalation exposure for building occupants. Expedited turnaround times for laboratory analyses may be appropriate given the priority (Step 1) and subsurface threat level (Step 2 or existing information). Typical sampling methods include:

- Conventional sampling methods (e.g., canisters) have sampling durations of 24 hours for residential exposure and eight hours for workplace exposure.
- Passive air sampling technology has advanced and should be considered for quantitative, time-integrated indoor air sampling over longer periods.[8] Appropriate use of passive samplers requires knowledge of the target chemicals, sorbent capabilities, and required detection limits. Passive samplers may not be suitable for all situations or chemicals (e.g., high moisture or poor chemical sorption). The analytical laboratory should be consulted when developing the sampling plan to ensure appropriate samplers are selected to meet data quality objectives. More information on passive samplers is presented in USEPA guidance (USEPA, 2015a).

8

Excerpts from Draft 2020 DTSC VI Guidance

Step 3D – Evaluate Temporal Variability

The goal of Step 3D is to understand the variability of indoor air contamination over time to ensure that risks are not underestimated.

[10] The recommendation for three samples assumes 24-hour Summa canisters are used. If passive samplers are deployed for two-week periods, a total of two events can be considered adequate. Similarly, high frequency, real-time sampling may be used as an alternate approach to address the goal of evaluating short-term temporal variability.

Public Draft - Supplemental Guidance: Screening and Evaluating Vapor Intrusion February 2020

Attachment 2 – Sewers and Other Vapor Conduits as Preferential Pathways for Vapor Intrusion

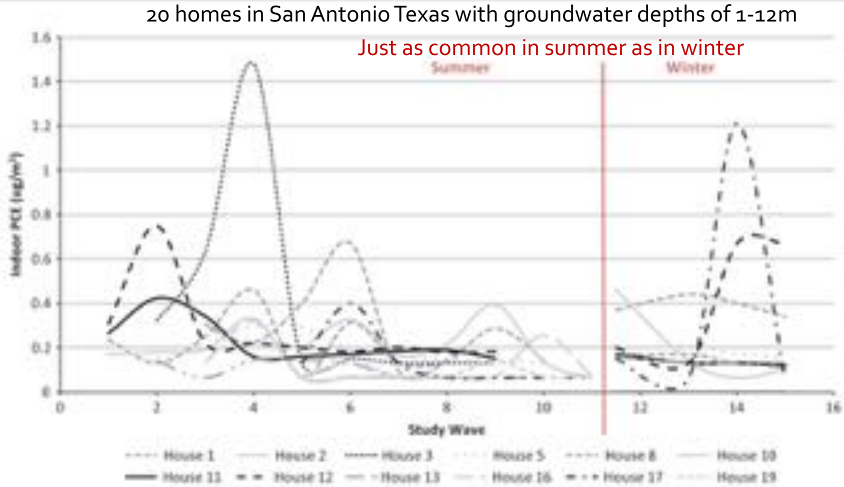
Passive Sampling

To provide an estimate of the average concentration over time, both street sewers and building cleanouts can be evaluated with passive air sampling devices. As discussed in Step 3B of this Supplemental Guidance, an appropriate evaluation of passive sampler efficacy should be performed before implementing a sampling program. The devices should be deployed in the middle of the maintenance hole or cleanout pipe, not contacting the maintenance hole or cleanout pipe walls, and maintenance holes and cleanouts should be covered with their lids to alleviate ambient air influences.

9

Seasonal Indoor Air Variability in Multiple Homes

20 homes in San Antonio Texas with groundwater depths of 1-12m



Key Takeaway: Magnitude and timing of episodic events are unpredictable

Source: Jill E. Johnston and Jacqueline MacDonald Gibson, 2014, Spatiotemporal variability of tetrachloroethylene in residential indoor air due to vapor intrusion: a longitudinal, community-based study, Journal of Exposure Science and Environmental Epidemiology, 564-871

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

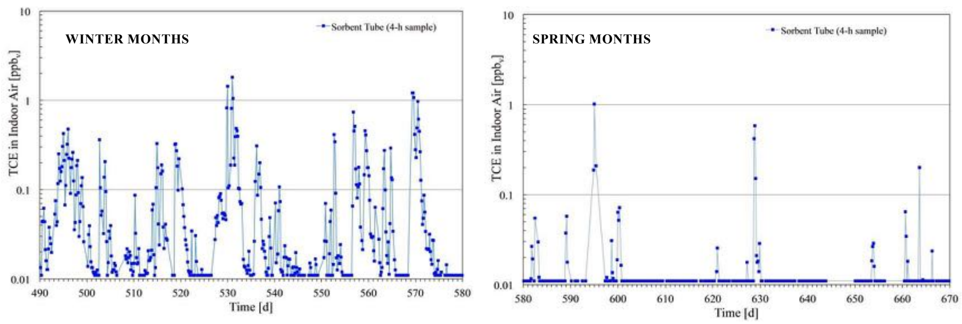
10

Dr. Paul Johnson Study House above Plume

Temporal Variability study by Dr. Paul Johnson

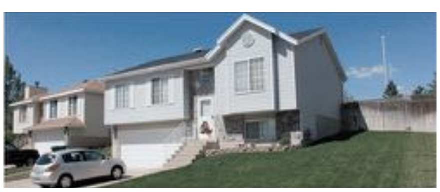
Indoor air concentrations can vary daily by orders of magnitude

Vapor intrusion has shown to be episodic – anomalous events occur



Source: Johnson, P. Multi-Year Monitoring of a House Overlying a Dilute Chlorinated Hydrocarbon Plume: Implications for Vapor Intrusion Pathway Assessment. SERDP & ESTCP Webinar Series, 2014.

Dr. Paul Johnson Controlled Study
23 and 52 day TWA vs 24hr sampling



Dr. Paul Johnson Study House:
Time-integrated passive samples collected over 20+ days vs. daily average samples

- Time-Integrated Beacon Passive Samplers compared to Daily 24-hour average measurements
- Daily 24 hour samples collected on sorbent tubes with pump (EPA Method TO-17)
- Time-integrated samples collected over multiple days using **Beacon Passive Soil Gas Samplers in Steady State** (Analysis by EPA Method TO-17)

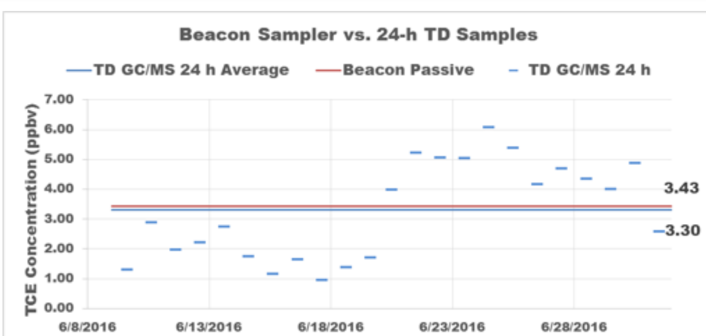
Study Set-Up

- Beacon Passive Samplers were collected in triplicate; exposed for the duration of the sampling periods
- Pumped samples were collected at a flow rate of 10 ml/min with a total volume of 14.4 L per day
  - Average concentrations were calculated from multiple 24hr day results

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

13

23 Days vs 24 hr Results



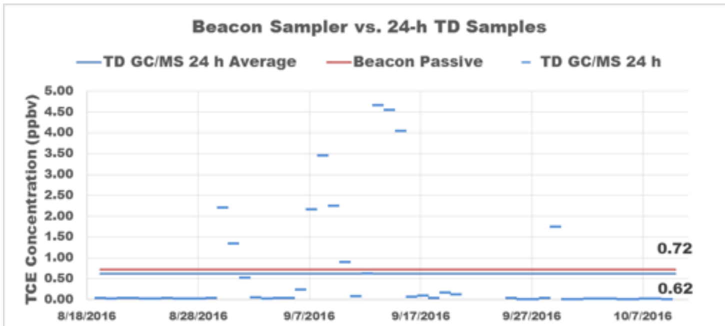
Average Concentrations = RPD of 4%
Daily 24-Hour Measurements (Method TO-17) = 3.30 ppbv
23-Day Time-Integrated Measurement with Beacon Sampler = 3.43 ppbv

Data Source: Arizona State Univ. Study House
Drs. Paul Johnson, Paul Dahlen, Yuanming Guo

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

14

52 Days vs 24 hr Results



Average Concentrations = RPD of 14%
Daily 24-Hour Measurements (Method TO-17) = 0.62 ppbv
52-Day Time-Integrated Measurement with Beacon Sampler = 0.72 ppbv

Data Source: Arizona State Univ. Study House
Drs. Paul Johnson, Paul Dahlen, Yuanming Guo

CALIFORNIA CUPA FORUM

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

15

Analysis of Precision of Beacon Passive Samplers

Beacon Samples Collected in Triplicate

Analysis of Trichloroethene (TCE) Results

Sampling Event	Sampling Days	B-X-01 ppbv	B-X-02 ppbv	B-X-03 ppbv	Average ppbv	Standard Deviation	Coefficient of Variation
1	26	1.41	1.22	1.24	1.29	0.10	0.08
2	23	3.73	3.33	3.22	3.43	0.27	0.08
3	20	3.11	2.84	3.16	3.04	0.17	0.06
4	30	1.95	1.73	1.89	1.86	0.11	0.06
5	52	0.78	0.74	0.63	0.72	0.08	0.11
6	20	1.09	1.28	1.01	1.13	0.14	0.12
7	7	2.39	2.2	1.77	2.12	0.32	0.15
8	7	0.8	0.7	0.78	0.76	0.05	0.07
9	6	0.99	1.03	0.86	0.96	0.09	0.09
10	30	U	U	U			
11	43	0.42	0.25	0.33	0.33	0.09	0.26
12	35	0.41	0.44	0.42	0.42	0.02	0.04
13	36	0.32	0.31	0.34	0.32	0.02	0.05
						AVERAGE	**0.10**

The Coefficient of Variation (CV) measures precision /variability and is the (StndDev/Mean)*100

Data Source: Arizona State Univ. Study House
Drs. Paul Johnson, Paul Dahlen, Yuanming Guo

CALIFORNIA CUPA FORUM

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

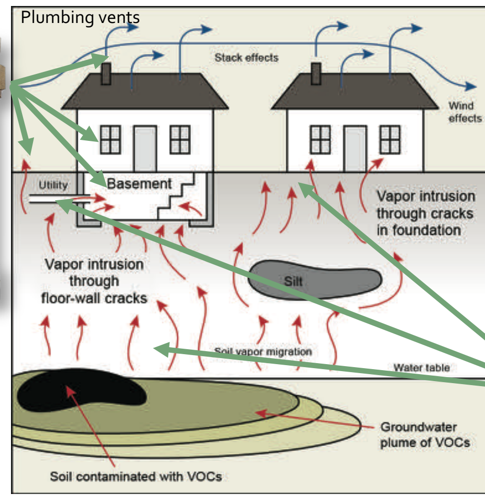
16

Sampling for Vapor Intrusion Studies

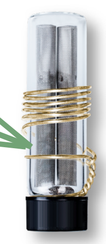
Where can vapor samples be taken?

The intrusion of pollutants into the vapor phase in buildings presents significant health risks.

Route of exposure: people breathe an average of 10,000 L of air per day.



Graphic: U.S. EPA



Easy to deploy and collect in numerous applications

Easy to operate reduces operator error

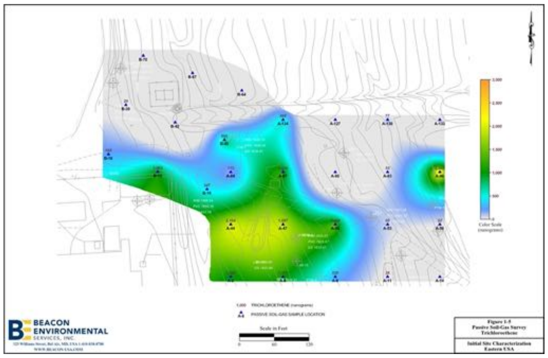
Easy to replicate from one event to the next

Challenges for Traditional Soil Gas Sampling

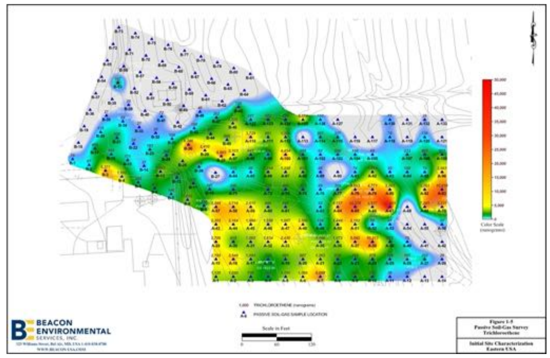
- Spatial Variability and High Resolution Site Characterization
  - Heterogeneity in vadose zone soil properties
    - Silty and clayey soils!
  - Contaminant distribution (e.g. near source or plume)
  - Ground cover (e.g. concrete, asphalt, dirt, grass)
- Temporal Variability from Meteorological Influences
  - Barometric pumping
  - Rain & irrigation > increased soil moisture
  - Groundwater table fluctuations
- Mechanical Limitations of Sampler devices
  - High humidity –high moisture soil conditions (e.g. perched water table, rain, irrigation)
  - High vacuum –clayey soil conditions

Why is collecting high resolution data important?

Sampling Grid with 90 foot spacing



Sampling Grid with 30 foot spacing



What might be causing some of the variability?

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

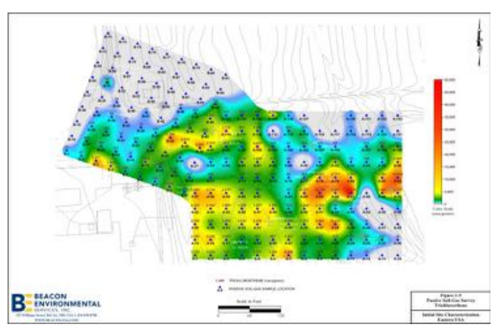
19

Benefits of HRSC with Soil Gas Surveys

HRSC data may allow you to overcome the challenges of SPATIAL VARIABILITY of subsurface contamination

Recommendations for Soil Gas Surveys:

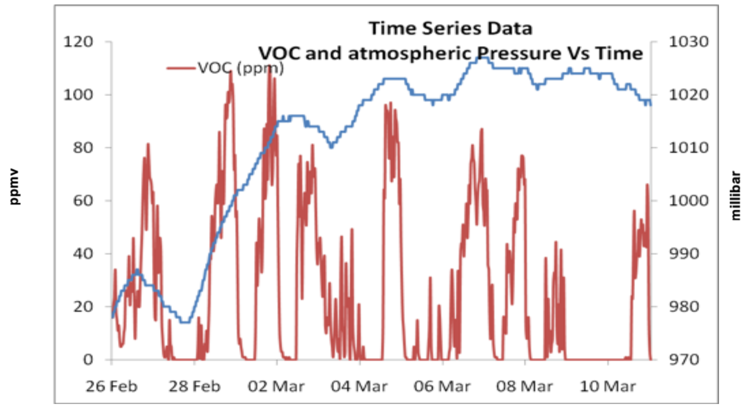
- **Maximize the number of locations that can be sampled**
  - **Reduce uncertainty, surprises, and unforeseen costs**
  - **Make well-informed and appropriate corrective action decisions**
  - **Lowers cost to develop accurate CSM**



24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

20

Temporal Variability of VOCs in Soil Gas



No surface cap effects.

Soil gas concentrations can change daily and even hourly at the same location.

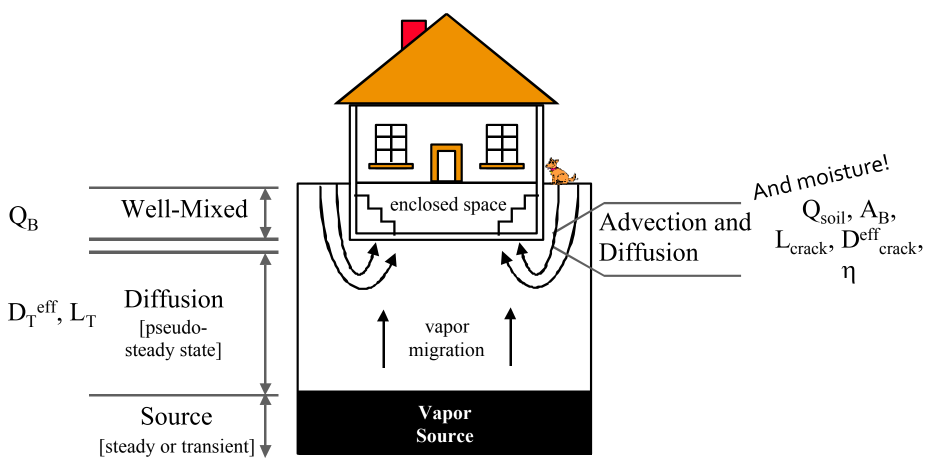
Chart courtesy of Ion Science

CALIFORNIA CUPA FORUM

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

21

Soil Gas Conceptual Site Model



From Johnson, 2002 (API)

CALIFORNIA CUPA FORUM

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

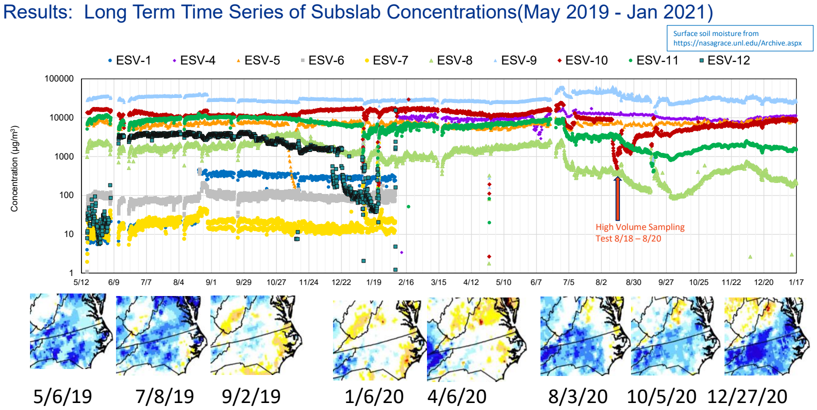
22

Temporal Variability in Subslab Data

Question: What is the role of evapotranspiration in this North Carolina region?

Results: Long Term Time Series of Subslab Concentrations(May 2019 - Jan 2021)

Daily to Weekly Sub-slab Soil Gas Temporal Variability



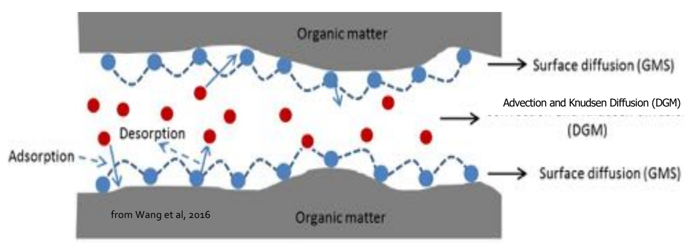
Key Point: Subslab concentrations display a small amount of temporal variability over long periods (CV 0.2 to 0.7), exceptions are gradual weeks long processes.

Source: AEHS 2021, Inter-comparison of multiple subslab sampling strategies-Defining temporal and spatial variability for vapor intrusion, Lutes, C., et al. 2021)

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

23

Soil Gas Diffusion



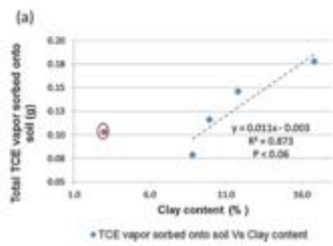
- Diffusion
  - Moisture (Henry's constant and Kow)
  - Soil properties (Organic content and clay content)
- Advection
  - Soil structure (porosity, soil pore tortuosity, fractures, soil type)
  - External influences driving convection
    - Pressure/vacuum
    - Flow

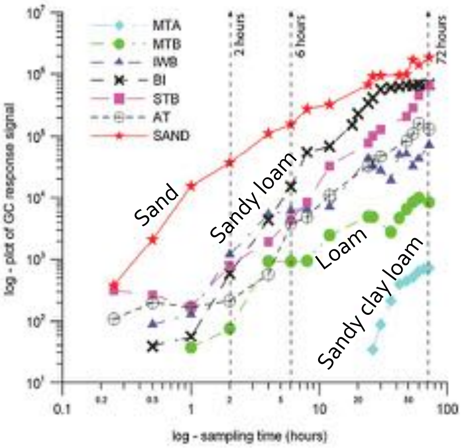
24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

24

Got Clay?

- Packed soil column study to evaluate diffusion rates to establish equilibrium conditions
- Sorption limitations apply
- 72 hrs required to achieve equilibrium conditions





Source: Influence of soil properties on vapor-phase sorption of trichloroethylene, Dawit N. Bekelea, b, Ravi Naidua, Sreenivasulu Chadalavada, Journal of Hazardous Materials 306 (2016) 34–40

Fig. 2. Trichloroethylene vapor emission rate at top headspace of soil column.

Soil Gas Models and Moisture Conditions

Millington-Quirk Model (1961)

- Calculates the effective diffusion coefficient across the capillary fringe where high moisture conditions prevail (EPA, J&E Model, V6, 2017).
- Defines conditions VOC diffusion under Steady-State inclusive of water moisture McAlary et al (2014).

Effective molecular diffusion coefficient

inclusive of Millington-Quirk for gas and water phases

Utilized in Johnson and Ettinger and EPA VI models

$$D^{eff} = D^{air}\frac{\theta_V^{3.33}}{\theta_T^2} + \left(\frac{D^{H2O}}{H_i}\right)\frac{\theta_m^{3.33}}{\theta_T^2}$$

where:

H_i = the chemical-specific Henry's Law constant [(ug/m^3-vapor)/(ug/m^3-H_2O)]
θ_m = the volumetric moisture content [m^3-H_2O/m^3-soil]
θ_T = the total porosity [m^3-voids/m^3-soil]
θ_V = the volumetric vapor content (=$\theta_T - \theta_m$) [m^3-vapor/m^3-soil]
D^{air} = the chemical-specific molecular diffusion coefficient in air [m^2/d]
D^{H2O} = the chemical-specific molecular diffusion coefficient in water [m^2/d]

High Moisture Conditions May Bias Results

- Wet season Sampling: Active soil gas sampling study
- Comparison of Flow/specific capacity from dry to wet season reveals reduction in flow.
- Impact to Sampling by Active Soil Gas Method:
  - Reduced flow rate during sampling.
  - Increased vacuum occurred during sampling.
- Conclusions:
  - Shallow soils more susceptible to moisture/rain.
  - Diffusion limitations are more pronounced with increased moisture.
  - Active soil gas sampling may provide non-steady state results.

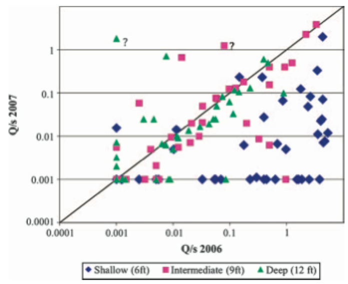


Figure 4. Comparison of Q/s values from October 2006 and June 2007.

From McAlary et al, 2009, A Case Study of Soil-Gas Sampling in Silt and Clay-Rich (Low-Permeability) Soils

27

Impacts of Rainfall on Soil Gas Concentrations

Rainfall
- Infiltration into vadose zone
- Contribution to groundwater
- Clean water lense

Potential Impacts
- Reduction in diffusion and advection
- Dilution of GW conc.
- Capping

Source: A numerical investigation of vapor intrusion — The dynamic response of contaminant vapors to rainfall events, Rui Shen *, Kelly G. Pennell 1, Eric M. Suuberg, Science of the Total Environment 437 (2012) 110–120

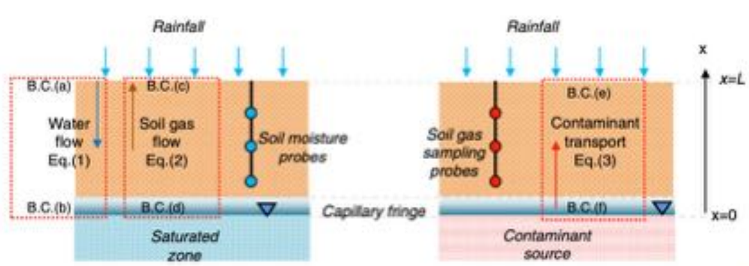


Fig. 1. The modeling scenario. Left panel: water-soil gas flow; right panel: contaminant transport. The equations and boundary conditions are in Table 1.

28

Are Changes in Groundwater Elevation Significant?

"As gas-filled porosity θ_g decreases with the increase of water-filled porosity θ_w, so does the time required for steady state conditions to be reestablished."

α = c/c$_{source}$
IA/SG Concentration Attenuation coefficient

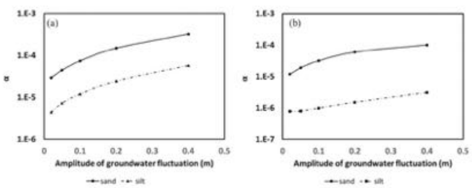


Fig. 8. Pollutant concentration attenuation coefficients with different groundwater fluctuation amplitudes for cases involving (a) basement and (b) slab-on-grade

α = c/c$_{source}$
IA/SG Concentration Attenuation coefficient

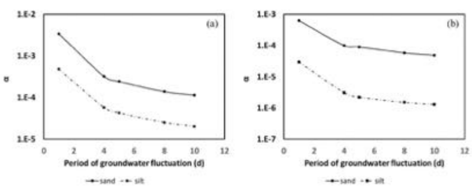


Fig. 9. Pollutant concentration attenuation coefficients with different groundwater fluctuation periods for cases involving (a) basement and (b) slab-on-grade.

Key Points:

- 0.1m change significant impact to AC
- Days to weeks for equilibrium to reestablish

Source: Investigating the role of vadose zone breathing in vapor intrusion from contaminated groundwater, Jun Man, Genfu Wang, Qiang Chen, Yijun Yao, Journal of Hazardous Materials 416 (2021) 126272

Understanding Soil Gas Models and Pressure

Change in pressure

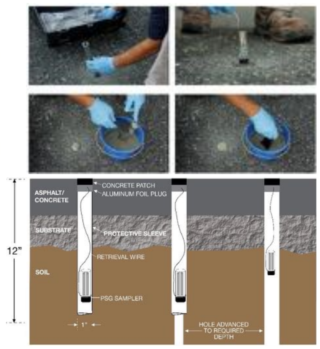
$$\underbrace{\frac{P}{RT}\nabla x_i}_{\text{Pressure gradient}} + \underbrace{\frac{x_i}{RT}\left(1+\frac{B_0 P}{\mu D_{iK}^e}\right)}_{\text{Advection}}\nabla P = \underbrace{\sum_{\substack{j=1\\ j\neq i}}^{n}\frac{x_i N_j - x_j N_i}{D_{i,j}^e}}_{\text{molecular diffusion}} - \underbrace{\frac{N_i}{D_{iK}^e}}_{\text{Knudsen diffusion}}$$

A complete view includes diffusive and advective flux of VOCs and Knudsen diffusion (occurs when gas mean free path is greater than pore radius: silty, clayey and organic materials).

Soil Gas Sampling Methods

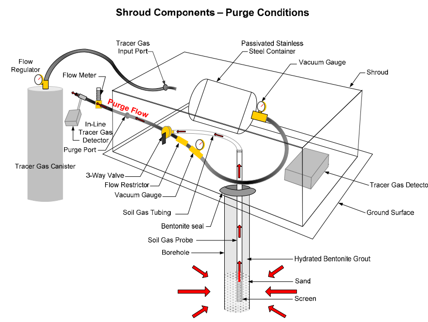
Passive Soil Gas (8260 or TO-17 ug/m3)

Utilizes tubes (subslab, 5ft, or deeper) containing an adsorbent material, placed in the ground and allowed to adsorb VOCs for hours to weeks under steady-state conditions.



Active Soil Gas (TO-15 ug/m3)

Extraction of soil **vapor sample** from a temporary or permanent probe inserted in the **soil** into a analytical device.



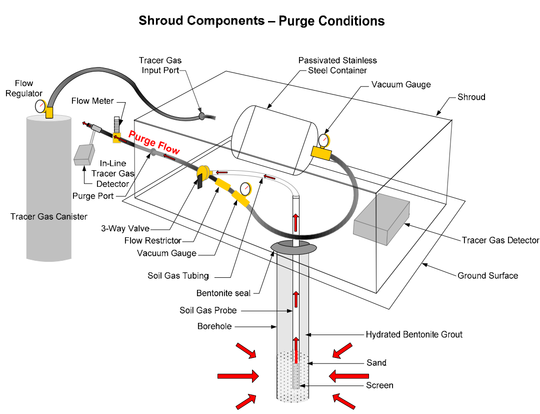
From DTSC April 2012 Active Soil Gas Advisory

CALIFORNIA CUPA FORUM

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

31

Active Soil Gas Sampling Methods



From California DTSC April 2012 Active Soil Gas Advisory

Active Soil Gas (TO-15 ug/m3)

- Extraction of soil **vapor sample** into an analytical device from a temporary or permanent probe inserted in the **soil**. Vacuum is applied.

CALIFORNIA CUPA FORUM

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

32

Active Soil Gas Sampling– Principles of Operation

Source: DTSC Active Soil Gas Advisory, 2012

- Install soil vapor probes and allow equilibrium conditions to establish. From 2 hours to weeks depending on installation method. How determined? Time series data collection and evaluation.
- Shut in test, leak test, purge volume test (10 volumes!) and retest if needed.
- Sampling sandy soils: Flow rate 100-200ml/min and max vacuums of 100 inH2O
- Sampling low permeability soils:
  - A) Repeat multiple iterations of purging and sampling under conditions of flow rate 100-200ml/min and max vacuum of 100 inH2O.
  - B) Install new well with larger sand pack zone and smaller diameter probe/tube
  - C) Perform passive soil gas sampling

CALIFORNIA CUPA FORUM

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

33

DTSC defines Steady State as…

California DTSC 2012 VI Guidance states:

- Appendix D page D-2: The occurrence of steady-state conditions is defined as less than a 130 pascal pressure change within 30 minutes.
- 130 pascal = 0.522 in H2O

However, active soil gas sampling in fine grained soils is done at 100 in H2O= 24,884 pascal!

Therefore active soil gas sampling is nowhere near conforming to steady-state conditions.

Question: If atmospheric changes ranging from 1 to 15 in H2O, result in change in VOC concentrations in soil gas. What does 100 in H2O do to soil gas concentrations?

Table 1
Expected Ranges of Flow and Vacuum

Soil Type	Flow (L/min)	Vacuum (in-H_2O)
Clean sand	1	0.5
Silty sand	1	5
Silt, loess	0.2	100
Glacial till	0.002	100
Marine clay	0.0001	100

From McAlary et al, 2009, A Case Study of Soil-Gas Sampling in Silt and Clay-Rich (Low-Permeability) Soils

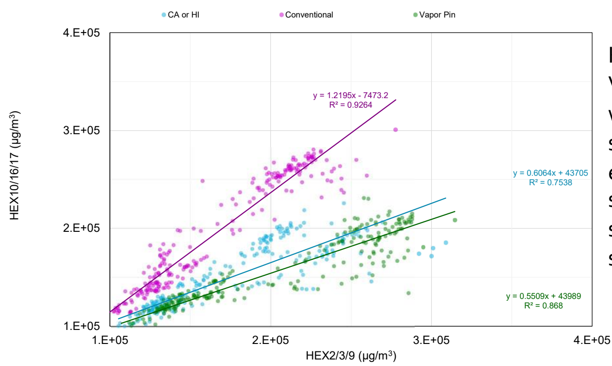
CALIFORNIA CUPA FORUM

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

34

Variability between active soil subslab sampling probes

Results: Agreement Between Pairs of Same Probe Type



Key Point: Variability exists with active soil gas sampling methods even when sampled at the same time in the same locations.

Primary Differences
- Depth >> moisture
- Flow rate>>pressure
- Sample Time
- Equipment complexity >> reduces precision

=Accuracy suffers

Source: AEHS 2021, Inter-comparison of multiple subslab sampling strategies-Defining temporal and spatial variability for vapor intrusion, Lutes, C, et al. 2021)

CALIFORNIA CUPA FORUM

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

35

Requirements for Steady State Soil Gas Sampling

Key Attributes Required for a Steady State Soil Gas Sampler
- Isobaric conditions- No vacuum.
- Extended Sampling Time
  - Temporal variability concerns.
  - Fine grained soil adsorption limitations.
  - Evapotranspiration/Hydrogeologic conditions

Key Attribute Required for any Soil Gas Sampler
- Works effectively without bias in high moisture conditions

CALIFORNIA CUPA FORUM

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

36

Beacon Passive Gas Samplers

- Actual size: 18 mm x 60 mm (0.7 x 2.4 inches)
- Hydrophobic Adsorbents
- Two types of adsorbents
- Two pairs of adsorbents for duplicates
- Uniform mass of adsorbents used (verified with analytical balance)
- Completely inert sampler
- Compliant with ASTM Standards D5314 and D7758
- Report Concentration Data (ug/m^3)

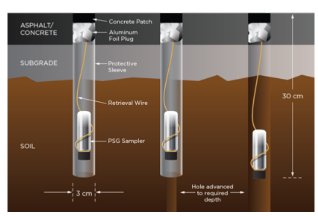
24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

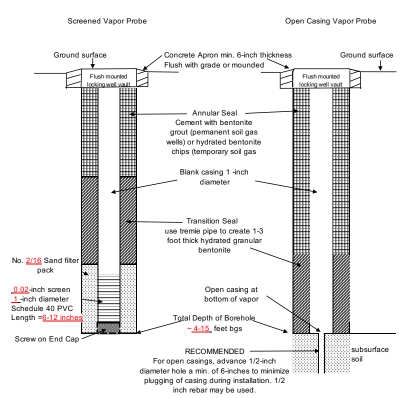
37

Passive Soil Gas Sampling Methods

Passive Soil Gas (TO-17 ug/m3)

- Utilizes tubes containing an adsorbent material, placed in the ground (subslab, 3-5ft, or deeper lengths) and allowed to adsorb VOCs for hours to weeks under steady-state conditions (no vacuum).





24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

38

Beacon Passive Sampler Uptake Rates and LODs

Longer Sampling Periods allow for:

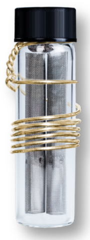
- Lower LODs
- Reduced influence of temporal variability
- Improved assessment of steady-state soil gas VOC concentrations

Example Sampling Periods Possible:

<24 hours

1-14 days

Longer Sampling Periods possible.



COMPOUND	Limits of Detection (ug/m^3)				
	1 Day	3 Days	7 Days	14 Days	26 Days
Vinyl Chloride	<4.29	<1.43	<0.61	<0.31	<0.16
1,1-Dichloroethene	<10.52	<3.51	<1.50	<0.75	<0.40
trans-1,2-Dichloroethene	<7.89	<2.63	<1.13	<0.56	<0.30
1,1-Dichloroethane	<4.08	<1.36	<0.58	<0.29	<0.16
cis-1,2-Dichloroethene	<6.55	<2.18	<0.94	<0.47	<0.25
1,2-Dichloroethane	<6.20	<2.07	<0.89	<0.44	<0.24
1,1,1-Trichloroethane	<3.31	<1.10	<0.47	<0.24	<0.13
Trichloroethene	<10.52	<3.51	<1.50	<0.75	<0.40
Tetrachloroethene	<8.47	<2.82	<1.21	<0.60	<0.33
Benzene	<13.10	<4.37	<1.87	<0.94	<0.50
Toluene	<17.36	<5.79	<2.48	<1.24	<0.67
Ethylbenzene	<8.17	<2.72	<1.17	<0.58	<0.31
Xylenes	<7.89	<2.63	<1.13	<0.56	<0.30

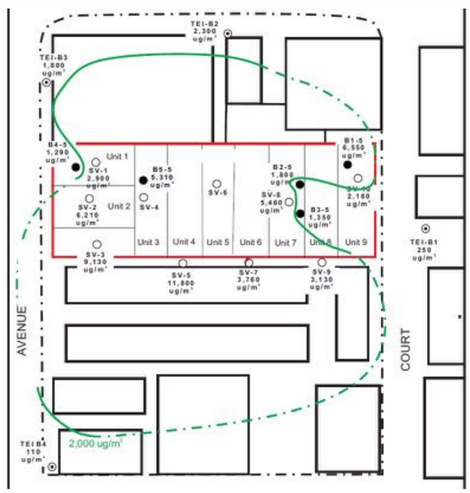
CALIFORNIA CUPA FORUM

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

39

Long Beach Dry Cleaner- Soil Vapor Sampling

Courtesy of MUREX environmental, inc

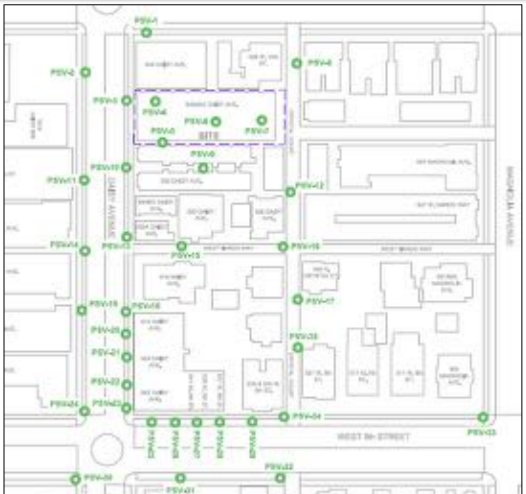


CALIFORNIA CUPA FORUM

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

40

Investigation of Critical Data Gaps- No known Source



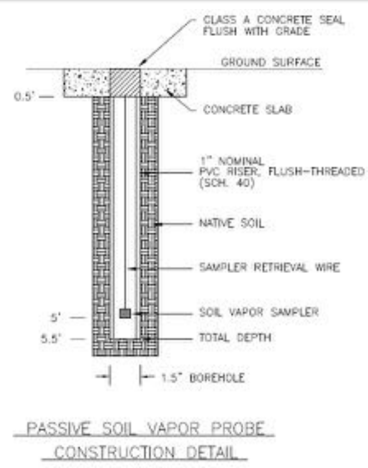
- Focus on *broader* area
- Search for the source(s)
- Include southern end of block, where historical dry cleaner was suspected
- Include alley where sewer main runs
- 35 PSV selected as best-fit HRSC approach

Courtesy of MUREX environmental, inc

24th California Unified Program Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

41

Deployment of PSV Samplers



Courtesy of MUREX environmental, inc

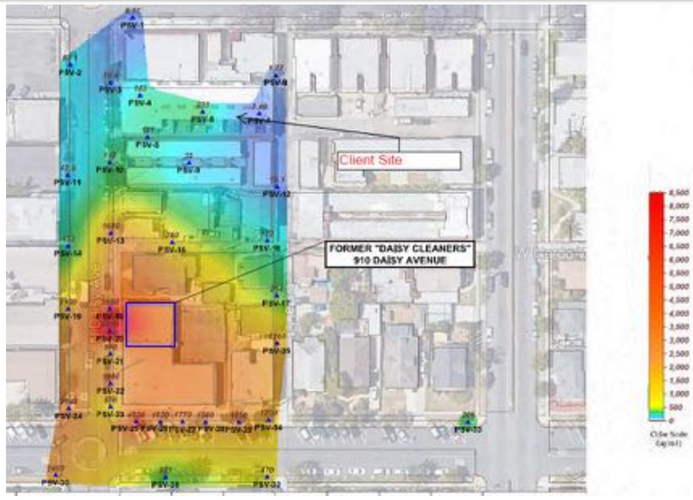
24th California Unified Program Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

42

Long Beach Investigation Findings

Key Takeaways of Strategy
- High resolution site characterization performed with passive soil gas sampling
- Factored in GW gradient for potential plume source
- Public right-of-way sampling
- Above/adjacent to sewer lines

Conclusions
- No source identified at Client Site.
- Prior Soil Vapor Extraction presumed to cause movement of off-site source to the north…exacerbating the problem.



Courtesy of MUREX environmental, inc

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

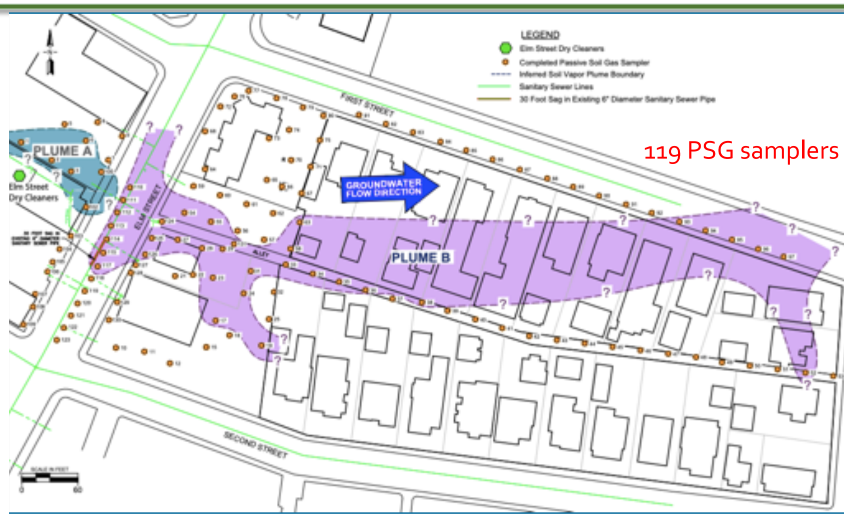
43

Dry Cleaner– Chlorinated Solvent Source and Plume

Northern California Site

Utilized Beacon PSG samplers to delineate two plumes related to chlorinated solvents across a residential neighborhood.

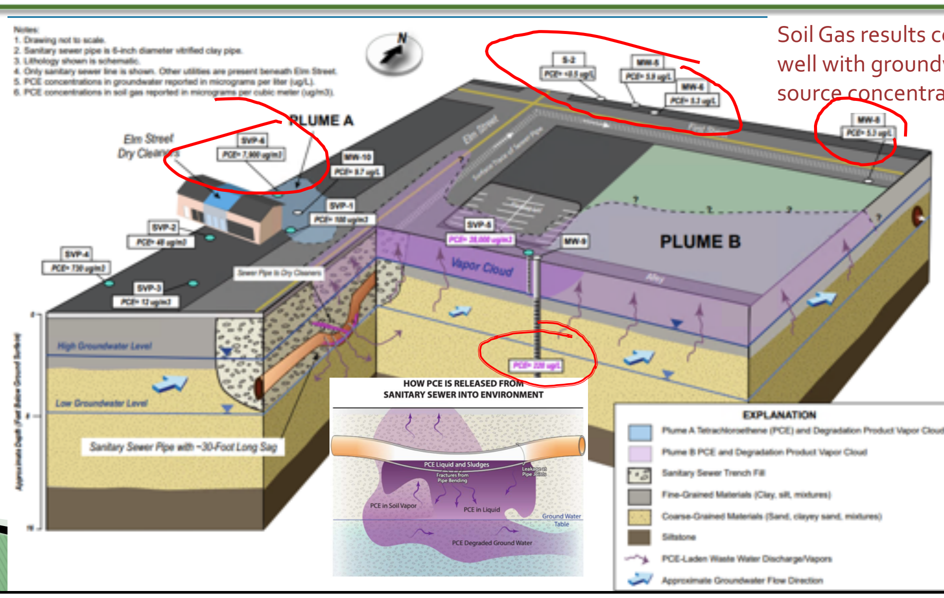
Benefits:
Low profile, public right of way Access, no lawyers for Access Agreements.



24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

44

Dry Cleaner– Chlorinated Solvent Source and Plume



Soil Gas results correlated well with groundwater source concentrations

45

Steady-State Sampling with Passive Soil Gas Samplers

Passive soil gas samplers allow for the steady-state collection of samples over hours, days or weeks to measure organic compounds in indoor air, ambient air, sewer lines, and soil gas. Data are reported as average concentrations collected over time and are more representative of both short- and long-term health risks.

- Adsorbent media is hydrophobic. Allowing for accurate sampling in high moisture environments.
- Passive soil gas samplers provide more accurate steady-state soil gas TWA data for risk assessments and site investigations
- Passive samplers are easy to use (quick installation and precise deployment)
- Sample periods range from hours to weeks
- No pumps or flow regulators required (minimal equipment or field errors)
- No risk of leaks, bypassing or sample dilution (no helium leak test required)
- State-of-the-art analytical procedures produce high quality data and low LODs
- No VOC carry-over issues. Thermal reconditioning of each sampler is performed at 20C higher than testing procedures before each deployment.
- Batch and individual certification.

24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

46

Quality Data = Better Decisions = Better Results

- Analysis by thermal desorption-gas chromatography/mass spectrometry (TD-GC/MS) following EPA Method 8260C, TO-17, or TO-15
- Analytical results based on 5-point initial calibration
- Internal standards and surrogates included with each analysis
- Daily continuing calibration checks
- Laboratory control samples
- System daily tunes
- Method blanks
- Method Detection Limit (MDL) Studies
- Limit of Detection and Quantitation (LOD and LOQ) Studies
- Meets requirements of Level III/Level IV data quality objectives

TD-GC/MS

Regulatory Status and Adoption

Quantitative Passive Soil Gas (QPSG) Time-Weighted Average data is being reported for projects:

- MANY California Sites have employed QPSG sampling with concentrations reported in ug/m3 with regulatory acceptance
- Many DTSC orphan sites have been sampled with QPSG by request of regulatory case manager
- Many sites across the US under state and federal oversight
- Many countries including Canada, European Union, Brazil and other South American countries.

Why is EPA interested?

- Accuracy and precision of the testing method in multiple project cases reveal:
  - Low variability in duplicates (i.e. <30% rpd)
  - Low influence from moisture on duplicate results
- Provides relevant TWA concentration for risk assessment
  - Mitigates the temporal variability (daily and longer periods) by sampling over longer durations
  - Longer duration sampling results in a better approximation of exposure risk
  - Passive Sampling= A TRUE MEAN CONCENTRATION
- Consistency and replicability of testing method results in higher confidence
  - Simple to use= consistent deployment of samplers = higher confidence in results between events/field personnel.
  - Data quality confidence is much higher with thermal reconditioning (i.e. NO VOC carry-over cross contamination as has been documented with individually certified summa canisters)

Advancements to Quantitative Passive Gas Sampling

- Got PAHs?
  - Beacon is accredited for PAHs out to Benzo(a)anthracene. When concentrations are required, a sorbent tube with a low flow sampling pump are used.
- Got PFAS?
  - Of course you do, but is it in soil vapor and air too?
  - Beacon is working on R&D to determine which compounds may be present in the vapor phase.

CALIFORNIA CUPA FORUM
24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

Advancements to Quantitative Passive Gas Sampling

- Got Terpenes from Marijuana operations?
  - Beacon is working on terpene and other hemp related target volatile compounds required in California for air quality monitoring. More news to come.
- NEXTGEN™ by Beacon – coming soon!
  - New passive sampler developed by Beacon that will be more versatile and capable than existing passive samplers.

51

Any Questions???

Expect the Best from Beacon!

Speaker
Lowell Kessel, P.G.
Los Angeles, California
714.709.3683
lowell.kessel@beacon-usa.com

Co-Author
Harry O'Neill, President
Forest Hill, Maryland
1-410-838-8780
Harry.ONeill@beacon-usa.com

CELEBRATING 1999 20 YEARS 2019 OF GLOBAL EXCELLENCE

www.Beacon-USA.com

Reporting air and soil gas concentrations to 1000's of clients, government agencies and universities around the world in more than 40 countries and across 7 continents (including Antarctica)

CALIFORNIA CUPA FORUM
24th California Unified Program
Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

52

Reporting

Data provided in 7 business days and survey reports that include color isopleth maps showing distribution of compounds are provided within 10 days of sample receipt

Additional reporting options include:

GEOTRACKER EDD file
Concentration Data (ug/m^3)
CLP Data Packages
Custom EDDs
Tentatively Identified Compound (TIC) Reports

CALIFORNIA CUPA FORUM

24th California Unified Program Annual Training Conference
March 22, 23, 24, 29, 30, 31 - 2022

53