Automated Continuous High-Frequency Vapor and Controlling Factor Monitoring for Reasonable Maximum Exposure, Cost Effective Decision Making, and Risk Reduction

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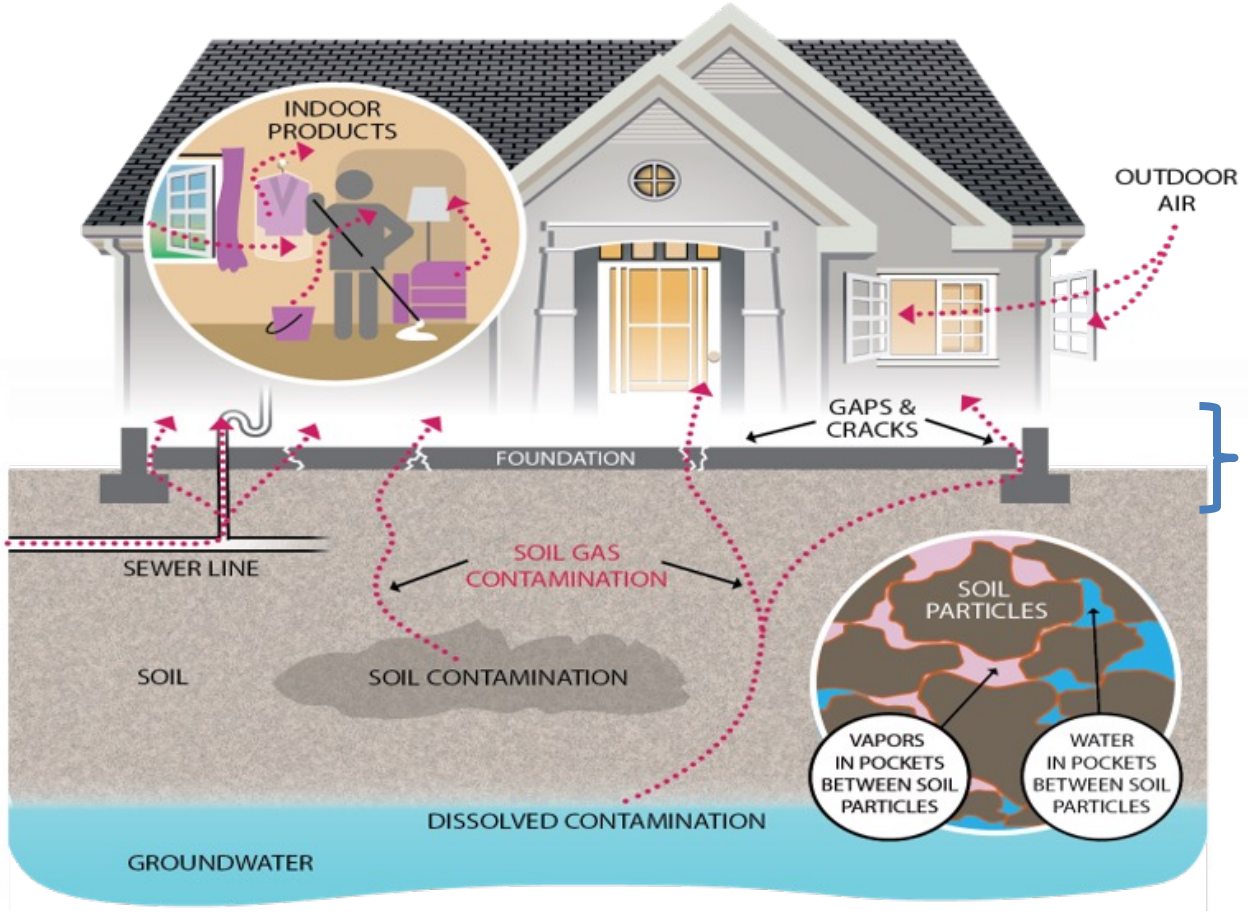
Vapor Intrusion
Complex *Dynamic* Processes



Advection Dominates!!

Volatile Compounds Migrating Into Buildings. *(Courtesy of CA Water Board)*

Don't forget fans, HVAC, wind, pressure, etc.!

USEPA 2023 AEHS Workshop

"Although indoor air concentration observations are considered the "gold standard" for evaluating the protectiveness of indoor air concentrations in buildings potentially impacted with VI, ***accurate assessment of reasonable maximum exposure (RME) requires a sampling approach that can handle temporal and spatial variability.***"

USEPA 2023 AEHS Workshop

*"**The typical Vapor Intrusion (VI) site assessment approach** uses a very small number of 'randomly-timed' samples to characterize indoor air exposure point concentration distributions. This practice continues after more than a decade of widely presented studies that highlight how it **can result in false-negative decisions and poor characterization of long-term exposures**."*

OK, but how to also save time & $, reduce risk?

Vapor Intrusion
Complex *Dynamic* Processes

- Essential to Know Causes of Dynamics! [Controlling Factors]
  - RME occurs when VI “On”
  - Distinguish between Indoor Source & VI
  - ID Vapor Entry Pathways
  - Evaluate Risk
  - Move Project Forward Faster ($, Reduce Exposures)

Vapor Intrusion
Complex *Dynamic* Processes

- Traditional Methods OK for Screening, BUT!
  - Don’t Know % VI “On”
  - Time/$ - Monitoring “Do-Loop”
  - Exposures/Liability
  - EPA RME Consistency?

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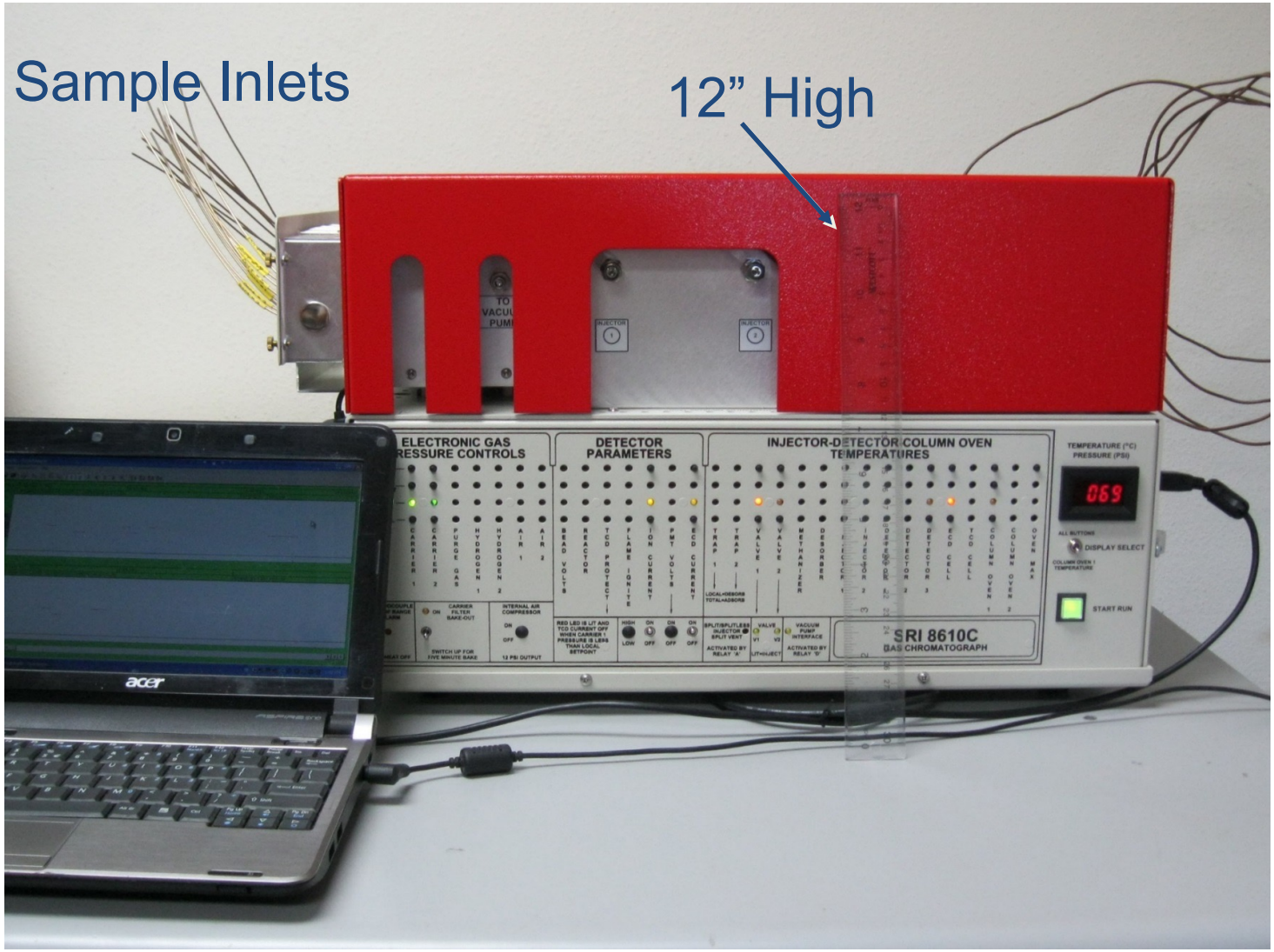
Continuous Monitoring System



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System Capability

- Fully Quantitative!
- Can Reach Ultra-Low Levels (<1 µg/m^3) for TCE, PCE, VC, BTEX, Methane, Tracers, etc.
- <10 min Analysis Time (~150 analyses/d)
- Spatiotemporal (16+ Points)
- Modified EPA Method TO-14A
- Stable - holds calibration for months
- Remote Control
- Real-Time “Cloud” IoT Data/Response
- Discrete Mode

Field Images

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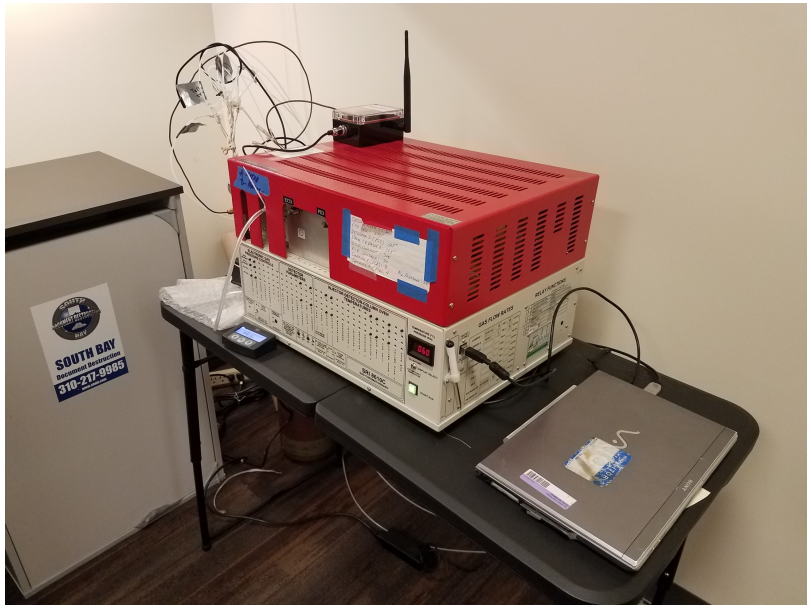
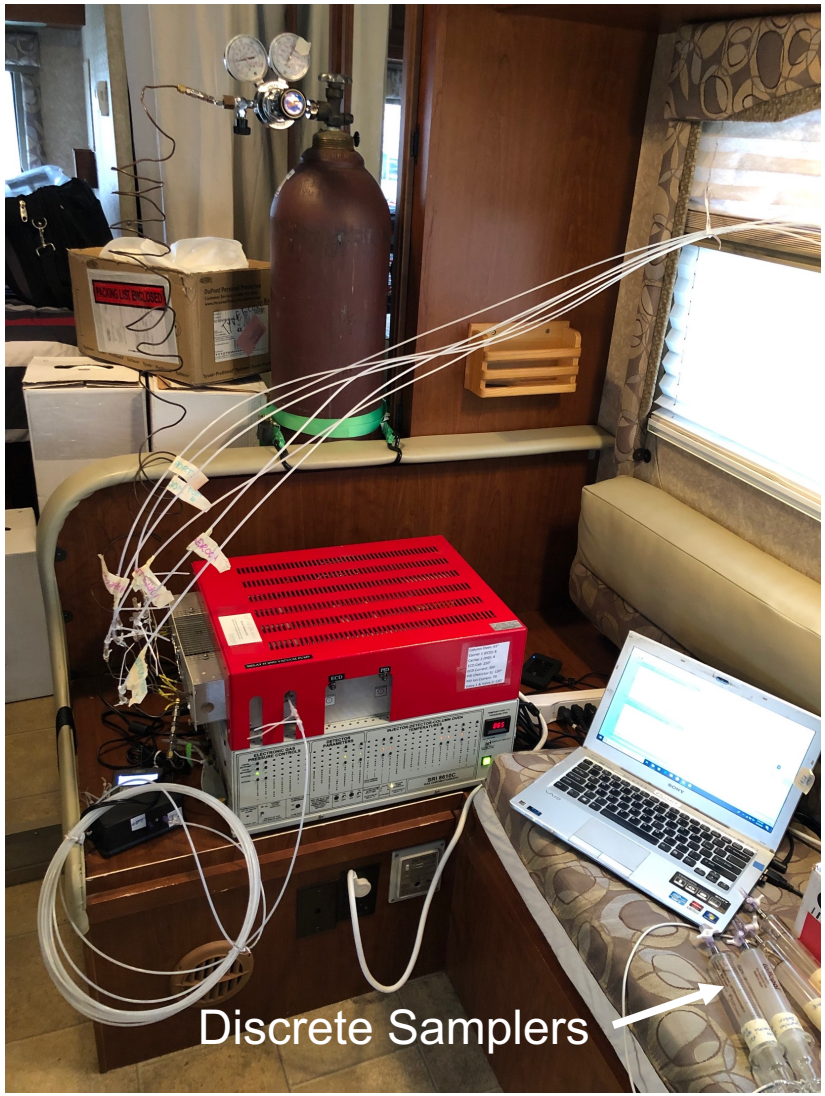
Field Images



Rapidly Assess Large VI Plumes



Rapid Screening Plus Monitoring

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Wireless Press Diff
Vapor Flux Direction

P Diff

To
SS Port

Antenna

Sends to Base Station

Real-Time Web Review/Alert

Coupled to Concentration, Weather & Activities

Key Questions

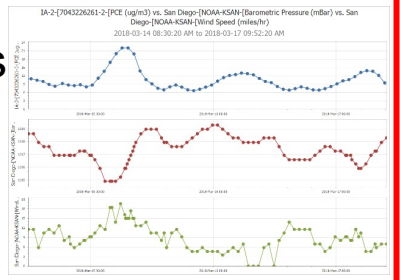
1
- Is there an indoor VOC concentration exceedance?
- If an exceedance exists, due to indoor sources or VI?
- If present, what/where is the indoor source?
- If VI occurring, where are the vapor entry points?
- If VI occurring, when is it occurring and for how long?

2
- What can be done to immediately reduce risk?
- Did solution work?

Dynamic Data Pattern = Answers!

Real-Time CM Approach

1-3 days



Goal #1

0 days

Test Remedies

1-3 days

Select Remedy

Goal #2

Remedy Selection Within a Week!
Reduce Exposures/Liability!

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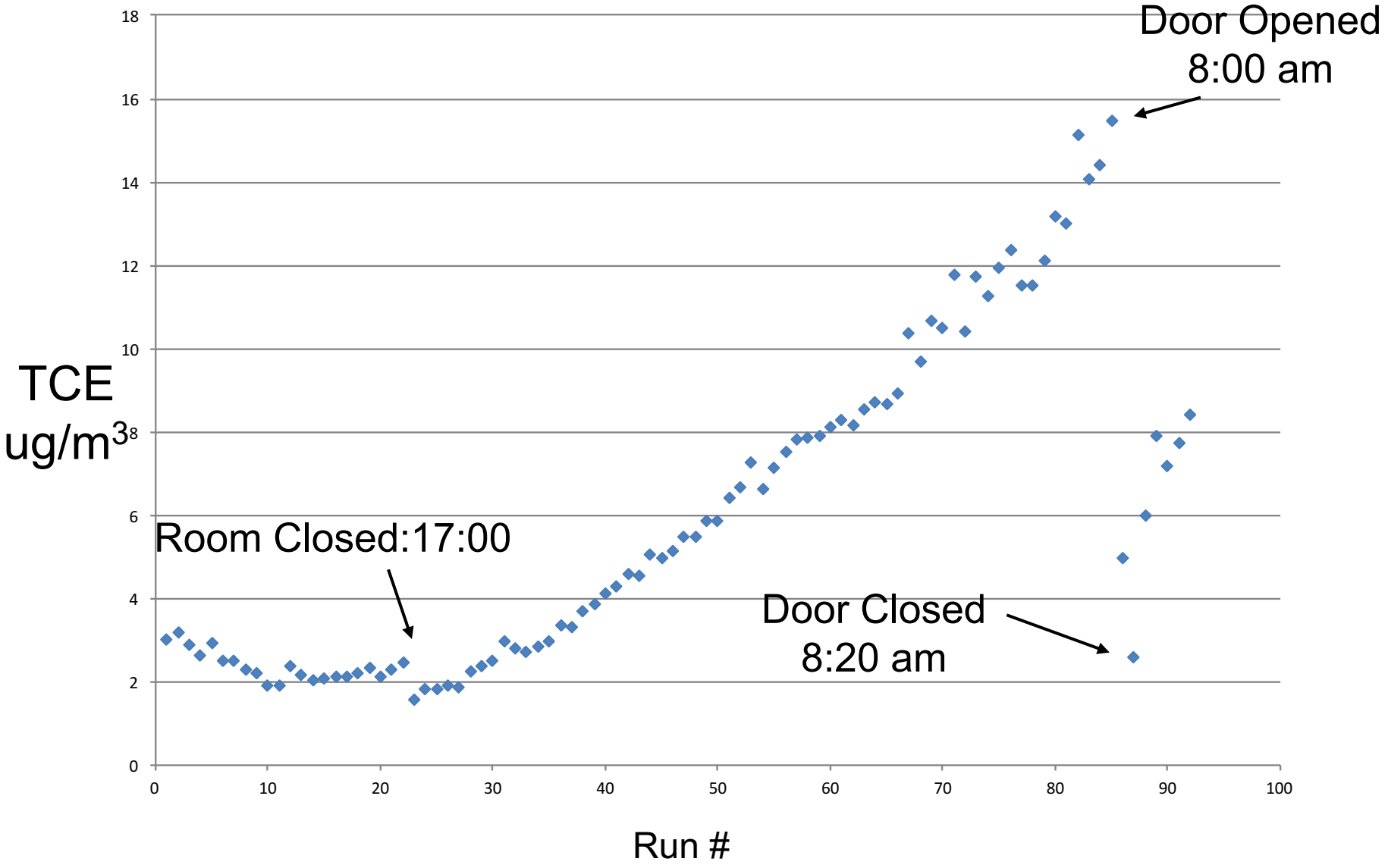
Applications

- Initial VI Screening
- Rapidly Answer Key Questions
- Site-Specific AF
- Risk Assessment
- Resolve “Mystery” Sites
- Test Mitigation Options
- Manage Remedial Emissions
  - Thermal
  - Amendment
  - Oxidation

Selected Examples (of >250) Lessons Learned

- All Examples - Previous Sampling Events
- Could Not Answer Critical Questions
- Single CM Mobilization Results

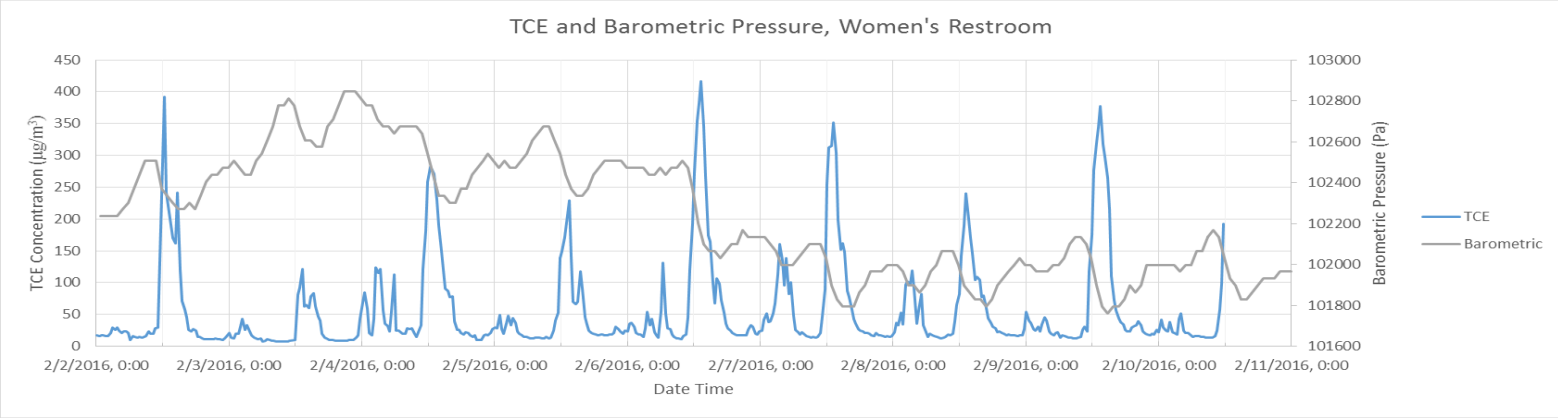
Locating Source/Pathway

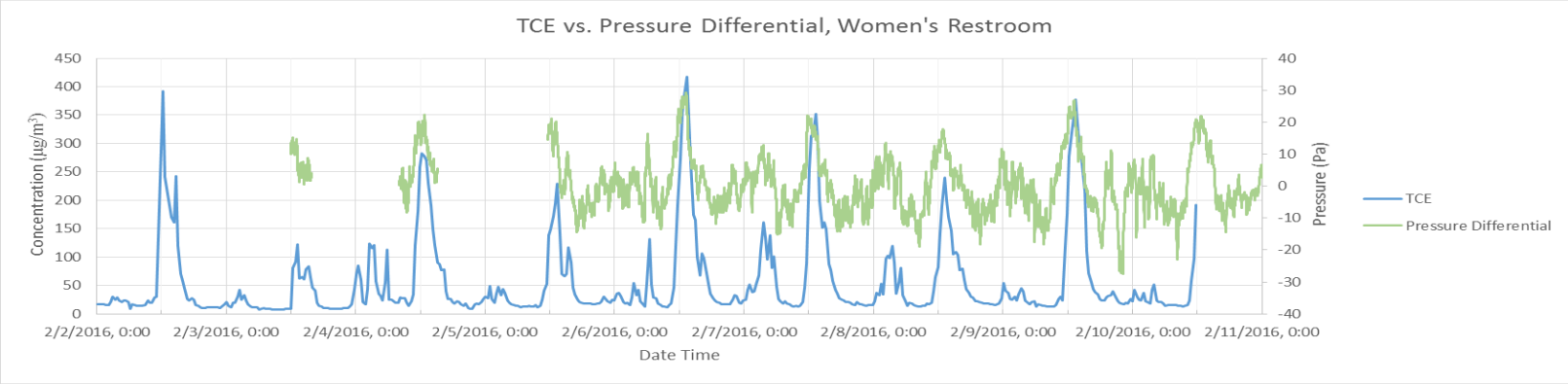


Locating Source/Pathway
Federal Bldg – 1 Day

- Savings:
  - Months/years
  - Tens of thousands of $
- Moved Project Forward
  - Reduced Exposures

Natural Fluctuations



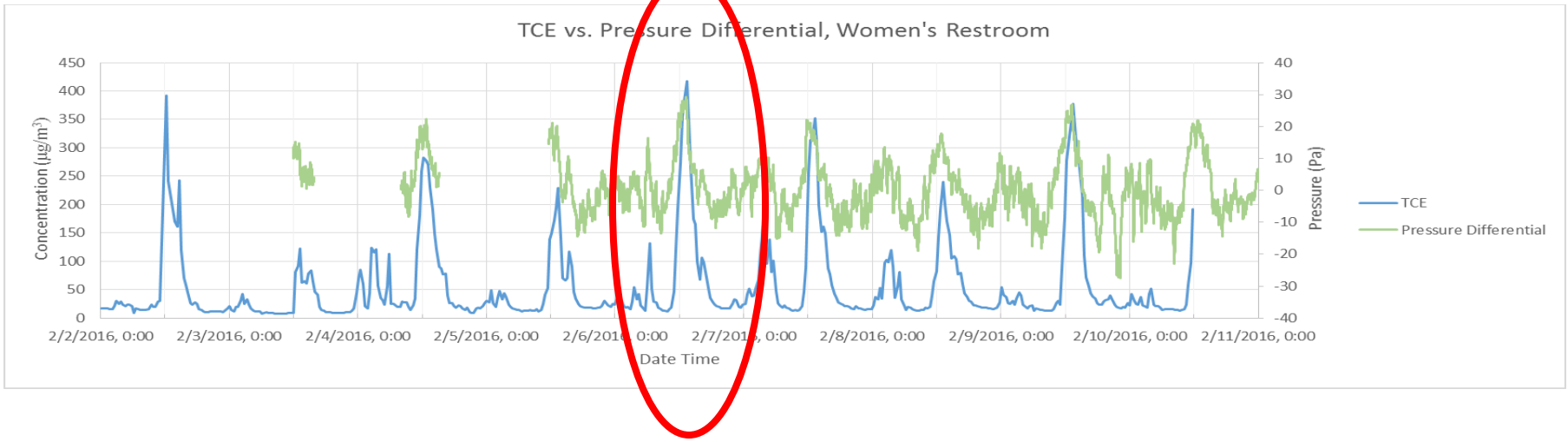


Daily BP Change ☛ Slight Pressure Diff ☛ VI "On"
Flux Direction Critical!

Hosangadi *et al*., 2017, *High Frequency Continuous Monitoring To Track Vapor Intrusion Resulting From Naturally Occurring Pressure Dynamics*, Journal of Remediation, Spring, v.27, no.2, p.9-25.

VI Risk Evaluation – Sample Timing

TWA Variability



- Three 24-hr, three 8-hr "windows"
- Simulate/emulate randomly timed samples
- Averages, results, recommendations compared

Kram, M. L., B. Hartman, C. Frescura, P. Negrao, and D. Egelton, 2020. "*Vapor Intrusion Risk Evaluation Using Automated Continuous Chemical and Physical Parameter Monitoring*", Remediation, v.30, p.65-74.

VI Risk Evaluation – Sample Timing

TWA Variability

Duration	Time range	Time-weighted average (µg/m^3)	Range (µg/m^3)
9 Days	2/2/16–2/10/16	54.2	7.3–417.0
24 Hr	12–12 p.m.	80.9	13.3–417.0
24 Hr	12–12 a.m.	74.2	11.2–417.0
24 Hr	5–5 p.m.	72.3	11.2–417.0
8 Hr	8 a.m.-4 p.m.	150.2	11.2–417.0
8 Hr	12–8 p.m.	150.9	17.4–417.0
8 Hr	5 p.m.–1 am	22.4	16.7–36.6

Δ5hr

22.4µg/m^3 – 150.9µg/m^3 TWA Range
Accelerated vs. Immediate Response
(Fix in Weeks vs. Evacuate!)

Kram, M. L., B. Hartman, C. Frescura, P. Negrao, and D. Egelton, 2020. "*Vapor Intrusion Risk Evaluation Using Automated Continuous Chemical and Physical Parameter Monitoring*", Remediation, v.30, p.65-74.

VI Risk Evaluation – Sample Timing (II)

TWA Variability

Duration	Time range	Time-weighted average (µg/m^3)	CA acute TCE recommendation	Range (µg/m^3)
5 days	2/8/19–2/12/19	13.9	Accelerated	0–121.4
8 h	8 a.m.–4 p.m.	41.5	Urgent	7.4–121.4
8 h	12 p.m.–8 p.m.	41.6	Urgent	8.3–121.4
8 h	5 p.m.–1 a.m.	9.9	Accelerated	5.1–19.2
24 h	8 a.m.–8 a.m.	19.3	Accelerated	3.6–121.4
24 h	12 a.m.–12 a.m.	19.5	Accelerated	0–121.4
24 h	5 p.m.–5 p.m.	6.8	Non-Acute	2.9–19.2

Δ5hr

Δ5hr

9.9 µg/m^3 – 41.6µg/m^3
Accelerated vs. Urgent Response

6.8 µg/m^3 (Non-Acute) vs. 19.5 µg/m^3 (Accelerated) Range!

Kram, M. L., B. Hartman, and C. Frescura, 2022. "Simultaneous Monitoring of Volatile Organic Contaminant Concentration and Controlling Factors for Vapor Intrusion Risk Evaluations—Two Select Cases". Remediation, v.32, issue 4, p.259-272.

Lessons Learned

- Pattern is Key (ID Cause, % VI "On", etc.)!!
- TWA depends upon **duration** sampling window coincides with **upward flux**!!
- **Traditional randomly timed samples yield different risk conclusions/responses** (evacuate vs. mitigate over time vs. NFA).
- Highs Correlated with Diff Pressure (DP), BP *trend*
- BP *trend* & DP >> [BP] value or Season!
- Assess Risks Over Proper Time Windows (RME)

*Kram, M. L., B. Hartman, C. Frescura, P. Negrao, and D. Egelton, 2020. "*Vapor Intrusion Risk Evaluation Using Automated Continuous Chemical and Physical Parameter Monitoring*", Remediation, v.30, p.65-74.

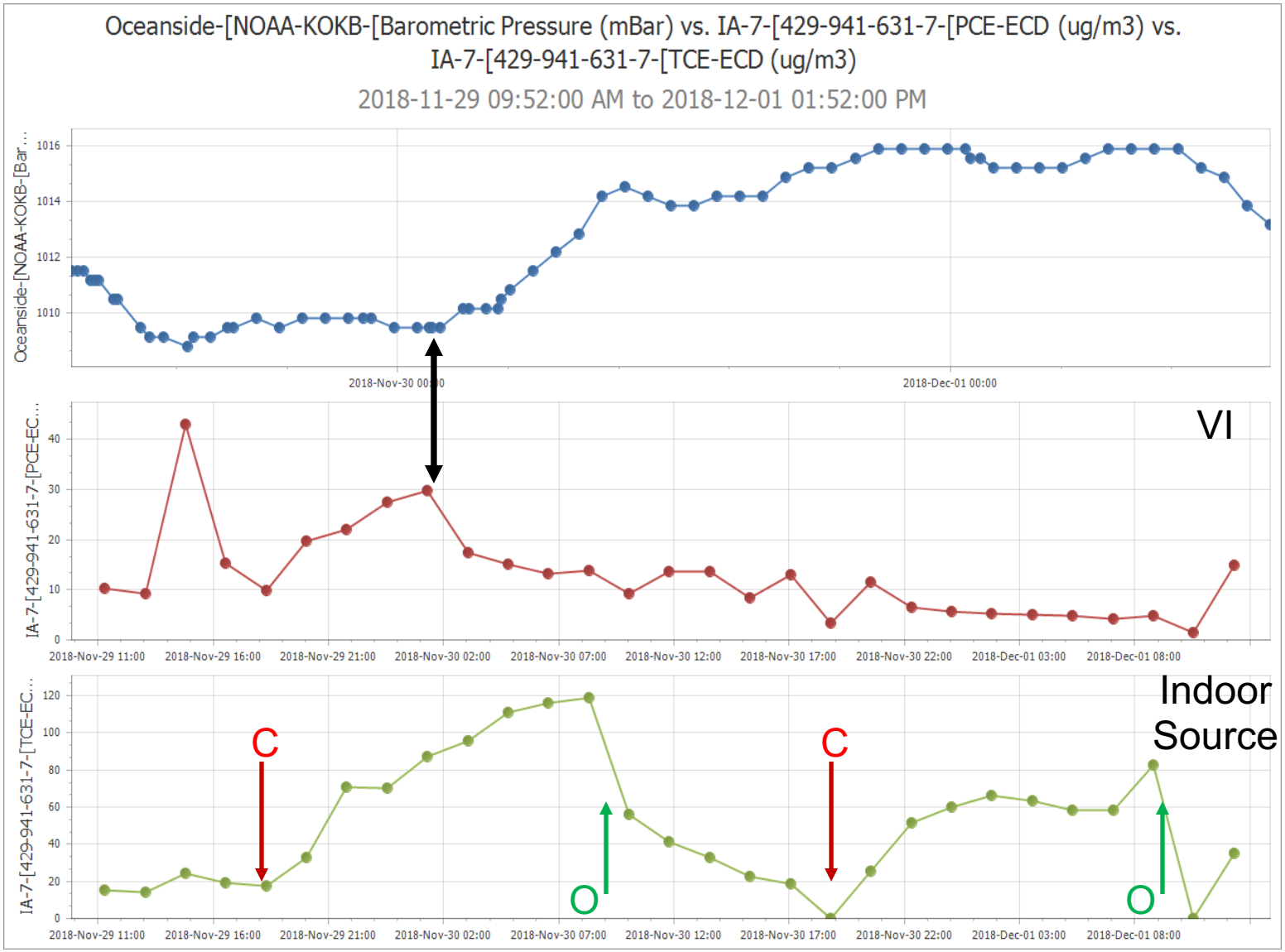
Indoor vs. VI Source

Former Drycleaner – 2.5 Days

Baro

PCE

TCE



Indoor vs. VI Source
Former Drycleaner – 2.5 Days

- Savings:
  - Months/years
  - Tens of thousands of $
- Moved Project Forward

CSI Vapor Intrusion

Mitigation System Mystery – Adaptive CSM

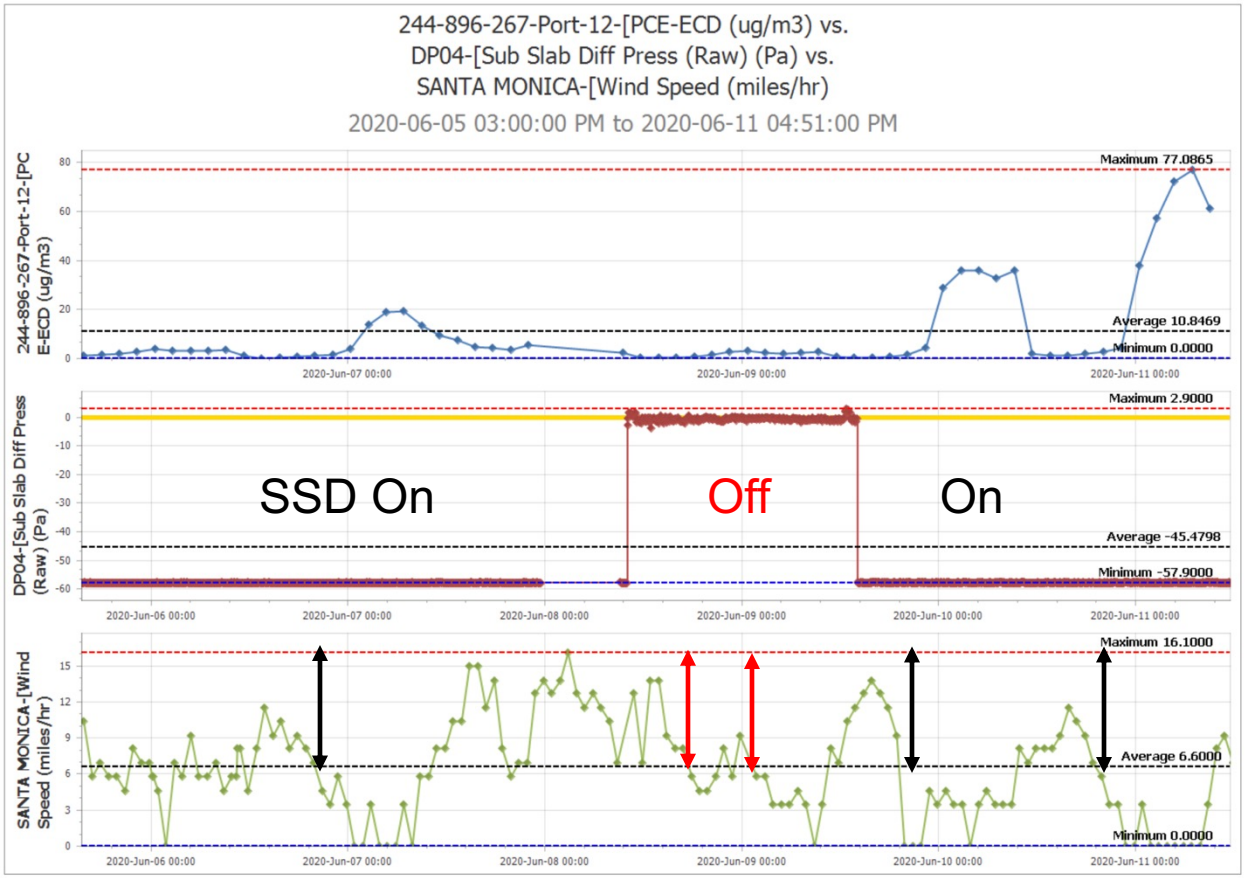
- Retail Store in LA, PCE in IA
- SSD Installed – PCE Still in IA – Many Sampling Rds
- VaporSafe Brought in – Discrete Samples
- Highest Values in Floor Drains – SSD Drawing In?
- Monitoring Begins – Highest Values at Night
- Seal Floor Drains – IA Values Still High At Night
- Turn Off SSD. IA Values Stay Low at Night
- Where is PCE Coming From?

Mitigation System Mystery

PCE

Diff P

Wind Speed



Mitigation System Mystery

Roof Penetration

Roof Mounted Fan/Blower

Mitigation System Mystery

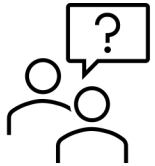
- Neg Pressure from SSD ➡ PCE from Roof Exhaust
- Easily Resolved
  - Added Booster Fan
  - Extended Discharge Pipe
  - Sealed Vent Pipe
- Years of Mystery – Resolved in 3.5 Days!
- Saved Tens of Thousands of $!
- Moved Project Forward

Advantages of Continuous Monitoring vs. Traditional Methods

- Indoor vs Subsurface Source in One Visit
- ID VI Pathways in One Visit
- Evaluate with VI on/off using DP
  - Superior AF, Risk Assessment/RME Est.
- Test Potential Remedies in Real-Time
- Move Forward/Reduce Risks/Save $

What'll It Be??

- Inconsistencies Between Risk Assessments and ITS
- Follow EPA's RME or Not?
- *Agencies/Industry Ignoring RME*
  - Either RME Could be Required
    - If So, Risk Assessments/Decisions More Conservative; OR
  - Continue to Ignore EPA RME
    - If So, Status Quo, Uncertainties/Debate
    - Can We Even Compare Trad'l Results Over Time?



Summary

- Time-Integrated Approaches
  - Screening, but Limited Pattern!
  - Ignores RME (Unless w/DP!)
- Pattern = Opportunity!
- CM to Rapidly Address w/Single Mob:
  - Accurate Risk v. No Risk situations
  - Acute TCE challenges
  - ID indoor sources, VOC entry locations, pathways
  - Estimate RME & AF
  - Optimize/confirm mitigation/remediation
  - Reduce Exposure Duration!!
  - Saved $M, One Visit Closures!

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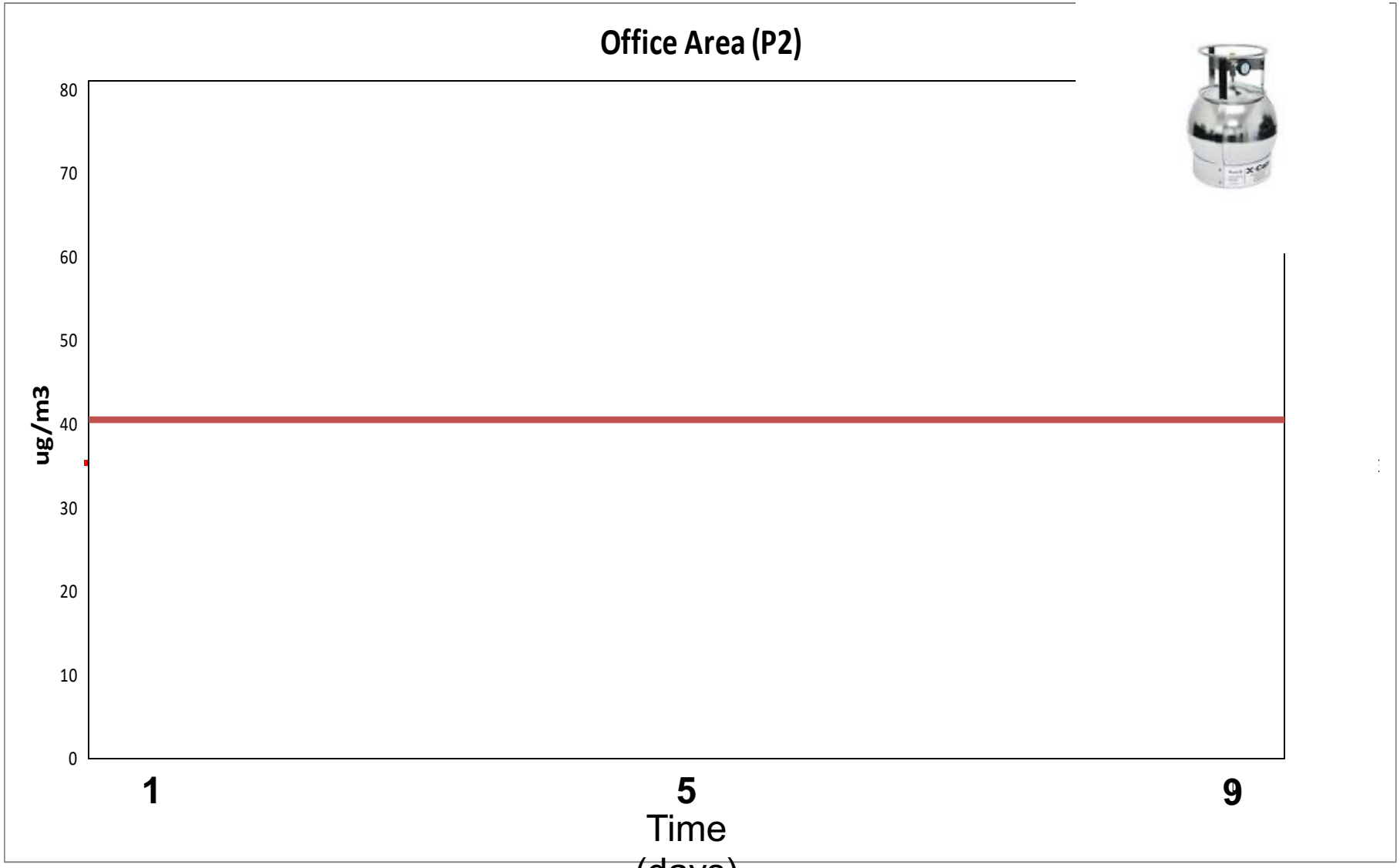
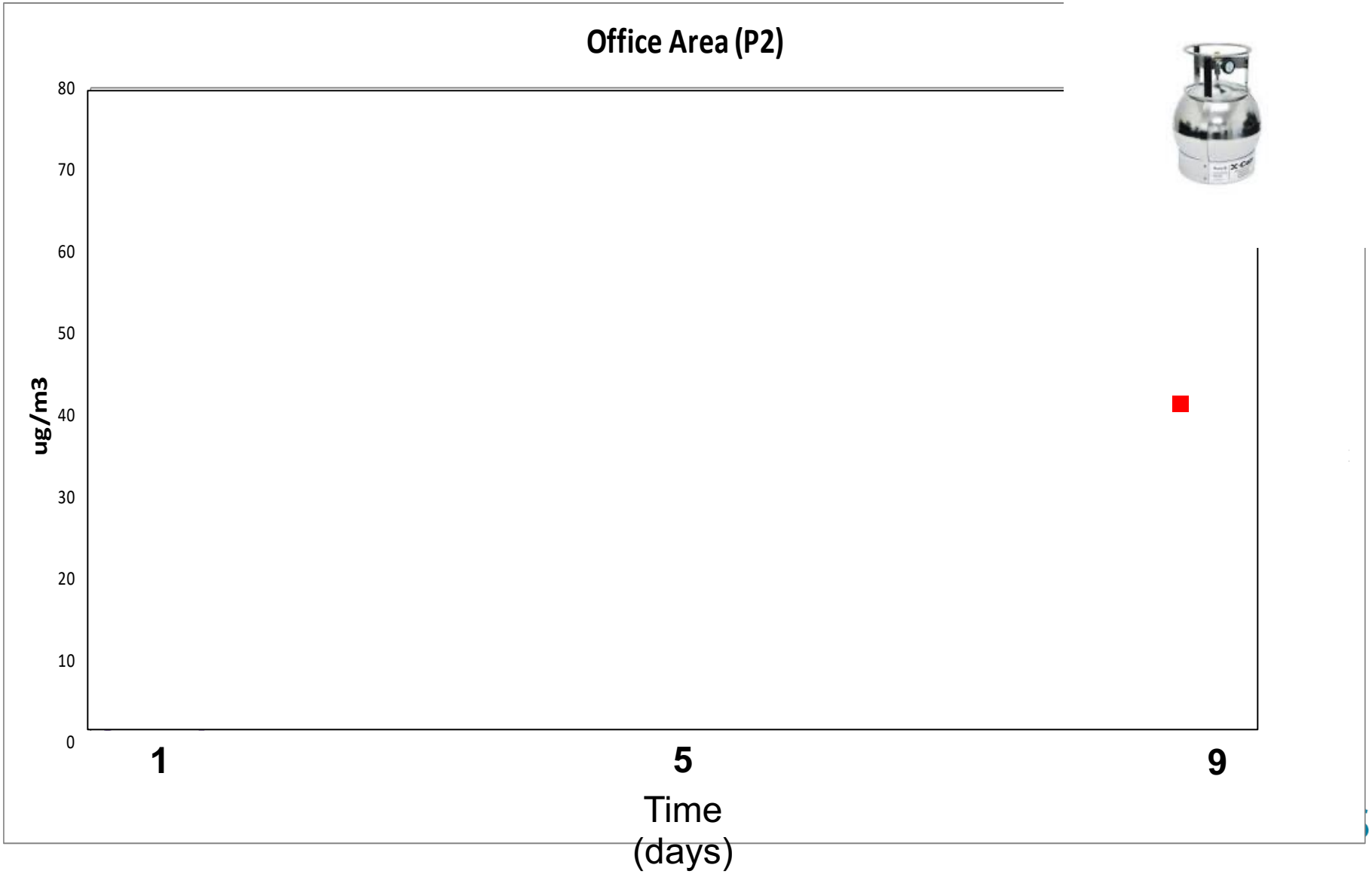
HARTMAN
ENVIRONMENTAL GEOSCIENCE

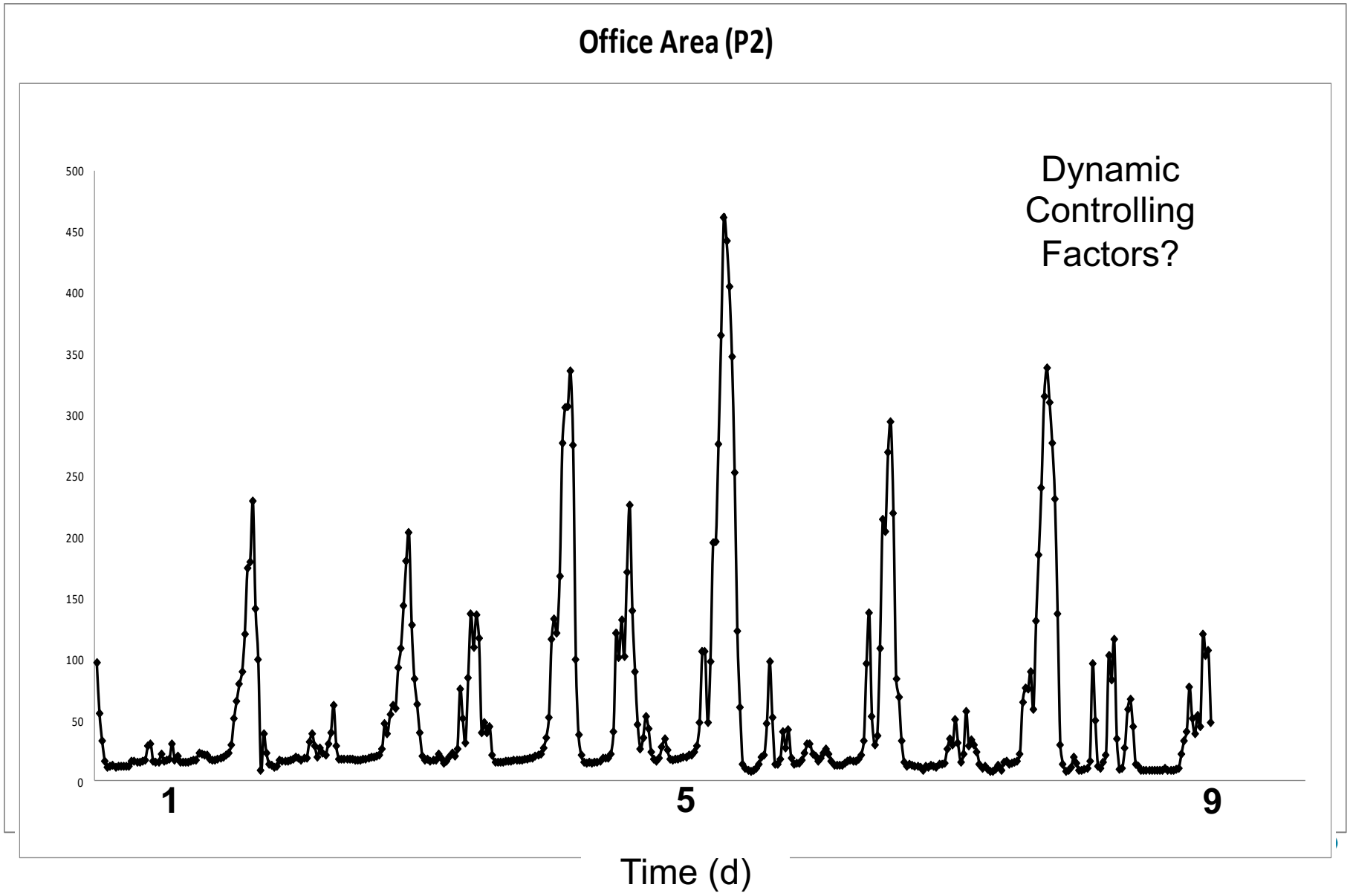
The “Truth” About IA Concentrations



Typical Air Sampling Result



Reality!!


Office Area (P2)
Dynamic Controlling Factors?
500
450
400
350
300
250
200
150
100
50
0
1
5
9
Time (d)