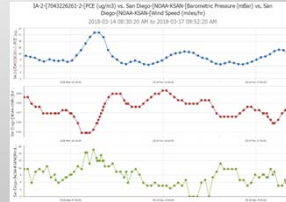


Resolving Vapor Intrusion Challenges via Automated Continuous Real-Time Monitoring and Response



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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.

Presentation Summary

- Brief System Description
- IA Temporal Variation
- Finding VOC Entry Points
- Expediting VI Assessments
- Expediting VI Remedies
- Monitoring Remediation Systems

All This in 20 Minutes!



The following topics will be covered very quickly in this 20 minute presentation.

Longer presentations are available which cover the material more slowly and completely.

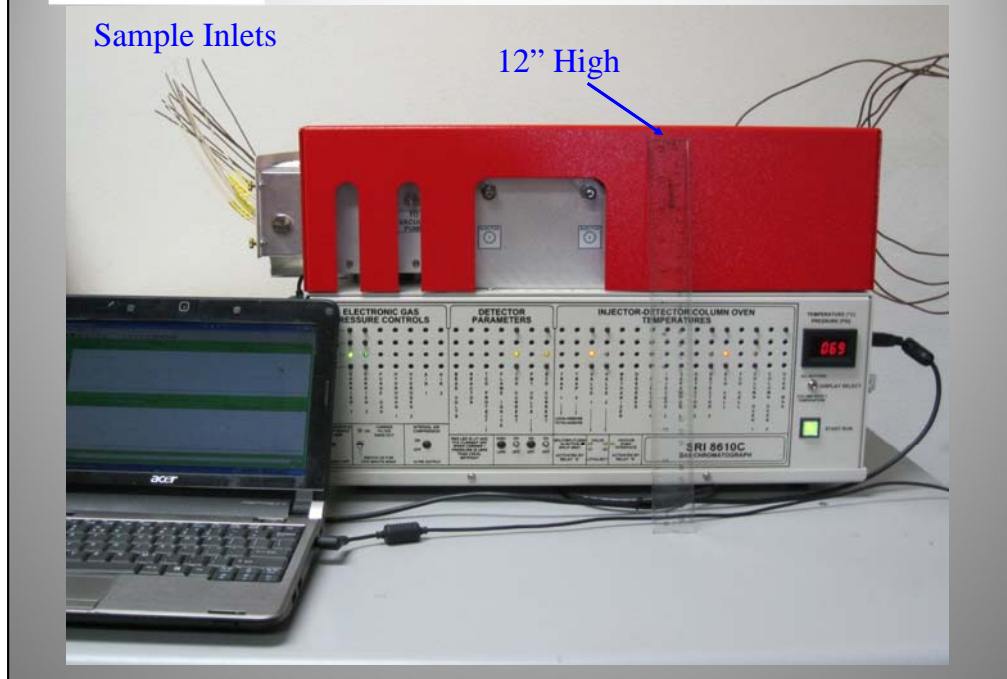


Photo of the Vaporsafe monitoring system. The instrument is about the size of a microwave and can fly around as checked baggage for less than \$100.

The 16 stainless steel tubes in the upper left are connected to small diameter (1/8" or 1/4") tubing which then run to the monitoring locations.



System Capability

- **Fully Quantitative!** EPA Method TO-14
- Can Reach Ultra-Low Levels (<1 ug/m³) for TCE, PCE, **Vinyl Chloride** & others
- <10 min Analysis Time for TCE & PCE
- Multiple Sample Locations (16 to 30)
- Very Stable - holds calibration for months
- Real-Time Data - Groundswell Dashboard
- **Discrete Sampling Mode**



VaporSafe monitoring system capabilities. Fully quantitative (not screening level data), measures the most critical compounds, can do that in 10 minutes and can monitor 16 or more locations. The data are sent to the web after every analysis to a server with a user-friendly interface enabling the client access to the data in real-time. The system can also be put in discrete sample mode enabling the user to look for VOC entry points or to collect confirmation samples if an unexpected compound occurs.



Data

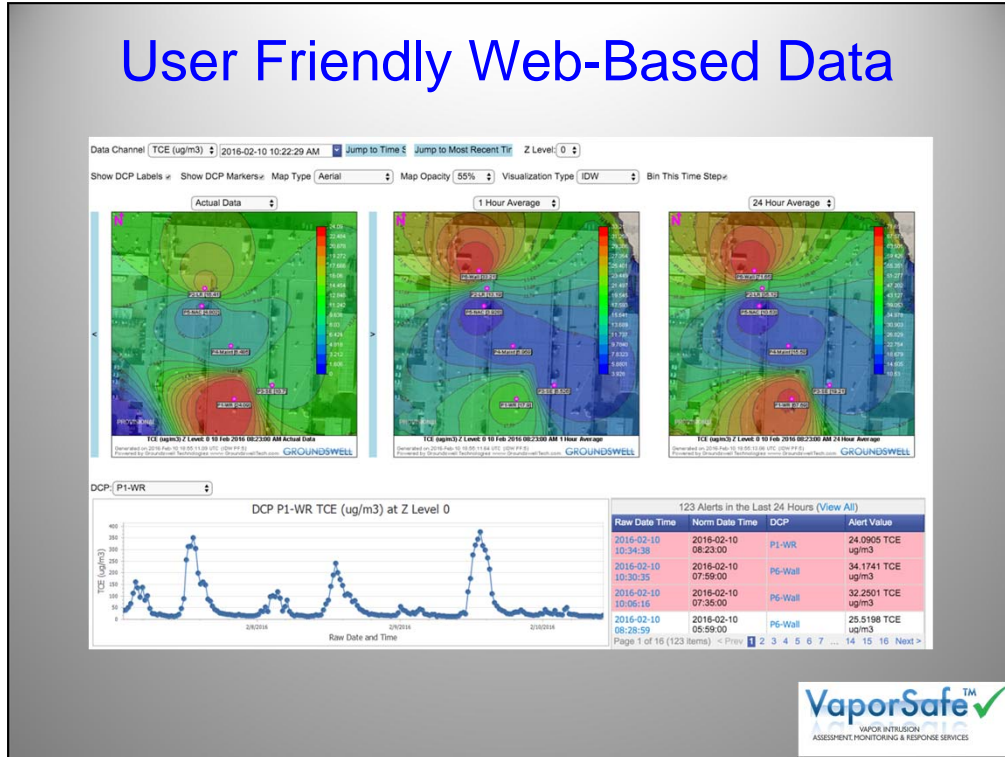
- Concentrations
- Pressure Differential
- Barometric, Temp., Wind Speed, etc.
- E-mailed Daily Reports
- Trigger Relays
- User Friendly Dashboard
 - VOC Conc vs Time
 - Contour/Isopleth Images
 - Moving Averages
 - Plots in Seconds

VaporSafe data reporting/management capabilities. In addition to concentration data, the system also can log differential (cross-slab) pressure, meteorological parameters such as barometric pressure, temperature and wind speed. Each day, a daily summary of the data is e-mailed to authorized personnel.

The system can trigger relays which can perform such functions as turn on/off fans and filtration units, open louver, or modify HVAC systems.

A user-friendly web-based interface enables authorized users immediate inspection and analysis of the data. Contour plots, plots of concentration versus time, stacked plots, and auto-alerts are all available from the dashboard. Plots can be easily exported into a jpeg file or into a ppt for rapid display to interested parties. Data can be easily downloaded in cvs or xls formats.

User Friendly Web-Based Data



A picture of the user-friendly interface. Contour plots, plots of concentration versus time, stacked plots, and auto-alerts are all available from the dashboard. Plots can be easily exported into a jpeg file or into a ppt for rapid display to interested parties. Data can be easily downloaded in cvs or xls formats.

System QA/QC

- EPA Method TO-14
- Calibrated with Validated Gas Standards
- Minimum of 5 Calibration Points
- Can Run Calibration Gas Every Cycle of Ports
- Precision on EPA Indy Site: <10% over 100 Days
- Accuracy vs off-site TO-15: 17%

EPA Documented:

<https://clu-in.org/download/issues/vi/VI-EPA-600-R-13-241.pdf>

(EPA/600/R-13/241 | June 2015 | www.epa.gov/research)

Quality assurance and quality control of the system. The analytical method is EPA TO-14 and the system calibration follows the method protocols. If desired, a cylinder of calibration gas can be connected to one of the 16 ports and analyzed every cycle of ports. Precision & accuracy of the system from 100 days of operation at the EPA Indianapolis test site were within 10% and 17%, respectively.

Method Detection Limits

15 repetitive analyses

Compound	Standard Conc	MDL (ug/m3)	EPA IA RSL* (ug/m3)
PCE	1 ppbv	0.35	11
TCE	1 ppbv	0.19	0.48
Vinyl Chloride	0.2 ppbv	0.07	0.17

* 1 in 1 million excess cancer risk - residential



Method detection limits of the system based upon 15 repetitive analyses of the listed calibration standards. All calibration standards were in air.

Set-Up Logistics

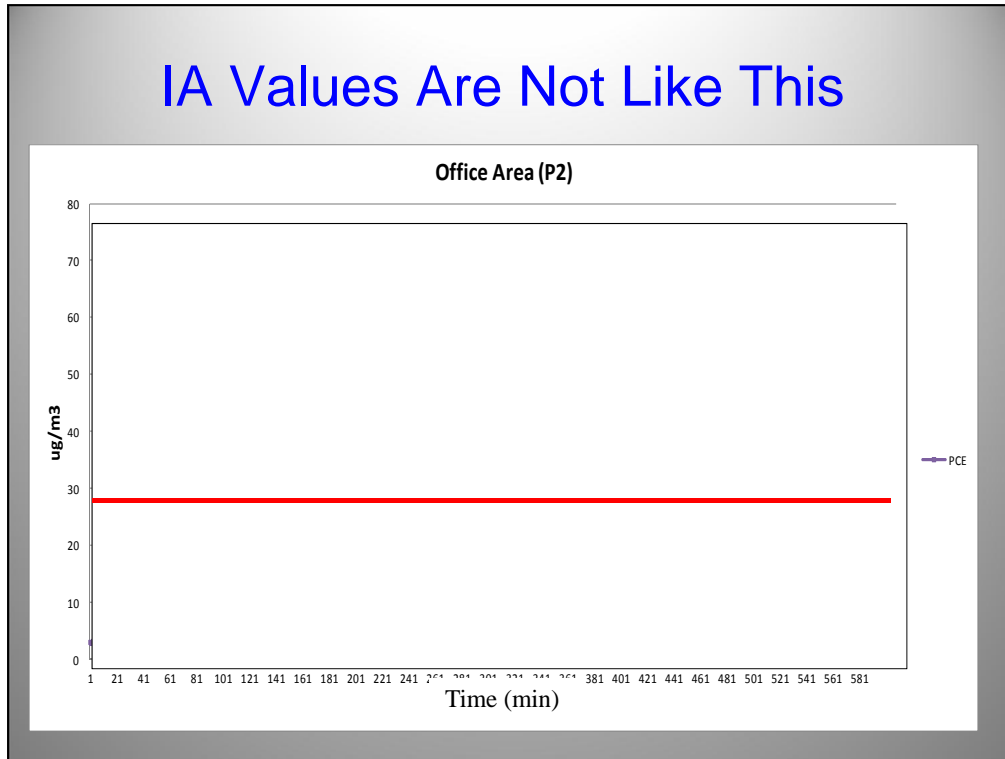
- **GC Setup**
 - Small footprint (~2' x 4' table required)
 - Standard wall power (115v)
 - Room with some temperature control
- **Sampling Lines**
 - Up to 100m from instrument possible
 - Small diameter tubing (1/8" or 1/4")
- **O&M**
 - Change nitrogen every 3 to 5 months
- **Internet Connectivity**
 - Ethernet cable, site Wifi or cellular modem

Set-up is very simple. Standard wall power, a cylinder of pure nitrogen, a small table and internet connection are all that is required.

There is very little O&M required.

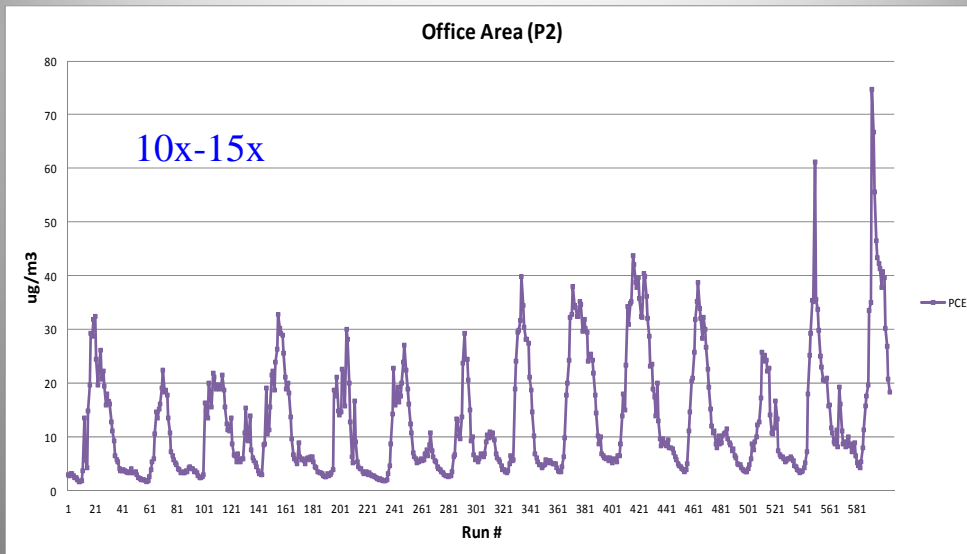
Sampling tubing can be run as far away as 100 meters.

IA Values Are Not Like This



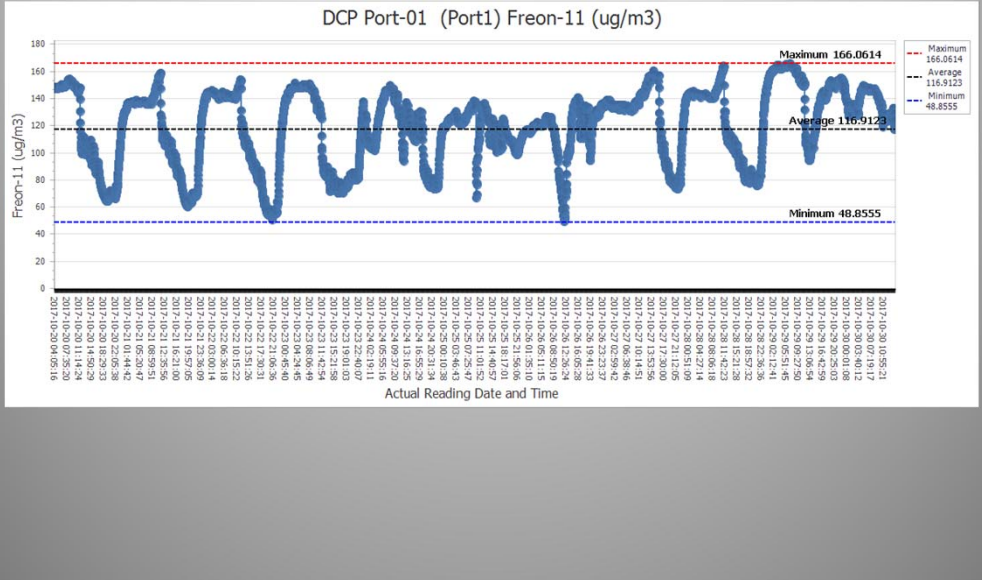
Indoor air VOC concentrations are not static.

Print Shop Air - PCE— June 2014



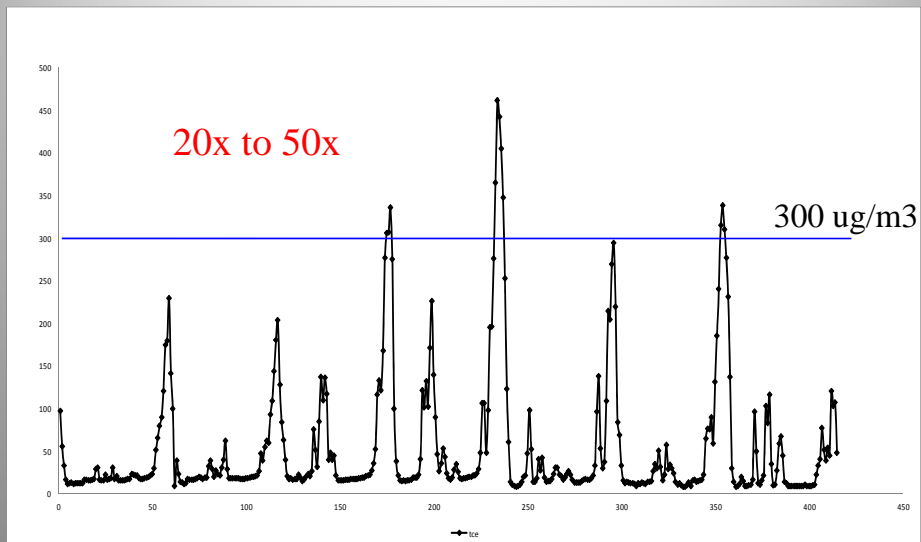
Fourteen days of PCE concentrations inside an active Print Shop: every night values increased, but were low during the day.

Freon 11 - Office Bldg – 10 Days



Freon-11 in indoor air over 10 days in the office building. The pattern was consistent from day to day and was a result of the HVAC system.

Large Industrial Building



VaporSafe™
VAPOR INTRUSION
ASSESSMENT MONITORING & RESPONSE SERVICES

Six days of continuous monitoring of TCE at a very large commercial warehouse in San Diego. The huge increases occur at about the same time every day. What is causing this to happen?

Exposures to VOCs How Often? For How Long?



The current hottest topic throughout the VI. world: Short term TCE exposure.

High resolution data (~150 analyses/day) enables determination of how often indoor air values exceed allowable levels and for how long.

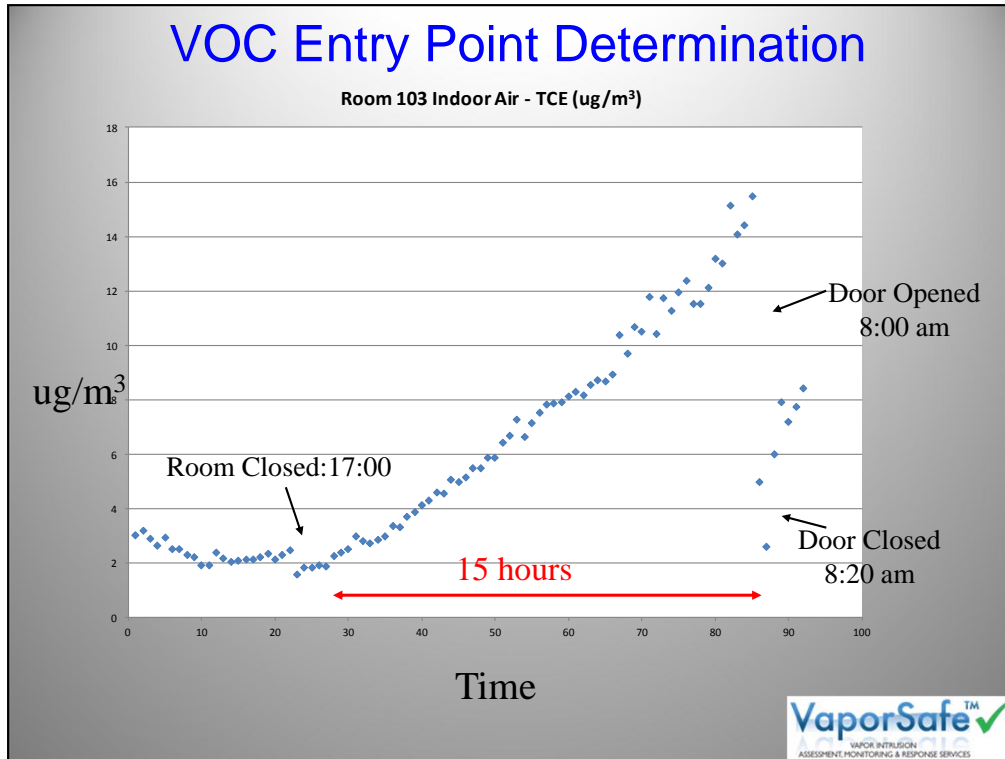
Expedited VI Assessments

- Can find VOC entry points overnight
- Can see pattern within days
- Can determine if from VI or indoor source
- Can determine cause & effect

Pattern = Opportunity



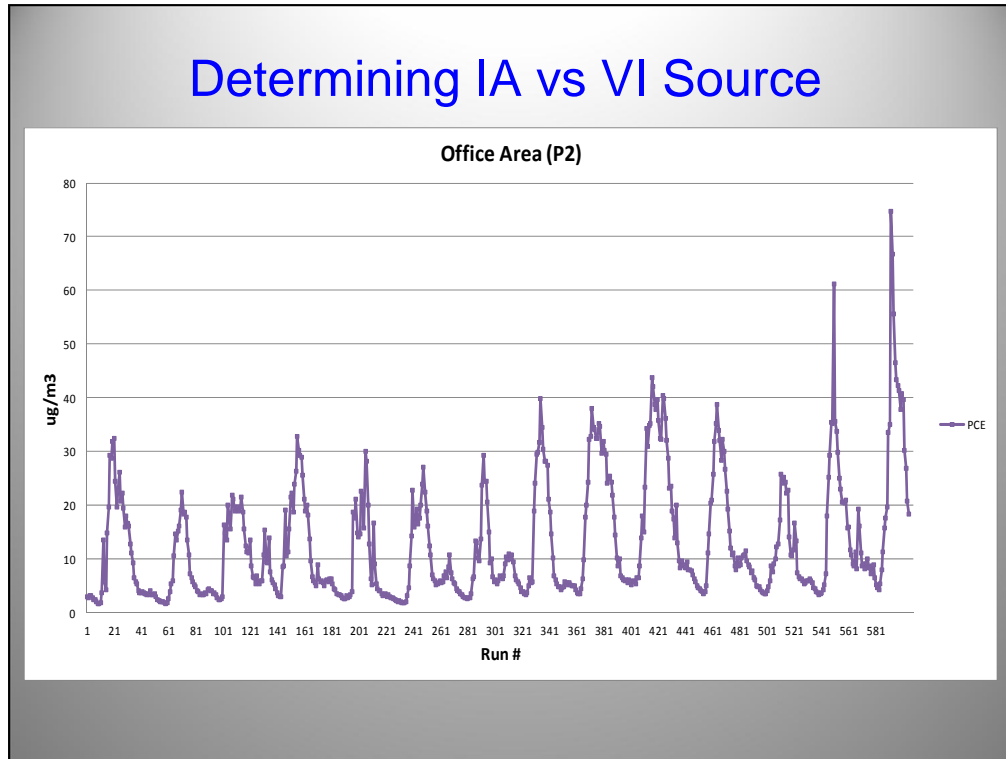
A huge benefit of monitoring is the ability to expedite vapor intrusion assessments. First, the system can be used to locate VOC entry points in one overnight sampling period. Then, the locations can be monitored. A temporal pattern can be seen and cause-and-effect possibly determined. This will allow immediate implementation of a remedy. Such quick response can possibly eliminate the need for future sampling rounds.



Here's an example of locating VOC entry points in one overnight sampling period. This plot shows indoor air TCE concentrations in a small room after the room was closed up for 15 hours. The continuous increase in TCE indoor air values documented that the room was the entry point for the TCE and the total mass entering the room (mass flux) could be calculated. At 8 am the next morning, the doors to the room were opened and an immediate drop was detected. The doors were closed again at 8:20 and concentrations immediately began to increase again.

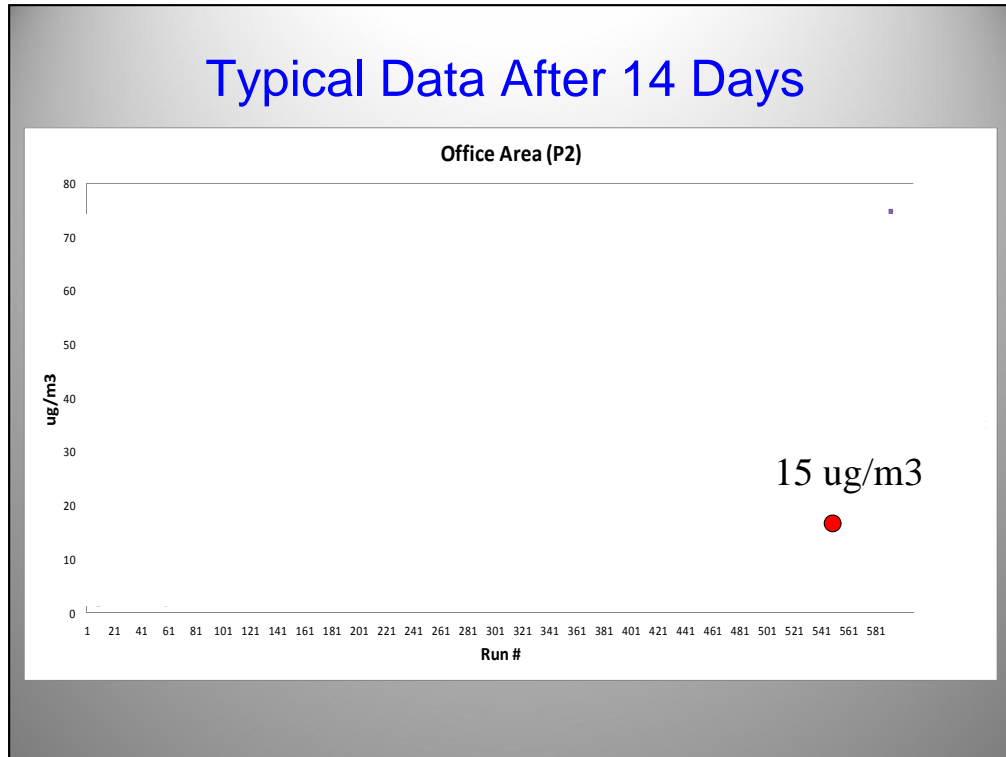
Imagine doing this at 16 locations in a building. You could readily see which locations showed increases and to what magnitude.

Determining IA vs VI Source



Fourteen days of PCE concentrations inside an active Print Shop: every night values increased, but were low during the day. The pattern was determined to be due to the HVAC system (higher during the day creating a positive pressure and lower at night reducing the inside pressure). The continuous monitoring showed that values were below allowable levels during the period when people were working.

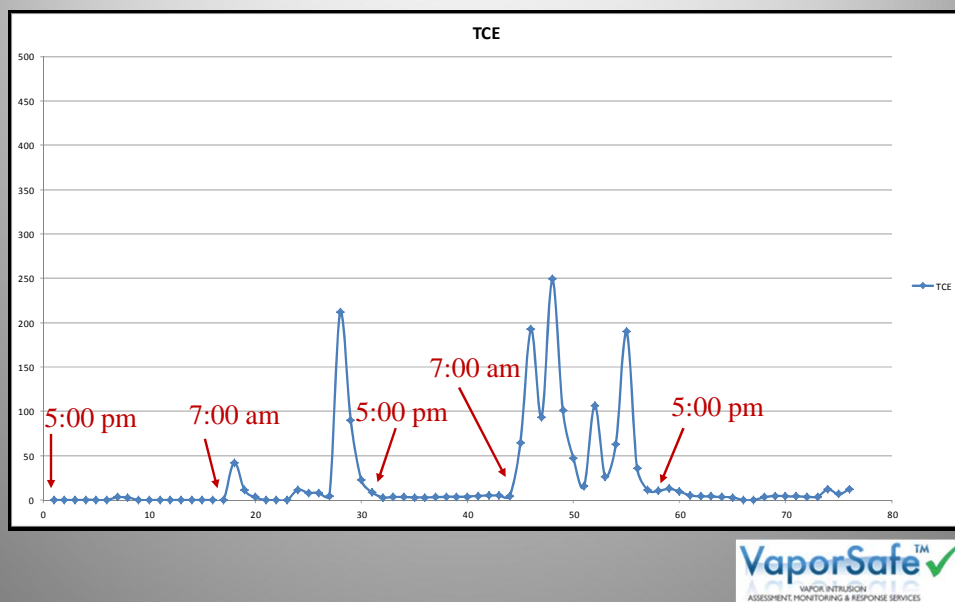
Typical Data After 14 Days



The dot in red shows the results if you had deployed a time-averaged sample for 14-days. The single value would have been biased high & indicated a problem. A false positive.

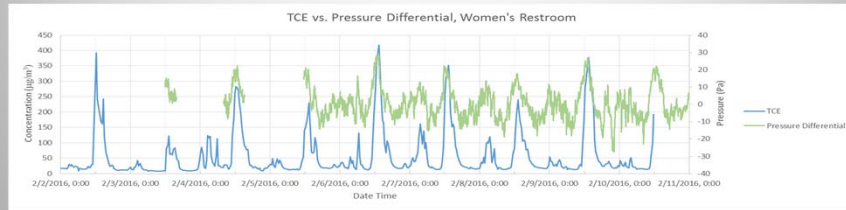
But equally important: a single data point does not show you a pattern so that cause-and-effect can be recognized.

Determining IA vs VI Source

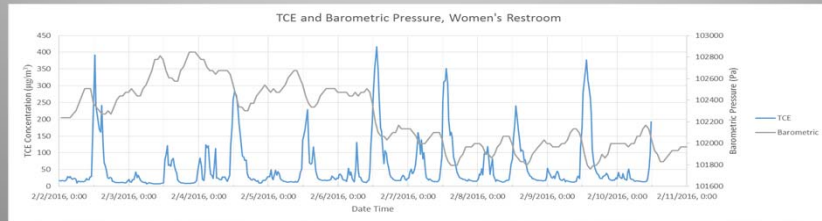


TCE indoor air concentrations in a furniture manufacturing facility. Concentrations were low at night, but then increased during the work day. If vapor intrusion was the source, values should have increased at night when the facility was closed up. The opposite was observed. It had to be coming from an inside source. What was the TCE source? On-site discrete sampling with the system found the hidden source.

Determining Cause & Effect



Definite Correlation with Differential Pressure



Correlation with Barometric Pressure Decrease

Comparison of the indoor TCE values to barometric pressure shows an increase in TCE concentrations when there is a drop in barometric pressure (probably due to ocean temperature effects).

Comparison of the indoor TCE values to sub-foundation pressure shows a direct correlation between indoor air concentrations to positive pressure under the slab.

Expedited Building Remedies

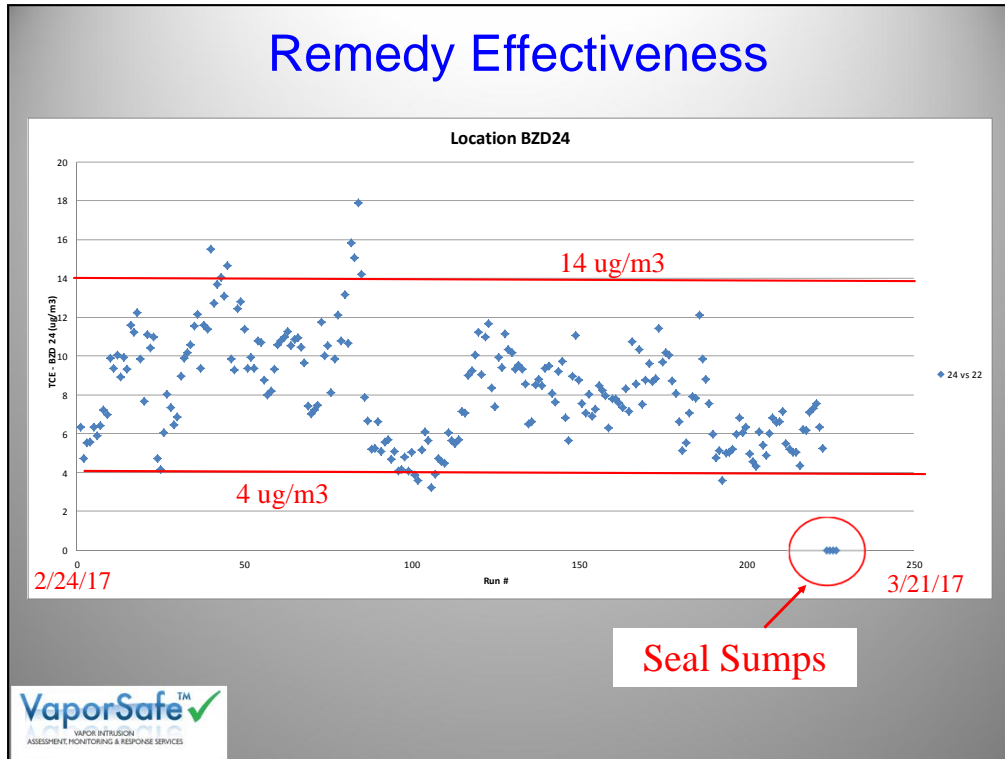
- Can Try Various Remedies & See Effects
 - HVAC modifications
 - Fans on/off
 - Air filtration units
 - Sealing sumps & cracks
 - Optimizing vapor recovery systems

Can put VI Issue to Rest in Days
Rather than Months or Years!!



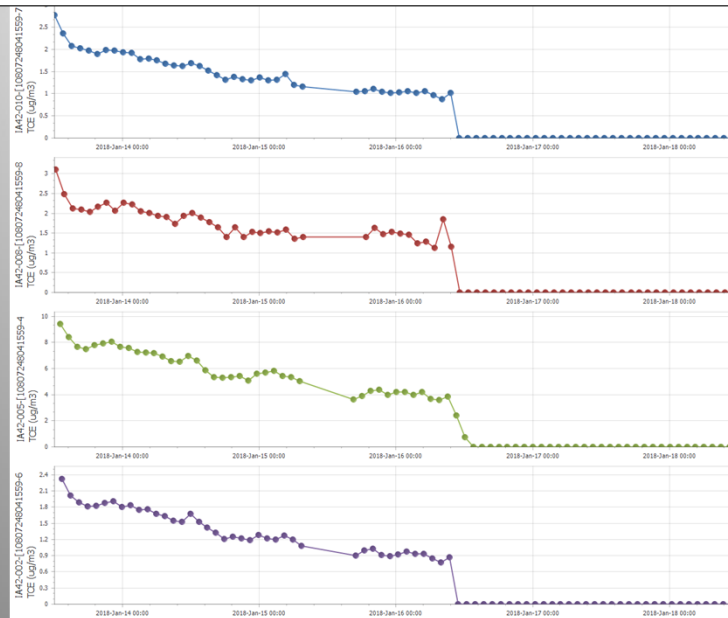
Monitoring data allow real-time evaluation of the effectiveness of a remedy. Adjustments to HVACs, vapor recovery systems, indoor air filtration units, exhaust fans can be made and the results seen in real-time.

Remedy Effectiveness



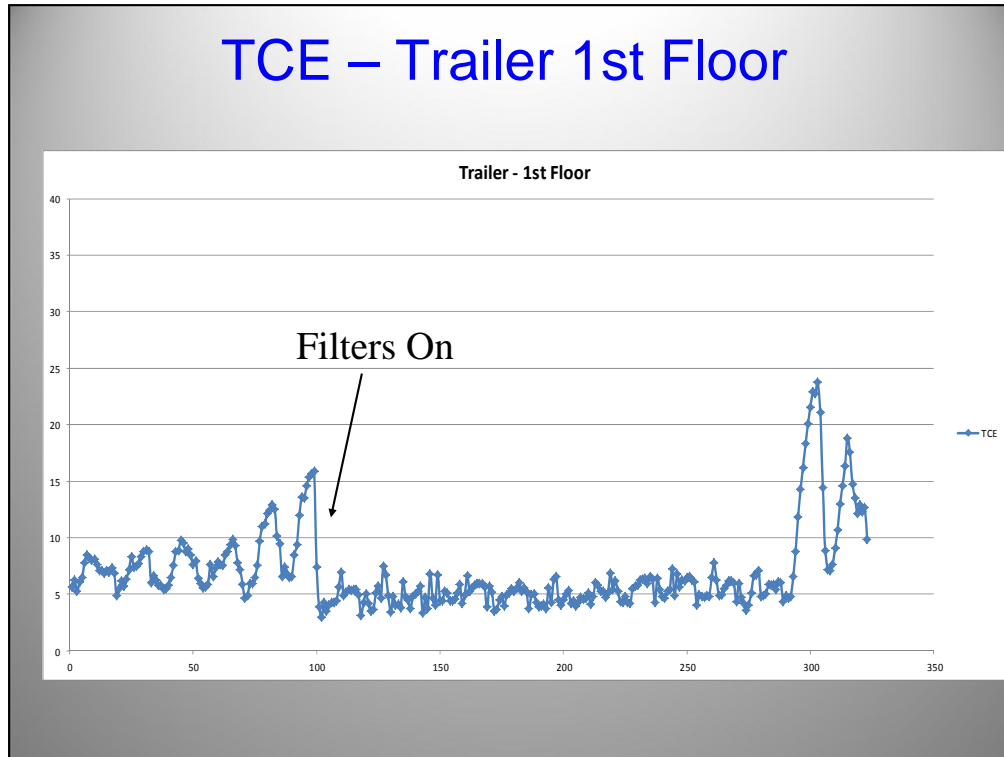
TCE concentrations in a basement at an industrial facility. Values ranged from 4 ug/m³ to 14 ug/m³ over the 1-month sampling period. But when two floor sumps were sealed up, values dropped to zero within a couple of hours. The monitoring data documented that this remedy would be effective and plans were made to seal the sumps permanently.

Proving the Effectiveness of a Remedy



TCE indoor air concentrations at 4 locations in an operating facility. Note instant drop in indoor air TCE concentrations when the mitigation system was started-up and to levels that were far below allowable levels. The consistent low TCE values over the next 3 days was proof of the effectiveness of the system over the footprint of the building.

TCE – Trailer 1st Floor



Indoor air concentrations of TCE in a double-wide trailer with a skirt underneath the trailer floor. Two indoor air filtration units were installed as a remedy to high TCE values (5 to 15 $\mu\text{g}/\text{m}^3$). The filters decreased the indoor air TCE concentrations, but not below allowable levels. Another remedy had to be selected.

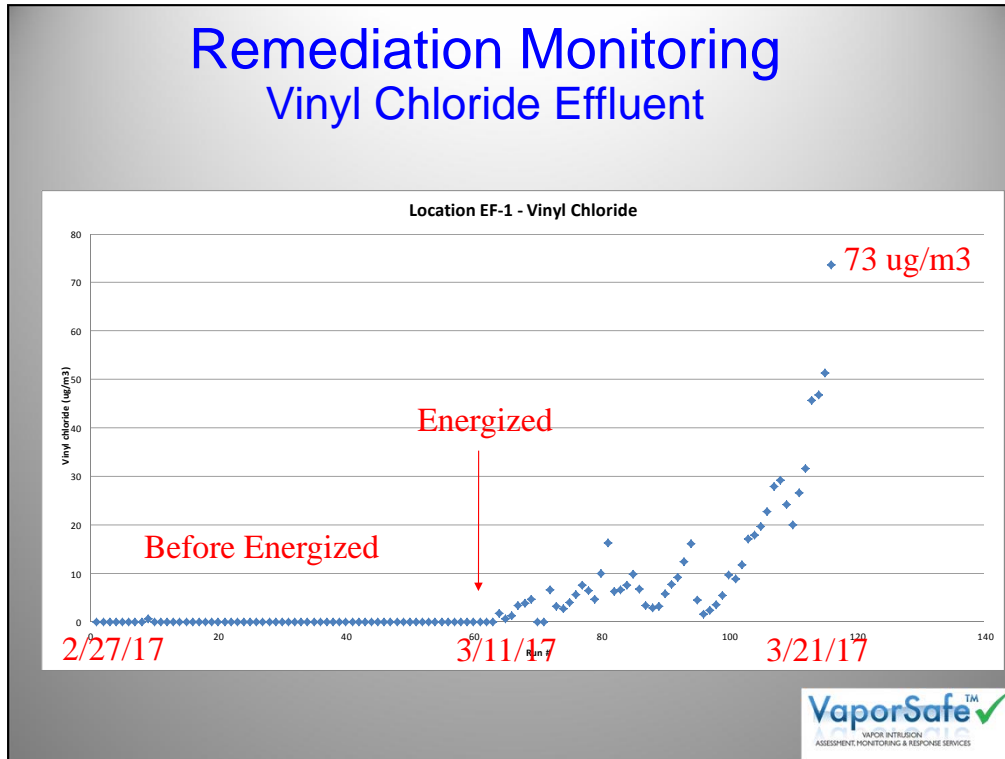
Monitoring Remediation

- Remediation & Mitigation System Monitoring
 - Thermal Heating - ERH
 - In-Situ GW/Soil Remediation - Peroxide
 - Sub-Slab Depressurization Systems

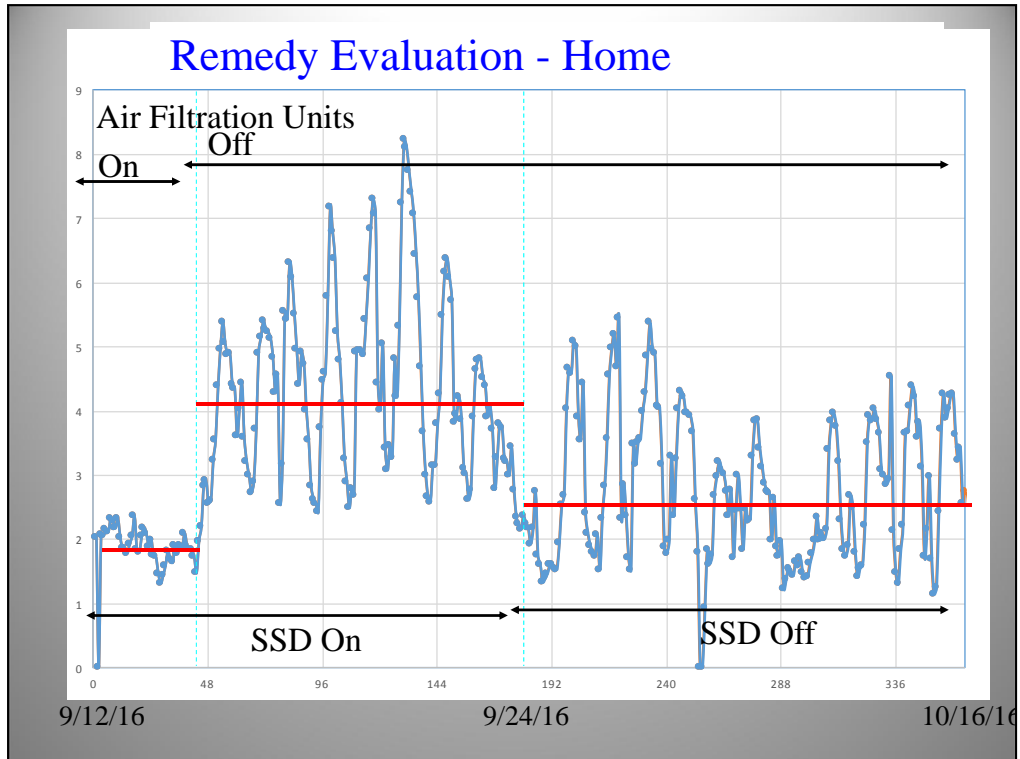


Vaporsafe can provide data from many locations around a site or a building to demonstrate the effectiveness of remediation systems and building mitigation systems.

Remediation Monitoring Vinyl Chloride Effluent



Vinyl Chloride in the effluent from a permanganate scrubber located immediately adjacent to a large thermal remediation project. The vinyl chloride concentrations started increasing almost immediately once the electrodes were energized. Vaporsafe data enabled rapid recognition of this situation and enabled the consultant to take immediate corrective action.



TCE in a single-family home over 30 days. The home had two mitigation systems operating: an air filtration unit and a vapor recovery system (SSD). Note that the average TCE concentration while the air filtration units & SSD were both operative was 1.9 ug/m³, then jumped to 4.2 ug/m³ when the air filtration units were turned off, but the SSD was still operating. Once the SSD was turned off, the mean concentration dropped to 2.6 ug/m³.

The daily oscillation correlated perfectly with wind speed.

None of this would have been recognized without high resolution monitoring data.

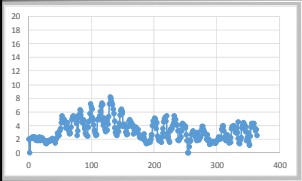
Summary



- High Resolution Data Allows Pattern
- **Pattern = Opportunity**
- Opportunity to:
 - Differentiate Indoor vs Subsurface Source
 - Find VOC entry locations, preferential pathways
 - Determine best remedy
 - Evaluate effectiveness of mitigation systems
 - Evaluate effectiveness of remediation systems

Within Days!

Summary of lessons learned from monitoring projects since March 2015. Continuous high frequency monitoring can be implemented during many phases of a vapor intrusion project life-span: initial evaluation, determining whether mitigation is required, and if so, to help optimize the remedy. The key to all of this is having enough data to recognize the pattern. Once you have the pattern, you have an opportunity to figure out the cause of the pattern and to find remedies for it. All this can be done with one mobilization.

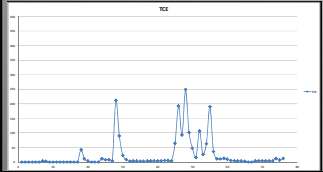


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The Obvious Questions:

- What Does it Cost?
 - ✓ \$1000 - \$2000/day (~\$10/analysis)
 - ✓ 10 canisters: \$5000
- Do Agencies Accept?
 - ✓ EPA Regions 1, 9, 10
 - ✓ CA, NH, IN, AZ, Navy
 - ✓ Upcoming: EPA-R5, NC, USAF
- How do Results Compare to TO-15?
 - ✓ No complaints to date

