FACT SHEET

Continuous Monitoring for Vapor Intrusion

Introduction

The assessment of vapor intrusion (VI) is complicated by a high degree of spatial and temporal variability. This fact sheet will focus on recent applications of a continuous monitoring (CM) technology that provides quantitative measurements of vapor concentrations in the field. CM can help to address site-specific building conditions that influence the VI pathway over time.

Technology Background

Real-time monitoring involves the collection and reporting of data and sampling results on the order of seconds to minutes. The CM system is designed to provide readings of contaminant concentrations in indoor air every 5 to 10 minutes depending on the analyte list (Figure 1). This provides a high density of time-correlated data across daily ranges of environmental conditions (144 measurements per 24-hour day from up to 16 locations). Typically, a one- to five-day deployment of the instrument is adequate. With regulatory stakeholder approval, CM can be used independently to monitor site conditions and/or in concert with conventional VI sampling techniques such as Summa™ canisters.

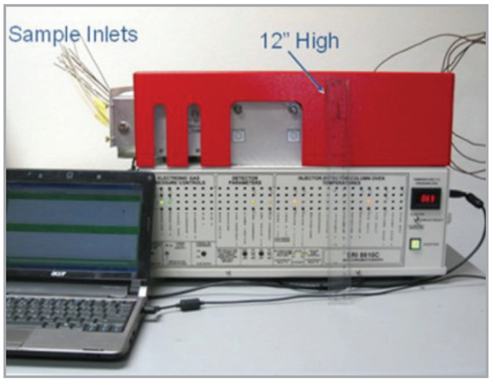

Figure 1. CM Instrument with Laptop (Courtesy of Groundswell Technologies)

How Does It Work?

CM is accomplished using a modified gas chromatograph (GC) equipped with an electron capture detector (ECD). The device is multiplexed with a 16-port valve to achieve sequential sample collection from multiple locations. CM can be applied to monitor tetrachloroethene (PCE), trichloroethene (TCE), dichloroethene (DCE), carbon tetrachloride, methane, benzene, toluene, ethylbenzene, and xylene, as well as several other volatile organic compounds (VOCs). Sampling lines can be extended up to 980 feet from the analytical instrument. Air from each sampling point is continuously drawn through each sampling line and sequentially analyzed. Analytical results are available within one minute. The analytical results may be combined with simultaneous measurements of barometric pressure, pressure differential across the foundation, wind speed, and temperature to identify time-correlated factors driving VI at the site. Remote processing can include automated contour displays and alerts based on project-specific thresholds.

How Can It Help?

The information collected can help to:

- ☐ Determine if a VI issue is present,
- ☐ Locate preferential pathways,
- ☐ Identify driving factors and corresponding vapor behavior, and
- ☐ Differentiate between VI from subsurface sources versus background VOCs from indoor sources.

Case Study 1: Naval Air Station North Island | **Case Study 2:** NALF San Clemente Island | **Lessons Learned**

CASE STUDY 1

Naval Air Station North Island

Project Objective: CM was deployed for nine days to evaluate potential VI risks associated with a documented TCE release under Building 379 at Naval Air Station North Island (NASNI), San Diego, California (Hosangadi et al., 2017; Kram et al., 2019). The main objective of this project was to understand exposure risks over space and time and to evaluate potential mechanisms controlling VI that could be used to design a long-term risk reduction strategy.

Site Background: Building 379 is used for carpentry, machining, and similar industrial operations. It overlies a high-concentration plume of TCE, PCE, and Stoddard solvent. The building was built in the 1940s and the concrete floor was in poor condition with over 15,000 ft of cracks that required sealing. Numerous floor drains were also present. Sub-slab soil vapor TCE concentrations as high as 6,000,000 µg/m^3 have been documented. Six indoor monitoring points were established for CM application in the 172,000-square-feet facility.

Results: Several visualizations of the CM data for TCE are shown in Figure 2. The lower left panel displays TCE concentration patterns from one of the sampling locations over three days, with regular peak concentrations of 300 to 400 µg/m^3 occurring late in the morning each day. The table in the lower right panel provides a record of alerts based on project-specific thresholds. The top three panels display geospatial contours of readings that include: instantaneous, 1-hour time-weighted average, and 24-hour time-weighted average.

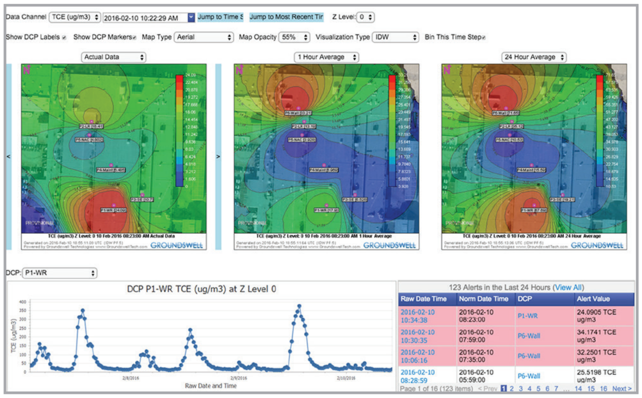

Figure 2. VI Monitoring Dashboard at NASNI (Courtesy of Kram et al., 2019)

The women's restroom in Building 379 was selected for additional evaluation because it represented an area of concern from an acute TCE risk perspective and because the highest observed concentrations were recorded there during prior VI sampling events. The pressure differentials between the indoor air and sub-slab were also continuously monitored. Findings from the continuous testing indicated that chlorinated volatile organic compounds (CVOCs) in indoor air showed peaks at noon and midnight, along with a corresponding trend in pressure differential (Figure 3).

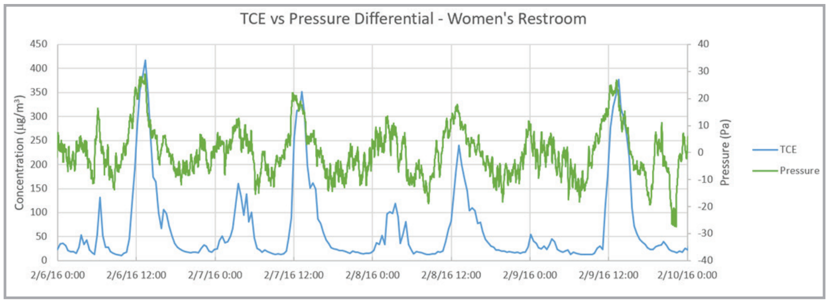

Figure 3. TCE Monitoring Results by ECD and Pressure Differential (Courtesy of Battelle)

An increase in pressure differential was found to correlate with an increase in TCE concentration. A statistical analysis indicated a positive correlation (r^2 of 0.6) between the TCE concentration in indoor air and positive pressure differential values. These data suggest that naturally occurring diurnal pressure changes can influence the pressure differential across a slab driving advective intrusion of TCE and resulting in the potential for short-duration exposure events.

Outcome: The CM results suggested that air sampling designs reliant on randomly timed grab or time-averaged samples could lead to over- or underestimations of indoor air concentrations. The CM system was also later deployed to confirm that the soil vapor extraction (SVE) system installed in the nearby subsurface successfully mitigated VI to Building 379.

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CASE STUDY 2
NALF San Clemente Island

Project Objective: CM was deployed for one week at Installation Restoration (IR) Site 17, Power Plant Building at Naval Auxiliary Landing Field (NALF), San Clemente Island, California (NAVFAC, 2020). The purpose of the CM investigation was to determine whether unacceptable PCE and TCE concentrations were present inside of the main power plant building at IR Site 17.

Site Background: IR Site 17 is an active power plant originally built in 1968 and remodeled in 1993. The building is a metal-sided structure on a concrete slab on a relatively flat, graded area. During reconstruction in 1993, chlorinated solvents and petroleum products were identified adjacent to and underneath the building. Contaminated soil was over-excavated, but impacted soils were left in place under the building. Sub-slab soil gas samples were collected from 12 locations under the building footprint in 2006 and modeling indicated no unacceptable risk. Three follow-up sub-slab soil gas samples were collected in 2013 from below the central portion of the generator room. The maximum concentrations of benzene, TCE, and PCE exceeded respective California residential risk screening levels and the maximum PCE concentration exceeded the industrial screening level. Although the results of a human health risk assessment indicated that unacceptable risks to workers were unlikely, the state regulator recommended additional monitoring of VOCs.

Results: CM was performed for one week to quantify concentrations of PCE and TCE in sub-slab air, indoor air, and background/outdoor air (see example plot in Figure 4). A pressure differential sensor was also installed at the sub-slab monitoring point. One-liter Summa^{TM} canister samples of indoor air, outdoor air, and sub-slab soil gas were collected during a time period matching one cycle of the CM (~10 minutes) from a location immediately adjacent to the CM sampling point. Confirmation samples were analyzed by an off-site laboratory for comparison to CM results.

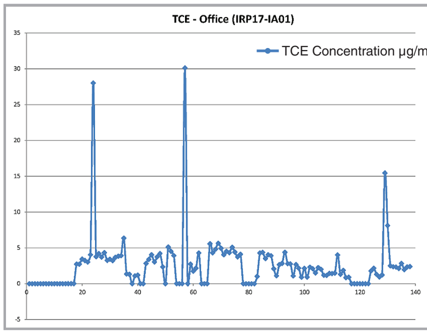

Figure 4. A Time Series Plot of TCE at NALF San Clemente Island (Courtesy of NAVFAC, 2020)

PCE and TCE were detected in each of the five indoor CM sampling points. For the office location, TCE results ranged from non-detect to 30.1 $\mu g/m^3$ (see Figure 4). No patterns were found to correlate indoor air values with wind speed or direction, pressure differentials, or office occupancy. All of the indoor air Summa^{TM} canister confirmation analyses were non-detect for both PCE and TCE, which is consistent with the CM results for the contemporaneous time periods. The ECD was successfully calibrated for the low concentrations in indoor air. However, the higher concentrations reported in the sub-slab were found to exceed the calibration range of the ECD. The TCE concentration in the sub-slab was found to be up to 860 $\mu g/m^3$ via Summa^{TM} canister sampling. There were no background or ambient air contributions to the indoor air VOCs.

Time-weighted averages were developed for the shifts in which the highest TCE concentrations were reported by CM in the office and switch room. A typical worker in the power plant building works 10-hour shifts for seven consecutive days every other week, resulting in an exposure frequency of 182 days per year. The site-specific parameters were input into the EPA Vapor Intrusion Screening Level Calculator (VISL-C) for a commercial/industrial scenario. The Annual Average and Lifetime Average Daily Exposures and the Hazard Quotient (HQ) and Excess Lifetime Cancer Risk (ELCR) were calculated (see Table 1).

Table 1. Annual Average and Lifetime Average Daily Exposures, Hazard Quotient, and Cancer Risk			
Annual Average Daily Exposure [$\mu g/m^3$]	0.472	Hazard Quotient [HQ]	$2.36E^{-01}$
Lifetime Average Daily Exposure [$\mu g/m^3$]	0.168	Excess Lifetime Cancer Risk [ELCR]	$6.19E^{-07}$

Outcome: The resulting HQ is well below the acceptable level of 1. The resulting ELCR is below the lower end of the target risk range of $1E^{-06}$ to $1E^{-04}$. Based on this calculation, TCE concentrations in indoor air do not pose an unacceptable risk to the IR Site 17 power plant workers. CM provided the detailed evidence to establish that unacceptable human health risks were not present with a high degree of confidence.

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Lessons Learned

Conclusions

High-frequency, real-time VI data from multiple locations provides critical, spatial, and temporal resolution. This allows practitioners to rapidly respond to dynamic vapor migration processes and controlling factors. These two case studies provide important lessons learned including:

- ☐ Understanding the temporal and spatial variability in indoor contaminant concentrations can support the selection and design of effective mitigation measures.
- ☐ Indoor vapor concentration dynamics are typically governed by barometric pressure changes, indoor air handling actions, and responses to active remediation efforts.
- ☐ Barometric pressure dynamics and building air-handling can induce pressure differentials adequate to cause advective vapor flux from the subsurface into buildings.
- ☐ CM supports precise identification of vapor entry locations, can generate correlated data to distinguish between indoor vapor sources and VI, and can be applied in active, adaptive strategic configurations to fine tune and optimize ongoing mitigation and remediation actions.
- ☐ As in the NASNI site case study, the use of CM can support remedy implementation by ensuring VI mitigation strategies are working and monitoring the potential for VI exposures.
- ☐ As in the NALF San Clemente Island case study, where the potential for VI was expected to be low, CM provided the detailed evidence to establish that unacceptable human health risks were not present, with a high degree of confidence.
- ☐ Through automated CM and programmed response plans, VI mitigation performance issues can be corrected before concentration levels exceed thresholds by better understanding the site-specific causes of VI.
- ☐ There are limitations to be aware of in relation to the type and the amount of VOCs present at a site. The system does not analyze for all compounds typically included in a traditional laboratory TO-15 method. The system only analyzes for a subset of VOCs, principally halogenated compounds. In addition, the CM system could be prone to interferences if an abundance of VOCs exists at a site.
- ☐ Information on the potential concentration range at the site is needed in order to avoid exceeding the calibrated concentration range for the CM system. This information will allow for the best detector to be selected and better calibration of the CM system.

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