FACT SHEET

High-Volume Sampling for Vapor Intrusion Assessments

Introduction

High-volume sampling (HVS) is an innovative method to characterize the nature and extent of volatile organic compound (VOC) vapor distributions beneath large buildings in less time, with less risk of missing vapor sources, and at a lower cost than conventional investigation methods. Conventional sub-slab soil gas samples contain 1 liter (L) or less, which represents a very small region below the floor and provides no data for areas between sample locations. Some regulatory guidance documents specify one conventional sample for every 2,500 square feet (ft^2) or less of floor space; therefore, large buildings may need numerous conventional samples to minimize the risk of missing a vapor source. This approach can be invasive to occupants and expensive to execute. In contrast, HVS tests consist of extracting 10,000 to 100,000 L of sub-slab soil gas per sample location, which provides data over large areas and reduces the number of sampling locations. If mitigation is required, HVS provides quantitative pneumatic data for the design and optimization of a vapor intrusion mitigation system (VIMS) without conducting a second monitoring event. The pneumatic data can also be used to evaluate how susceptible the specific building is to vapor intrusion (VI).

Technology Background

HVS involves extracting thousands of liters of sub-slab soil gas and monitoring total VOC concentrations and pneumatic response during a typical 1-hour test. Vapor concentrations are monitored as a function of the volume of gas removed, providing insight into the spatial distribution of vapors at progressively larger distances from the extraction point. Fixed gases (oxygen, carbon dioxide, and methane) are also monitored to quantify dilution of VOCs in the extracted sub-slab soil gas caused by the downward flow of indoor air across the floor slab during testing. HVS reduces the number of sampling locations, thereby also reducing the time, cost, and risk of missing significant subsurface sources of VOCs. The equipment and procedures are similar to those used in a soil vapor extraction (SVE) pilot test (Figure 1).

Figure 1. HVS Sampling Apparatus (Courtesy of Geosyntec)

How Does It Work?

HVS equipment consists of a fan connected by a pipe to a suction pit, which is excavated through a hole cored in the slab. A sampling port and vacuum gauge are set at the extraction point. Extracted gas is monitored in real time with portable instruments, such as a photoionization detector (PID) to record total VOC concentrations and a landfill gas meter to measure oxygen, carbon dioxide, and methane. The flow rate achieved by the fan depends on the permeability of the material below the floor slab, which is typically a highly permeable, granular fill material. Vacuum versus (vs.) distance profiles are generated by measuring vacuum below the floor at multiple monitoring points installed through the slab at varying distances and directions from the suction point. Transient pneumatic testing (vacuum vs. time) is also conducted at the end of the HVS test by turning the fan on and off. The pneumatic data are entered into a spreadsheet (Environmental Security Technology Certification Program [ESTCP], 2019), and software (AQTESOLVE v4.5) is used to calculate the transmissivity of the sub-slab material and to quantify the leakage of air across the slab. Both are critical parameters for VIMS design, if needed (McAlary et al., 2020). Samples for laboratory analysis can be collected to provide compound-specific concentration data for comparison to appropriate screening levels. In addition, the pneumatic data can be used to calculate building-specific attenuation factors and site-specific screening levels, which are more defensible than generic screening levels. This building-specific approach reduces the potential for a false-positive assessment of inhalation risks and unnecessary mitigation (McAlary et al., 2018).

How Can It Help?

HVS tests help with the following:

- Characterizing the sub-slab VOC distribution with fewer sampling locations and more certainty between locations
- Reducing investigation costs and operational disruption compared to conventional sampling
- Identifying the presence and location of preferential pathways of vapor transport
- Evaluating building-specific susceptibility to VI through the calculation of building-specific attenuation factors and screening levels
- Collecting data concurrent to the site investigation for an optimized VIMS design including radius of influence (ROI) information

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CASE STUDY 1

Naval Air Station Corpus Christi, Texas

Project Objective: Conduct a VI pathway evaluation in a 23-acre military manufacturing building with minimal disruption to mission-critical manufacturing operations performed at Naval Air Station (NAS) Corpus Christi, Texas.

Site Background: Previous operations resulted in trichloroethene (TCE) releases to soil and groundwater beneath an industrial building. Conventional sub-slab sampling would have required hundreds of sample locations across nearly 1 million ft^2 of floor space. The conventional sampling approach originally planned would have been prohibitively expensive and disruptive to manufacturing operations, while taking months to execute.

Results: The VI assessment was completed by conducting 33 HVS tests. The HVS testing demonstrated no TCE sources under 95% of the building, identified one significant TCE source area, and provided sufficient data for designing a focused VIMS. The investigation was conducted over 3 weekends and caused no interruptions to mission-critical operations. The HVS approach helped to reduce the cost of the VI investigation by approximately 10 times compared to original plans (saving more than $1M).

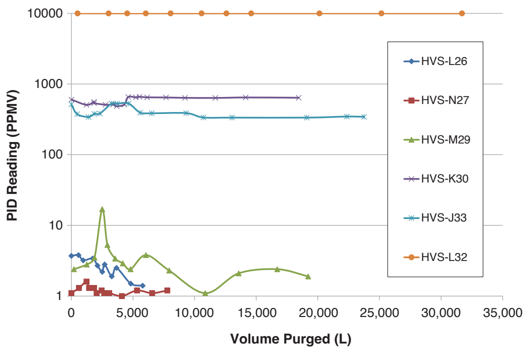

Figure 2. Total Organic Vapor Concentration vs. Volume Purged for Six Typical HVS Tests from Building 8, NAS Corpus Christi (Courtesy of Geosyntec)

Figure 2 shows the total organic vapor concentration vs. volume purged for six HVS tests conducted at the site. These results illustrate how patterns in extracted VOC concentrations can be used to differentiate between various soil or groundwater VOC sources. Figure 2 indicates that one location had PID readings of greater than 10,000 parts per million by volume (ppmv) throughout 30,000 L of gas extraction, clearly indicating a substantial source of vapors. HVS test results from the other locations in Figure 2 showed progressively lower VOC concentrations, consistent with an expected decrease in vapor concentrations with increasing distance from the source. Most locations showed VOC concentrations of a few ppmv or less.

The pneumatic data from the HVS testing was used to design the VIMS for the building without the need for a separate pilot test, which resulted in significant time and cost savings. In general, the ROI for a VIMS can be estimated based on key parameters including vacuum, velocity, travel time, and proportion of flow across the floor. For more information on ROI calculations, see the Vapor Intrusion Mitigation Model - VIM Model V2.2 (ESTCP, 2019). For the NAS Corpus Christi project, the estimated ROIs ranged from 6 meters (m) to 27 m at various suction points. A combined SVE/VIMS was installed and operated with off-gas treatment to address VOCs in the subsurface. As shown in Figure 3, the mass removal of TCE from the subsurface proceeded rapidly and successfully mitigated indoor air concentrations (Creamer et al., 2022, Martin et al., 2022).

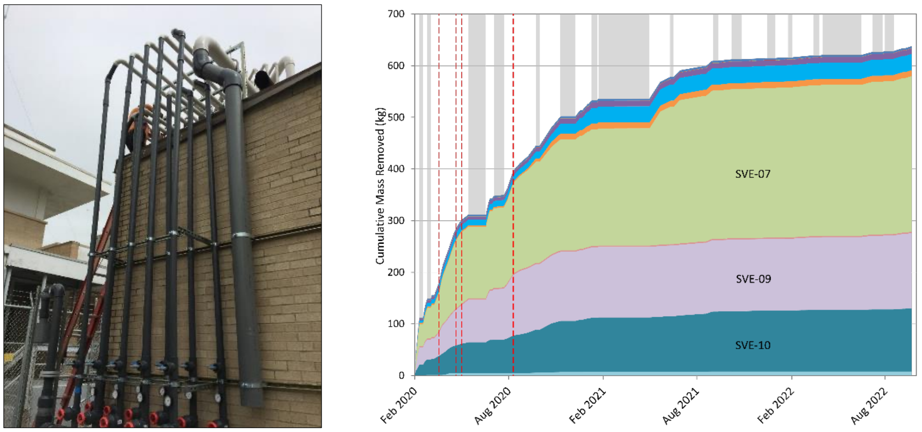

Figure 3. Combined SVE/VIMS Manifold and TCE Mass Removal (Courtesy of Geosyntec)

Outcome: HVS allowed for rapid and low-cost investigation and mitigation of TCE VI under a 23-acre building without causing disruptions to operations. HVS identified the location of the VI source and provided data for optimization of the VIMS design.

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CASE STUDY 2

Naval Station Norfolk, Virginia

Project Objective: Compare various methods of sub-slab sampling and analysis to assess whether the type of sampling method would result in different site management decisions.

Site Background: The United States Environmental Protection Agency (U.S. EPA) collaborated with the Navy and contractors to perform this applied research project at Naval Station (NS) Norfolk, Virginia. The study was performed in a large (120,000 ft^2), one-story industrial warehouse that had elevated VOC concentrations below the floor slab.

Results: Sub-slab samples were collected using several methods (Table 1). Real-time analysis by onsite gas chromatography (GC) with an electron capture detector (ECD) was conducted for 24 months to assess temporal variability. Tests were also conducted to compare results from active and passive sorbent samplers, canister samples, and HVS. These tests were used to evaluate whether the measured concentrations of VOCs collected for VI assessment were influenced by sample and purge volumes, sample collection time, or the method of sampling and analysis.

HVS was performed at 7 locations (Figure 4). The study was conducted for 14 total hours for 7 HVS tests for a typical deployment of 2 hours per test. Between 6,000 and 28,000 L of soil gas were extracted from below the slab. PID readings vs. volume extracted are shown in Figure 4. In areas where traditional sampling and HVS were co-located, results indicated only small differences in observed sub-slab concentrations and would not have changed site management decisions. One HVS test showed increasing PID readings after about 5,000 L of soil gas extraction (see data series labeled “4in5” in Figure 4). This test result indicated the presence of a previously unidentified VOC source for future investigation (Williams et al., 2023). For the NS Norfolk project, the ROIs from the HVS tests were estimated to range from approximately 8 m to 18 m.

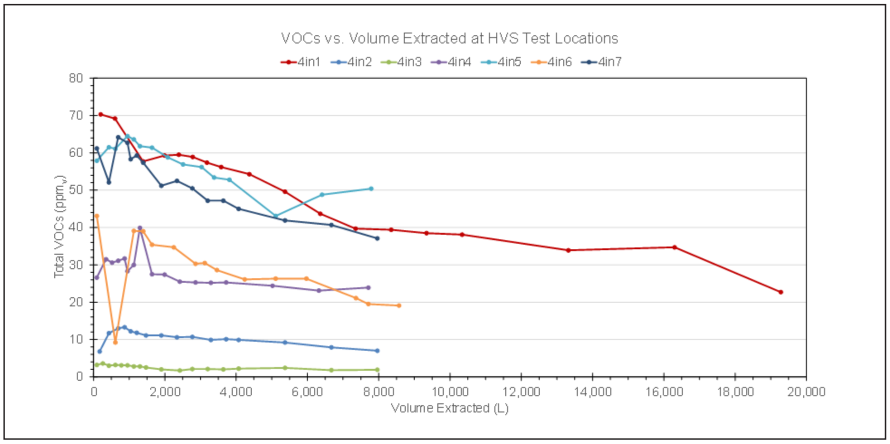

Figure 4. PID Readings vs. Time at Seven HVS Locations (Courtesy of U.S. EPA)

Table 1. Comparison of Sub-slab Sampling Methods

Sub-slab Sampling Method	Duration of Sample Collection (min)	Total Volume Purged/ Collected (mL)	Flow Rate of Sampling (mL/min)
GC-ECD	5	300/20	60
Passivated Canister	2–1,440	7,000/1,000	<200
Syringe Pulled Sorbent Tubes	1	50/150	<200
Passive Samplers (2 Types)	2,900–10,000	0	0
HVS	69–97	6,200,000–28,000,000	67,000–300,000

Outcome: The study validated the use of HVS for VI assessment compared to conventional sampling methods. At most sampling locations, conventional sampling and HVS produced analytical results that would have led to similar site management decisions. The HVS results also provided data to assess vapor distributions between sample locations.

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Conclusions

Conclusions

Important lessons learned regarding the HVS technology, compared to traditional sub-slab sampling, are summarized in the table below. As with all technologies, HVS has capabilities and limitations that should be considered before selection and application.

Advantages	Limitations
• HVS can significantly reduce the sampling number, frequency, and cost required for VI assessment. • HVS decreases interruptions to site operations and uncertainty regarding vapor distributions between or beyond sample locations. • HVS samples are comparable to conventional sub-slab sampling methods for use in comparison to screening levels. • HVS has a lower risk of a false negative outcome or of failing to identify an area of elevated vapor concentrations that may exist between or beyond sample locations. • HVS can capture sub-slab vapor from under nearby restricted access areas. • HVS provides data for optimal VIMS design and evaluation of the ROI of venting system suction points using vacuum, velocity, travel time, and mass-balance lines of evidence. • HVS can identify the presence of atypical preferential pathways via analysis of pneumatic and tracer test data. • HVS provides a measure of the leakage of the floor slab to support decisions regarding the necessity of floor sealing. • HVS can be used to calculate a building-specific attenuation factor, which may result in site-specific screening levels that are more appropriate than generic screening values.	• HVS is not well-suited to buildings with badly disintegrated floor slabs. • HVS may not be feasible if the water table is very shallow (< 2 feet) below the floor slab. • HVS may not be possible if the floor slab is too thick for coring. • Buildings with slabs on clay-rich or wet soils can yield very low flow rates, which could render the HVS test method ineffective. • Flow to the suction point may not be radial if the material below the floor slab has irregular permeability (this can be assessed using vacuum monitoring points in different directions and tracer testing). • The effluent gas may need to be treated (e.g., carbon filtration) if the building is too large to run a discharge hose through an exterior door or window. • Special considerations for safety are required if methane is present below the floor slab near the explosive range (5 to 15 volume to volume percentage) or higher. • Regulatory acceptance of new tools for VI investigation is variable.

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