DoR-VOAP-G-01-Vapor Mitigation Guidance-01102023

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This document is guidance only and does not create legal rights or obligations. Agency decisions in any particular case will be made applying applicable laws and regulations to the specific facts. TDEC decision-makers retain the discretion to adopt or approve investigation and mitigation approaches for VOAP Brownfield project sites on a case-by-case basis that differ from this guidance document, where appropriate.

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1	1.10.2023	Corrected Typographical Errors & Adjusted Select Formatting

Vapor Mitigation Guidance for Sites Enrolled in the Brownfield Projects Voluntary Cleanup Oversight and Assistance Program

FINAL

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Tennessee Department of Environment and Conservation
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1.0 INTRODUCTION

This technical guidance document presents the preferred methodology of the Tennessee Department of Environment and Conservation (TDEC) Division of Remediation (DoR or Division) on how to identify vapor intrusion (VI) risks that warrant mitigation at sites enrolled in the Brownfield Projects Voluntary Cleanup Oversight and Assistance Program (VOAP).

The guidelines and technical recommendations presented herein can be used to satisfy Division expectations regarding vapor intrusion under the VOAP so that program participants are eligible to receive liability protection or otherwise obtain a letter of No Additional Action.[1]

The risk-based, data-driven process described herein intentionally focuses on one line of evidence to guide mitigation decision making: soil gas data—either sub-slab soil gas in the case of an existing building, or exterior soil gas in the case of new construction. It has been the experience of the Division that by focusing on soil gas data, mitigation decisions can be made on a relatively rapid time frame that can often be compatible with VOAP Brownfield project development timelines. Mitigation decisions based on soil gas are protective, defensible, and transparent.

This document establishes a process for evaluating concentrations of volatile organic compounds (VOCs) in soil gas and determining when vapor mitigation is warranted at Brownfield projects being managed under the VOAP. The steps described in this guidance provide a path that will help ensure human health is adequately protected from vapor intrusion risks at VOAP sites and that VOAP Brownfield projects will be safe for their intended re-use.

This document was prepared by TDEC-DoR staff from the Central Office and Regional Environmental Field Offices and establishes a state-wide process to ensure consistency across Regional Environmental Field Offices. While the intended audience is primarily DoR Project Managers (PMs), it is also intended to be used by environmental professionals so that Division expectations regarding VI mitigation decision making is understood for sites enrolled or planning to enroll in the VOAP. An external comment period was held between

[1] This guidance was primarily developed with non-liable party VOAP sites in mind (i.e., sites managed under a Brownfield Voluntary Agreement). Responsible parties with sites in the VOAP being regulated under a Voluntary Consent Order may utilize the guidance to determine if vapor mitigation is warranted at existing or planned buildings, however all other applicable TDEC-DoR rules regarding conducting a remedial investigation and determining remedial goals should also be followed.

10/11/21 and 12/13/21. All received comments were considered, and appropriate changes were incorporated into the document.

While this guidance focuses on soil gas collection in the context of existing or planned buildings, some VOAP participants may need to collect soil gas data from other areas of a site, as well as data from other media, to meet overarching VOAP characterization requirements.

2.0 SCOPING AND PLANNING

The Division considers soil gas data—either sub-slab soil gas in the case of an existing building, or exterior soil gas in the case of new construction—to be the type of environmental data that are most useful in guiding mitigation decisions at VOAP Brownfield projects. If soil gas data are unable to be collected due to site-specific reasons, the DoR PM and the Brownfield project's environmental professional should discuss acceptable alternatives during scoping and planning.

While comprehensive site-specific VI investigations are often conducted by examining multiple lines of evidence, this guidance presents a streamlined approach focusing on quantitative soil gas data as a primary line of evidence. By focusing on soil gas data, the VI pathway can be investigated expeditiously so that potential current and future VI risk can be determined relatively quickly, and appropriate mitigation strategies can be rapidly integrated into a VOAP Brownfield project.

Plan to collect and use soil gas data as the primary line of evidence to determine the need to mitigate the VI pathway at VOAP Brownfield project sites.

The collection of the appropriate amount and type of soil gas data (i.e., sub-slab or exterior soil gas) will be a primary planning and scoping activity. Other scoping activities will involve understanding the planned end use of the project and deciding whether residential or commercial screening and risk evaluation will occur (see Section 4.2 Residential vs. Commercial Screening).

While determining when VI mitigation is required at a VOAP Brownfield project is the primary goal of this guidance, remediation of VI source mass should be evaluated as a more permanent option for addressing vapor intrusion risk at VOAP sites and may be required at some sites.

After project scoping and planning, and prior to beginning a VI investigation involving soil gas sampling, a VI sampling work plan should be submitted to the PM for review and approval.

2.1 Existing Buildings

Sub-slab soil gas collected from beneath a potentially impacted building of interest provides the primary line of evidence for making VI risk-based mitigation determinations for existing buildings. Collecting this type of soil gas data allows for quantitative analysis of VOCs directly below the slab of a building and enables estimates of current and future exposure and risk to building occupants from indoor air concentrations predicted from sub-slab concentrations. Note that when existing buildings are the subject of a VI investigation, in addition to sub-slab soil gas samples, indoor air samples should be collected to gauge current exposure to any current or potential building occupants. In addition, if receptors are present in existing buildings and indoor air concentrations are elevated, contributions from preferential pathways should be considered, and preferential pathways sampled if identified.

For existing buildings, mitigation decisions will be primarily based on sub-slab soil gas. However, indoor air samples will be needed to assess current risks if receptors are present.

2.2 New Construction

For new construction, exterior soil gas collected within the proposed footprint of a planned building will be the primary line of evidence for planned buildings and will be used to predict exposure and risk to future occupants.

For new construction, mitigation decisions will be primarily based on exterior soil gas collected within the footprint of the planned building(s).

3.0 SAMPLING AND CHARACTERIZATION

For the sampling described in this guidance: (1) time-integrated samples will be collected for indoor air, and (2) flow-controlled samples will be collected for soil gas. Samples will be collected in either: evacuated stainless steel or silica-lined canisters that are under negative pressure relative to the environment and are certified by the laboratory to be clean and leak free; or, in pumped sorbent packed tubes that are batch or individually certified clean for soil gas and individually certified for indoor air. Soil gas and air samples are collected and analyzed via Method TO-15 (EPA 1999) or TO-17 (EPA 1999). For indoor air samples, a selected ion monitoring (SIM) analysis may be needed to provide sufficiently low detection limits for indoor air screening evaluations. Indoor air samples are often collected over a 24-hour period in residences or over an 8-hour period (or workday equivalent) in commercial or industrial settings. Sub-slab and exterior soil gas samples can be collected over a much shorter sampling duration with flow rates typically set between 100 mL/minute and 200 mL/minute.

3.1 Sub-Slab Soil Gas Data

The minimum number of sub-slab soil gas collection locations are presented below in **Table 3-1**. Sample collection should be biased toward potential contaminated areas (e.g., suspected source locations such as near former drycleaner machines or waste storage areas) and areas where human occupancy is expected. Biasing sample locations in this manner may increase the number of samples above the minimum.

Features and conditions that may justify altering the number of samples or biasing a sample location include, but are not limited to, the following:

- presence of sensitive populations
- past usage (e.g., dry cleaners, vapor degreasers, underground storage tanks)
- building construction, type of slab, footers, utility lines, etc.
- presence of earthen or damaged floors

- presence of sump pits
- requests from building owner
- elevator pits
- portion of building overlying or contacting the highest levels of VOCs previously detected in the subsurface
- areas of frequent use (e.g., playrooms, family rooms, classrooms, offices)
- homogeneity and composition of sub-slab material

After the initial round of sub-slab soil gas is collected, additional samples may be necessary to adequately delineate sub-slab soil gas impacts and properly design the mitigation system.

Table 3-1 Minimum Number of Sub-Slab Soil Gas (SSSG) Samples*

Square footage of building	Number of SSSG Samples
Up to 1,500	2
1,501 to 3,000	3
3,001 to 5,000	4
5,001 to 10,000	5
10,001 to 20,000	6
20,001 to 100,000	One additional sample every 10,000 sq. ft.
100,001 to 250,000	14 minimum. One additional sample every 15,000 sq. ft. above 100,000 sq. ft.
250,001 and greater	24 minimum. One additional sample every 18,000 sq. ft. above 250,000 sq. ft.

(*Note Table 3-1 is also basis for number of exterior soil gas samples in planned building footprint)

3.2 Exterior Soil Gas Data

For VOAP Brownfield projects that involve new construction, exterior soil gas will be considered the primary line of evidence for making mitigation decisions for planned buildings. Exterior soil gas samples should be collected in the proposed footprint of planned buildings, also using **Table 3-1** and the square footage of the planned building as the basis for determining the appropriate minimum number of samples. Typical depth of exterior soil gas samples is 3–5 feet below ground surface. However, if final planned first floor elevation is below current site elevation, the depth of soil gas samples should be at or below the expected first floor elevation. In cases such as this, it may be appropriate to collect soil gas after the site has been graded.

There may be practical reasons for collecting exterior soil gas at a VOAP Brownfield project site beyond the perimeter of planned building footprints that are outside the scope of this guidance; for example, delineating soil gas impacts related to a VOC subsurface source known to be present in another area of the site away from planned buildings.

3.3 Leak Testing

To ensure that subsurface vapor samples are not compromised by ambient air, leak testing should be conducted during sampling. There are two types of leak testing associated with soil gas sampling that should always occur as part of sampling events: vacuum testing of the sampling apparatus, and tracer testing of the sample tubing soil/slab interface.

For a description of the vacuum leak check, see Section V.B. "Vacuum Testing" of the State of Tennessee Department of Environment and Conservation, Division of Underground Storage Tanks, Technical Guidance Document – 018, Requirements for Conducting Soil Gas Surveys, effective January 1, 2008 (ust_tgd-018).

There are several ways to leak test the sample tubing soil/slab interface in the field using tracers. There are advantages and disadvantages to each method. The two most common field leak testing methods employ helium gas or isopropyl alcohol as a tracer. Using helium allows for on-site detection of leaks prior to sample collection and therefore reduces the need to return and recollect samples if a leak has occurred. When isopropyl alcohol is used as a tracer, leaks can only be discovered through laboratory analysis, which may require returning to the site and collecting additional representative soil gas samples.

3.4 Indoor Air Data

While this guidance does not consider indoor air as a primary line of evidence necessary to make VI mitigation decisions, there are important reasons for collecting indoor air samples at VOAP sites. If the VOAP Brownfield project involves an existing building, collecting indoor air samples can confirm current vapor intrusion pathways and enable the characterization of exposures and risks current at the time of sampling to any receptors present in the building. In some cases, it may be necessary to relocate workers or conduct immediate mitigation measures based on the sampling results. When mitigation is required in either new construction or in existing buildings, indoor air sample collection will be the primary means of verifying mitigation system effectiveness and performance. **Table 3-2** can be used to determine the appropriate number of indoor air samples when sampling indoor air.

Table 3-2 Minimum Number of Indoor Air Samples

Square footage of building	Number of Indoor Air Samples
Up to 1,500	1
1,501 to 5,000	2
5,001 to 10,000	3
10,001 to 20,000	4
20,001 to 100,000	One additional sample every 40,000 sq. ft. above 20,000 sq. ft.
100,001 to 500,000	6 minimum. One additional sample every 100,000 sq. ft. above 100,000 sq. ft.
500,001 and greater	10 minimum. One additional sample every 250,000 sq. ft. above 500,000 sq. ft.

3.5 Passive Vapor Sampling Devices

Passive (diffusion) sampling technology can be considered for quantitative, time-integrated indoor air sampling. Passive samplers may be less intrusive for some building owners and occupants and more convenient for field staff. Passive samplers are also capable of being deployed for longer durations than evacuated canisters, thereby providing a more economic means of obtaining average indoor air concentrations over longer periods of exposure. These factors make them good candidates for use when indoor sampling is needed at VOAP sites. However, appropriate use of passive samplers requires knowledge of the target chemicals, sorbent capabilities, and required detection limits. Also, specific situations (e.g., low chemical sorption and a high moisture environment) may limit the use of passive samplers. Consultation with the analytical laboratory during the development of a sampling plan can help ensure the appropriate use and selection of passive samplers.

For soil gas collection, certain data quality limitations exist when passive samplers are deployed in the sub-slab environment or the soil column. Quantitative passive sampling for soil gas is still undergoing research and is not typically used as a single line of evidence when conducting soil gas screening evaluations. Passive sampling limitations in generating quantitative data suitable for risk assessments also hamper the ability to make risk-based decisions regarding mitigation requirements.

Despite these limitations, passive samplers can be a very useful semi-quantitative tool for measuring VOC mass in sub-slab and exterior soil gas, and DoR staff often apply these samplers during site characterization to delineate the lateral extent of contamination and identify potential vapor intrusion pathways. Passive samplers with validated uptake rates are also able to report data in units of concentration (e.g., $\mu g/m^3$) that can be used as an additional line of evidence for assessing potential vapor intrusion risks. Final risk-based mitigation decisions will be determined by the collection of a sample using a canister (Method TO-15) or sorbent tube with pump (Method TO-17). When appropriate, a comparison of passive sampler results to TO-15 or TO-17 sample results can be performed to validate the continued use of passive samplers on the project site.

4.0 RISK ANALYSIS

Risk analysis of collected soil gas data involves an initial screening step where concentrations of detected VOCs are compared to risk-based soil gas screening levels. The result of this comparison is the list of Chemicals of Potential Concern (COPCs) for the project, followed by a risk calculation step for each COPC. EPA's Vapor Intrusion Screening Level (VISL) Calculator can be used for both steps. During screening it is important to know if the laboratory reporting limits have been raised. Laboratory reporting limits can be raised for several reasons, for example, due to elevated concentrations of an analyte that can mask the presence of other analytes. Chemical concentrations reported as non-detect (ND) present a point of uncertainty and must be taken into consideration if the laboratory detection limits are above initial screening levels.

4.1 Screening Level Comparison for Soil Gas

Initial screening should be completed using the more protective soil gas screening levels based on an excess lifetime cancer risk (CR) of 1E-06 or a non-cancer hazard quotient (HQ) of 0.1.

TDEC-DoR recommends the use of the EPA VISL Calculator (epa-visl.ornl.gov) to screen analytes and develop a list of COPCs associated with VI. Guidance on using the EPA VISL Calculator to conduct soil gas screening and subsequent risk calculations can be found in **Appendix B** and **Appendix C**.

4.2 Residential vs. Commercial Screening

The selection of residential or commercial screening values depends on the planned land use of the VOAP Brownfield project. If residential or mixed-use development is planned for the project, residential screening levels should be used. Residential screening levels should also be used when sensitive receptors are expected to be present on a recurring basis in certain non-residential scenarios, such as children attending a daycare or a school. If commercial or industrial use is planned for the project **and** land use restrictions are, or will be, established that restrict residential use and other uses that involve sensitive receptors, then less conservative commercial screening levels can be used for screening purposes. The

Division considers land use restrictions as the primary means of controlling future land-use, regardless of current zoning.

When the concentration of a particular VOC is less than or equal to its corresponding screening value, the VOC is considered "screened out." Screened out VOCs do not need to be carried forward to the risk calculation phase. VOCs that do not screen out should all be listed as COPCs for the site. The maximum concentration detected in soil gas (either exterior or sub-slab) for each COPC is then used to predict indoor air risk using the EPA VISL Calculator and the default exposure variables and attenuation factor used in the calculator. See **Appendix C** for additional information. Note that the EPA VISL Calculator uses a default sub-slab to indoor air attenuation factor for simulating sub-slab soil gas migration to indoor air. A site-specific attenuation factor developed using radon measurements collected in the sub-slab environment and indoor air, or by other means, may be proposed for discussion between the PM and the environmental professional. If non-default inputs are used, TDEC will request written justification to be submitted for approval. This may lengthen the time required to determine if mitigation is warranted and may add delays to development timelines.

5.0 VAPOR INTRUSION MITIGATION

5.1 Determining if Vapor Mitigation is Required

Indoor air carcinogenic risk and non-carcinogenic hazard for each individual COPC is calculated using the VISL Calculator as described in **Appendix C**, and if the resulting cumulative carcinogenic risk is greater than 1E-05, or the sum of the non-carcinogenic hazard quotients (hazard index) is greater than 1.0, then vapor mitigation will be required as part of the VOAP Brownfield project[2]. Note that if the hazard index is greater than 1.0, target organs can be researched, and hazard indices can be calculated based on grouped chemicals that share the same target organ. See **Appendix D** for a list of target organs associated with common VOCs. It is recommended that the PM consult a Division risk assessor during this step. Each COPC that individually exceeds either a 1E-05 carcinogenic risk or a hazard quotient of 1.0 is considered a Contaminant of Concern (COC), as well as those COPCs that significantly contribute to exceedances of a 1E-05 cumulative carcinogenic risk or a hazard index of 1.0. The COCs for the site drive the need to mitigate and will therefore be the focus of post-installation indoor air verification monitoring.

[2] TDEC PMs retain the discretion to adopt or approve investigation and mitigation approaches for VOAP Brownfield project sites on a case-by-case basis that differ from this guidance document, where appropriate.

5.2 Selecting a General Vapor Mitigation Strategy

The two broad categories of vapor mitigation systems can be described as active or passive. Active mitigation of the VI pathway involves interception, dilution, or diversion of soil gas entry into a building using mechanical means that are powered by electricity. The performance of an active mitigation system is quantifiable by measurement of vacuum, area of influence, flow rates, mass flux, etc. Passive mitigation of the VI pathway involves interception, dilution, diffusion, or diversion of soil gas entry into a structure without the use of electrically powered mechanical means. Passive mitigation strategies physically block the entry of vapors into a building and can rely on natural mechanisms, such as chemical diffusion and pressure gradients, to divert VOCs and soil gas beyond the building footprint and around the building (e.g., to riser pipes). For the purposes of this guidance, passive systems will at a minimum employ a VOC-resistant vapor barrier into its design.

Both types of systems – active and passive - can be effective mitigation solutions to elevated soil gas concentrations, although active systems are considered more appropriate mitigation strategies when elevated soil gas concentrations result in higher predicted indoor air risk levels. Passive strategies can have a high degree of success in new construction scenarios due in part to the relative ease of incorporating passive systems into the design and construction of new buildings.

For existing buildings, as stated above, mitigation is required when cumulative carcinogenic risk is greater than 1.0E-5 or the hazard index is greater than 1.0. An active system will be required when predicted indoor air risk is greater than 1E-04 cumulative carcinogenic risk or a hazard index of 3.0.

For new construction, mitigation is required if the cumulative 1E-05 or hazard index of 1.0 risk thresholds are surpassed. All passive and active systems are acceptable provided that employed vapor barriers are VOC resistant and a system's performance is verified through post-installation verification sampling and other applicable performance measures. If the cumulative 1E-04 or hazard index of 3.0 threshold is exceeded, an active system or a passive system with installed venting that can easily be converted to an active system is required. Post-installation verification sampling will be the primary method of determining a required system's effectiveness and will help determine if a passive system should be converted to an active system. See **Figures 5-1** and **5-2** below for a pictorial representation of the above-described mitigation risk criteria concepts.

For active systems, permanent sub-slab monitoring points should be installed to monitor the induced negative pressure field in the sub-slab environment. Monitoring of negative pressure through these types of points is frequently a component of performance monitoring and operation and maintenance (O&M) inspections of active systems. For both active and passive systems, monitoring points can be used to collect post-installation sub-slab soil gas concentration data should that information be necessary to obtain as part of performance monitoring, O&M activities, or possible decommissioning activities.

Figure 5-1 Existing Buildings Mitigation Risk Criteria

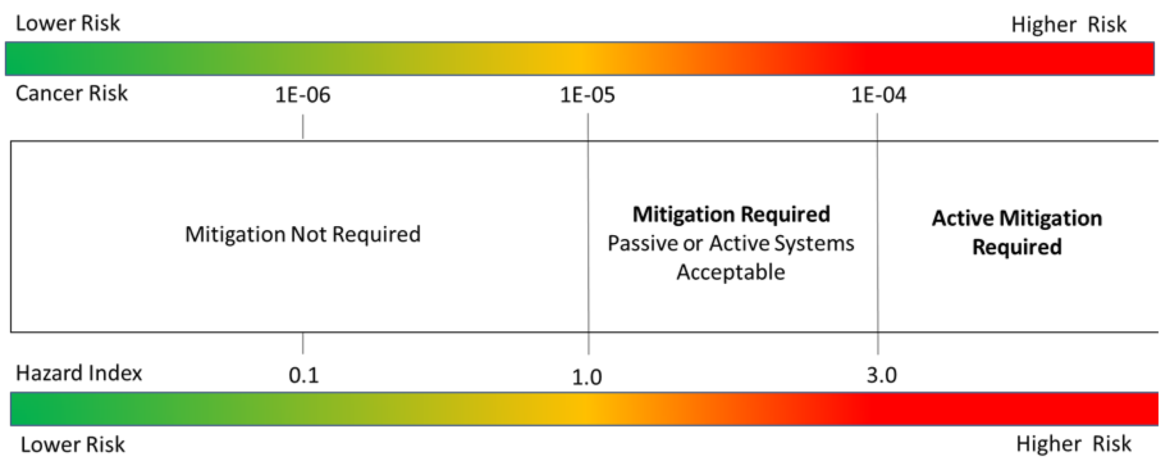
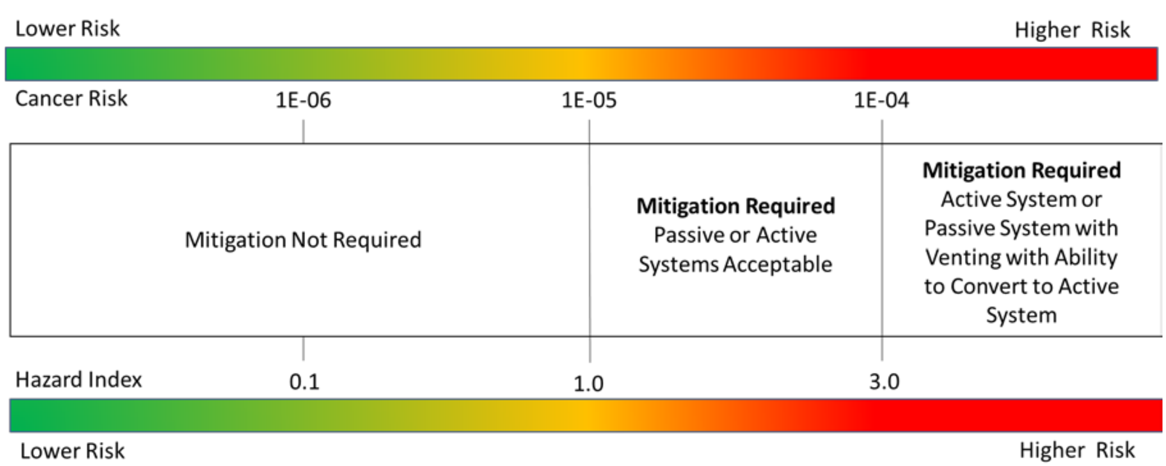


Figure 5-2 New Construction Mitigation Risk Criteria



Building design can be an effective method of preemptively mitigating vapor intrusion risks. For example, a building designed with a highly ventilated area, such as an open parking garage constructed at ground level, can prevent vapors from entering occupied upper floors that may be present above the parking garage. Proposed building design should not be used as rationale for not collecting soil gas data. Building design will have to be considered as part of a vapor intrusion mitigation system (VIMS) work plan if soil gas concentrations and subsequent risk calculations lead to required mitigation. See Section 5.3 for more information on VIMS work plans.

An HVAC system may be used to assist in preventing VI from the subsurface if a positive pressure differential between indoor air and the sub-slab environment can be established and maintained for interior spaces. However, because it is extremely difficult to document and verify the effectiveness of positive pressure, which can only be maintained while the HVAC system is running, sole use of an HVAC system as a mitigation method is not typically considered a viable stand-alone mitigation option.

5.3 Vapor Intrusion Mitigation System Work Plan

Before a VIMS is installed, the following submittals are expected as part of the VIMS work plan:

1) A summary of the site data used to predict the vapor intrusion risk at a site.

2) The calculated vapor intrusion risk used to determine the vapor mitigation strategy proposed for the site.

3) A post-VIMS-installation verification sampling plan that presents site COCs and discusses planned pressure field monitoring for active systems and indoor air sampling along with target indoor air target concentrations for COC verification monitoring. Typically, the number of proposed indoor verification air samples should be based upon the square footage of the building footprint (see Table 3-1). If an alternative indoor air sampling strategy will be used, then the work plan must thoroughly explain the rationale. If a passive system is installed, target indoor air concentrations should be included in the work plan that will determine when consideration should be given to converting the passive system to active (e.g., installing blowers or fans to a passive system with pre-existing venting). Target indoor air concentrations can be calculated using the EPA's VISL Calculator and a CR of 1E-06 and an HQ of 0.1.

4) A description of land use restrictions, either planned or already established, that will provide for the maintenance and continued operation of the VIMS.

5) VIMS Design Plans - While the Division expects design submittals to be included in the VIMS Work Plan, they will not be formally reviewed or approved. The PM, however, is

expected to identify any issues that call into question the ultimate performance of the system and its ability to meet target indoor air concentrations used in verification sampling.

6) Predicted COC yearly emission rates for active systems.

5.4 Permitting

In general, the installation of a VIMS on sites enrolled in the VOAP is considered a "clean-up activity" conducted under the purview of DoR. Therefore, the following permit exemption is applicable:

Tenn. Code Ann.§ 68-212-222. Permit exemption -- On site clean-up activities.

"No state or local permits shall be required for clean-up activities which are conducted entirely on site and in accordance with this part; provided, that such clean-up activities meet the standards that would apply if such permits were required."

The VOAP Brownfield project property owner will, however, be required to follow the substantive requirements of any applicable regulations. Contacting the local air pollution control programs at counties where the State's permitting authority is delegated to a local jurisdiction is recommended (i.e., Davidson, Hamilton, Knox, and Shelby counties).

6.0 POST VAPOR INTRUSION MITIGATION SYSTEM INSTALLATION CONSIDERATIONS

6.1 Indoor Air Verification Sampling

After a VIMS is installed, there will be a period of performance monitoring primarily based on indoor air verification sampling. The purpose of this monitoring will be to evaluate VIMS performance and confirm that the system is functioning as designed. Indoor air verification sampling will be conducted using an appropriate analytical method (see Section 3.0) according to a PM approved schedule. Typically, this will consist of four consecutive quarters of indoor air sampling that can focus on the site related COCs as analytes. To allow for system equilibration, sampling should begin a minimum of 60 days after system startup. The results of each indoor air verification sampling event should be compared to target indoor air concentrations developed with the EPA VISL Calculator. Target indoor air concentrations should be based on a CR of 1E-06 and an HQ of 0.1 for the appropriate site-specific land use scenario—residential or commercial/industrial. Alternative sampling schedules and sampling methodologies may be considered. For active systems, sub-slab vacuum pressure readings that confirm negative sub-slab pressure is being induced by the system should be another component of performance monitoring with pressure readings collected concurrently with indoor air verification samples. A micromanometer can be used to collect pressure field measurements through permanent sub-slab monitoring points to confirm a minimum vacuum of -0.004 inches of water is being met at all monitoring point locations.

6.2 Performance Monitoring Report Submittals and Schedule

Following each round of verification sampling, a report documenting performance monitoring activities, including indoor air verification sampling and pressure monitoring (if applicable), should be submitted in accordance with the DoR approved VIMS work plan. If exceedances of target indoor air concentrations are noted the PM should be notified within 72 hours and proposed system corrective action and optimization components should be included in the report, and implemented upon consultation with the PM. When four quarters of verification sampling results confirm the VIMS is performing as intended, verification sampling can end with DoR approval, and the system can be considered commissioned. Otherwise, additional verification sampling will be required according to a schedule approved by DoR. While the typical verification sampling period is expected to be one year of quarterly samples, sampling can occur more frequently than quarterly or last longer than a year. Factors that can lead to an increased frequency or duration of verification sampling include, but are not limited to, continued exceedances of target indoor air concentrations, source strength, proposed or intended future land use, and potentially exposed sensitive populations. In general, if verification sampling extends beyond the initial year of quarterly sampling events, verification sampling will continue until there are at least two consecutive quarterly sampling events that meet target indoor air concentrations. Within 60 days of successful completion of verification sampling a commissioning report will be submitted that summarizes verification sampling data and system performance and includes the O&M components appropriate for the type of system being commissioned. See Section 6.5 for further discussion of O&M.

6.3 Alternative Indoor Air Verification Sampling

Indoor air verification sampling using evacuated canisters in newly occupied buildings may sometimes be cumbersome, and it may be more practical to demonstrate VIMS effectiveness by alternative sampling methodologies. It is important for the VOAP Project Manager and the VOAP site’s environmental professional to discuss alternative verification sampling procedures early in the planning process so that alternative sampling concepts can be included in the VIMS work plan, and any necessary sampling ports can be incorporated into system and building design with agreed upon target concentrations and monitoring parameters.

6.4 Converting Passive Systems to Active

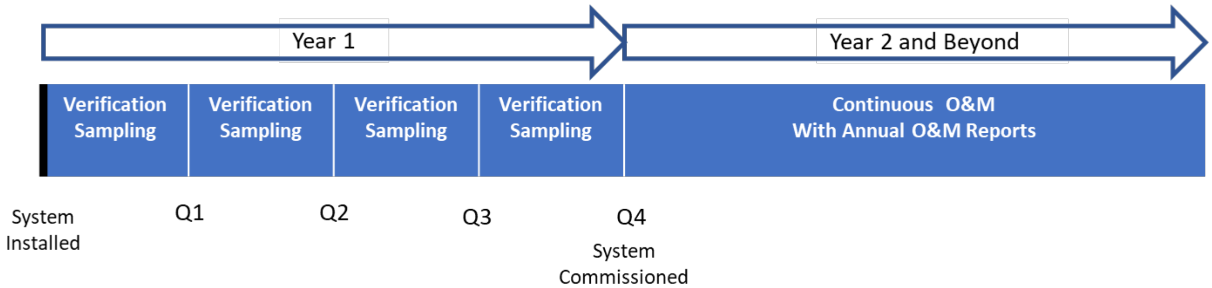
Passive systems can be appropriate for when mitigation is required for certain lower risk ranges (see Section 5.2 and Figures 5-1 and 5-2). If post-installation verification sampling results do not achieve target indoor air concentrations and therefore fail to confirm the passive VIMS is effectively mitigating vapor intrusion risk, it may be necessary to convert the passive system to an active system. Decision criteria for requiring the conversion of a passive system to an active system, including target indoor air concentrations, should be detailed in the VIMS work plan.

6.5 Operation and Maintenance

Operation and Maintenance (O&M) will be required for both active and passive systems. O&M inspections will occur annually after the verification period has ended and the system is commissioned. Annual O&M inspections are expected to continue in perpetuity unless the system is decommissioned according to Section 6.7. Inspections will, at a minimum: 1) Use field instrumentation (e.g., PID) to document any elevated indoor air VOC concentrations; 2) Check floor integrity for holes, gouges, and cracks; 3) When floor coatings are part of a mitigation system, evaluate floor coating integrity, spot repairs for minor issues should be performed in accordance with the manufacturer's instructions; and 4) For active systems, employ a micromanometer to collect pressure field measurements through permanent sub-slab monitoring points to confirm a minimum vacuum of -0.004 inches of water is being met at all monitoring point locations. Additionally, riser pipe vacuum and airflow; total system vacuum and airflow; motor power in volts and amps; and the speed of the motor in Hertz (Hz) or percentage of base speed for high-RPM brushless motors can be O&M components for active systems.

O&M records will be maintained in the owner/operator's files. A system's O&M annual report documenting the O&M inspections will be submitted to DoR within 60 days of each inspection. DoR should be notified within 72 hours if any system issues are identified that are outside of normal operating parameters. The measures implemented to address system issues discovered during O&M should be transmitted to DoR within 30 days.

Figure 6-1 Idealized Verification Sampling and O&M Timeline



6.6 Monitoring Emissions

If predicted emissions for each individual COC are considered insignificant according to the definition of "insignificant activity" or "insignificant emissions unit" contained in the Division of Air Pollution Control Rule 1200-03-09-.04(2)(a)(3), then no monitoring of system emissions will be necessary.

However, if emissions for each individual COC exceed the definition of "insignificant activity" or "insignificant emissions unit" contained in the Division of Air Pollution Control Rule 1200-03-09-.04(2)(a)(3), then post-installation emissions monitoring or other COC emission treatment may be required based on the applicable TDEC regulations.

6.7 Decommissioning

It is expected that a commissioned mitigation system will operate and be maintained in perpetuity unless a change is approved by TDEC. If remediation of source mass occurs while the system is operating, or concentrations of soil gas COCs are suspected of having decreased significantly through other means, there may be an opportunity, as determined on a site-specific basis, to demonstrate that COC soil gas concentrations are no longer driving the need to mitigate. At that point, an environmental professional may present a decommissioning proposal to DoR. Each proposal is reviewed on a site-specific basis. A key component to any decommissioning proposal will most likely involve sub-slab soil gas sampling to determine if levels of soil gas are at acceptable levels and no longer requiring vapor mitigation.

REFERENCES

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APPENDIX A - ACRONYMS

Agency for Toxic Substances and Disease Registry	ATSDR
Conceptual Site Model	CSM
Brownfield Projects Voluntary Cleanup, Oversight and Assistance Program	VOAP
Brownfield Voluntary Agreement	BVA
Cancer Risk (Excess Lifetime)	CR
Chemicals of Potential Concern	COPCs
Contaminants of Concern	COCs
Cubic Feet per Minute	CFM
Detection Limit	DL
Division of Remediation	DoR or “Division”
Environmental Site Assessment	ESA
Granular Activated Carbon	GAC
Hazard Quotient	HQ
(EPA) Health Effects Assessment Summary Tables	HEAST
(EPA) Integrated Risk Information System	IRIS
Non-Detect	ND
Operation and Maintenance	O&M
Project Manager	PM
(EPA) Provisional Peer-Reviewed Toxicity Values	PPRTV
Sub-Slab Soil Gas	SSSG
(EPA) Screening Toxicity Values to certain PPRTV Assessments	SCREEN
Tennessee Department of Environment and Conservation	TDEC
Vapor Intrusion	VI

Vapor Intrusion Mitigation System	VIMS
Vapor Intrusion Screening Level	VISL
Volatile Organic Compounds	VOCs
Voluntary Party	VP

Appendix B - Calculating Vapor Intrusion Screening Levels using the USEPA Vapor Intrusion Screening Level (VISL) Calculator

1) Select a hazard quotient of 0.1 and a target risk of 1E-06.
2) Select the applicable exposure scenario (Resident or Commercial) for the current land use and/or for the potential future land use scenario.
3) "Predict indoor air concentrations, and risk, from media concentrations?" Select "No".
4) "Select Screening Level Type" as "Default".
5) "Groundwater Temperature (°C)" Leave as default (25).
6) "Select Individual Chemicals." Make sure the chemical has the correct Chemical Abstracts Service (CAS) number. Or under "Select All Chemicals" click "Yes" to get screening values for all available chemicals. (This is generally not recommended because a very large table will be generated that will consist of all of the chemicals currently in the RSL table, many of which are not considered volatile chemicals and therefore not a concern for vapor intrusion.)
7) "Select Include Metadata" Do not click "Yes".
8) Hit the "Retrieve" button at bottom of page – generates next page.
9) Scroll down to the second table presented which should be "Resident (or Commercial if selected) Vapor Intrusion Screening Levels (VISL)".
10) Scroll over and find Target Indoor Air Concentration, Target Sub-Slab, and Near-source Soil Gas (considered equivalent to exterior soil gas) Concentration
11) These are the VISL numbers to screen detected volatiles against for indoor and/or soil gas data collected.

Appendix C - Determining Vapor Intrusion Risk using the USEPA VISL Calculator

1) Select a hazard quotient of 1.0 and a target risk of 1E-05. This is the risk criteria that determines if mitigation is required.
2) Select the applicable exposure scenario (Resident or Commercial) for the current land use and/or for the potential future land use scenario.
3) "Predict indoor air concentrations, and risk, from media concentrations?" Select "Yes".
4) The Select Medium option will become available. Select "Site Sub-slab or Near-source Soil Gas Concentration (Csg)"
5) "Site Specific" will be selected as Screening Level Type (screening levels will be calculated along with vapor intrusion risk).
6) Leave "Database hierarchy defaults" under "Selected Source for Chemical Physical Properties and Toxicity Values."
7) "Groundwater Temperature (°C)" Leave as default (25).
8) Under "Select Individual Chemicals" select COPCs as determined in previous screening step described in Appendix B (do not select all chemicals).
9) Under "Select Include Metadata" do not click "Yes".
10) Hit the "Retrieve" button at bottom of page – generates next page.
11) Enter the maximum detected sub-slab or exterior soil gas concentration for each COPC.
12) Scroll down to bottom of page and hit "Retrieve" again.[3]
13) The retrieved page will include Vapor Intrusion Risk in the third table presented, "Resident (or Commercial) Vapor Intrusion Risk".
14) Scroll over to the right and find the "VI Carcinogenic Risk CR", and "VI Hazard HQ" columns.
15) VI Carcinogenic Risk and VI Hazard Quotients will be listed for individual COPCs and will be summed for all COPCs.

[3] Note that for existing buildings there is an opportunity here to enter a site-specific attenuation factor based on radon measurements or other means if pre-approved by TDEC.

Appendix D – Common Volatile Chemicals and Corresponding Target Organs for Non-Carcinogenic Effects

Chemical	CASNUM	Toxicity Source	Inhalation Chronic Reference Concentration Target Organ
Acrylonitrile	107-13-1	IRIS	Nasal
Benzene	71-43-2	IRIS	Blood
Butadiene, 1,3-	106-99-0	IRIS	Ovaries
Carbon Tetrachloride	56-23-5	IRIS	Liver
Chloroform	67-66-3	ATSDR	Hepatic
Dibromoethane, 1,2-	106-93-4	IRIS	Nasal
Dichlorobenzene, 1,2-	95-50-1	HEAST	Whole body
Dichlorobenzene, 1,4-	106-46-7	IRIS	Liver
Dichloroethane, 1,2-	107-06-2	PPRTV	Neurological
Dichloroethylene, 1,1-	75-35-4	IRIS	Liver
Dioxane, 1,4-	123-91-1	IRIS	Nasal cavity
Ethyl Tertiary Butyl Ether (ETBE)	637-92-3	IRIS	Urinary
Ethylbenzene	100-41-4	IRIS	Developmental
Isopropanol	67-63-0	PPRTV	Testes

Chemical	CASNUM	Toxicity Source	Inhalation Chronic Reference Concentration Target Organ
Methyl tert-Butyl Ether (MTBE)	1634-04-4	IRIS	Liver and Kidney
Methylene Chloride	75-09-2	IRIS	Liver
Naphthalene	91-20-3	IRIS	Nervous, Respiratory
Tetrachloroethylene	127-18-4	IRIS	Nervous System
Toluene	108-88-3	IRIS	Neurological
Trichloroethane, 1,1,1-	71-55-6	IRIS	Liver
Trichloroethane, 1,1,2-	79-00-5	SCREEN	Nasal
Trichloroethylene	79-01-6	IRIS	Thymus, Developmental
Trimethylbenzene, 1,2,3-	526-73-8	IRIS	Nervous system
Trimethylbenzene, 1,2,4-	95-63-6	IRIS	Nervous system
Trimethylbenzene, 1,3,5-	108-67-8	IRIS	Nervous system
Vinyl Bromide	593-60-2	IRIS	Liver
Vinyl Chloride	75-01-4	ATSDR	Hepatic
Xylenes (m,o,p)	1330-20-7	IRIS	Nervous system