Ohio Environmental
Protection Agency

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Memorandum

To: Environmental Consultants, VAP Certified Professionals, Attorneys, and Other Interested Parties

From: Mike Proffitt, Chief, Division of Environmental Response and Revitalization

Date: May 24, 2016

Re: Ohio EPA's 2010 Vapor Intrusion Guidance

The Division of Environmental Response and Revitalization (DERR) is rescinding aspects of its guidance document titled, "Sample Collection and Evaluation of Vapor Intrusion to Indoor Air for Remedial Response and Voluntary Action Programs (May 2010)." DERR considers Chapter 10 (Data Evaluation) and Chapter 11 (Modeling the Vapor Intrusion Pathway) to be out of date and are no longer considered appropriate guidance for projects seeking cleanup under any of DERR's programs.

Until DERR has the opportunity to revise these chapters or issue new guidance, it is appropriate to rely on U.S. EPA's guidance document titled, "Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air (June 2015)" and U.S. EPA's Vapor Intrusion Screening Level (VISL) calculator.

In light of this memorandum, projects should re-evaluate the vapor intrusion pathway to ensure on and off-property receptors are not at risk from the vapor intrusion pathway. Projects currently under review will be re-evaluated against this change in guidance. Please contact the DERR Site Coordinator leading the review of your project for further questions.

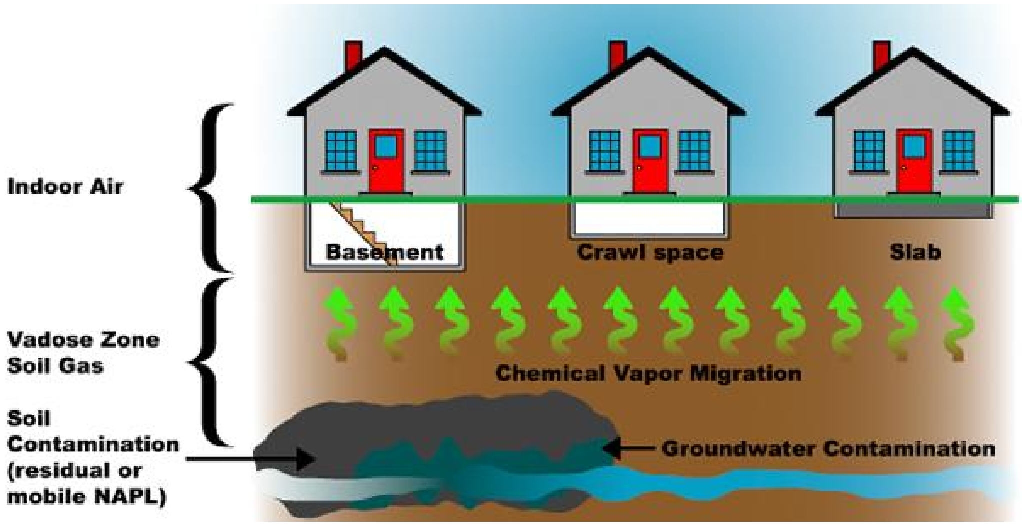
Ohio Environmental Protection Agency

Division of Emergency
and Remedial Response

SAMPLE COLLECTION AND EVALUATION OF VAPOR INTRUSION TO INDOOR AIR

FOR REMEDIAL RESPONSE AND VOLUNTARY ACTION PROGRAMS

Guidance Document



May 2010

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Acknowledgements

This guidance was developed by a workgroup representing Ohio EPA staff from the Division of Emergency and Remedial Response (DERR) and the Division of Air Pollution Control (DAPC) and environmental consultants, most of whom are Certified Professionals (CPs) for Ohio EPA's Voluntary Action Program (VAP).

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The following document was developed using established guidance from U.S. EPA, the Interstate Technology Resource Council (ITRC), American Society of Testing and Materials (ASTM), and other states, modified for the purposes of complying with remedial response and voluntary actions in Ohio. Special thanks to the California Environmental Protection Agency, Department of Toxic Substances Control, for permission to use the Interim Final Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air, December 2004, as a template. In some instances, exact phrasing from California's guidance was used.

Disclaimer

This guidance was developed solely for sites in the Remedial Response Program (RRP) and VAP, DERR, Ohio EPA. Use of this guidance for other Ohio EPA programs or state agencies may not be appropriate.

The guidance serves as an instructional tool for the investigation and evaluation of vapor intrusion at sites in Ohio. It is not meant as a regulatory document and any statements provided herein are not legally binding.

ACRONYMS

ASTM	American Society of Testing and Materials
BGS	Below Ground Surface
BUSTR	Bureau of Underground Storage Tank Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COCs	Chemicals of Concern
CP	Certified Professional
CSM	Conceptual Site Model
DERR	Division of Emergency and Remedial Response
DQOs	Data Quality Objectives
ELCR	Excess Lifetime Cancer Risk
GC/MS	Gas Chromatograph/Mass Spectrometer
HI	Hazard Index
HQ	Hazard Quotient
HVAC	Heating, Ventilation and Air Conditioning
ITRC	Interstate Technology Resource Council
J&E Model	Johnson and Ettinger Vapor Intrusion Model
NCP	National Contingency Plan
O&M	Operation and Maintenance
Ohio EPA	Ohio Environmental Protection Agency
OSWER	Office of Solid Waste and Emergency Response (U.S. EPA)
PCBs	Polychlorinated Biphenyls
PPBV	Parts per Billion Volume
PPM	Parts per Million
PPMV	Parts per Million Volume
RAGS	Risk Assessment Guidance for Superfund
RI/FS	Remedial Investigation/Feasibility Study
RRP	Remedial Response Program
RSL	Regional Screening Level
SARA	Superfund Amendments and Reauthorization Act
SCIA	Source Control Interim Action
SIM	Selected Ion Monitoring
SOP	Standard Operating Procedure
U.S. EPA	United States Environmental Protection Agency
VAP	Voluntary Action Program
VOCs	Volatile Organic Compounds (includes all compounds listed in **Appendix A**)

EXECUTIVE SUMMARY

The intrusion of subsurface vapors into buildings is one of many exposure pathways that must be considered in assessing human health risk posed by releases of hazardous substances and petroleum. In this document, the Ohio EPA, DERR recommends a stepwise approach and sampling methodologies for evaluating vapor intrusion.

DERR currently administers two clean-up programs. The VAP is semi-privatized; site assessments and clean-ups are conducted by VAP CPs. The VAP operates under Ohio Revised Code (ORC) 3746 and Ohio Administrative Code (OAC) 3745. Site clean-ups under the RRP are directed by Ohio EPA staff, and follow the requirements of the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) as modified by the Superfund Amendments and Reauthorization Act (SARA), the National Contingency Plan (NCP), guidance outlined in the site orders (*e.g.,* consensual Remedial Investigation/Feasibility Study (RI/FS), unilateral), and the generic or site-specific statement of work. There are some differences between the programs and their methods of assessment, decision points and remedy selection. However, the approach discussed here applies to both programs unless explicitly noted.

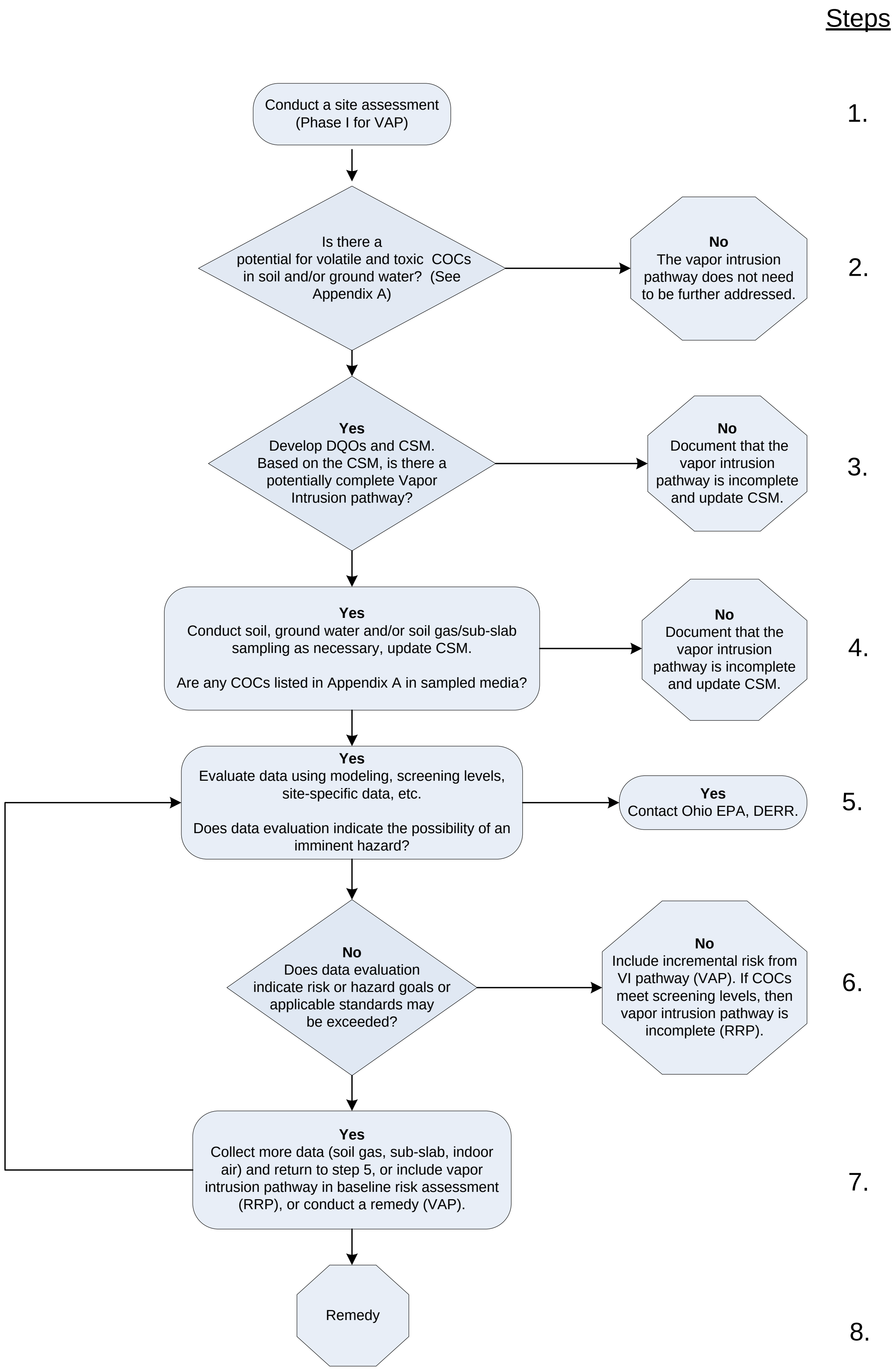
Special consideration is given for potential vapor intrusion to residential structures. Risk communication issues may arise if sampling and evaluation of the pathway does not follow a stepwise succession from contaminated media through soil gas to indoor air. See **Appendix B** for considerations when evaluating vapor intrusion potential for residential properties.

Step-Wise Approach

If volatile organic compounds (VOCs) are present in the subsurface at a site, the vapor intrusion pathway should be evaluated along with other complete or anticipated exposure pathways identified through site assessment. Due to the complexity of vapor intrusion, many professional disciplines may be needed to evaluate and mitigate exposure.

Ohio EPA, DERR recommends a step-wise approach as discussed below and depicted in **Figure 1** for the evaluation of vapor intrusion to indoor air. **Figure 1** provides the framework for the site characterization and risk assessment for the vapor intrusion exposure pathway. It is not necessary to investigate a site for potential vapor intrusion risk in the order presented in this guidance. For sites where the environmental release history is unknown, the step-wise approach should be most useful and effective. However, many sites in DERR programs have been assessed in some manner prior to investigating potential vapor intrusion issues. Therefore, entering the flowchart at various steps may be appropriate.

Figure 1. Step-Wise Approach for Evaluating the Vapor Intrusion Pathway



Step 1 **Conduct a Site Assessment (Phase I for VAP).** The site assessment is paramount to determining whether the potential for the vapor intrusion pathway exists at a site. Generally, a site assessment involves examining the site history for release or potential release of hazardous substances or petroleum to environmental media at a site. A site walkover/inspection is also necessary.

Step 2 **Determine if there is the potential for any volatile and toxic chemicals of concern (COCs) in soil or ground water (Appendix A).** Compare potentially released COCs identified through the Site assessment to those listed in **Appendix A**. The COCs listed in Appendix A were determined to be sufficiently toxic and volatile to warrant an evaluation of the vapor intrusion pathway.

Step 3 **If there is a potential release of any COCs listed in Appendix A, develop a Conceptual Site Model (CSM) and Data Quality Objectives (DQOs) for evaluating the vapor intrusion pathway.** The potential for a complete vapor intrusion pathway depends on factors such as existing or future land use, distance between contamination and existing or proposed buildings, preferential pathways, and whether contaminant plumes are at steady state. The DQOs and CSM are not static; these components are continually refined and revised as data are collected at the site. Note that DQOs and a CSM are also necessary components for any VAP Phase I Property Assessment and RI/FS for RRP sites.

Step 4 **If the CSM indicates that the vapor intrusion pathway is potentially complete, sample soil, ground water, exterior soil gas, and/or subslab soil gas.** Data from only one environmental medium is generally not sufficient to fully assess the vapor intrusion exposure pathway. A multiple lines of evidence approach is preferred to evaluate pathway completeness from all environmental media, to assess the complete and potentially complete vapor intrusion exposure pathway to human receptors, and to reduce uncertainties.

Step 5 **Evaluate the data using modeling, screening levels, and/or site-specific data. Contact Ohio EPA if there is a possibility of imminent hazard.** A number of tools can be used at this stage to determine if the vapor intrusion pathway poses a potential unacceptable risk for building occupants. ~~This guidance allows a conservative evaluation of soils in addition to the evaluation of soil gas and ground water through the U.S. EPA Johnson & Ettinger Model for Subsurface Vapor Intrusion into Buildings (J&E Model). The J&E Model has several associated assumptions and limitations. Review the CSM to ensure that use of the J&E Model is appropriate.~~ Update the CSM depending on the outcome of data evaluation.

If data indicate the possibility of an imminent hazard, Ohio EPA should be contacted as soon as possible.

Step 6 **Evaluate the potential risk and hazard from the vapor intrusion pathway.** For RRP sites, if data evaluation indicates that concentrations are below screening values, those COCs are eliminated from further vapor intrusion assessment. For VAP properties, the screening values are used to calculate incremental site-wide risk.

Step 7 **If data evaluation indicates risk or hazard goals are or may be exceeded, then additional data may be collected, or a remedy may be implemented (see Step 8).** If there is a potential for unacceptable risk, further investigation may include the following:

- Collecting data to define physical and chemical parameters for site-specific soil using recommended test methods.

- Collecting soil gas samples to define the vapor plume at sites where buildings do not exist.

- Collecting subslab soil gas samples or crawl space samples at an existing building.

- Collecting indoor air samples in conjunction with subslab soil gas samples

- Additional evaluation of the environmental data may be needed to derive an exposure point concentration for use in a property-specific risk assessment.

Step 8 **Remediation, Mitigating Indoor Air Exposure and/or Conducting Long-Term Monitoring.** If data evaluation indicates the potential for unacceptable risk, there are several remedies that may be considered to mitigate vapor intrusion to indoor air. For VAP sites, the volunteer selects the remedy. For RRP sites, the remedy is selected following procedures outlined in CERCLA as amended by SARA and the NCP and may be defined by site specific orders.

Potential remedies may include:

- Removing VOC contamination through site remediation.

- Installing passive or active vent systems (existing buildings).

- Installing passive and/or active vent systems/membrane systems (future buildings).

- Design of ventilation systems to mitigate indoor air concentrations (HVAC).

- Institutional controls restricting structures or types of structures on contaminated property.

- The implementation and monitoring of appropriate engineered remedies to prevent or mitigate vapor intrusion. Monitoring of engineered controls must continue until risk-based clean-up levels as measured in environmental media have been met.

For any remedy chosen for a site, long-term monitoring of soil gas and indoor air may be necessary under an Operations and Maintenance (O&M) plan. The frequency of the monitoring will depend upon site-specific conditions and the degree of VOC contamination.

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1.0 INTRODUCTION

VOCs, whether in soil or ground water, can migrate through the subsurface and enter into buildings, causing an unacceptable chemical exposure for building occupants. If VOCs are present at a site, Ohio EPA, DERR requires that risk to potential exposure from vapor intrusion be included in the human health risk evaluation. This guidance provides a framework for site characterization and investigation of the vapor intrusion exposure pathway.

Evaluation of the indoor air exposure pathway involves characterizing subsurface VOC releases, obtaining appropriate environmental data, potential use of fate and transport models to predict indoor air concentrations from vapor intrusion, and conducting indoor air sampling, if necessary. This guidance outlines the technical aspects of evaluating this exposure pathway and provides recommendations for elements that should be included in a site/facility investigation. Due to the complexity of vapor intrusion, many professional disciplines may be needed to evaluate and mitigate exposure. Accordingly, an appropriate project team should be gathered when evaluating vapor intrusion issues. This guidance is not intended to provide detailed information on conducting a baseline or property specific risk assessment.

Ohio EPA anticipates that this guidance will be used by regulators, responsible parties, environmental consultants, community groups, and property developers. Because vapor intrusion is a developing field, many technical aspects are not well understood. Hence, it is anticipated that some of the procedures and practices within this guidance will change as our understanding of vapor intrusion progresses. Ohio EPA DERR will update this document as needed to accommodate refinements and advances in our understanding.

2.0 SCOPE

This guidance provides technically defensible and consistent approaches for evaluating vapor intrusion to indoor air, based upon the current understanding of this exposure pathway. This guidance document provides a technical framework for evaluating vapor intrusion and is not meant as regulation and does not impose any requirements or obligations on the regulated community. Other technically equivalent procedures may exist. Hence, users of this guidance document can use other technically sound approaches. Furthermore, this guidance does not alleviate a volunteer or potentially responsible party from any obligations that U.S. EPA may require.

This guidance is meant to be used to evaluate the vapor intrusion to indoor air pathway only. All other media characterization and evaluation of complete exposure pathways at a site must be done in accordance with the rules and procedures of the appropriate program (VAP or RRP). This guidance should not be used in lieu of a property-specific risk assessment. Rather, this guidance is meant to supplement the requirements necessary to fully characterize risk at a site. For purposes of this guidance, the term “site” also includes “property” as defined in OAC 3745-300-01(105).

This guidance assists in addressing, but is not limited to, the following questions:

- What sites are candidates for potential risks from vapor intrusion to indoor air?
- What site characterization data are needed to conduct a vapor intrusion evaluation?
- What methods are recommended for sampling subsurface media and indoor air?
- Should indoor air sampling be conducted?
- What are the data requirements for an evaluation of the vapor intrusion pathway?
- How are vapor intrusion models used and what are the appropriate site-specific inputs?
- What measures are available to mitigate indoor air exposures?

3.0 VAPOR INTRUSION EVALUATION OVERVIEW

The following text describes the step-wise approach for evaluating vapor intrusion found in **Figure 1.** The step-wise approach in this guidance document is meant to be flexible and may be tailored to site-specific circumstances. Pathway evaluation may begin at any step provided that the data collection and the CSM clearly justify the entry step. However, it is important to note that a vapor intrusion exposure pathway is assumed to be complete unless shown otherwise. For this reason, soil gas data is preferred for decision-making. Most risk decisions and the need for mitigation are not made through indoor air sampling results alone.

3.1 Vapor Intrusion Assessment

The steps in **Figure 1** apply at sites whether or not there are buildings currently present and/or occupied at a site. Current buildings and future anticipated building scenarios, as appropriate, will determine sampling strategy and data evaluation. While the assessment process is presented in a step-wise fashion, the vapor intrusion pathway may be evaluated in an iterative manner.

Flowchart Step 1: Conduct a Site assessment Property Assessment. Identification of potential releases of hazardous substances and/or petroleum to environmental media at the site.

A comprehensive evaluation of the current and historical operations at a site should be conducted. Compilation of complete site information is essential for identifying all potential exposure pathways. For VAP properties, a complete Site assessment must be conducted in accordance with the Ohio Administrative Code (OAC) 3745-300-06. RRP sites may use ASTM (E1527 – 05) - or most recent version) Standard Practice for Environmental Site Assessments: Site assessment Environmental Site Assessment Process.

For simplicity, this guidance will not repeat the requirements necessary to conduct a Site assessment. However, developing a CSM is a necessary component of this guidance. See the discussion in Step 3 for more details on CSM components for evaluating the vapor intrusion pathway.

Flowchart Step 2: Determining whether there is potential for any volatile and toxic COCs in soil or ground water at a site (Appendix A).

The chemicals in the subsurface must be sufficiently volatile and toxic to present a vapor intrusion risk. If any of the chemicals listed in **Appendix A** were potentially released, the site should be evaluated for vapor intrusion.[1] This includes evaluating the history of adjacent properties for potential VOCs that may have affected the subject site. If there is no reason to believe that a release of VOCs from Appendix A may have affected the site then the risk associated with potential vapor intrusion does not need further evaluation.

The chemicals in **Appendix A** were taken from the U.S. EPA Vapor Intrusion Guidance Document (U.S. EPA, 2002), with the addition of hydrogen sulfide and n-hexane. Monochloro- and dichloro- biphenyls are also listed. However, it may not be necessary to evaluate vapor intrusion at every site that could have a potential PCB release. PCBs can be produced as byproducts of a number of chemical processes containing chlorine and hydrocarbon sources. Currently U.S. EPA rules control the use of commercial PCB mixtures through the Toxic Substances Control Act. While PCB mixtures (*e.g.*, Aroclors) are generally considered semivolatile, they may become degraded over time, The mono- and dichlorobiphenyls which can be produced during this natural degradation process are volatile. Although the mono- and dichlorobiphenyls are not (poly)chlorobiphenyls, they are considered members of the PCB chemical class.

Studies have shown that in areas with high PCB concentrations, up to 98% of the indoor air concentrations were due to monochlorobiphenyls (Davis et. al, 2002). Thus, site-specific conditions will determine whether there is a likely vapor intrusion pathway due to PCBs. It is not likely that sites with minor PCB issues, such as the presence of transformer pads, will necessitate an evaluation for the vapor intrusion pathway. Please contact a DERR risk assessor for further information on how to evaluate congener-specific PCBs for the vapor intrusion pathway.

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[1] Methane is not specifically addressed in this guidance, although some of the procedures described may apply to evaluated sites with methane.

Flowchart Step 3: If there is a potential release of any COCs listed in Appendix A, develop a conceptual site model (CSM) and Data Quality Objectives (DQOs) for evaluating the vapor intrusion pathway.

3.2 Conceptual Site Model

The CSM is part of all site investigations. The purpose of a CSM is to provide a conceptual understanding of the potential for exposure to hazardous contaminants at a site based on the sources of contamination, the release mechanisms, the transport media, the exposure pathways, and the potential receptors. The CSM should include a diagrammatic or schematic presentation that relates the source of contamination to human and ecological receptors and identifies all potential sources of contamination, the potentially contaminated media, and exposure pathways.

The CSM organizes and communicates information about the site characteristics and is a necessary component of any health risk assessment. However, the CSM should not be considered static. As the vapor intrusion investigation progresses, the CSM will be updated as more information becomes available. Ohio EPA recommends that the following items be included in a CSM for the vapor intrusion pathway. However, in the early stages of investigation, not all components listed will be necessary.

- <u>Primary Sources of Contamination.</u> For each potential contaminant source, describe what potentially caused the contamination and provide a list of chemicals released into the environment.

- <u>Primary Release Mechanism.</u> For each potential contaminant source, describe the means by which the release, or suspected release, is thought to have occurred.

- <u>Secondary Sources of Contamination.</u> Include all the environmental media potentially contaminated by the primary sources, such as surface soil, subsurface soil, and ground water. Contaminated building materials, such as concrete foundations, can be a source area for a potential release to an environmental medium and should be considered.

- <u>Contaminant Transport Mechanisms.</u> For each potentially contaminated medium, describe the transport mechanism to indoor air, (usually advection and diffusion through the vadose zone), and describe the characteristics of the subsurface. Consider whether any preferential contaminant migration pathways, such as sewer or utility lines, are present.

- Exposure Routes. Describe current buildings, potential future building scenarios, as appropriate, and areas where vapors may accumulate. Discuss any preferential contaminant migration pathways associated with the buildings, such as foundation cracks, voids, utility ports, pipes, elevator shafts, sumps, and drain holes.

- Potential Receptors. List all the current and potential future receptors, as appropriate, that could potentially contact contaminated indoor air.

To document current site conditions, a CSM should be supported by maps, subsurface cross-sections, site diagrams, and any other property/site specific details which may be pertinent (such as building characteristics). The narrative description should clearly describe known site conditions and state what assumptions were made to generate the CSM. The narrative should include a description of ambient sources and the presence of nearby potential sources of VOCs, such as neighboring dry cleaning operations. As additional data are collected and analyzed through the evaluation of the vapor intrusion pathway, the CSM should be updated. The CSM is an essential decision-making and communication tool for all interested parties. Additional information on the development of a CSM can be found in guidance published by U.S. EPA, Risk Assessment Guidance for Superfund (RAGS, Part A, 1989), Standard Guide for Developing Conceptual Site Models for Contaminated Sites, ASTM E1689 - 95(2008), DERR guidance, and/or U.S. EPA DQO guidance.

The CSM may conclude that the vapor intrusion pathway is incomplete. However, if the CSM indicates the possibility of a complete exposure pathway for vapor intrusion, proceed with Step 4 in **Figure 1** (*i.e.,* collect samples from environmental media on the site). For RRP sites, the CSM cannot be used to eliminate the vapor intrusion pathway without sampling potentially affected environmental media.

For VAP properties, a demonstration that the vapor intrusion pathway is incomplete or is effectively mitigated can be made if any of the following apply:

- The current and proposed land use is known and does not include occupied structures.

- A pre-emptive remedy is in place to mitigate vapor intrusion. Such systems may include vapor barriers or passive or active venting systems. An engineered system used to mitigate the vapor intrusion pathway requires an O&M plan and agreement. Please see OAC 3745-300-11 for more information. For sites being evaluated through an RI/FS or other RRP framework, a vapor mitigation system may be required until such time as the remedy is selected by Ohio EPA and completed for the site.

- The existing or future buildings at a site are greater than 100 feet away laterally from subsurface contamination, provided there are no preferential pathways (*e.g.*, sewer lines) that can be a direct conduit from a vapor source to a building. If buildings are not located near (*i.e.*, within 100 feet) areas of concern, vapor intrusion is not likely and no further consideration of the exposure pathway should be needed.

  Evaluations of building distance from contamination should only be conducted if the movement of subsurface contamination has reached steady-state conditions (*i.e.*, when the maximum migration potential of the subsurface plumes has been reached). For ground water, the migration potential can be evaluated with data from routine sampling of ground water monitoring wells. If COCs in ground water indicate stable or decreasing contaminant trends, the maximum contaminant migration for ground water has probably occurred. For soil gas, a similar evaluation can be conducted if routine sampling data is available from permanent or temporary sampling points. If sufficient time has passed since the chemical release to allow for diffusional movement to the building in question, then steady-state conditions have probably transpired. If contaminant plumes, whether in soil gas or ground water are increasing, 100 feet is not an appropriate distance for potential pathway elimination.

  When evaluating the distances between subsurface contaminant plumes and buildings, it is important to consider whether preferential pathways exist which could allow vapors to migrate more than 100 feet laterally. These preferential pathways could be either natural or anthropogenic. Examples of preferential pathways include fractures, macropores, gravel base for utility conduits, and subsurface drains.

A checklist of information to assist in the development of a CSM for vapor intrusion and for planning a soil gas sampling strategy for a site can be found in **Appendix C.**

3.3 Data Quality Objective Process

The scope and objectives of environmental media sampling should be established before the study is conducted. For voluntary actions, the DQO process is part of the Site assessment site assessment (see OAC 3745-300-07(C)). For RRP sites, the CERCLA RI/FS guidance should be followed when designing a sampling plan. The DQO process establishes the scope and objectives of the assessment before sampling is conducted. The DQOs are qualitative and quantitative statements that:

- Clarify the study objective.
- Identify the chemicals of concern (COCs).
- Define if the sample will provide qualitative or quantitative information.
- Define the type, quantity, and quality of each piece of data collected in the study.
- Determine required analytical detection limits
- Define how each sample will be used to assess if vapors are intruding into buildings.
- Determine the most appropriate locations, sampling method, and sampling duration for data collection.
- Specify the amount of acceptable uncertainty in the sampling results.
- Specify how the data will be used to test the exposure hypothesis.

Additional information on the DQO process can be found in U.S. EPA. 2006. "Guidance on Systematic Planning Using the Data Quality Objectives Process. Office of Environmental Information." Washington, DC. EPA/240/B-06/001.

See Also Ohio EPA, Division of Emergency and Remedial Response, Data Quality Objectives Process Summary, DERR-00-DI-32, 2002.

3.4 Sampling Strategy

Flowchart Step 4. If the CSM indicates that the vapor intrusion pathway is potentially complete, sample soil, ground water, subslab soil gas and/or exterior soil gas.

The type of environmental media sampled for the evaluation of the vapor intrusion pathway is dependent on the release history, prior site investigations, the CSM, and whether the site is being evaluated under the VAP or RRP. For VAP sites, the sampling strategy may depend on whether or not the remedy includes mass removal or pathway blocking mechanisms.

For RRP sites, the sampling strategy is directed by the RI/FS process (including the CSM & RI workplan) and is completed as part of the site characterization step of the RI. The sampling strategy should be sufficient to characterize the complete nature and extent of contamination. During site characterization, the sampling and analysis plan that was developed during the project planning is implemented and field data are collected and analyzed to determine if a complete vapor intrusion pathway exists and to what extent the site poses a threat to human health and the environment. This is an iterative process and the resulting data and information will be used for selecting a remedy for the site.

In most cases, soil gas data is part of the multiple lines of evidence approach to determine whether the vapor intrusion pathway is potentially complete. If ground water and soil matrix data are used instead of actual soil gas data, the data must be converted to vapor concentrations using assumptions about the partitioning of the contaminant into the gas phase. While partitioning equations are readily available, using them increases the uncertainty in evaluating vapor intrusion. For existing buildings, subslab soil gas concentrations best reveal the potential for vapor intrusion directly into the building. The flow chart at Step 4 does not necessarily require that environmental media be sampled in a linear fashion (*i.e.*, ground water (or soil), soil gas, subslab soil gas, indoor air). However, for potentially impacted residential properties, the preference is to determine impacts from soil gas, soil, and ground water first to determine if a potential for vapor intrusion exists. A more detailed discussion of the relative importance and iterative sampling of the different media is provided in **Sections 4.6, 4.7, and 10.1.** If soil gas, soil and/or ground water data indicate a potential risk to building occupants, then subslab soil gas and indoor air data should be collected and used in the risk evaluations. Special considerations are advisable when evaluating residential properties and/or imminent threat situations, and are discussed in **Appendix B** and **Section 12**, respectively.

Although measuring indoor air concentration is a direct measurement at the exposure point, many factors, including materials used or stored indoors, disturbance of sampling equipment during testing, and the possibility of ventilating the building during the sample event (*i.e.*, opening doors/windows) can influence indoor air results. Additionally, indoor air values can be influenced by concentrations of VOCs in ambient outdoor air that are unrelated to releases in soil or ground water. For these reasons, outdoor ambient air and subslab soil gas should also be collected when sampling indoor air.

4.0 ACTIVE SOIL GAS SAMPLING PROCEDURES

4.1 Overview

The following section provides basic guidelines for conducting soil gas sampling for assessing the vapor intrusion pathway. **Appendix D** contains Ohio EPA's standard operating procedures for advancing soil gas probes subslab or using direct push techniques for collection of exterior soil gas.

Soil gas sampling can be used for a number of purposes including initial site characterization, delineation of ground water plume influence, identification of source areas and potential receptors, remediation and post-remediation monitoring and for developing and refining a CSM.

4.2 Designing a Soil Gas Sampling Plan

A soil gas sampling plan should be site-specific and a function of the DQOs. Ohio EPA DERR recommends using the conceptual site model checklist for vapor intrusion included in **Appendix C** to assist in developing a soil gas sampling strategy. General considerations should include the following:

- Identify the objectives of the study.
- Identify the chemicals of concern including parent and breakdown products.
- Determine physical site characteristics (*e.g.*, soil type, depth to ground water, water table fluctuations, building construction, etc.)
- Identify possible preferential pathways.
- Determine land use, building characteristics, and potential receptor population.
- Determine if vertical profiles are needed to assess potential biodegradation/attenuation.
- Establish soil gas probe installation and sampling protocols.
- Establish the number, location and analytical method for soil gas samples to satisfy the plan objective including appropriate QA/QC protocols, such as leak testing, sample duplicates, detection limits and limitations, and equipment blanks.

4.3 Preferential Pathway Survey

A survey should be conducted to evaluate potential preferential vapor migration pathways. Underground utility lines can be important preferential migration pathways for vapors and can allow contaminants to migrate significant distances from source areas. The survey should evaluate underground utilities such as water, sewer, gas, electric, and telecommunication lines. In areas where radon gas is common, a radon detection meter may provide a means to evaluate where vapors are entering a structure. Subslab or indoor air sampling locations can be biased to areas where radon gas is detected. However, please note that the absence of radon gas does not preclude vapor intrusion. Sources of information for the preferential pathway survey may include: site walkovers, geo-databases, construction blueprints, utility maps, Sanborn maps, historical aerial photos, interviews, utility companies, Bureau of Underground Storage Tanks Regulations (BUSTR), etc. Fill materials and sand lenses or crack in clay materials may also act as a preferential pathway. The preferential pathway survey can assist in developing a soil gas sampling strategy and in development of the CSM.

See Wisconsin's Chemical Vapor Intrusion and Residential Indoor Air Guidance and the ITRC guidance for additional information.

4.4 Sample Collection and Analysis

Depending on the scope of the study and the DQOs, soil gas samples may be collected using gas-tight syringes, glass vials, sorbent media, canisters or Tedlar® bags. Gas tight syringes are appropriate only when an on-site field laboratory is used and samples are analyzed immediately following sample collection. Field screening and use of a mobile lab are acceptable in order to refine DQOs by conducting on-site, real time field analysis.

Prior to collecting the soil gas sample for analysis, Ohio EPA DERR recommends conducting a purge test (until parameters stabilize) in order to determine the optimal purge volume for the location. The purge volume should be consistent for all samples collected from the study area. When purging or collecting samples using a vacuum pump or a canister, the vacuum applied to the soil gas probe should not exceed ten inches of mercury or 100 inches water and the flow rate generally should not exceed 200 milliliters per minute. This should limit the potential for ambient air being drawn into the sample from the ground surface and it should limit desorbing of vapors from contaminated soils, although research has shown that flow rate does not appear to be an important variable on soil gas concentrations for relatively coarse grained soils.

To maintain sample integrity:

- Maximum holding times for soil gas samples should not be exceeded. Contact laboratory for holding times and to ensure using best collection method.

- Soil gas samples should not be chilled during storage unless specified by the method.

- Keep all gas samples out of direct sunlight.

- Complete / maintain all sampling records (*e.g.,* chain of custody, sample data forms, etc).

The appropriate sample method is dependent on the DQOs developed for the project. Coordinate with the laboratory to ensure that sufficient volume is collected. Soil gas samples should be analyzed for the appropriate COC including breakdown products as part of the vapor intrusion assessment. The analytical method used should be able to identify and quantify the target analytes and be capable of meeting program specific requirements. Soil gas sample results submitted to Ohio EPA DERR should be reported in units of ppbv and / or µg/m^3. Soil gas sampling field data should be recorded on the Soil Gas Probe Field Data Report Form (**Appendix E**) and submitted with the results.

4.5 Analytical Detection Limits

Analytical detection or reporting limits for soil gas samples should be sufficiently low to adequately evaluate the vapor intrusion pathway (per project's DQOs). For VAP sites, an estimate of the applicable standard, adjusted for the presence of multiple chemicals, provides the basis for the minimum detection limits. For screening at RRP sites, the minimum detection limit is determined by the appropriate screening value. In general, application of the generic attenuation factors can be used as a basis for developing the minimum analytical detection limits in media.

Table 1 provides a list of several soil gas analytical methods and reporting limit ranges.

TABLE 1: Comparison of Soil Gas Analytical Methods

Method No.	Examples of Collection Device and Methodology$^{\#}$	Type of Compounds	Reporting Limit Range**
TO-1	Tenax solid sorbent GC/MS or GC/FID	VOC	0.02 – 200 µg/m^3 (0.01-100 ppbv)
TO-2	Molecular sieve sorbent GC/MS	VOC	0.2 – 400 µg/m^3 (0.1-200 ppbv)
TO-3	Tedlar® bag or canister GC/FID	BTEX, MTBE, TPH	1-3 µg/m^3
TO-4A*	Filter media$^{\$}$ GC/ECD	Pesticides PCBs	Pesticides (0.5 - 1 µg/sample) PCBs (1 – 2 µg/sample)
TO9A	Filters designed for PCB collection High resolution GC/MS	Mono/Di-PCBs	Contact lab
TO-10A*	Filter media$^{\$}$ GC/ECD	Pesticides PCBs	Pesticides (0.5 - 1 µg/sample) PCBs (1 – 2 µg/sample)
TO-13A*	Polyurethane foam (PUF)$^{\$}$ GC/MS	SVOCs	5-10 µg/ sample
TO-13A SIM*	PUF or XAD-2 resin media$^{\$}$ GC/MS	Low Level SVOCs	0.5-1 µg/sample
TO-14A	Canister / Tedlar® bag GC/ECD/FID or GC/MS	Non-polar VOCs	1-3 µg/m^3
TO14A	Silica lined canisters/Tedlar® bag/sorbent media	H_2S	Contact lab
TO-15	Canister / Tedlar® Bags GC/MS	VOC (polar/nonpolar)	0.4 – 20 µg/m^3 (0.2-2.5 ppbv)
TO-15	Silica lined canisters/Tedlar® bag/sorbent media	H_2S	Contact lab
TO-15	Canister / Tedlar® bag GC/FID	TPH – Alkanes (C4-C12)	0.1 ppmv
TO-15 SIM	Canister / Tedlar® bag GC/MS	Low level VOCs	0.011-0.5 µg/m^3
TO-17*	Sorbent tube (chilled) GC/MS	VOCs	1-3 µg/m^3
8021B modified	Syringe / Tedlar® bag / Canister/ glass vial GC/PID	VOC	1 – 60 µg/m^3
8260 A/ B	Silica lined canisters/Tedlar® bag/sorbent media	H_2S	Contact lab
8260B modified	Syringe / Tedlar® bag / Canister / glass vial GC/MS	VOC	50 – 100 µg/m^3
8260	Tedlar® bag / canister GC/MS	TPH - alkanes (C4-C12)	1 ppmv*
8270C	Tedlar® bag / Canister GC/MS	SVOC	1000 µg/m^3 (20,000 ppbv to 100,000 ppbv)
8015 modified	Tedlar bag / canister GC/FID	TPH – alkanes (C4-C24)	10 ppmv
7471A	Inductively Coupled Plasma / Mass Spectrometry (ICP/MS)	Hg	Contact lab
Air Toxics IO-5	Gold trap Dual amalgamation	Hg	Contact lab

TABLE 1: Comparison of Soil Gas Analytical Methods

Method No.	Examples of Collection Device and Methodology[#]	Type of Compounds	Reporting Limit Range**
	cold vapor atomic fluorescence spectrometry (CVAFS)		
NIOSH 6009	Hopcalite cold vapor / Atomic Absorption (CV/AA)	Hg	Contact lab
9056	Silica lined canisters / Tedlar® Bag / sorbent media	H_2S	Contact lab
1668A	Filters designed for PCB collection High resolution GC/MS	Mono/Di-PCBs	Contact lab
U.S. EPA 3C	Tedlar® bag / Canister GC / FID	Methane	10 ppmv
		nitrogen, oxygen, carbon dioxide, carbon monoxide	0.1% (1,000 ppmv)
ASTM D-1946	Tedlar ® bag/ canister GC / TCD / FID	Methane, nitrogen, oxygen carbon dioxide, carbon monoxide	1000 – 2000 µg/m^3
ASTM D-1945	Tedlar ® bag / canister GC / FID	Natural gases	1000-2000 µg/m^3

NOTE: the laboratory should be consulted prior to choosing the analytical method. The laboratory can advise sampler on holding times and any method specific requirements.

* The indicated methods use a sorbent-based sampling technique. The detection limits will depend on the amount of air passed through the media.

** Reporting limits are compound specific and can depend upon the sample collection and the nature of the sample. Detection limits shown are for the range of compounds. Consult laboratory for specific information.

[#] ECD – electron capture detection; FID – flame ionization detection; GS – gas chromatography; MS – mass spectrometry; PID – Photoionization detection; TCE – thermal conductivity detection

[$] High volume collection (may require large sample volume; *e.g.* 300 m^3)/ chilled 4^{o}C

4.6 Exterior Soil Gas

The CSM, including soil stratigraphy, depth to ground water and permeable zones, should be used to determine appropriate sampling depths. In most situations, it will be necessary to install probes at multiple depths at one location (nested) to evaluate the vertical distribution of contaminants in soil gas.

For commercial properties with buildings, soil gas samples should be taken under the building (*i.e.,* subslab sampling) due to the potential for vapor accumulation under the foundation. If this is not practical, then the samples should be collected as close to the building as possible. Soil gas samples should be collected based on the CSM with the sampling locations/depths biased toward the expected highest concentrations. For sites that overlie contaminated ground water, soil gas samples should be collected from immediately above the capillary fringe zone and half-way to the surface.

Exterior soil gas samples may exhibit a high degree of spatial and temporal variability (U.S. EPA, 2008). According to U.S. EPA, "…soil gas concentrations measured exterior to a building may not be representative of soil gas concentrations measured directly beneath the building foundation (i.e., subslab). The bias introduced by these factors may be high or low depending on climatic and building conditions and the extent to which the samples accurately represent the spatial and temporal variability of concentrations under the building." Bias should be given to preferential pathways, such as utilities and fill materials located at the site.

Ohio EPA recommends that permanent vadose monitoring points for sample collection be installed when practical to evaluate the temporal variations in soil gas concentrations. Soil gas sampling should be postponed at least 24 hours after a major rain event (one half inch or more) and the sampling area must be free of ponded water. For vertical delineation at sites without contaminated ground water, soil gas samples should be collected at various depths based on the site conceptual model (*e.g.*, 5 feet, 10 feet, and 20 feet below ground surface (bgs)). Deeper samples should be collected as needed to define vertical trends in vapor concentrations.

Ohio EPA DERR recommends that two rounds of exterior soil gas data be collected when eliminating vapor intrusion as an exposure pathway. The two rounds should account for temporal and seasonal variations at the site and other site-specific factors which may influence the migration of vapors. The maximum concentration detected should be used to evaluate risk. If exterior soil gas samples exceed screening values then subslab soil gas samples should be collected.

At most sites, exterior soil gas samples should not be collected at depths shallower than 5 feet bgs, due to potential atmospheric interference. For sites where the depth to ground water is less than five feet, an attempt should be made to collect soil gas samples from beneath existing impermeable surfaces such as garage floors, patios, parking lots, or roads etc. If an impermeable surface is not present, it may be more appropriate to rely on additional lines of evidence such as passive soil gas sampling and groundwater sampling. If shallow soil sampling is performed, leak testing is a critical element of the sampling **(Section 5.0).** Subslab, crawl space or indoor air sampling may be more appropriate in this situation.

For undeveloped sites, soil gas samples should be collected to assess vapor intrusion for potential receptors, as appropriate. The number and depth of soil gas samples should be based on the CSM to evaluate concentrations in soil gas and the attenuation of soil gas as it migrates to the surface. Note that once a building is constructed vapors may accumulate below the foundation and reassessment of the vapor pathway may be warranted depending on the site specific situation.

Soil Gas Probes. Soil gas samples are collected from the vadose zone and analyzed at a fixed laboratory or using an on-site mobile laboratory. Temporary soil gas probes are only sampled once and all equipment is removed upon sample completion. Permanent soil gas probes are sampled over time to evaluate seasonal or other variations in concentrations. Whether installing a temporary or permanent soil gas probe, it is necessary to prevent ambient air from diluting the soil gas sample. A leak test should be performed to verify the integrity of the vapor probe seal **(Section 5.0)**. **Figure 2** shows several types of soil gas probes and well material.

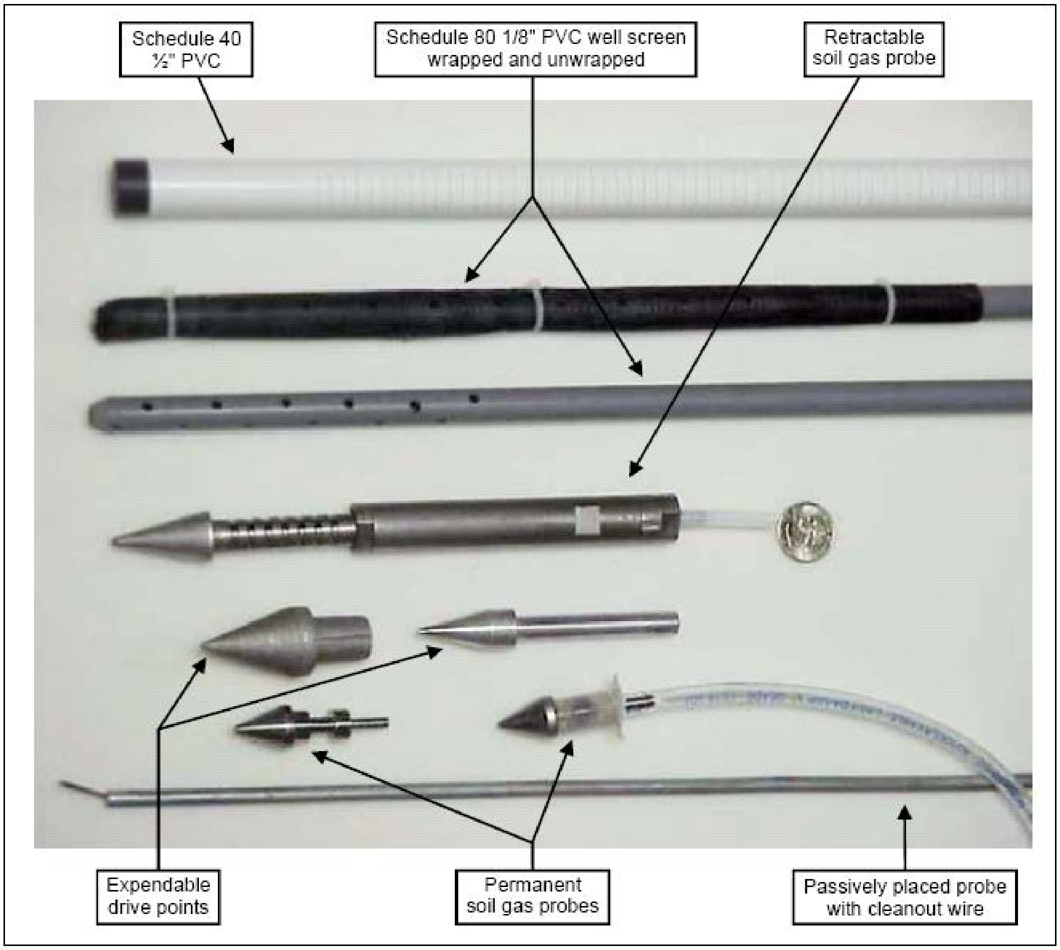


Figure 2. Examples of Soil Gas Sampling Probes and Well Material. (NJDEP 2005)

Figure 3 is a schematic of a permanent soil gas probe. Permanent soil gas probes should be installed when collecting soil gas samples for risk assessments. Samples should be collected over an appropriate seasonal or temporal time frame in order to adequately assess the risk from soil gas. Common installation methods include direct push equipment (*e.g.*, Geoprobe®), hollow stem auger and manual slide hammer (see **Appendix D** for the standard operating procedure for advancing soil gas probes). However, air rotary and mud rotary methods are not recommended.

Temporary vapor probes also can be installed by a variety of methods. The most common methods are direct push and manual slide hammer.

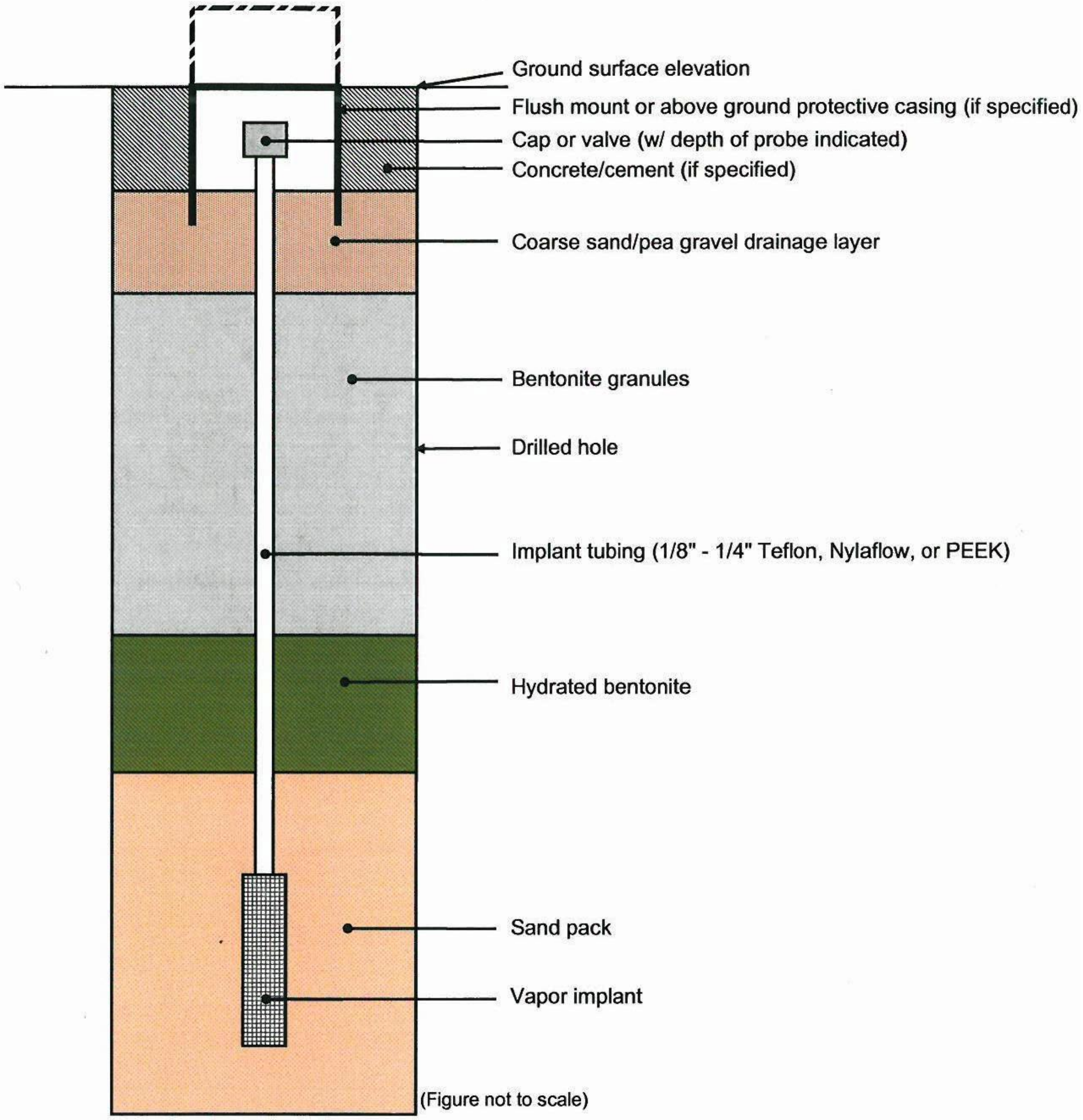


Figure 3: Permanent Soil Gas Probe Schematic

These methods allow sample tubing to be placed at the desired depth for sampling then removed once a sample is collected. Temporary vapor probes use a retractable or removable drive tip. Typically ¼" nylon, Teflon or polyethylene tubing is used to collect subsurface vapors for sampling in temporary applications. Ohio EPA uses Geoprobe® methodology for soil gas sampling; however, there are other direct push manufacturers, such as Strataprobe and AMS.

Permanent soil gas probes typically consist of a screen or sample port installed at the tip of the tubing. Stainless steel, Teflon or nylon tubing are preferred in permanent applications. Tubing selections should be based upon duration of sampling, type of COCs, and how long the sampling point needs to remain (See **Appendix G** for comparison of sample tubing type to vapor absorption). The soil gas probe is installed to a specific depth in a bore hole created with a slide hammer, direct-push system or a hollow stem auger. Sand is placed in the annulus around the sampling port screen and the remainder of the bore hole is sealed with hydrated bentonite. The tubing is usually labeled and capped at the surface. The bore hole is completed with a protective cover at the surface. Refer to **Figure 3** for details.

4.7 Subslab Soil Gas Sampling

Subslab soil gas data, which is collected from under the foundation slab and is within the advective envelope of the building-driven depressurization, indicate whether contaminants have accumulated directly under the building (see **Appendix D** for example SOPs). Analytical detection limits should be low enough to effectively evaluate the indoor air risk. See **Section 10** for more information on calculating risk levels.

Subslab soil gas sampling may shorten the timeframe for evaluation of the exposure pathway and may help reduce the overall cost of a vapor intrusion evaluation. When proceeding directly to subslab soil gas sampling, further characterization of the subsurface soil gas around the building, determination of the physical character of the vadose zone through geotechnical testing, and site-specific vapor intrusion modeling may not be needed.

However, the collection of subslab soil gas samples can be inconvenient to building occupants since it requires the removal of floor coverings and coring or drilling of the foundation slab. If chemicals are detected in subslab soil gas, installation of permanent sampling ports may be necessary to determine the temporal variability of the data. When subslab soil gas sampling is conducted, an appropriate number of samples should be taken to characterize the subslab area. The number, type (time-integrated or grab samples) and locations of subslab soil gas samples should be determined based on information collected during the building survey, an understanding of the building foundation, the results from nearby soil gas sampling, and the site specific DQOs. At least two subslab soil gas samples should be taken with one sample taken in the center of the building's foundation. For foundations greater than 5000 square feet, Ohio EPA suggests that, at a minimum, subslab soil gas be collected from biased locations, e.g., directly over source areas, maximum ground water concentration areas or near preferential pathways. If indoor air sampling is subsequently needed, the indoor air samples should be analyzed only for the chemicals detected in the subslab soil gas (see **Section 6.0**).

During subslab soil gas sampling, be careful not to damage the integrity of the slab. Subslab utilities or tension cables need to be located prior to selecting sampling locations. Blueprints can assist in locating these features. Since penetrating the slab creates a preferential pathway, proper sealing of the sampling port is essential to avoid leaks. Subslab soil gas sampling should be avoided in areas where ground water might intersect the slab. **Figure 4** is a schematic of a subslab soil gas probe.

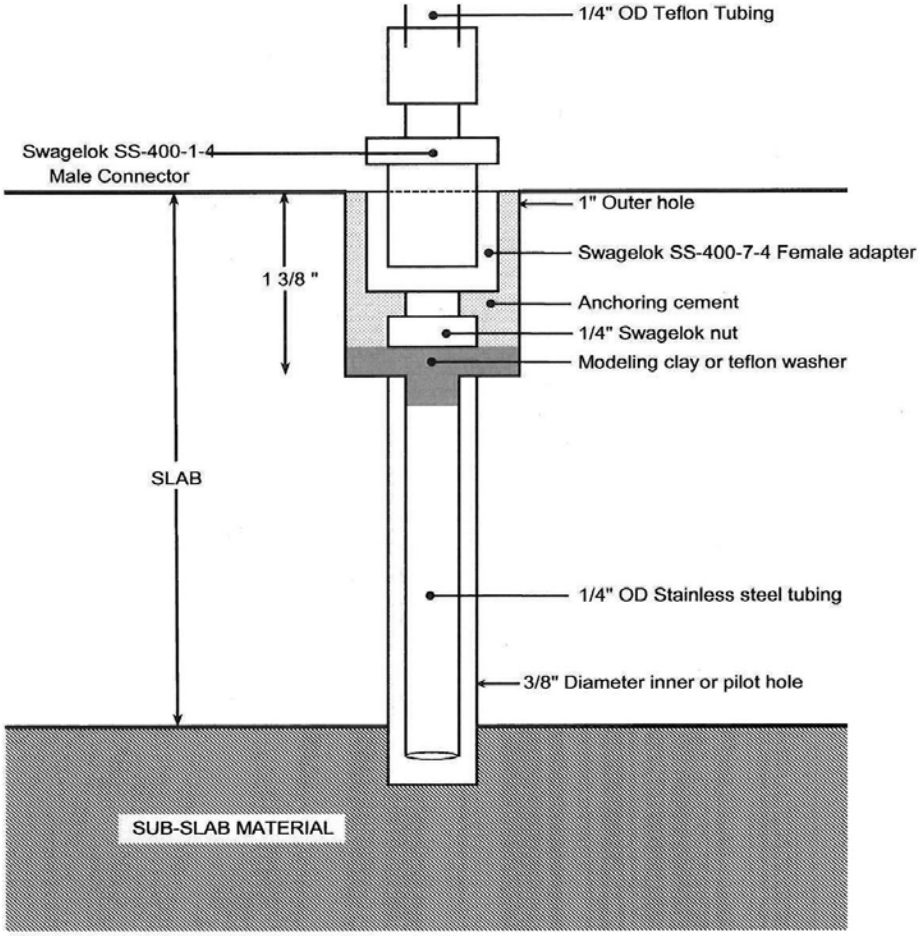


Figure 4: Example of a Sub-slab Soil Gas Probe

When possible, permanent sampling points should be used so that repeated sampling can be conducted to evaluate seasonal or temporal variations. Multiple sample locations should be chosen and multiple sampling events should be conducted. Samples should be collected with a bias towards worst-case conditions (*i.e.*, areas or times of expected highest concentrations).

4.8 Sampling Crawl Spaces

Air within a crawl space without a slab can be sampled similarly to indoor air. For evaluating the human health risk associated with crawl space air, an attenuation factor of 1.0 should be used for crawl spaces, consistent with U.S. EPA guidance (2002). Thus, the indoor air quality is assumed to be equal to the crawl space air quality for evaluation purposes.

5.0 LEAK TESTING

Atmospheric air drawn into the soil gas probe can result in diluted soil gas samples that do not represent soil gas concentrations for the COC. To ensure that valid soil gas samples are collected as part of a vapor intrusion assessment, a tracer compound can be used to check for surface/annular seal leaks.

Depending on the nature of the contaminants of concern a number of different compounds can be used as a tracer, as shown in **Table 2**. Sulfur hexafluoride (SF_6) and helium are commonly used as tracers because they are readily available, have low toxicity, and can be monitored with portable measurement devices. Isopropanol, the main ingredient in rubbing alcohol, can also be used as a tracer but requires laboratory analysis for the tracer. In all cases the same tracer should be used for all sampling probes at any given site. The leak test should be conducted using a tracer that is not expected to be present in the soil gas being tested. When choosing a liquid tracer, check with the laboratory to determine the reporting limit for the proposed tracer. Ideally, the reporting limit for the tracer should be similar to the constituents present in the soil gas.

Potential short circuiting of atmospheric air during sampling can also be indirectly evaluated through measurement of oxygen and carbon dioxide data collected from soil gas probes (not for subslab soil gas sampling). For example if oxygen concentrations at a probe installed within a petroleum hydrocarbon source area are at atmospheric levels, the soil gas data should not be considered reliable and the probe seal should be modified and the probe re-sampled. Ohio EPA DERR recommends collecting oxygen and carbon dioxide data when conducting soil gas surveys to assess the vapor intrusion pathway. The Soil Gas Probe Field Data Report Form in **Appendix E** is useful for recording data when conducting soil gas evaluations.

TABLE 2: Common Tracers

Tracer	Advantages	Disadvantages
Helium	Can check for leaks on site with handheld detector Can quantify amount of leakage accurately Does not interfere in TO-15 analysis	Party-grade helium may have low ppbv VOC contamination. If used, send a QC sample to lab for analysis. Process is more cumbersome than some others. Cannot be analyzed by TO-15 Can be difficult to apply to sampling train connections.
Liquid Tracers	Easy to use in identifying leaks. Can be detected by VOC analytical methods. Easier to apply to sampling train connections.	Concentration introduced to assess leak is estimated. Large leak may lead to VOC analysis interferences. No simple field screening method. May leave residual contamination on sampling train. Qualitative.
Sulfur Hexafluoride	Can check for leaks with on-site instrument with very low detection limits.	Very expensive. Field instrument subject to interference with chlorinated solvents. Cannot be analyzed by TO-15. A greenhouse gas.
Ambient Air Oxygen	Cost effective, easy Check for leaks with on-site multi-gas meter	Cannot be used in an environment where oxygen is expected to be present at ambient levels. Qualitative.

Because minor leakage of a quantitative leak test chemical compound such as helium (10% or less of the total concentration of the tracer compound in the shroud) around the probe seal should not affect data quality, the presence of low concentrations of helium in the sample is not a major cause for concern. If elevated levels of helium the leak test chemical (greater than 10% in the shroud) are observed in a sample, the soil gas data should not be considered reliable and the probe seal should be modified to reduce the infiltration of ambient air and re-sampled. Portable, tracer gas specific field monitoring devices with detection limits in the low part per million (ppm) range should be adequate for screening samples for tracer leak testing. In order to ensure minimal or no leakage in the sampling train, a shut-in test can be conducted. In this test a vacuum of 100 inches of water is applied to the “closed-off” sampling train and potential leaks are verified with an in-line vacuum gauge (see McAlary et. al. 2009).

6.0 INDOOR AIR SAMPLING

6.1 General Approach

Indoor air sampling can be conducted when soil, ground water and/or soil gas (including subslab soil gas) data indicate the potential for unacceptable risk due to vapor intrusion. Indoor air sampling may also be necessary under other circumstances where exterior or subslab soil gas sampling is not viable, such as: ground water elevations in close proximity to the foundation, during or after corrective actions have been taken; or where preferential pathways exist that would limit the usefulness of ground water or soil gas data.

There are several steps that should be considered when conducting indoor air sampling as part of a vapor intrusion pathway assessment.

- Define the study goals and DQOs.
- Identify the VOC(s) including parent and breakdown products.
- Building inspection and product inventory (see **Section 6.2**).
- Select number and location of indoor sampling locations.
- Select the number and location of exterior ambient sampling locations.
- Select duration of sampling event based on DQOs and risk assessment needs.
- Select sampling method with appropriate detection limit.
- Establish QA/QC requirements.

When planning indoor air sampling to assess large plumes that have the potential to impact a significant number of structures, Ohio EPA DERR recommends a tiered approach, identifying primary (the most at risk) and secondary structures based on ground water concentrations, structural characteristics, exterior soil gas concentrations and subslab soil gas concentrations. Conduct indoor air sampling at the primary structures first. Expand the scope of indoor air sampling to the secondary structures if vapors in primary structures are at unacceptable risk levels. This “step-out process,” should be conducted in a sequential manner until a perimeter of structures with concentrations at acceptable risk levels is defined.

DERR recommends that subslab soil gas samples be collected concurrently and of similar duration to the indoor air samples results so that a direct comparison of the data can be made. However, indoor air samples may be collected after review of the subslab soil gas results. Whenever collecting indoor air samples, ambient air (outdoor) samples are required in order to compare the chemicals found inside the structure with concentrations of COCs present in ambient air.

It is important to limit COC selection to only those found in media and subslab. For larger facilities, indoor air background samples should be collected to address contribution from building materials, operations, or product material storage.

When reviewing indoor air data, it is important to distinguish between background contaminants and contaminants as a result of vapor intrusion. Subslab soil gas data combined with indoor air data can be particularly helpful in determining when COCs are likely to be present from background sources. Also, when evaluating indoor air data, the ratios of COC concentrations at various levels within a building may assist in determining the vapor source.

6.2 Site Inspection, Product Inventory and Field Screening

Prior to indoor air sampling, an inventory of all potential volatile sources present must be evaluated to determine the presence of indoor sources (see **Appendix F** for the Indoor Air Sampling Form). When field screening a building for indoor vapor sources, a field instrument capable of detecting vapors in the part per billion range (ppbv) should be used. To minimize the impact of cross contamination from indoor air sources during residential or commercial sampling, indoor activities such as smoking, use of sprays, solvents, paints, etc., should be suspended a minimum of 24-48 hours prior to and during sampling. Outdoor activities that could influence indoor air levels such as mowing, painting, and asphalting, should also be suspended during sampling. For additional information see ITRC, 2007, Section 1.6.1, Background Air Concentrations.

An evaluation of potential preferential pathways into the structure should also be done. The evaluation should identify any foundation penetrations such as water, sewer, gas, electric, telecommunication lines, or sumps as well as foundation integrity (*e.g.,* cracks, dirt floors).

6.3 Sample Collection and Analysis

When collecting indoor air samples, it is preferable to collect samples at a time and location that will result in the highest potential concentrations. (see **Table 3**). Samples should be collected from the lowest level of the structure where vapors are expected to enter, including basements, crawl spaces, and where preferential pathways have been identified. An outdoor location representative of background outdoor ambient air should also be collected for comparison. Ohio EPA DERR recommends that indoor air samples be collected concurrent with subslab soil gas samples, when appropriate, for a better understanding of the vapor intrusion conceptual model at a site.

TABLE 3: Comparison of Indoor Air and Subslab Soil Gas Sampling Conditions

Parameter	Most desirable	Least desirable
Season	Late winter/early spring	Summer
Temperature	Indoors 10^0 F greater than outdoors	Indoor temperature less than outdoor
Wind	Steady greater than 5 mph	Calm
Soil	Saturated with rain (1/2" of rain or more within 24 hours)	Dry
Doors/Windows	Closed	Open
Mechanical Heating System	Operating	Off
Mechanical fans	Off	On

Modified from Massachusetts Indoor Air Sampling and Evaluation Guide (2002)

Note: Sampling under the conditions specified above is the ideal, however, it is acknowledged that it may be very difficult to sample when the "most desirable" conditions are present for all circumstances. The sampler must make a decision based on site specific circumstances and each individual project's DQOs.

For details on collecting indoor air, see **Figure 5** and **SOP 2.5.3.** The sample duration should be reflective of the site specific exposure scenario that represents the true time-integrated average concentration to which an inhabitant may be exposed. When evaluating exposure for a residential scenario, a 24-hour sample duration should provide a representative sample. For non-residential sampling, such as a work place scenario, a sampling duration commensurate with exposure may be appropriate. For commercial exposures, an eight hour minimum sampling duration is required. Ideally the duration and frequency of sampling should cover the range of conditions that may influence concentrations. Seasonality can affect COC concentrations in groundwater as well as the rate of vapor intrusion and indoor air concentrations. Thus, groundwater, indoor air, subslab soil gas, and/or exterior soil gas samples may need to be collected on a quarterly basis to adequately account for temporal variation.

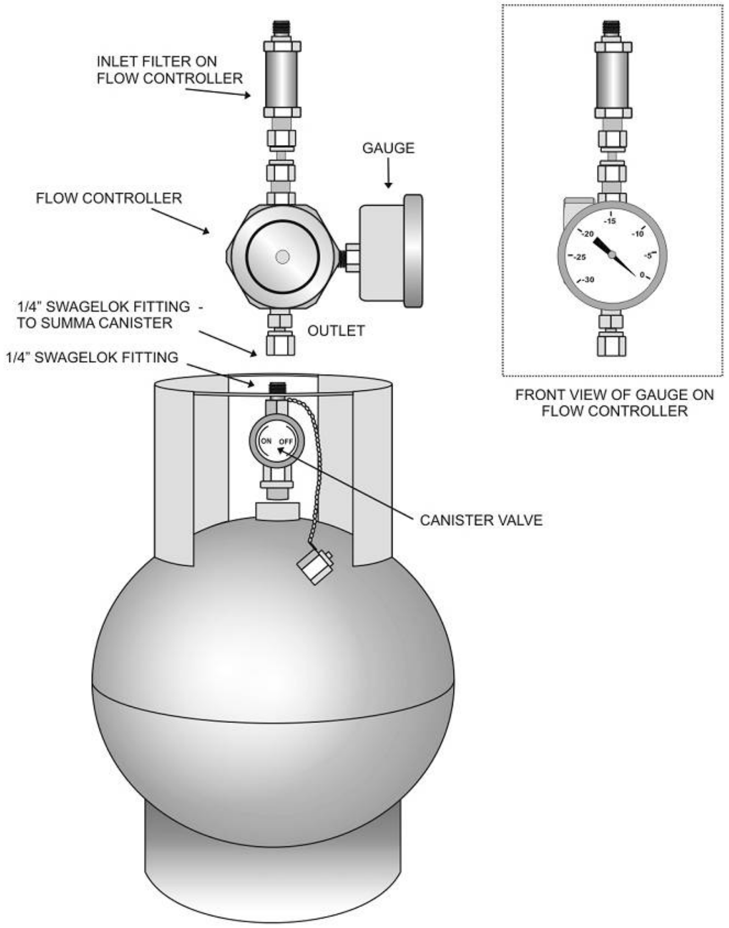


Figure 5. Schematic of Summa Canister

Note: When requesting Summa Canisters from a lab, it is recommended that you request canisters that are dedicated to indoor air sampling,. Request canisters that are certified clean to appropriate levels for indoor air screening.

The analytical method must be able to identify and quantify the target VOCs and be capable of meeting acceptable indoor air risk levels. Ohio EPA DERR recommends that laboratory analysis for VOCs be done using gas chromatography/mass spectrometry (GC/MS) and where appropriate, using the high resolution selected ion monitoring (SIM) mode for low level detection. All indoor air sample results submitted to Ohio EPA DERR should be reported in units of ppbv and/or µg/m^3 along with the original laboratory reports.

7.0 OTHER SAMPLING METHODS

7.1 Passive Soil Gas

Soil gas can be qualitatively assessed by passive sampling with an adsorbent material are placed in the subsurface and left for a period of time. The sampling devices are then retrieved and analyzed. Passive soil gas sampling can be an effective tool in understanding the composition and the location of subsurface vapor plumes. Ohio EPA DERR does not recommend using passive soil gas samples for quantifying contaminant concentrations in soil gas.

Although not quantitative, passive soil gas sampling methods can be a useful tool for:

1) collecting soil gas from low-permeability and high moisture settings where conventional active soil gas sampling may be problematic.

2) detecting compounds present at very low concentrations.

3) assessing preferential vapor migration pathways such as utility corridors and foundation cracks to determine if these pathways are acting as significant VOC migration pathways into a structure.

For additional information on passive sampling techniques, see ITRC guidance, January 2007, Appendix D, page D-16.

7.2 Emission Flux Chamber Method

Flux chambers are enclosures that are placed directly on a surface for a few hours to a few days, and the resulting contaminant concentration in the enclosure is then measured which yields the contaminant flux at a surface. Flux chambers are a qualitative tool that can be used to locate surface fluxes of VOC contamination and entry points into structures. Flux chambers may be suitable for structures with dirt floors, larger slabs in good condition, and for future use scenarios on undeveloped land. Specialized equipment and experienced staff is necessary when conducting flux chamber evaluations. For additional information, see ITRC guidance January 2007, Appendix D, page D-24.

7.3 Indoor/Subslab Differential Pressure Measurements

Measurement of the pressure gradient between the subslab and overlying structure can assist in interpreting the direction of vapor transport, whether into or out of the structure. If the building is over-pressured relative to the subslab, measured indoor concentrations might be more likely attributed to above-ground sources from within the building. Conversely if the building is under-pressured relative to the subslab, measured indoor concentrations might be more likely attributed to below-ground sources associated with vapor intrusion. The success of this approach may require multiple indoor air measurements to establish long-term patterns.

8.0 GROUND WATER

Ideally, soil gas sampling should be conducted in conjunction with ground water monitoring. However, ground water data alone sometimes can be used to model potential vapor intrusion.

For technical guidance on installing and sampling ground water monitoring wells, please see the Ohio EPA Division of Drinking and Ground Waters Technical Guidance Manual.

Some special considerations for constructing ground water monitoring wells for the purposes of assessing the vapor intrusion pathway include:

Screen Placement:
Contaminants volatilize from the top of the water table. Hence, monitoring wells used to make vapor intrusion evaluations should be screened across the air-water interface, meaning the well screens should not be submerged below the top of the water table. However, additional assessment of the plume may be necessary to demonstrate that the vapor intrusion pathway is not a concern for a downgradient receptor.

Screen Lengths:
Monitoring wells with long well screens, regardless of screen placement, should not be used to make vapor intrusion evaluations. When sampling long well screens, clean water entering the well screen at depth may dilute the contaminated ground water near the top of the screen, biasing the sampling results and the associated risk determination. Hence, short screen lengths are preferred for monitoring wells that will be used to make vapor intrusion evaluations. Ideally, the saturated thickness in a well screen should be less than 10 feet.

Well Sampling:

Ohio EPA prefers low flow sampling bladder pumps or submersible pumps. These pumps minimize the loss of VOCs during sample collection and handling. For well characterized sites, ground water can be sampled with diffusion bags following the procedures in Interstate Technology and Regulatory Council (2004). However, if COCs in ground water collected using diffusion bags are near risk levels, the determination that risk goals are met may need to be verified using bladder or submersible pump sampling techniques.

For properties where mitigative controls are contemplated early in the evaluation process, a limited number of well locations and sampling events may suffice. However, risk goals should not be considered met for ground water plumes without sufficient sampling to determine ground water fate and transport. The intent of establishing contaminant trends within monitoring wells for vapor intrusion from ground water is two-fold. First, the degree of natural temporal variability of the VOC contamination must be established so that an appropriate contaminant input concentration can be used for modeling purposes. Second, the stability of the VOC plume must be demonstrated so that the risk to receptors would not be expected to increase due to contaminant migration and/or degradation.

9.0 SOIL

Soil matrix data are needed to define the location of the VOC source, extent of soil contamination, and to assess the risk from direct contact with soils. However, soil matrix data are less than ideal for evaluating vapor intrusion risk because of the uncertainty associated with using partitioning equations and the potential loss of VOCs during sample collection. Human health risk calculated from soil matrix samples may be biased low due to inherent VOC escape during sample collection (Hewitt, 1994; Hewitt, 1999; Liikala et al., 1996; Vitale et al., 1999). These factors should be carefully considered when evaluating the vapor intrusion exposure pathway with soil matrix samples.

Loss of VOCs during sampling can be minimized using SW-846 Method 5035A (U.S. EPA, 2002). U.S. EPA (2002) provides the minimum requirements and minimum standards to prevent loss of VOCs during sample collection and handling. Specific soil collection requirements for SW-846 Method 5035A include chemical preservation in the field, using multi-functional sampling devices, or using empty, tared and labeled VOA vials with a PTFE-lined septum caps. Refer to the method for specific instructions.

~~10.0 DATA EVALUATION~~

~~Flowchart Step 5: Evaluate the data using modeling, screening levels, and/or site-specific data. Contact Ohio EPA if there is a possibility of imminent hazard   (See Section 12.0).~~

~~Once analytical results have been collected the data should be compared to the appropriate risk - based levels or used in the base line risk assessment. Ohio EPA DERR recommends a multiple lines of evidence approach when evaluating the vapor intrusion pathway. Typically, this multiple lines of approach starts with sampling soil or ground water within release areas and comparing concentrations to screening levels or estimating risk through modeling.~~

~~After initial data collection, various tools can be used to evaluate whether the concentrations of volatile COCs can potentially pose an unacceptable risk to building occupants. This step can include the use of screening tools and values, models, risk assessment or refined data collection to determine if the pathway is complete and of possible concern.~~

~~10.1 Use of Screening Levels~~

~~The use of screening levels for vapor intrusion evaluation is program-specific. Screening levels listed in U.S. EPA, OSWER Vapor Intrusion Guidance (November 2002) are available for ground water, soil gas and indoor air. For soil, see Section 11.2.~~

~~For both VAP and RRP sites, exceedance of a screening level can serve as a trigger for more refined data collection and evaluation or indicate the need for a remedial action. U.S. EPA lists screening levels for COCs at the target range of 1E-04 to 1E-06 risk levels. The values listed represent the lower value of either the noted excess lifetime cancer risk (ELCR) goal, or noncancer endpoint represented by the hazard quotient equal to 1 (HQ=1). For sites in the RRP or VAP, the cumulative cancer risk goal is 1E-05 and noncancer endpoint is the hazard index (HI) of 1.~~

~~Screening levels are listed for ground water, deep soil gas (> 5 feet bgs), shallow soil gas (a.k.a. subslab or < 5 feet bgs) and indoor air. The indoor air value was calculated using intake exposure factors for a residential exposure and chemical-specific toxicity factors. The remaining values (soil gas and ground water) were derived through the use of attenuation factors developed by U.S. EPA.~~

~~The following default attenuation factors (AF or α) are recommended in this guidance:~~

~~$\alpha = 0.1 = \frac{C_{indoor\ air}}{C_{soil\ gas}}$~~

~~$\alpha = 0.001 = \frac{C_{indoor\ air}}{C_{ground\ water}}$~~

~~The default attenuation factors assume the following conditions for their use in evaluating an existing or future building:~~

~~The subsurface is reasonably homogeneous (uniform).~~

~~No fractures exist in the subsurface.~~

~~Ground water is greater than 10 feet below surface grade.~~

~~Fluctuations of the ground water surface are minimal.~~

~~Non-aqueous phase liquid (NAPL) is not present on the water table.~~

~~Preferential pathways do not exist.~~

~~Biodegradation of vapors is not occurring.~~

~~Contaminants are homogeneously distributed.~~

~~Contaminant vapors enter a building primarily through cracks in the foundation and walls.~~

~~Building ventilation rates and the indoor-outdoor pressure differentials are constant.~~

~~Model assumptions are representative of site conditions.~~

~~If the above conditions do not exist, the default attenuation factors should not be used. Instead, Ohio EPA recommends either developing site-specific attenuation factors or iteratively sampling multiple media.~~

~~For VAP properties, some of the screening values listed in the 2002 OSWER guidance must be recalculated using toxicity data listed in the VAP Program Chemical Information Database and Applicable Regulatory Standards (CIDARS) database. Using the OSWER 2002 screening values at 1E-5 ECLR goal and HQ of 1, the resultant incremental risk and hazard ratios are then carried forward as part of the site-wide risk calculation.~~

~~For RRP sites, the U.S. EPA Regional Screening Levels (see the RSL User’s Guide), residential air, and the 2002 OSWER screening values can be used in conjunction with the above attenuation factors to develop screening levels for indoor air, exterior or subslab soil gas data. The ground water screening values in OSWER 2002 may also be used for sites in the RRP. These screening levels (2002 OSWER or RSLs) may be used to focus efforts on COCs by eliminating COCs that are below levels considered to adversely impact human health as described in the Ohio EPA DERR Technical Decision Compendium (TDC) document titled “Use of U.S EPA’s Regional Screening Levels as Screening Values in Human Health Risk Assessments”.~~

~~Consistent with this TDC, the screening value for each COC would be the residential value listed on the RSL table for carcinogenic COCs at the 1E-6 risk goal and an adjustment of 0.1 the value for non-carcinogenic COCs. Similarly, the 2002 OSWER screening values should be selected from the table listing the ELCR goal of 1E-06 (Table 2c). In addition, because the OSWER screening values for noncarcinogens are based on an HQ of 1, these values should be multiplied by 0.1 to develop the appropriate screening levels. Please note that Ohio EPA DERR is not using the toxicity criteria listed in the OSWER 2002 guidance document for trichlorethene (TCE, CAS No. 79016). Presently, toxicity criteria from California EPA is being used for TCE. Please contact the site coordinator and/or risk assessor for updated toxicity criteria on this and other potential COCs.~~

~~**COCs with maximum concentrations that are less than the corresponding screening levels may be excluded from a human health risk evaluation, providing that the current and future use of the site is not anticipated to result in exposures greater than those used in the derivation of the screening values.**~~

~~10.2 Data Analysis~~

~~**If ground water and/or soil data indicate the potential for vapor intrusion, a soil gas sampling program should be conducted to delineate the extent of the subsurface vapor plume. The results of soil gas sampling should then be compared with the program-specific soil gas screening levels. Where soil gas samples do not exceed the screening levels, but ground water exceeds the screening levels, further site characterization is recommended to further assess the vapor intrusion pathway. This evaluation would require an understanding of the site conceptual model and should take into consideration the following:**~~

~~**Shallow ground water concentrations will not likely increase in the future.**~~

~~**Site conditions at the time of soil gas sampling are not likely to result in higher soil gas concentrations due to seasonal, atmospheric, hydrogeologic, or other reasons.**~~

~~**Due to the potential for variability in soil gas concentrations, Ohio EPA DERR does not recommend the averaging of soil gas samples (each data point should be evaluated separately). Similarly, ground water and soil data should not be averaged unless it can be demonstrated that the exposure point concentration is protective.**~~

~~**If indoor air values are exceeded as a result of vapor intrusion, remedial activities are likely necessary. If subslab soil gas concentrations exceed the screening levels or applicable standards but indoor air values meet, then continued monitoring or further assessment may be warranted. Multiple sampling events may be necessary to rule out vapor intrusion as a pathway of concern. An O&M plan may be necessary for ongoing monitoring and/or implementation of remedial activities.**~~

~~10.3 Identified Areas and Exposure Units~~

~~**An identified area or site may be relatively large while containing smaller exposure units or areas of concern. As an example, a ground water plume may be present beneath**~~

~~multiple buildings or beneath a large building. Alternatively, a large building may contain multiple identified areas and exposure units. Separate vapor intrusion assessment of smaller enclosed spaces within a building footprint with multiple identified areas, or separate buildings or areas within a large identified area, is generally needed to assess the potential vapor intrusion exposure to the various receptors at a site.~~

~~11.0 MODELING THE VAPOR INTRUSION PATHWAY~~

~~Ohio EPA recommends the U.S. EPA Johnson & Ettinger (J&E) model spreadsheets as a predictive tool for evaluating subsurface vapor intrusion into buildings. The most current version should be used. As of the date of this guidance, the most current is Version 3.1, dated February 2004.~~

~~While this guidance provides recommended acceptable J&E model input values, it does not include detailed discussions on the derivation or sensitivity of model inputs, other than acceptable site-specific model inputs. For further information on model specifics, please refer to the U.S. EPA Johnson and Ettinger Model "User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings":~~

~~For Voluntary Actions, refer to the CIDARS database for appropriate toxicology for use in the model. Oral slope factors (SF_o) and reference doses (RfD_o) are generally not~~

~~extrapolated to assess inhaled exposures for compounds lacking inhalation values. However, for pathways where inhalation is the only exposure route, it may be appropriate to extrapolate an oral value to an inhalation value. An Ohio EPA Division of Emergency and Remedial Response representative should be consulted to confirm whether extrapolation of an oral toxicity value to an inhalation toxicity value is appropriate.~~

~~11.1 Overview of the Johnson and Ettinger Model~~

~~Fate and transport models can assist in evaluating the intrusion of subsurface volatile contaminants into enclosed spaces. However, models are not intended to serve as the exclusive approach for evaluating human health risk due to vapor intrusion. When used in combination with site-specific information, the results of modeling will add to the multiple lines of evidence for this exposure pathway.~~

~~The Johnson and Ettinger (1991) model (J&E model) is one of the most commonly used models for evaluating the vapor intrusion to indoor air exposure pathway. U.S. EPA programmed the J&E model into Microsoft EXCEL™ and added a health risk component that calculates the risk from inhaling the specific chemical at the concentration estimated in indoor air. Other vapor intrusion models are available and the intent of this guidance is not to exclude the use of different models to evaluate vapor intrusion to indoor air. However, it is recommended that the use of any other vapor~~

~~intrusion to indoor air model at a site be approved by Ohio EPA DERR prior to its use.~~

~~The J&E model is a simple, deterministic model, having single-point inputs and outputs, and is based on the basic principles of contaminant fate and transport, contaminant partitioning between media, and the physical and chemical properties of the contaminants themselves. The model incorporates both diffusion and advection as mechanisms of transport of subsurface vapor into the indoor air environment. For the J&E model, diffusion is the dominant mechanism for vapor transport within the vadose zone. Once the vapor enters into the building zone of influence, the vapors enter into the building through foundation cracks by advection due to the indoor – outdoor building pressure differential. The distance of the building zone of influence (*i.e.,* the advection zone) is usually less than a few feet. The J&E model uses the conservation of mass principle and is based on the following assumptions:~~

~~Steady-state conditions exist.~~

~~An infinite source of contamination exists (for the ground water and soil gas models).~~

~~The subsurface is homogeneous.~~

~~Air mixing in the building or enclosed space area is uniform.~~

~~Preferential pathways do not exist.~~

~~**Biodegradation of vapors does not occur.**~~

~~**Contaminants are homogeneously distributed.**~~

~~**Contaminant vapors enter a building primarily through cracks in the foundation and walls.**~~

~~**Buildings are constructed on slabs or with basements.**~~

~~Ventilation rates and pressure differences are assumed to remain constant.~~

~~The J&E model is most robust under homogeneous site conditions with uniform building construction features. Conversely, the model is weakest under variable conditions. Using a range of potential input parameters, the model can predict a wide range of indoor air impacts spanning over several orders of magnitude. Thus, when using the J&E model, the input parameters for a site must be appropriately conservative and match site-specific conditions. It is important to understand the sensitivity of the input parameters on the results of the model, and it is recommended that all vapor intrusion evaluations include a sensitivity analysis.~~

~~Vapor intrusion can be modeled using site-specific inputs for soil type, building parameters and exposure. However, the model does not use an exposure time, and assumes a 24 hour exposure. Please see US EPA, RAGS F for guidance on exposure times for inhalation exposure scenarios.~~

~~According to Johnson 2002, an important step in evaluating the reasonableness of the J&E modeling results for residential settings is to ensure that the ratio of~~ ~~Q_{soil}/Q_B~~ ~~is~~

~~between 0.01 and 0.0001, where Q_{soil} is the pressure-driven soil gas flow rate from the subsurface into the enclosed space and Q_B is the enclosed space volumetric air flow rate of fresh air entering the building. In the J&E model, these parameters are calculated from user inputs and can be found in the INTERCALC sheet of the model. The range in values for the ratio of Q_{soil}/Q_B comes from a search of the radon and contaminant transport literature where both sub-slab and indoor air concentrations were reported (Johnson, 2002). Therefore, J&E model results having a Q_{soil}/Q_B ratio less than 0.0001 should be considered suspect.~~

~~11.2 Bulk Soil~~

~~There are large uncertainties associated with measuring concentrations of VOCs during soil sampling, preservation, and chemical analysis, as well as the uncertainties associated with soil partitioning calculations. However, allowing evaluation of bulk soil without requiring additional soil gas collection is useful for sites where VOCs are not risk drivers and relatively low concentrations in soil are encountered. Allowing bulk soil data is particularly useful at VAP sites, where applicable standards must be developed for all COC's and all media. When bulk soil results from J&E modeling do not exceed 1 E-06 cancer risk goal and 0.1 hazard quotient for VOCs, further evaluation soil for vapor intrusion is not necessary.~~

~~Table 4 **summarizes the acceptable J&E model input parameters for use with bulk soil data. Sand is the default soil type unless site-specific geotechnical data, including grain size analysis, is collected in accordance with this guidance.**~~

~~11.3 Soil Gas and Ground Water~~

~~Table 5 **summarizes the acceptable J&E model input parameters for use with the advanced soil gas and ground water models. Sand is the default soil type unless site-specific geotechnical data, including grain size analysis, is collected in accordance with this guidance. After evaluation through the J&E modeling, and considering the presence of multiple chemicals, the site may be further investigated through additional exterior and/or subslab soil gas sampling. For commercial or industrial properties with existing buildings, collecting subslab soil gas data is preferable.**~~

~~Table 4. Acceptable J&E Model Inputs for Bulk Soil~~

~~Variable~~	~~Default Value~~	~~Comments~~	~~Restrictions~~
~~Average soil temperature~~	~~11 degrees C~~	-	-
~~Depth below grade to bottom of enclosed floor space~~	~~15 cm and 200 cm~~	~~Run model with slab and basement unless building already exists, in which case use current building characteristics~~	~~Deed restriction may be necessary to limit slab on grade or other types of construction as needed~~
~~Depth to below grade to top of contamination~~	~~Site specific~~	-	-
~~Depth to below grade to bottom of contamination~~	~~Site specific~~	~~Use bottom of soil interval for highest detected concentration in IA~~	-
~~Thickness of soil~~	~~Site specific~~		-
~~Soil vapor permeability~~	~~Default value, Sand~~	~~Values generated by the model for soil type may be used.~~	~~For all site-specific soil parameters, empirical data used must be co-located with areas containing COCs~~
~~Soil Type*~~	~~Default Value, Sand~~	~~Soil characteristics for additional soil strata can only be used with site-specific geotechnical data~~	~~If using site-specific soil type, based on site-specific analyses, default values from J&E can be used~~
~~Bulk density~~	~~Default values, Sand~~	~~See comment for Soil Type~~	-
~~Total Porosity~~	~~Default values, Sand~~	~~See comment for Soil Type~~	-
~~Soil water filled porosity~~	~~Default values, Sand~~	~~See comment for Soil Type~~	-
~~Fraction organic content~~	~~Default values, Sand~~	~~See comment for Soil Type~~	-
~~Enclosed floor space thickness~~	~~10 cm~~	~~No other value accepted~~	-

~~Table 4. Acceptable J&E Model Inputs for Bulk Soil~~

~~Variable~~	~~Default Value~~	~~Comments~~	~~Restrictions~~
~~Soil-bldg pressure differential~~	~~40 g/cm-s^2~~	~~No other value accepted~~	~~-~~
~~Enclosed floor space length~~	~~1000 cm~~	~~J&E default~~	~~Larger value may require deed restriction~~
~~Enclosed floor width~~	~~1000 cm~~	~~J&E default~~	~~Larger value may require deed restriction~~
~~Enclosed floor height~~	~~10 feet = 304.8 cm~~	~~Typical average ceiling height~~	~~Larger value may require deed restriction**~~
~~Floor-wall seam crack width~~	~~0.1 cm~~	~~Minimum value accepted~~	~~-~~
~~Indoor air exchange rate~~	~~0.25/hr~~	~~Assuming residential land use. 1.0/hr for commercial/industrial~~	~~Restriction required if commercial/industrial~~
~~Average vapor flow rate into building~~	~~5 L/min~~	~~use 5 L/min or allow model to calculate based on soil type~~	~~-~~
~~AT, non-carcinogens~~	~~30 years~~	~~Residential land use assumed~~	~~-~~
~~AT, non-carcinogens~~	~~25 years~~	~~Commercial/Industrial land use~~	~~Commercial/Industrial values would require deed restriction~~
~~ED~~	~~30 years~~	~~Residential land use assumed~~	~~-~~
~~ED~~	~~25 years~~	~~Commercial/Industrial land use~~	~~Commercial/Industrial values would require deed restriction~~
~~EF~~	~~350 days/year~~	~~Residential land use assumed~~	~~-~~
~~EF~~	~~250 days/year~~	~~Commercial/Industrial land use~~	~~Commercial/Industrial values would require deed restriction~~
~~Target risk~~	~~1 E-6~~	~~No other value accepted~~	~~-~~
~~Target hazard quotient~~	~~0.1~~	~~No other value accepted~~	~~-~~

~~* Use of all site-specific soil types requires geotechnical analysis. Please see sections 11.5 and 11.6 of this guidance~~

~~** for residential: 8 feet for slab and 12 feet for basement for a residential. May not be appropriate to use whole building height as one big box model since likeliest highest concentrations of volatiles will be in the lowest levels based on site specific data.~~

-

~~Table 5. Acceptable J&E Model Inputs for Soil Gas and Ground Water~~

~~Variable~~	~~Default Value~~	~~Comments~~	~~Restrictions~~
~~Average soil/ ground water temperature~~	~~11 degrees C~~	-	-
~~Depth below grade to bottom of enclosed floor space~~	~~15 cm and 200 cm~~	~~For residential receptors, run model with slab and basement unless building already exists~~	~~For residential structures, it may be necessary to limit slab on grade or other types of construction as needed. Deed restriction necessary for commercial/industrial.~~
~~Depth below grade to water table or soil gas sampling depth~~	~~Site specific~~		
~~Thickness of soil strata~~	~~Site Specific~~		-
~~Soil Type* directly above water table~~	~~Default Value, Sand~~	~~Soil types other than default (sand) can only be used with site-specific geotechnical data. Applies to all soil strata used in the model.~~	
~~Soil vapor permeability~~	~~Default values for soil type~~	~~See guidance at Section 11.6 for user defined values.~~	
~~Bulk density~~	~~Default values, Sand~~	~~Default values from J&E model for site-specific soil type, or user-defined values from geotechnical data.~~	-
~~Total Porosity~~	~~Default values, Sand~~	~~Default values from J&E model for site-specific soil type, or user-defined values from geotechnical data.~~	-

~~Table 5. Acceptable J&E Model Inputs for Soil Gas and Ground Water~~

~~Variable~~	~~Default Value~~	~~Comments~~	~~Restrictions~~
~~Soil water filled porosity~~	~~Default values, Sand~~	~~Default values from J&E model for site-specific soil type, or user-defined values from geotechnical data.~~	-
~~Enclosed floor space thickness~~	~~10 cm~~	~~Can be site specific in lieu of default values~~	~~Site specific value requires documentation. May require O&M~~
~~Soil-bldg pressure differential~~	~~40 g/cm-s^2~~	~~Can be site specific in lieu of default values~~	~~Site specific value requires documentation. May require O&M~~
~~Enclosed floor space length~~	~~1000 cm~~	~~J&E default~~	~~Larger value may require deed restriction~~
~~Enclosed floor width~~	~~1000 cm~~	~~J&E default~~	~~Larger value may require deed restriction~~
~~Enclosed floor height~~	~~10 feet = 304.8 cm~~	~~Typical average ceiling height~~	~~Larger value may require deed restriction**~~
~~Floor-wall seam crack width~~	~~0.1 cm~~	~~0.1 cm is the minimum value accepted~~	-
~~Indoor Air Exchange Rate~~	~~0.25/hr~~	~~Assuming residential land use. 1.0/hr for commercial/industrial~~	~~Deed restriction required for commercial/industrial. Other rates requires documentation and may require O&M~~
~~Average vapor flow rate into building~~	~~5 L/min~~	~~use 5 L/min or allow model to calculate based on soil type~~	-
~~AT, Non-carcinogens~~	~~30 years~~	~~Residential land use~~	-
~~AT, Non-carcinogens~~	~~25 years~~	~~Commercial/Industrial land use~~	~~Commercial/Industrial values would require deed restriction~~
~~ED~~	~~30 years~~	~~Residential land use~~	-
~~ED~~	~~25 years~~	~~Commercial/Industrial land use~~	~~Commercial/Industrial values would require deed restriction~~
~~EF~~	~~350 days/year~~	~~Residential land use~~	-
~~EF~~	~~250 days/year~~	~~Commercial/Industrial land use~~	~~Commercial/Industrial values would require deed restriction~~
~~Target Risk~~	~~1 E-5~~	~~No other value accepted; except for industrial land use only for VAP properties (1E-04)~~	-
~~Target Hazard Quotient~~	~~1.0~~	~~No other value accepted~~	-

~~* Use of all property-specific soil types requires geotechnical analysis. Please see sections 11.5 and 11.6 of this guidance.~~

~~** for residential: 8 feet for slab and 12 feet for basement for a residential. May not be appropriate to use whole building height as one big box model since likeliest highest concentrations of volatiles will be in the lowest levels based on property specific data.~~

~~11.4 Acceptable J&E Model Input Parameters~~

~~Tables 4 and 5 **of this guidance summarize the acceptable J&E Model input parameters for bulk soil and soil gas and ground water, respectively. It is important to note here that the target risk goal is 1 E-6 for cancer risk and 0.1 for target hazard quotient for the bulk soil assessment, whereas it is 1 E-5 for cancer risk and 1.0 for target hazard quotient for soil gas and ground water assessments. Cumulative excess lifetime cancer risk and noncancer hazard are then calculated, and applicable risk goals and standards are assessed within the site specific risk assessment.**~~

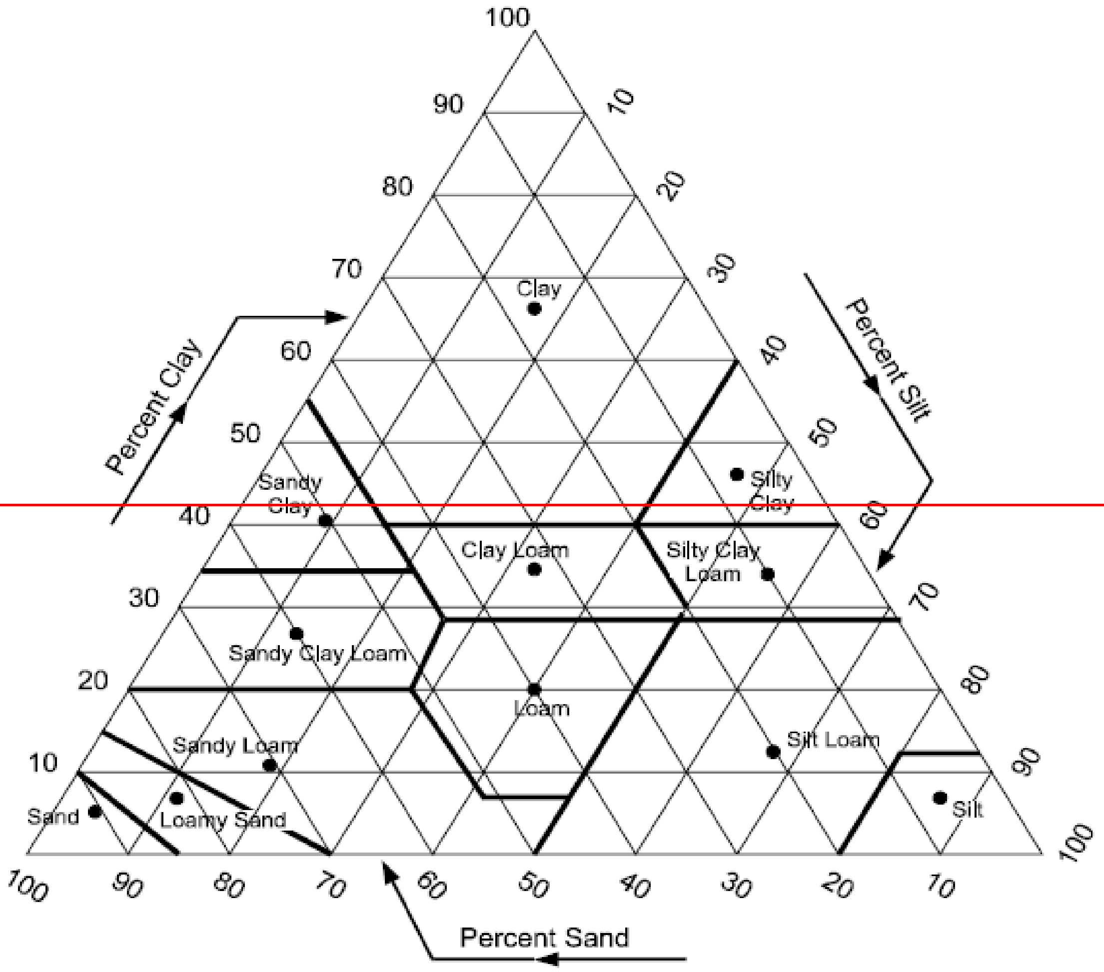
~~Tables 4 and 5 **indicate that the enclosed floor space length and width are assumed to be 1000 cm (32.8 feet) for both the residential and commercial/industrial land use scenarios. These are the default values taken from the U.S. EPA "User's Guide for Evaluating Subsurface Vapor Intrusion Into Buildings" (J&E User's guidance). The enclosed floor height is assumed to be 304.8 cm (10 feet). Even in the case where a commercial or industrial building has a larger overall building footprint, buildings are commonly subdivided into smaller work areas, offices, or retail establishments. These smaller areas can comprise the exposure unit for the receptor population (*i.e.* commercial worker) and need to be assessed. For developed properties or those properties where the redevelopment plan is known, the enclosed floor space and height input values can be property-specific,**~~

~~provided that the building dimensions used in the modeling also consider the smallest anticipated exposure unit.~~

~~11.5 Use of Site Specific Soil Type and Input Parameters in the J&E Model~~

~~The authors of the J&E model recognize that the model is sensitive to soil input parameters, and particularly to the relationship between total and water filled porosity. Because this and other soil input parameters can vary widely from region to region, site specific soil parameters may be used when sufficient information is available to justify their use. This guidance is not intended to be prescriptive in the methods of determining or estimating these soil variables. It is recognized that standard geotechnical and geophysical methods exist for measuring or estimating these values. J&E input soil parameters most readily determined or estimated from site specific testing include soil bulk density, total porosity, water filled porosity and fraction organic carbon. For the purposes of this guidance, these are the "soil input parameters." These parameters can be determined directly following ASTM (and other) standard methods, or can be estimated from field and laboratory measurements and/or using equations describing soil phase (solid, water, gas) relationships.~~

~~**The first step in using site specific soil properties is to determine the proper United States Soil Conservation Service (US SCS) soil classification,** Figure 6. **This classification system is referenced widely in the J&E model User's Manual and is used by soil scientists and in agriculture. However, it is not widely used in the geotechnical engineering and environmental field in Ohio, where the Unified Soil Classification System (USCS) is routinely employed. For the J&E model, the US SCS must be used.**~~



~~Figure 6. U.S. Soil Conservation Service Classification Chart Showing Centroid Compositions (Solid Circles)~~

~~In addition to visual examination, laboratory testing is required to determine a representative grain size distribution in each layer for which soil values other than default values will be used. Atterberg limit determinations may also be used to assist in soil classification. Ohio EPA recommends no less than three sieve analyses (grain size distribution determination) to classify each soil layer. Depending on the variability observed when logging samples, additional sieve analyses may be needed.~~

~~To justify the use of site specific soil input parameters (soil bulk density, total porosity, water-filled porosity and fraction organic carbon), sufficient vertical and lateral characterization of the migration media must be performed. The user should note that the fraction organic carbon is not an input parameter in either ground water or soil gas model.~~

~~To use site specific soil input parameter(s) in lieu of default values in a given soil layer, the input parameter(s) must be measured or estimated at no less than three (3) locations in that soil layer. Depending on the volume of soil being evaluated, additional locations may be warranted. If taking the minimum required samples, the value of the soil input parameter used in the J&E model must be the site specific value which results in the most conservative estimate of risk. The selected value should fall within the practical range of values for that parameter as shown in Tables 7 and 10 of the J&E model User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings (User's Guide). If the selected value~~

~~does not fall within this range, the modeler should provide sufficient justification for the use of the selected value.~~

~~To use a statistical representation (such as a mean value) of site specific soil input parameter(s) in lieu of default values in a given soil layer, the input parameter(s) must be measured or calculated at no less than eight (8) locations (excluding any outliers) in that soil layer. Depending on the volume of soil being evaluated, additional locations may be warranted. If taking sufficient samples to perform a valid statistical evaluation of the data, the value of the soil input parameter used in the J&E model for a soil layer may be a site specific value which is considered representative of the soil layer. Again, the selected value should fall within the practical range of values for that parameter as shown in the User's Guide. If the selected value does not fall within this range, the modeler should provide sufficient justification for the use of the selected value.~~

~~11.6 Determining Site Specific Soil Vapor Permeability Value in the J&E Model~~

~~Soil vapor permeability (Kv) is one of the most sensitive parameters in the J&E model. Typically, the model estimates Kv using either the default soil type or site specific soil input values. However, a user-defined Kv may be input into the model in lieu of the model calculated value. To permit the user to define Kv, the Ohio EPA recommends direct measurement of this value using laboratory testing procedures. Although the J&E model User’s Guide for Evaluating Subsurface Vapor Intrusion into Buildings (User’s Guide) provides a method for the user to estimate Kv by indirect methods, only a direct measurement of this should be used in lieu of the model calculated value.~~

~~The American Society for Testing and Materials (ASTM) Designation: D 6539-00, entitled “Standard Test Method for Measurement of Pneumatic Permeability of Partially Saturated Porous Materials by Flowing Air” provides a method for laboratory determination of the coefficient of permeability for air flow (pneumatic permeability) through partially saturated porous materials. Laboratory testing of undisturbed soil samples may be performed using the procedures outlined in ASTM D6539-00 to directly measure Kv in representative soil samples obtained from within the migration pathway between the vapor source and the receptor.~~

~~To use a site specific Kv parameter in lieu of default values in a given soil layer, the input parameter(s) must be measured or estimated at no less than three (3) locations in that soil layer. Depending on the volume of soil being evaluated, additional locations may be warranted. If taking the minimum required samples, the value of Kv used in the J&E model should be the site specific value which results in the most conservative estimate of risk. The selected value should fall within the practical range of values for that parameter as presented in Table 7 of the J&E User's Guide. If the selected value does not fall within this range, the modeler should provide sufficient justification for the use of the selected value.~~

~~To use a statistical representation (such as a mean value) of Kv in lieu of default values in a given soil layer, the input parameter(s) should be measured or estimated at no less than eight (8) locations (excluding any outliers) in that soil layer. Depending on the volume of soil being evaluated, additional locations may be warranted. If taking sufficient samples to perform a valid statistical evaluation of the data, the value of the soil input parameter used in the J&E model for a soil layer may be a site specific value which is considered representative of the soil layer. Again, the selected value should fall within the practical range of values for that parameter as shown in the User's Guide. If the selected value does not fall within this range, the modeler should provide sufficient justification for the use of the selected value.~~

12.0 EVALUATION OF IMMINENT HAZARD IN AN EXISTING BUILDING

If data evaluation indicates the possibility of an imminent hazard from a known or suspected nearby source, immediate action is necessary to verify or abate threats to human health. For the purposes of this guidance, imminent hazard is defined as any condition which poses a significant immediate risk of harm to public health, safety, or the environment. This action may be limited to the prompt implementation of a vapor intrusion investigation. Alternately, the decision may be made that an interim (or emergency) remedial measure is required. For any site in the RRP or VAP, Ohio EPA, Division of Emergency and Remedial Response should be contacted immediately if data collection indicates the possibility of an imminent hazard. Ohio EPA's Spill Hotline number is 1-800-282-9378.

The following list contains examples of indicators for the potential of an imminent hazard:

- Known spill in a structure (*e.g.*, heating oil tanks);
- Physiological effects reported by occupants (with a known or suspected source nearby);
- Wet basement or sump with contaminated ground water nearby;
- Chemical, solvent, or petroleum odor reported in a structure (with a known or suspected source nearby);
- Free product at the water table under or immediately adjacent to a structure; and,
- Other short-term safety concerns.

Consistent with the U.S. EPA (2002), short term safety concerns are "known, or are reasonably suspected to exist, including: a) measured or likely explosive or acutely toxic concentrations of vapors in a building or connected utility conduits, sumps, or other subsurface drains directly connected to the building and b) measured or likely vapor concentrations that may be flammable/combustible, corrosive, or chemically reactive."

Professional judgment should be applied to these qualitative criteria when a determination is made that an imminent hazard is present. The condition in question should be related to an event or observation in or immediately adjacent to the potential affected structure. As with all indoor air sampling events, the investigator should properly assess the relative impact from background sources on the overall indoor air quality.

Note that methane is not part of this vapor intrusion evaluation guidance. If methane is near explosive levels in a building, then the local fire department should be contacted immediately.

13.0 RISK CHARACTERIZATION

Flowchart Step 6: Calculate the potential risk and hazard from the vapor intrusion pathway.

Use of Occupational Safety and Health Administration (OSHA) Standards

For DERR commercial and industrial sites, the OSHA Permissible Exposure Limits (PELs) are not an appropriate standard for evaluating the risk associated with vapor intrusion to indoor air. Hence, for vapor intrusion, potential adverse effects to humans should be evaluated in terms of acceptable exposure based on U.S. EPA risk assessment methodologies rather than by comparison to OSHA PEL values. An exception is made for operating facilities, provided that the contaminant of concern is used in site processes within the area of the building being investigated. OSHA generally will take the lead role in addressing occupational exposures.

For releases of contaminants to soil or ground water that are the same as those used in on-site processes, a distinction must be made between the contribution to indoor air risk derived from the environmental media and the portion derived from on-site processes. A remedy is necessary if release to environmental media results in exceedance of risk or hazard goals.

Use of Maximum Contaminant Levels (MCLs)

The vapor intrusion target level for ground water defaults to the MCL, consistent with U.S. EPA, OSWER (2002). For VOCs that do not have an associated MCL, ground water concentrations must meet target risk and hazard levels for the vapor intrusion pathway and must be adjusted for the presence of multiple chemicals.

Use of BUSTR Petroleum Standards for Voluntary Actions

At VAP sites, a volunteer may use BUSTR action levels, including action levels for soil and groundwater to indoor air contained in look-up tables found in OAC 1301:7-9-13(J)(3), as the generic numerical standards for petroleum at residential, commercial, and industrial properties in the VAP. For more information on applying BUSTR action levels as VAP applicable generic standards, please see Applying Generic Petroleum Standards under the VAP.

Determining Applicable Risk Goals and the Need for Further Evaluation

Refer to U.S. EPA's "Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air (June 2015)" and Vapor Intrusion Screening Level (VISL) calculator.

~~Comparison of results to applicable risk goals and whether further evaluation is needed depends upon which program the site clean-up follows:~~

~~For VAP properties, a multiple chemical adjustment is necessary and the resultant risk ratio for the vapor intrusion pathway is carried through as a vapor intrusion contribution to site-wide risk. Please note the VAP does not use screening values to determine pathway completeness or to eliminate COCs from further vapor intrusion risk assessment.~~

~~For RRP properties, screening values (either OSWER 2002 or the RSLs) serve as thresholds to evaluate whether the vapor intrusion pathway is complete, or whether further evaluation, including evaluating the pathway in the baseline human health risk assessment is warranted.~~

~~The data evaluated in this step may come from ground water, soil gas, subslab soil gas, and/or indoor air. However, scrutiny will be applied to risk decisions made for ground water or soil gas where the models are significantly manipulated. In such cases, the Ohio EPA reviewer may require further evaluation of media closer to the receptor. As an example, if the calculated risk from ground water data alone is below values derived through application of default attenuation factors, or is below target risk using conservative or reasonable property-specific assumptions in the J&E model, then further evaluation of the VI pathway through soil gas and indoor air will likely not be necessary. However, if concentrations of ground water are at or near risk goals with significant manipulation of model inputs and/or use of site-specific attenuation factors, or NAPL is present, then further sampling of the site, including soil gas, subslab gas sampling or indoor air monitoring may be required.~~

~~Please refer to U.S. EPA, Risk Assessment Guidance for Superfund, Part F (2009) to evaluate inhalation exposures.~~

Flowchart Step 7: If data evaluation indicates risk or hazard goals are or may be exceeded, then additional data may be collected, or a remedy may be implemented.

If collected data indicates that risk goals may be exceeded, then further data collection, analysis and evaluation may be necessary in order to make a decision based on multiple lines of evidence. Alternatively, a remedy can be conducted to prevent exposure from subsurface vapors.

14.0 REMEDY

Flowchart Step 8: Remediation, Mitigating Indoor Air Exposure and/or Conducting Long-Term Monitoring

A remedy or a combination of remedies can be implemented to mitigate or eliminate risks from vapor intrusion. Remedies can generally be separated into three main types: 1) remediation of environmental media; 2) institutional controls; and 3) building controls. Please note that some remedies may include long term operation and maintenance, including monitoring. For VAP, please see 3745-300-11 for specific remedy requirements. For RRP properties, Ohio EPA will direct the remedy selection based on existing RRP/U.S. EPA guidance (*e.g.*, RI/FS, SCIA). Three recommended documents that provide a detailed assessment of remedies that address impacts from the vapor intrusion exposure pathway are:

1) Indoor Air Vapor Intrusion Mitigation Approaches. Office of Research and Development. EPA/600/R-08-115, October 2008.

2) U.S. EPA Brownfields Technology Primer: Vapor Intrusion Considerations for Redevelopment. Solid Waste and Emergency Response. EPA 542-R-08-001, March 2008, and

3) Interstate Technology Regulatory Council (ITRC) Technical and Regulatory Guidance, Vapor Intrusion Pathway: A Practical Guide, January 2007.

Remediation of Environmental Media

The media source of vapor intrusion can be addressed through application of a soil or ground water remedy. Remediation of soil and ground water contamination may include source removal, technologies to reduce contaminant concentrations in soils and soil gas, such as soil vapor extraction, or technologies to reduce concentrations in ground water such as in situ bioremediation or pump and treat. In general, source removal and soil vapor extraction remedies are likely to reduce or eliminate soil gas migration and thus may prevent the need for institutional or building control remedies.

Institutional Controls

Institutional controls are activity and use limitations that are recorded with the deed record. Examples of institutional controls include restricting a property to commercial or industrial uses only, prohibitions of inhabitable structures in areas where vapor intrusion risk goals are exceeded, or building-specific conditions, such as prohibition of basements.

Building Control Remedies

Building control remedies can be used to reduce or eliminate the potential for vapor intrusion impacts in new and existing buildings. Some examples of available technologies are provided in **Table 6,** along with some of the advantages and disadvantages of each (ITRC, 2007).

Table 6. Comparison of Mitigation Methods

Technology	Typical Applications	Challenges
Passive barrier	• New construction • Crawl spaces • Often combined with passive or active venting, sealing openings in the slab, drains, etc.	• Preventing tears, holes • May not suffice as a stand-alone technology • Some states do not accept • Ensuring caulking seals, cracks in floors, etc.
Passive venting	• New construction • Low soil gas flux sites • Should be convertible to active system if necessary	• Relies on advective flow of air due to wind and heat stack effects • Air flows and suction typically far less than achieved by fans
Aerated floor	• New construction or extensive remodeling • May be useful for large structures	• Not yet widely used • May not be suited for all soil types
Subslab depressurization (SSD)	• New and existing structures • Sumps, drain tiles, and block wall foundations may also be depressurized if present	• Low permeability and wet soils may limit performance
Submembrane depressurization	• Existing structures • Crawl spaces	• Sealing to foundation wall, pipe penetrations • Membranes may be damaged by occupants or trades people accessing crawl space
Subslab pressurization	• Same as SSD • Most applicable to highly permeable soils	• Higher energy costs and less effective than SSD • Potential for short-circuiting through cracks
Building pressurization	• Large commercial structures, new or existing • Specialized cases only	• Requires regular air balancing and maintenance • May not maintain positive pressure when building is unoccupied
Indoor air treatment	• Specialized cases only	• Typically generates a waste disposal stream • Effective capture of air contaminants may be difficult • Energy-intensive, with significant operation, maintenance, and monitoring burden
Sealing the building envelope	• Cracks and holes in existing building	• Access to perforations • Permanence

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APPENDIX A

Chemicals of Concern for Vapor Intrusion

Refer to regional screening levels (RSL) tables or the VISL calculator

~~Chemical~~	~~CAS Number~~
~~1,1,2-Trichloro-1,2,2-trifluoroethane~~	~~76-13-1~~
~~1,2,4-Trichlorobenzene~~	~~120-82-1~~
~~1,2-Dibromo-3-chloropropane~~	~~96-12-8~~
~~1,2-Dibromoethane (ethylene dibromide)~~	~~106-93-4~~
~~1,3-Dichlorobenzene~~	~~541-73-1~~
~~1-Chlorobutane~~	~~109-69-3~~
~~2-Chloro-1,3-butadiene (chloroprene)~~	~~126-99-8~~
~~2-Chlorophenol~~	~~95-57-8~~
~~2-Chloropropane~~	~~75-29-6~~
~~2-Methylnaphthalene~~	~~91-57-6~~
~~2-Nitropropane~~	~~79-46-9~~
~~Acenaphthene~~	~~83-32-9~~
~~Acetaldehyde~~	~~75-07-0~~
~~Acetone~~	~~67-64-1~~
~~Acetone Cyanohydrin~~	~~75-86-5~~
~~Acetonitrile~~	~~75-05-8~~
~~Acetophenone~~	~~98-86-2~~
~~Acrolein (Propenal)~~	~~107-02-8~~
~~Acrylonitrile~~	~~107-13-1~~
~~Aldrin~~	~~309-00-2~~
~~alpha-HCH (alpha-BHC)~~	~~319-84-6~~
~~Allyl Chloride~~	~~107-05-1~~
~~Amyl Alcohol, tert-~~	~~75-85-4~~
~~Aroclor 1221~~	~~11104-28-2~~
~~Aroclor 1232~~	~~11141-16-5~~
~~Azobenzene~~	~~103-33-3~~
~~Benzaldehyde~~	~~100-52-7~~
~~Benzene~~	~~71-43-2~~
~~Benzo(b)fluoranthene~~	~~205-99-2~~
~~Benzyl Cchloride~~	~~100-44-7~~
~~beta-Chloronaphthalene~~	~~91-58-7~~
~~Biphenyl, 1,1'-~~	~~92-52-4~~
~~Bis(2-chloroethyl)ether~~	~~111-44-4~~
~~Bis(2-chloro-1-methylethylisopropyl)ether~~	~~108-60-1~~
~~Bis(2-chloromethyl)ether~~	~~542-88-1~~
~~Bromo-2-chloroethane, 1-~~	~~107-04-0~~
~~Bromobenzene~~	~~108-86-1~~
~~Bromochloromethane~~	~~74-97-5~~
~~Bromodichloromethane~~	~~75-27-4~~
~~Bromoform~~	~~75-25-2~~
~~Bromomethane~~	~~74-83-9~~
~~Butadiene, 1,3-~~	~~106-99-0~~
~~Carbon Disulfide~~	~~75-15-0~~

~~Carbon Tetrachloride~~	~~56-23-5~~
~~Chloro-1, 1-difluorethane, 1-~~	~~75-68-3~~
~~Chlordane~~	~~57-74-9~~
~~Chlorobenzene~~	~~108-90-7~~
~~Chlorobenzotrifluoride, 4-~~	~~98-56-6~~
~~Chlorodibromomethane~~	~~124-48-1~~
~~Chlorodifluoromethane~~	~~75-45-6~~
~~Chloroethane (ethyl chloride)~~	~~75-00-3~~
~~Chloroform~~	~~67-66-3~~
~~Chloromethane~~	~~74-87-3~~
~~Chloromethyl Methyl Ether~~	~~107-30-2~~
~~Chrysene~~	~~218-01-9~~

~~**Chemical**~~	~~**CAS Number**~~
~~Chloropicrin~~	~~76-06-2~~
~~Crotonaldehyde (2-butenal)~~	~~123-73-9~~
~~Cyanide (CN-)~~	~~57-12-5~~
~~Cyclohexane~~	~~110-82-7~~
~~Cyclohexene~~	~~110-83-8~~
~~Dibenzofuran~~	~~132-64-9~~
~~Dibromomethane (Methylene Bromide)~~	~~74-95-3~~
~~Dichloro-2-butene, 1,4-~~	~~764-41-0~~
~~Dichloro-2-butene, cis-1,4-~~	~~1476-11-5~~
~~Dichloro-2-butene, trans-1,4-~~	~~110-57-6~~
~~Dibromochloromethane~~	~~124-48-1~~
~~Dichlorobenzene, 1,2 - (o)~~	~~95-50-1~~
~~Dichlorobenzene, 1,4 - (p)~~	~~106-46-7~~
~~Dichlorobiphenyl (PCB)*~~	~~na~~
~~Dichlorodifluoromethane~~	~~75-71-8~~
~~Dichlorodiphenyldichloroethene (DDE)~~	~~72-55-9~~
~~Dichloroethane, 1,1 -~~	~~75-34-3~~
~~Dichloroethane, 1,2 -~~	~~107-06-2~~
~~Dichloroethene, 1,1 -~~	~~75-35-4~~
~~Dichloroethene, cis - 1,2~~	~~156-59-2~~
~~Dichloroethene, cis -1,2~~	~~156-59-2*~~
~~Dichloroethene, trans - 1,2 -~~	~~156-60-5~~
~~Dichloropropane, 1,2 -~~	~~78-87-5~~
~~Dichloropropene, 1,3 -~~	~~542-75-6~~
~~Dicyclopentadiene~~	~~77-73-6~~
~~Dieldrin~~	~~60-57-1~~
~~Difluoroethane, 1,1-~~	~~75-37-6~~
~~Dihydrosafrole~~	~~94-58-6~~
~~Diisopropyl Ether~~	~~108-20-3~~
~~Dimethylvinylchloride~~	~~513-37-1~~
~~Endosulfan~~	~~115-29-7~~
~~Epichlorohydrin~~	~~106-89-8~~
~~Epoxybutane, 1,2-~~	~~106-88-7~~
~~Ethyl Ether~~	~~60-29-7~~
~~Ethylacetate~~	~~141-78-6~~
~~Ethylbenzene~~	~~100-41-4~~
~~Ethylene oxide~~	~~75-21-8~~
~~Ethyleneimine~~	~~151-56-4~~
~~Ethylmethacrylate~~	~~97-63-2~~
~~Fluorene~~	~~86-73-7~~
~~Furan~~	~~110-00-9~~
~~Heptachlor~~	~~76-44-8~~
~~Hexachloro- 1,3 - Butadiene~~	~~87-68-3~~
~~Hexachlorobenzene~~	~~118-74-1~~
~~Hexachlorocyclopentadiene~~	~~77-47-4~~

~~Hexachloroethane~~	~~67-72-1~~
~~Hexamethylene Diisocyanate, 1,6-~~	~~822-06-0~~
~~Hexane, n -~~	~~110-54-3~~
~~Hexanone, 2-~~	~~591-78-6~~
~~Hydrogen cyanide~~	~~74-90-8~~
~~Hydrogen sulfide*~~	~~7783-06-4~~
~~Isobutyl Alcohol (Isobutanol)~~	~~78-83-1~~
~~Isopropylbenzene (Cumene)~~	~~98-82-8~~
~~Lindane~~	~~58-89-9~~
~~Mercury (elemental)~~	~~7439-97-6~~
~~Methacrylonitrile~~	~~126-98-7~~
~~Methoxychlor~~	~~72-43-5~~
~~Methyl acetate~~	~~79-20-9~~
~~Methyl acrylate~~	~~96-33-3~~
~~Methyl bromide (bromomethane)~~	~~74-83-9~~
~~Methyl butyl ketone~~	~~591-78-6~~
~~Methyl chloride (chloromethane)~~	~~74-87-3~~
~~Methyl Ethyl Ketone (MEK)~~	~~78-93-3~~

~~Chemical~~	~~CAS Number~~
~~Methyl Isobutyl Ketone (MIBK)~~	~~108-10-1~~
~~Methyl Isocyanate~~	~~624-83-9~~
~~Methyl Methacrylate~~	~~80-62-6~~
~~Methyl Styrene (Mixed Isomers)~~	~~25013-15-4~~
~~Methyl tert- Butyl Ether (MTBE)~~	~~1634-04-4~~
~~Methylcyclohexane~~	~~108-87-2~~
~~Methylene bromide~~	~~74-95-3~~
~~Methylene chloride~~	~~75-09-2~~
~~Mineral Oils~~	~~8012-95-1~~
~~Methylmethacrylate~~	~~80-62-6~~
~~Monochlorobiphenyl (PCB)*~~	~~na~~
~~m-Xylene~~	~~108-38-3~~
~~Naphtha, High Flash Aromatic (HFAN)~~	~~64724-95-6~~
~~Naphthalene~~	~~91-20-3~~
~~n-butyl benzene~~	~~104-51-8~~
~~Nitrobenzene~~	~~98-95-3~~
~~Nitromethane~~	~~75-52-5~~
~~Nitropropane, 2-~~	~~79-46-9~~
~~N-Nitroso-di-n-butylamine~~	~~924-16-3~~
~~Nonane, n-~~	~~111-84-2~~
~~n-propyl benzene~~	~~103-65-1~~
~~o-Nitrotoluene~~	~~88-72-2~~
~~o-Xylene~~	~~95-47-6~~
~~Polychlorinated Biphenyls*~~	~~1336-36-3~~
~~p-Xylene~~	~~106-42-3~~
~~Pentane, n-~~	~~109-66-0~~
~~Phosgene~~	~~75-44-5~~
~~Propionaldehyde~~	~~123-38-6~~
~~Propyl benzene~~	~~103-65-1~~
~~Propylene~~	~~115-07-1~~
~~Propylene Oxide~~	~~75-56-9~~
~~Pyrene~~	~~129-00-0~~
~~Sec-butyl benzene~~	~~135-98-8~~
~~Styrene~~	~~100-42-5~~
~~Tert-butyl benzene~~	~~98-06-6~~
~~Tetrachloroethane , 1,1,1,2 -~~	~~630-20-6~~
~~Tetrachloroethane, 1,1,2,2 -~~	~~79-34-5~~
~~Tetrachloroethene~~	~~127-18-4~~
~~Tetrafluoroethane, 1,1,1,2-~~	~~811-97-2~~
~~Tetrahydrofuran~~	~~109-99-9~~
~~Toluene~~	~~108-88-3~~
~~Total Petroleum Hydrocarbons (Aliphatic Low)~~	~~NA~~
~~Total Petroleum Hydrocarbons (Aliphatic Medium)~~	~~NA~~
~~Total Petroleum Hydrocarbons (Aromatic Low)~~	~~NA~~
~~Total Petroleum Hydrocarbons (Aromatic Medium)~~	~~NA~~
~~Trichloro-1,2,2-trifluoroethane, 1,1,2-~~	~~76-13-1~~

~~Trichlorobenzene, 1,2,4-~~	~~120-82-1~~
~~Trichloroethane, 1,1,1 -~~	~~71-55-6~~
~~Trichloroethane, 1,1,2 -~~	~~79-00-5~~
~~Trichloroethene~~	~~79-01-6~~
~~Trichlorofluoromethane~~	~~75-69-4~~
~~Trichloropropane, 1,2,3 -~~	~~96-18-4~~
~~Trichloropropene, 1,2,3-~~	~~96-19-5~~
~~Triethylamine~~	~~121-44-8~~
~~Trimethylbenzene, 1,2,3-~~	~~526-73-8~~
~~Trimethylbenzene, 1,2,4~~	~~95-63-6~~
~~Trimethylbenzene, 1,3,5~~	~~108-67-8~~
~~Vinyl Acetate~~	~~108-05-4~~
~~Vinyl Bromide~~	~~593-60-2~~
~~Vinyl Chloride~~	~~75-01-4~~
~~Xylene, m-~~	~~108-38-3~~
~~Xylene, o-~~	~~95-47-6~~
~~Xylene, P-~~	~~106-42-3~~
~~Xylenes, Total~~	~~1330-20-7~~

~~* Not all releases of PCBs need to be evaluated for vapor intrusion. Please see Section 3.3 for further information.~~

~~Note: The appropriate analytical method should be chosen based on discussions with the laboratory.~~

APPENDIX B
Special Considerations for Evaluating Residential Properties

Evaluating the vapor intrusion pathway using the prescribed step-wise approach listed in **Figure 1** is preferred when volatilization to indoor air is potentially complete to residential receptors. Subslab soil gas and indoor air collection for vapor intrusion should be conducted after a reasonable assessment from affected environmental media (soil and/or ground water), indicates that risk goals may be exceeded.

Prior to conducting any direct sampling within a residential scenario, the volunteer/site coordinator should consider how the potentially impacted community and local government should be notified. Proper community involvement efforts are critical to the effective implementation of sample collection, screening and risk communication. Public meetings may be necessary, including a pre-sampling meeting to explain results from previous sampling, and a post-sampling meeting to explain any findings. Meetings may also be necessary to discuss additional and/or follow-up air sampling or the determined remedy.

The quality of outdoor air is important to consider in the CSM and remedy selection. Thus, collecting outdoor ambient vapor samples concurrently with indoor air sampling is required. Additionally, the indoor air/sub slab sampling form found in **Appendix F** should be completed prior to any indoor air or subslab soil gas sampling at residential properties.

For further guidance on community outreach, please see Appendix A (Community Stakeholder Concerns) in the ITRC guidance, and Appendix H (Community Involvement Guidance) in the U.S. EPA OSWER (2002) guidance.

APPENDIX C

Vapor Intrusion Conceptual Site Model Checklist

Utilities and Process Piping

☐ Identify on a site plan all underground utilities near the soil or ground water impacts; pay particular attention to utilities that connect impacted areas to occupied buildings.

☐ Identify on a site plan all underground process piping near the soil or ground water impacts.

Buildings

☐ Identify on a site plan all existing and future buildings under investigation.

☐ Identify the occupancy and use of each building (*e.g.,* residential, commercial)

☐ Describe building construction materials (*e.g.*, wood frame, block,), openings (*e.g.,* windows, doors), and height (*e.g.*, one-story, two-story, multiple-story); identify if there is an elevator shaft in the building.

☐ Describe building foundation construction including:

- Type (*e.g.,* basement, crawl space, slab on grade)
- Floor construction (*e.g.,* concrete, dirt)
- Depth below grade.

☐ Describe the building HVAC system including:

- Furnace/air conditioning type (*e.g.*, forced air, radiant)
- Furnace/air conditioning location (*e.g.*, basement, crawl space, utility closet, attic, roof)
- Source of return air (*e.g.,* inside air, outside air, combination)
- System design considerations relating to indoor air pressure (*e.g.*, positive pressure is often the case for commercial buildings).

☐ Identify subslab ventilation systems or moisture barriers present on existing buildings.

Source Area

☐ Identify the COC's related to the vapor intrusion pathway.

☐ Describe the distribution and composition of any NAPL at the site.

☐ Identify on a site plan all source areas for the COC's related to the vapor intrusion pathway.

☐ Identify on a site plan soil and ground water results for the COC's, between the source area and the buildings under investigation.

☐ Identify on a geologic cross section soil and ground water results including depth.

☐ Describe the potential migration characteristics (*e.g.,* stable, increasing, decreasing) for the distribution of COC's.

Geology/Hydrogeology

☐ Review all boring logs and soil sampling data to understand the locations of:

- Sources: NAPL, soil, ground water, suspected vapor leaks.
- Soil types:
  - Finer-grained soil layers
  - Higher-permeability layers that may facilitate vapor migration.

☐ Identify on a geologic cross section distinct strata (soil type and moisture content, *e.g.*, "moist," "wet," "dry") and the depth intervals between the vapor source and ground surface, and include the depth to ground water.

☐ Describe ground water characteristics (*e.g.*, seasonal fluctuation, hydraulic gradient).

Site Characteristics

☐ Estimate the distance from the ground water concentration contour interval for each COC to buildings under investigation.

☐ Estimate the distance from vadose zone source area to buildings under investigation.

☐ Describe the surface cover between the vapor source and buildings under investigation.

APPENDIX D
Standard Operating Procedures (SOPs) for Sample Collection

NOTE: the following SOPs are specific to the Ohio EPA, Division of Emergency and Remedial Response. They are provided as a reference only and are not meant to dictate an exclusive method for soil gas sampling.

SOP # 2.5.1 - Procedures for Active Soil Gas Collection Using Direct-Push Systems

1.0 Scope and Application

1.1 Vapor intrusion is defined as vapor phase migration of VOCs into occupied buildings from underlying contaminated ground water and/or soil. Soil gas surveys provide information on the soil atmosphere in the vadose zone that can aid in assessing the presence, composition, source, and distribution of contaminants. The purpose of this document is to provide guidance for conducting soil gas sampling, and shall pertain to active soil gas surveys, whereby a volume of soil gas is pumped out of the vadose zone into a sample collection device for analysis.

1.2 Detection of individual constituents by active soil gas sampling is limited by the physical and chemical properties of individual contaminants of concern* and the soil characteristics of the site. In general, chemical parameters or criteria to be considered prior to selecting soil gas sampling activities are as follows:

- Vapor Pressure > 0.1 mm Hg
- Henry's Law Constant > 0.1
- Degree of soil saturation (chemical and/or water) < 80%
- Sampling zone is permeable and permits vapor migration

*Please refer to **Appendix A**, Chemicals of Concern for Vapor Intrusion, in the *"Sample Collection and Evaluation of Vapor Intrusion to Indoor Air, Guidance for Ohio EPA'S Remedial Response and Voluntary Action Programs"* for a complete list of the volatile chemicals which can be detected using soil gas sampling techniques.

1.3 Results from soil gas surveys are used in both qualitative and quantitative evaluations. The quality and application of the data is dependent upon many factors, including but not limited to: the DQO's used to develop the sampling plan, the number of sample locations and data points, the selection of the sample locations, the soil characteristics of the site, the distribution of the contaminants in both the vadose and saturated zones, the equipment and personnel used to gather the data, etc. The work plan should be finalized before any sampling is conducted. The work plan will provide specific information on the type and quality of data gathered during the soil gas sampling event. Any questions regarding data needs and usage should be resolved prior to sampling.

1.4 The evaluation of the indoor inhalation pathway at contaminated sites is a relatively recent development. As a result, procedures and technology related to evaluating the pathway continue to evolve. This guidance pertains to the active collection of soil gas using direct-push systems (*i.e.* driven probe rod) [see also ITRC Vapor Intrusion Guidance: A Practical Guide, January 2007, Appendix D, Section 4]. Ohio EPA does not intend for this guidance to be overly limiting with respect to the use of other appropriate methods, procedures, and equipment for measuring concentrations of chemicals of concern in soil gas.

1.5 Limitations

1.5.1 A soil gas survey is only applicable to volatile contaminants;

1.5.2 Barriers exist that interfere with vapor migration such as perched water, clay or man-made structures can lead to non-representative sampling with low or false negative readings, or may produce localized areas of high concentrations;

1.5.3 Soil gas readings taken within 24 to 48 hours of heavy precipitation can produce drastically reduced or non-existent readings;

NOTE: Separation between the contamination source and the sample location increases the influence due to biodegradation or abiotic transformation.

2.0 Health and Safety Warnings

2.1 Overhead and Buried Utilities

The use of direct push systems on a site within the vicinity of electrical power lines and other utilities requires that special precautions be taken by the operators. Underground electrical utilities are as dangerous as overhead electricity. Be aware and always suspect the existence of underground utilities (water, natural gas, cable/phone lines, fiber optic cables, storm water & sewer lines, etc.).

REMEMBER.....Call B-4-U Dig:

Ohio Utilities Protection Service (OUPS): 800-362-2764
&
Oil & Gas Producers Underground Protection Service (OGPUPS):
800-925-0988

2.2 Operators must wear OSHA-approved Personal Protective Equipment (PPE). Refer to the site specific Health and Safety Plan.

3.0 Apparatus and Materials

3.1 The following is a list of equipment, tooling, and supplies typically used for soil gas sample collection:

PPE:
- Hearing protection
- Nitrile (or similar) disposable gloves
- Steel-toed boots
- Safety glasses
- Leather gloves
- Hard hat

Equipment/Tooling/Supplies needed for all probing:
- 4-foot probe rods
- Inner Extension Rods (48")
- Drive Cap
- Miscellaneous tools
- Bentonite granules
- 2-foot probe rods
- Rod Grip Pull System
- Pull Cap
- Logbook

Soil Gas Sampling:
- Expendable Point Holder
- Expendable Drive Points w/ O-ring
- Adapter for ¼“ tubing w/ O-ring
- Tedlar® gas sampling bags (1 L) w/ bag sampler (*e.g.* Lung Box)
- Implant Expendable Point Holder
- Air tight fittings/valves
- Expendable Point Popper
- Plastic or stainless 3-way valves
- Equipment for leak testing
- ⅛” -¼“ Tubing (Teflon, Nylon or PEEK)
- 20/40 grade sand
- Implants (stainless steel aluminum, ceramic, or plastic)
- Funnel
- Vacuum canisters (*e.g.* Summa®)
- 60cc Syringe
- Multi-gas meter

Equipment Clean-Up:
- Decontamination Supplies
- Various Brushes
- Pressurized Sprayer
- Polyethylene Sheeting
- Non-phosphate Soap
- Tap & ASTM Water
- Wash Tubs/Buckets

4.0 Summary of Probe Installation Methods

4.1 Post-Run Tubing System

This is a temporary, single use application for collecting a grab soil gas sample. Using the post-run tubing system (PRT), probe rods are driven to the desired depth, and then internal tubing is inserted and sealed for soil gas sampling. Using the inner tubing for soil gas collection has many advantages - potential for leakage is reduced, dead air volume that must be purged is reduced, and decontamination problems are reduced as the sample does not contact the rod bore.

4.1.1 Clean all parts prior to use. Inspect all probe rods and clear them of obstructions. Install O-rings on the PRT expendable point holder and the PRT adapter.

4.1.2 Test fit the adapter with the PRT fitting on the expendable point holder to assure that the threads are compatible and fit together smoothly.

NOTE: PRT fittings are left-hand threaded and must be rotated counter-clockwise to engage the point holder threads.

4.1.3 Push the PRT adapter into the end of the selected tubing. Tape may be used on the outside of the adapter and tubing to prevent the tubing from spinning freely around the adapter during connection - especially when using Teflon tubing.

REMEMBER: The sample will not come into contact with the outside of the tubing or adapter.

4.1.4 Attach the PRT expendable point holder (with O-ring) to the female end of the leading probe rod.

4.1.5 Attach an O-ring to an expendable drive point and insert into the expendable point holder. Attach the drive cap to the male end of the drive rod and position rod under probe.

4.1.6 Drive the PRT rod configuration into the ground, connecting probe rods as necessary to reach the desired depth.

4.1.7 After desired depth has been achieved, disengage the expendable drive point. Using the inner rods, insert the expendable point popper to the bottom of the rod string and then slowly pull up on the probe rods using the rod grip pull system. Retract the rods approximately 4"- 6" up to create a void from which to sample the soil gas. Position the probe unit to allow room to work around the sample location.

4.1.8 Insert the PRT adapter end of the tubing down the inside diameter of the probe rods.

4.1.9 Feed the tubing down the rod bore until it hits bottom on the expendable point holder. Allow approximately 4-6 ft. of tubing to extend out of the hole before cutting it. Grasp the excess tubing end and apply some downward pressure while turning it in a counter-clockwise motion to engage the adapter threads with the expendable point holder. Continue turning until the PRT adapter O-ring bottoms out in the expendable point holder.

4.1.10 Pull up lightly on the tubing to test the engagement of the threads. Failure of the PRT adapter to thread could mean that intrusion of soil may have occurred during driving of the rods or disengagement of the expendable drive point. At this time, the sample train should be tested for leaks.

4.1.11 Sampling the location can commence following an equilibrium period (minimum of 15 minutes). Connect the sampling tubing and follow appropriate purging and sampling procedures. Refer to Section 5.1 for sampling procedures using the bag sampler.

4.2 Installation of Soil Gas Implants

For long-term soil gas monitoring applications (multiple sampling events from the same location) or when using evacuated canisters, a stainless steel, aluminum, plastic or ceramic implant can be installed at any depth by direct push. Implants are inserted down inside the probe rods when the appropriate sampling depth has been achieved.

4.2.1 Drive probe rods to the desired depth using the implant point holder and an implant anchor point or expendable drive point. If using steel implants that attach (screw-in) to the drive point, DO NOT disengage the drive point when depth of interest has been reached. If using implants which do not need to be attached to the drive point, the drive point may be disengaged using the point popper. Pull the tool string back approximately 1”- 2” to push the expendable point out with the point popper.

4.2.2 Attach appropriate sample tubing (Teflon, nylon, or PEEK). Depending on implant type and diameter of sample tubing, Tygon® tubing of appropriate size may be used to securely connect the implant to the sample tubing. If sample tubing is pre-cut, allow it to be approximately 48 inches longer than required depth of the implant (*e.g.*, if the sampling depth is at 6.5 feet then tubing should be cut at 10.5 feet). Cover or plug the open end of the tubing with a sealed fitting or valve.

4.2.3 Lower the implant and tubing down the inside of the probe rods until the implant hits the top of the anchor/drive point. Note the length of the tubing to assure that proper depth has been reached.

4.2.4 If using attachable steel implants, rotate tubing (and attached steel implant) counter-clockwise while exerting a gentle downward force to engage the implants threads into the threads of the expendable point. Pull up on the tubing lightly to test the connection. DO NOT cut the excess tubing at this time.

4.2.5 Position the rod grip pull system or rod pull plate on the top probe rod. Exert downward pressure on the tubing while slowly pulling the probe rods up. Pull up about 12 inches (or twice the distance of the implant length) to create an annulus for backfilling with sand or rounded glass beads.

4.2.6 If using ¼” O.D. tubing or smaller, thread excess tubing through a funnel and position it over the top of the probe rod. If using larger tubing (*i.e.*, ⅜”), it may not be possible to install the sand since the spacing between the outside of the larger tubing and the probe rods has been reduced and may not allow sand to sufficiently flow to the bottom of the tool string. Bridging of the sand is most likely to occur in this scenario.

4.2.7 Pour sand down the inside diameter of the probe rods around the outside of the tubing so that the sand extends several inches above the implant. Use the tubing to “stir” the sands into place around the implant. Do not lift up on the tubing. It should take less than 150 mL of sand to fill the space around the implant. The sand therefore will act as a grout barrier, inhibiting the grout from impacting the implant.

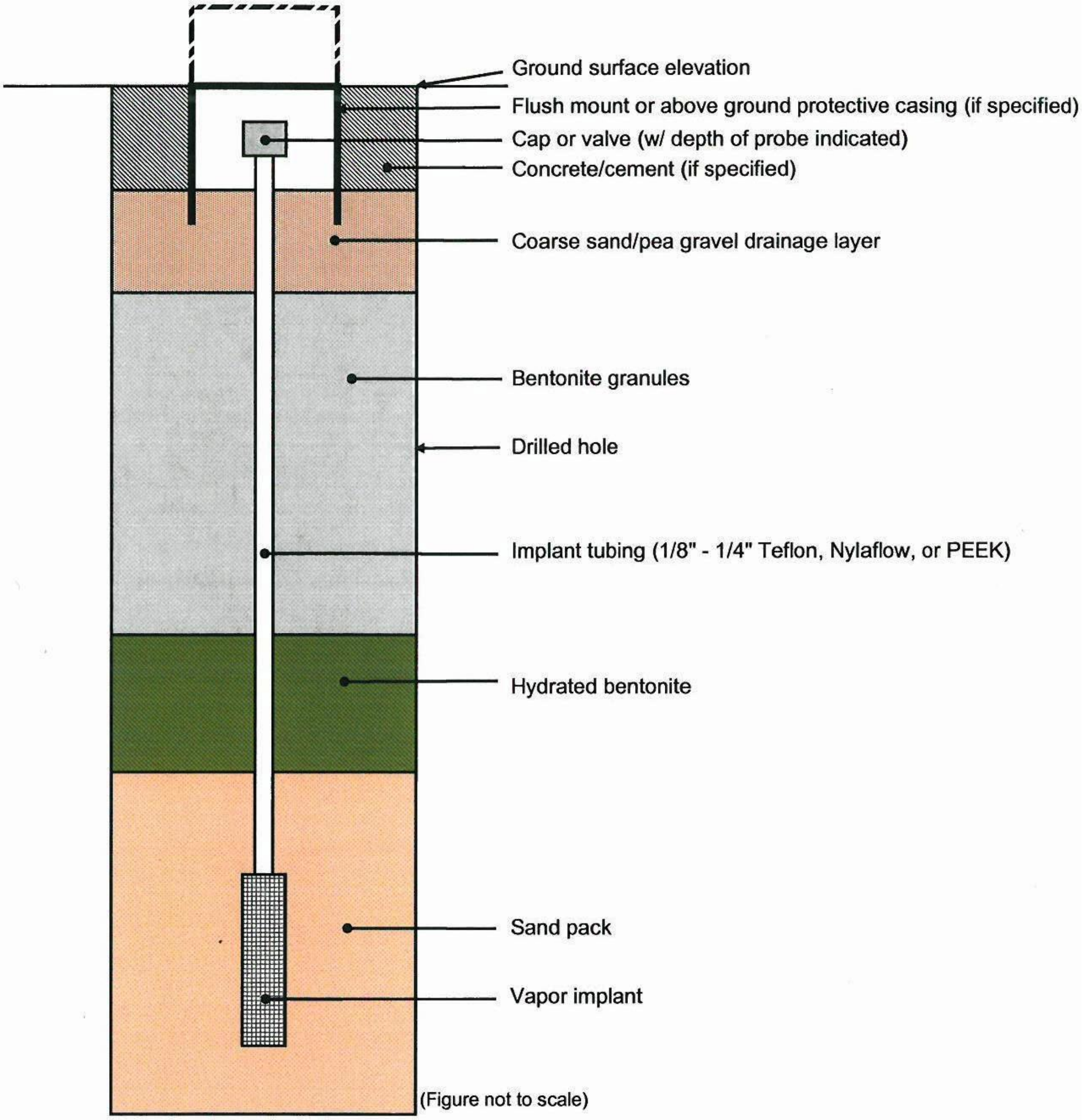
NOTE: Implants come in various sizes and the drive rods can vary in diameter, so it is best to calculate the necessary volume of sand for each implant installation. Placement of the grout barrier by backfilling through the rods with sand can only be performed in the vadose zone, not below the water table.

4.2.8 Lift the probe rods up an additional 18-24 inches and pour the bentonite granules granules into place as in Step 4.2.7. The volume to be filled is about 154 mL per foot. It may be necessary to “chase” the seal mixture with distilled water to initiate a seal. This results in a tight seal preventing gas migration down the column.

4.2.9 After the probe rods have been removed, cut the tubing to a manageable length, attach a 3-way valve connector or air tight (*e.g.* Swagelok®) plug, and mark the location with a pin flag or stake. Attach a piece of tape to the tubing indicating the depth at which the implant was set for future reference when sampling. At this time, the sample train should be tested for leaks.

4.2.10 A minimum equilibrium time should be established to prior to sampling the implant. While a 24-hour equilibrium period will ensure adequate equilibration, three to four hours is generally sufficient. After equilibration, the implant is ready for sampling. Refer to Section 5.0 for sampling procedures using the bag sampler (*e.g.* Lung Box) or vacuum canister (*e.g.* Summa® or Silco).

4.2.12 To provide long term security to the sampling port, the installation of a riser pipe protector with cap can be installed and finished with a concrete pad. If desired, less secure finishing of a sampling port can be completed using 2”-4” (ID) PVC pipe sections with associated caps.



Example of a Soil Gas Implant

5.0 Sample Collection Methods

Four common methods of sample collection for COCs are discussed in this SOP. Two of the methods use Tedlar bags as sample containers while the third method uses evacuated canisters and the last method adsorbents. DQOs for the project should determine which sample collection method is used.

5.1 The Lung Box Sampler (Bag Samplers)

The Lung Box allows direct filling of a Tedlar® air sample bag using negative pressure without passing gas through the pump. This eliminates the risk of contaminating the pump or the sample. The Lung Box pictured below includes an in-line pump. Other types of bag samplers may require the use of a separate air pump or hand pump.

Semi-permanent soil gas probe location with multi-depth implants. The blue bag sampler is used to collect soil gas samples using 1-liter Tedlar bags. Note that each tube is labeled with the sampling depth; the PVC pipe is used to protect the soil gas tubing.

5.1.1.1 Prior to sampling, and after an appropriate equilibrium period, ambient air needs to be removed from the sample train by purging. Purging of the filter pack is required if sampling occurs within 24 hours of installation. At least three volumes should be removed. For example, the sample tubing can be purged using a 60 cc syringe with an attached 3-way valve (~4 cc/ft for ¼" ID tubing/volume). Other methods may be used as long as a minimum of 3 volumes are purged from the tubing. Once purging is complete, the sample may be collected. Field screening may be performed using a direct reading instrument.

5.1.1.2 Install new tubing in the bag sampler before collecting each sample. Place a new Tedlar sample bag (already labeled) inside the bag sampler. Attach the inside portion of the tubing to the inlet valve on the sample bag. Open the sample valve on the sample bag following the manufacturer's instructions. Close sampler lid and secure.

5.1.1.3 Attach external part of the inlet tubing to the sample tubing. Make sure that the purge valve is closed (closed for fastest fill rate, open for slower fill rate).

5.1.1.4 Turn on the sample pump or initiate hand pumping. While filling, watch through the observation window of the Bag sampler as the Tedlar® bag fills with gas. Avoid filling bag more than 80% of its maximum volume. Turn the pump off when the bag has filled to the desired volume. Do not over fill sample bags. The vacuum pump may be strong enough to break a sample bag.

NOTE: Be sure to watch the sample line for the first sign of water coming up the line. Pulling water up the line is not uncommon, especially in cases where the position of the water table is unknown. This is a good reason why ample lengths of tubing should be used for the sample line. If water is drawn up the tubing, the tubing can be cut before the water reaches the sampling equipment.

NOTE: Exercise extreme caution if filling sample bags with explosive gases.

5.1.1.5 Once filling of the sample bag is complete, turn off the pump, open the purge valve to equalize the pressures, unlatch the bag sampler lid and open. Close the sample bag inlet valve by holding the side stem and turning the entire upper portion of the fitting clockwise until snug. Remove the filled sample bag from the internal inlet tubing.

5.1.1.6 If measurements with a portable meter are to be made (*e.g.*, oxygen), conduct measurements after collecting the soil gas sample(s).

5.2 Peristaltic Pump

5.2.1 Connect the Teflon sample tubing to the peristaltic pump tubing. The exact tubing connection method is up to the sampler. However, ensure that all connections are secure (without leaks). Use hose clamps to secure tubing if needed or desired.

5.2.2 Turn on the peristaltic pump and set the pumping rate such that the Tedlar bag fills at approximately one minute (1 liter/min pump rate).

5.2.3 Once the gas sample is collected, turn off the pump, close the valve on the bag and then detach the bag from the tubing.

5.2.4 Complete the Sample Data Sheet with all applicable information.

5.3 Evacuated Canister

5.3.1 Follow the procedures described in Ohio EPA DERR SOP #2.5.3

5.4 Collection of Samples on Adsorbents

5.4.1 An alternative approach to collecting soil gas in a sample container is to concentrate the soil gas on an adsorbent. This type of method is required for SVOCs and is often used for mercury (generally compounds heavier than naphthalene). Typically, a pump is used to draw soil gas through the adsorbents, and the adsorbent is then analyzed by a laboratory. A variety of adsorbent cartridges and pumping systems are available from commercial vendors. In addition, it is essential that the soil gas be drawn through the adsorbent by the pump, not pumped through the adsorbent to eliminate the chance for cross-contamination by the pump. It is often recommended that two tubes be used in series to avoid breakthrough losses in areas of suspected higher concentrations. The adsorbent, purge rate, and sample volume must be determined by discussion with the analytical laboratory.

SOP # 2.5.2 - Construction and Installation of Permanent Subslab Soil Gas Ports

1.0 Scope and Application

This standard operating procedure (SOP) outlines the procedure used for the construction and installation of permanent subslab soil gas ports. The ports are used to sample gas beneath the floor slab of dwellings and other structures.

2.0 Method Summary

Using an electric hammer drill or rotary hammer, an inner or pilot hole is drilled into the concrete slab to a depth of approximately 2” with the ⅜” diameter drill bit. Using the pilot hole as the center, an outer hole is drilled to an approximate depth of 1⅜” using the 1” diameter drill bit. The 1” diameter drill bit is then replaced with the ⅜” diameter drill bit. The pilot hole is then drilled through the slab and several inches into the subslab material. Once drilling is completed, a stainless steel probe is assembled and inserted into the pre-drilled hole. The probe is mounted as flush as possible with the surrounding slab so it will not interfere with pedestrian or vehicular traffic and cemented into place. A length of Teflon® tubing is attached to the probe assembly and to a sample container or system.

3.0 Sample Preservation, Containers, Handling and Storage

3.1 SUMMA® Canister Sampling

After the subslab soil gas sample is collected, the canister valve is closed, an identification tag is attached to the canister and the canister is transported to a laboratory under chain of custody for analysis. Upon receipt at the laboratory, the data documented on the canister tag is recorded. Sample holding times are compound dependent, consult with the laboratory for holding times. Refer to Ohio EPA SOP # 2.5.3 for details on sampling using a Summa Canister.

3.2 Tedlar® Bag Sampling

Tedlar® bags most commonly used for sampling gas have a 1-liter volume capacity. Typically, Tedlar® bags are filled using a lung box. After sampling, the Tedlar® bags are stored in a clean cooler (without ice), a cardboard box or an opaque plastic bag at ambient temperature to prevent photodegradation. It is essential that sample analysis be undertaken within 24 to 48 hours following sample collection since VOC’s may escape or become altered. Refer to Ohio EPA SOP # 2.5.1, Section 5.1.1, “Sample Preparation and Collection using a Lung Box” for more details.

4.0 Interferences and Potential Problems

The thickness of a concrete slab will vary from structure to structure. A structure may also have a single slab where the thickness varies. A slab may contain steel reinforcement (*e.g.*, rebar). Drill bits of various sizes and cutting ability may be required to penetrate slabs of varying thicknesses or those that are steel reinforced. Ensure that all subslab utilities (public and building specific) have been located and marked prior to installation.

5.0 Equipment/Apparatus

- Hammer drill or Rotary Hammer
- Alternating current (AC) extension cord
- AC generator, if AC power is not available on site
- Hammer or Rotary Hammer drill bit, ⅜" diameter
- Hammer or Rotary Hammer drill bit, 1" diameter
- Portable vacuum cleaner
- 1 – ¾" open end wrench or 1 – medium adjustable wrench
- 2 – $^9/_{16}$" open end wrench or 2 – small adjustable wrenches
- Hex head wrench, ¼"
- Tubing or pipe cutter
- Disposable cups, 5 ounce (oz.)
- Disposable mixing implement (*i.e.,* popsicle stick, tongue depressor, etc.)
- Swagelok® SS-400-7-4 Female Connector, ¼" National Pipe Thread (NPT) to ¼" Swagelok® connector
- Swagelok® SS-400-1-4 Male Connector, ¼" NPT to ¼" Swagelok® connector
- Hose barb adapter, brass, 3/16" barb x ¼" MIP (Male Iron Pipe)
- ¼" NPT flush mount hex socket plug
- ¼" outer diameter (OD) stainless steel tubing, pre-cleaned, instrument grade
- Teflon washer ID ¼", OD ¾"
- ¼" OD Teflon® tubing
- Teflon® thread tape
- ⅛" OD stainless steel rod, 12" to 24" length
- Swagelok® Tee, optional (SS-400-3-4TMT or SS-400-3-4TTM)

6.0 Reagents

- Anchoring cement/grout – quick-setting, contaminant free
- Tap water, for mixing anchoring cement/grout

7.0 Procedures

7.1 Probe Assembly and Installation

7.1.1 Drill a ⅜" diameter pilot hole approximately 2 inches in depth (**Figure 1** in the attached schematic drawings).

7.1.2 Using the ⅜" pilot hole as your center, drill a 1" diameter outer hole to a depth of approximately 1 ⅜". Vacuum any cuttings out of the hole (**Figure 2**).

7.1.3 Continue drilling the ⅜" inner or pilot hole through the slab and a few inches into the subslab material (**Figure 3**). While drilling, carefully vacuum out any cuttings from the outer hole. (Note: if area highly contaminated with volatiles, volatiles may be drawn into the building, use caution).

7.1.4 Determine the length of stainless steel tubing required to reach from the bottom of the outer hole, through the slab and into the open cavity below the slab. To avoid obstruction of the probe tube, ensure that it does not contact the subslab material. Using a tube cutter, cut the tubing to the desired length.

7.1.5 Attach a measured length (typically 3"-4") of ¼" OD stainless tubing to the female connector (SS-400-7-4) with the Swagelok® nut. Make sure that the tubing rests firmly in the fitting body and that the nut is finger tight. While holding the fitting body firmly, tighten the nut 1¼ turns.

7.1.6 Insert the ¼" hex socket plug into the female connector. If using a stainless steel socket plug, wrap one layer of Teflon® thread tape around the threads to prevent binding. If using a brass socket plug, no Teflon® tape is needed. Tighten the plug slightly. Do not over tighten. If excessive force is required to remove the plug during the sample set up phase, the probe may break loose from the anchoring cement.

Assembled subslab port ready for installation

7.1.7 Place the completed probe into the outer hole to check fit and to ensure that stainless steel tubing is not in contact with the subslab material. Make necessary adjustments to the hole or probe assembly.

7.1.8 In a disposable cup or other container, mix a small amount of the anchoring cement or grout. Add water sparingly to create a mixture that is fairly stiff and moldable. Place a spoonful or two of the cement/grout around the stainless steel tubing adjacent to the female connector nut. Mold the cement/grout into a mass around the connector nut and up around the main body of the probe assembly. Slide the Teflon washer onto the stainless steel tube so that it rests next to the cement/grout mixture. The washer will prevent any anchoring cement/grout from flowing into the inner hole during the final step of probe installation.

7.1.9 Carefully place the probe assembly into the drilled hole, applying light pressure to seat the assembly. While inserting the probe assembly, work the concrete/grout mixture to fill voids. Clean up cement/grout that discharged out of the hole during placement; avoid getting any of the concrete/grout into fittings or on fitting threads. Allow the cement/grout to cure according to manufacturer's instructions before sampling (**Figure 4**).

7.2 Sampling Set-Up

7.2.1 Wrap one layer of Teflon® thread tape onto the NPT end of the male connector, OR wrap one layer of Teflon® tape onto the threaded end of the hose barb adapter (3/16” barb x ¼” MIP).

7.2.2 Carefully remove the ¼” hex socket plug from the female connector. Refer to Section 7.3 if the probe breaks loose from the anchoring cement/grout during this step.

7.2.3 To ensure that the subslab port has not been blocked by the collapse of the inner hole below the end of the stainless steel tubing, a stainless steel rod, ⅛” diameter, may be passed through the female connector and the stainless steel tubing. The rod should pas freely to a depth greater than the length of the stainless steel tubing, indicating an open space or loosely packed soil below the end of the stainless steel tubing. Either condition should allow a soil gas sample to be collected. If the port appears blocked, the stainless steel rod may be used as a ramrod in an attempt to open the well. If the well cannot be opened, the probe should be reinstalled or a new probe installed in an alternate location.

7.2.4 Screw and tighten the Teflon® taped male connector into the female connector, OR screw and tighten the hose barb adapter (3/16” barb x ¼” MIP) into the female connector. Do not over tighten. This may cause the probe assembly to break loose from the anchoring cement/grout during this step or when the male connector/hose barb adapter is removed upon completion of the sampling event (**Figure 5**). Refer to Section 7.3 if the probe breaks loose from the anchoring compound during this step.

7.2.5 If a co-located subslab soil gas sample or split sample is desired, a stainless steel Swagelok® tee, may be used in place of the male connector (**Figure 6**).

7.2.6 Attach a length of ¼” Teflon® tubing to the sampling container (*e.g.*, SUMMA canister) or system (*e.g.*, lung box for Tedlar® bag) to be used for sample collection. Connect the other end of the Teflon® tubing to the male connector with a Swagelok® nut, or connect to the barbed hose adapter.

SUMMA canister connected to port and ready for sampling

7.2.7 After sample collection, remove the male connector or barbed hose adapter from the probe assembly and reinstall the ¼” hex socket plug. Do not over tighten the hex socket plug. If excessive force is required to remove the plug during the next sampling event, the probe may break loose from the anchoring compound. Refer to Section 7.3 if the probe breaks loose from the anchoring compound during this step.

7.3 Repairing a Loose Probe Assembly

7.3.1 If the probe assembly breaks loose from the anchoring compound while removing or installing the hex socket plug, the Swagelok® male connector, or the barbed hose adapter, lift the probe assembly slightly above the surface of the concrete slab.

7.3.2 Hold the female connector with the ¾“ open end wrench.

7.3.3 Complete the step being taken during which the probe broke loose, following the instructions contained in this SOP (*i.e.,* Do not over tighten the hex socket plug, the male connector, or the barbed hose adapter).

7.3.4 Push the probe assembly back down into place and reapply the anchoring cement/grout.

7.3.5 Modeling clay (verified to be VOC free) may be used as a temporary patch to achieve a seal around the probe assembly until the anchoring cement/grout can be reapplied.

8.0 Quality Assurance/Quality Control

An additional co-located soil gas port is installed at a frequency of 10% (1 in 10) or as specified in the site-specific Quality Assurance Project Plan (QAPP). The following general Quality Assurance (QA) procedures apply:

8.1 A rough sketch of the area is drawn where the ports are installed, with the major areas noted on the sketch.

8.2 A global positioning system (GPS) unit may be used to document coordinates outside of a structure as a reference point.

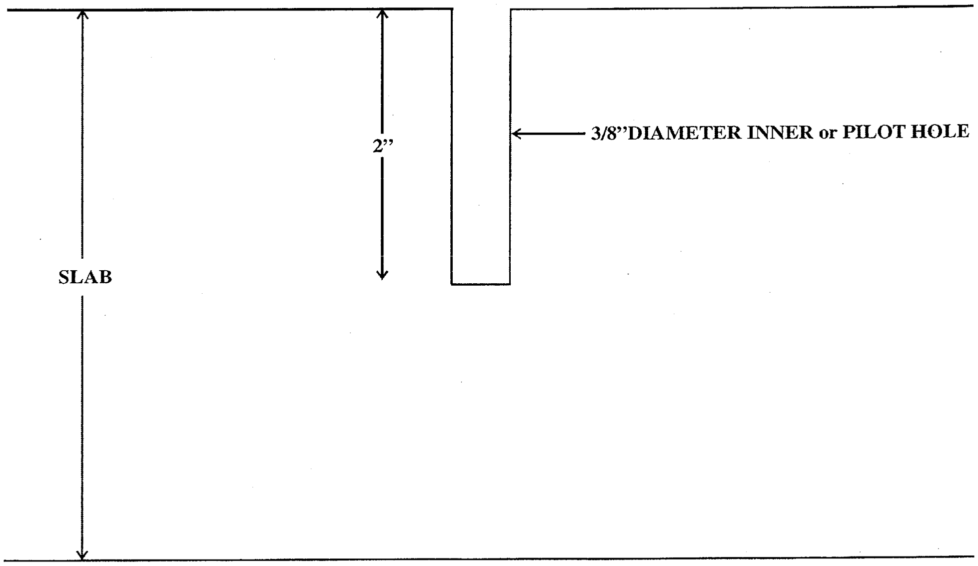
8.3 Equipment used for the installation of sampling ports should be cleaned by heating, inspected and tested prior to deployment.

9.0 Health & Safety

When working with potentially hazardous materials, follow site specific health and safety procedures. All site activities should be documented in the site-specific Health and Safety Plan (HASP).

FIGURE 1

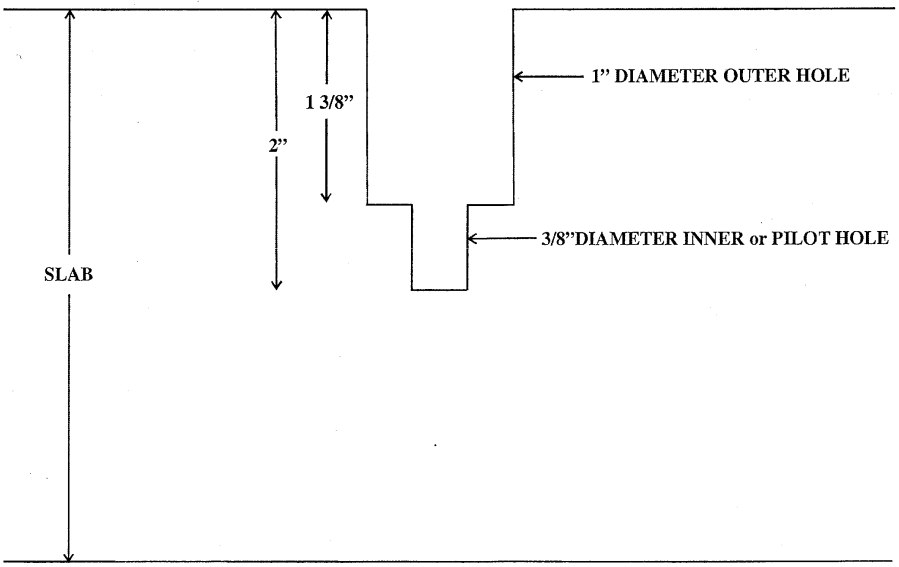
INNER or PILOT HOLE



CONSTRUCTION AND INSTALLATION OF PERMANENT SUB-SLAB SOIL GAS WELLS

FIGURE 2

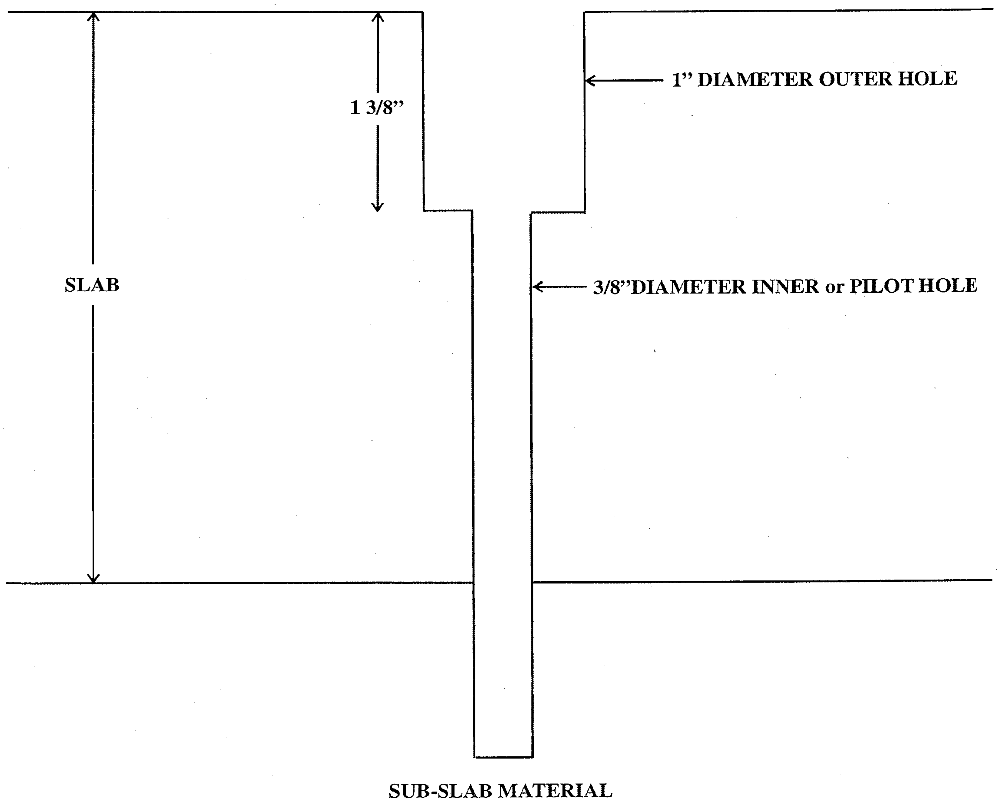
OUTER HOLE



CONSTRUCTION AND INSTALLATION OF PERMANENT SUB-SLAB SOIL GAS WELLS

FIGURE 3

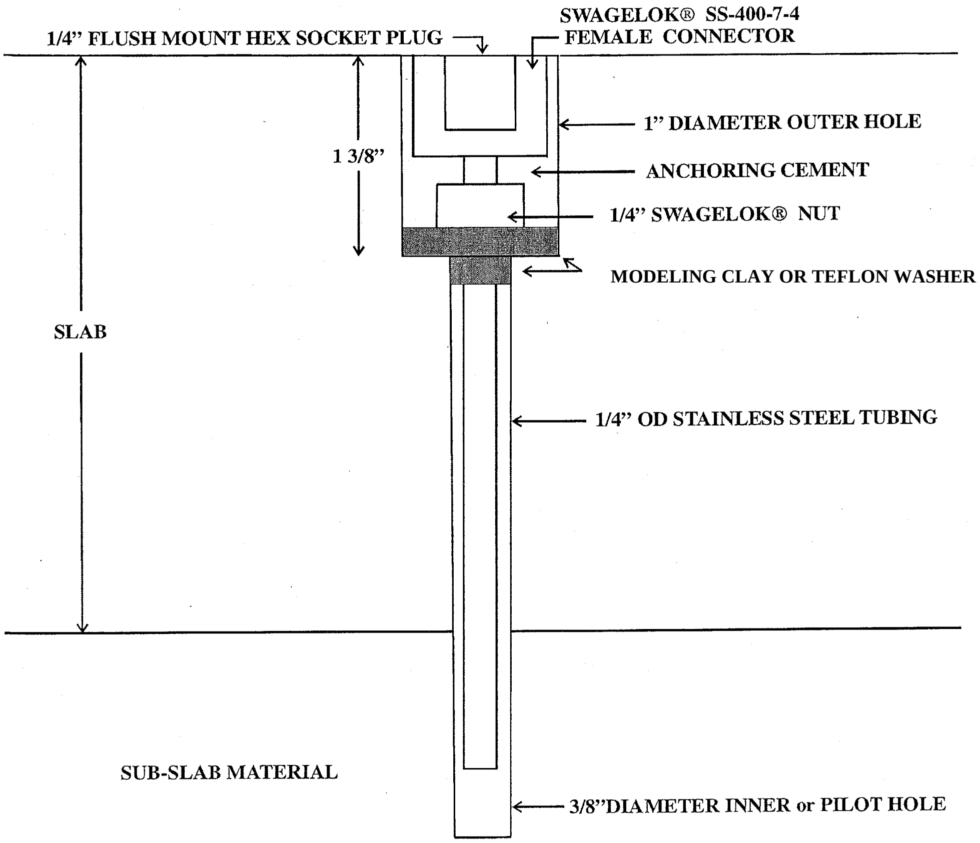
COMPLETED HOLE PRIOR to PROBE INSTALLATION



CONSTRUCTION AND INSTALLATION OF PERMANENT SUB-SLAB SOIL GAS WELLS

FIGURE 4

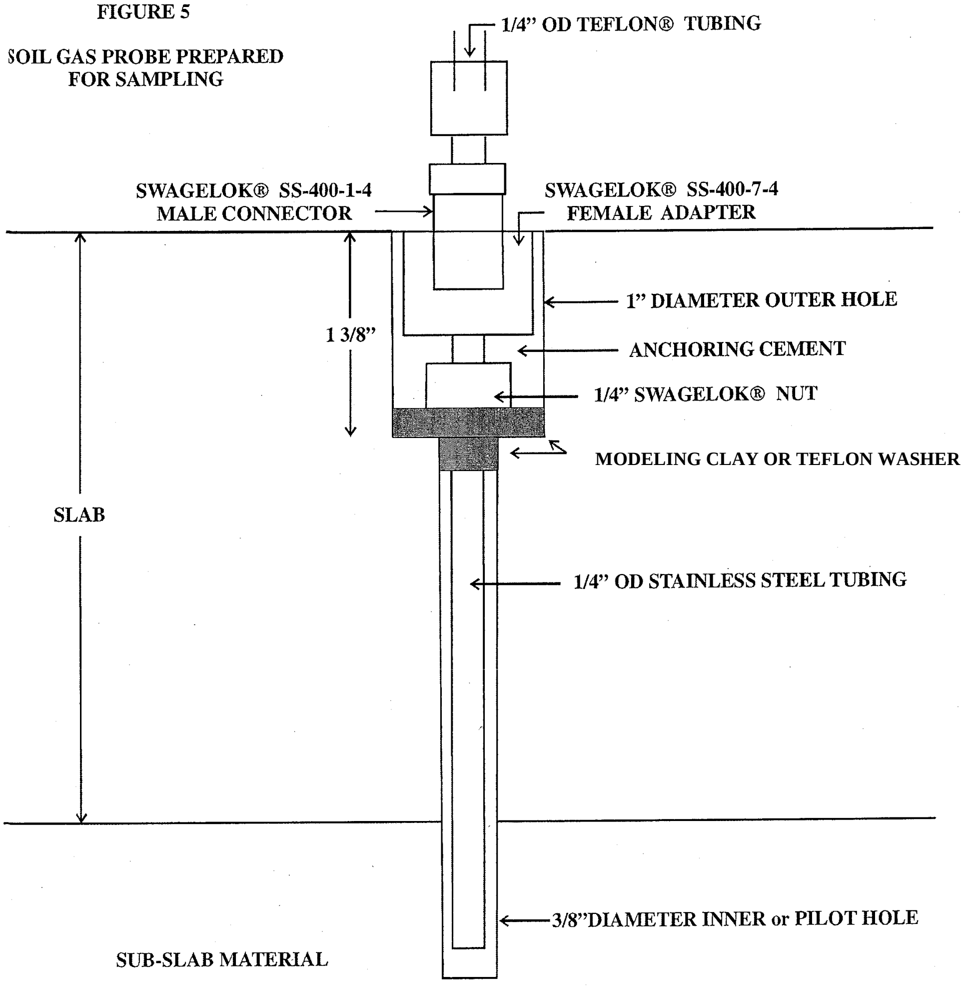
SOIL GAS PROBE INSTALLED



CONSTRUCTION AND INSTALLATION OF PERMANENT SUB-SLAB SOIL GAS WELLS

FIGURE 5

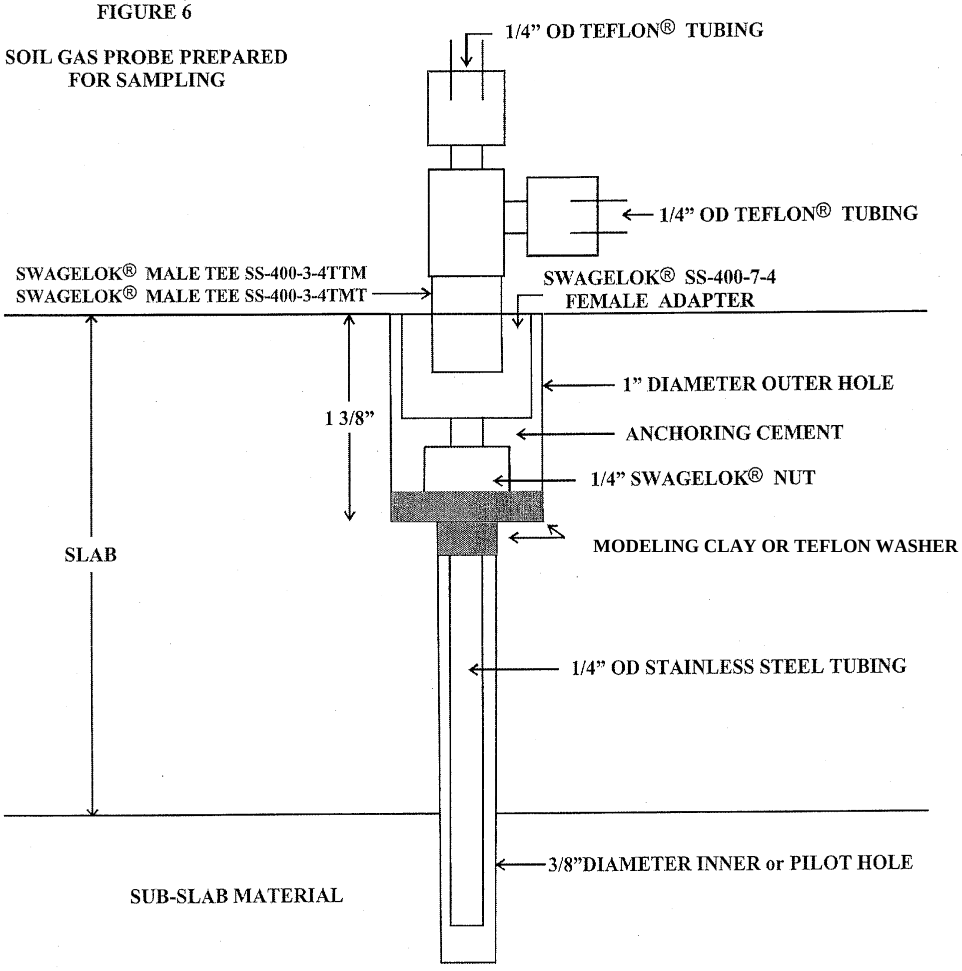
SOIL GAS PROBE PREPARED FOR SAMPLING



CONSTRUCTION AND INSTALLATION OF PERMANENT SUB-SLAB SOIL GAS WELLS

FIGURE 6

SOIL GAS PROBE PREPARED FOR SAMPLING



SOP 2.5.3 - Procedures for Collection of Indoor Air

1.0 Scope and Application

This standard operating procedure (SOP) describes the procedures used for the collection of ambient and indoor air vapor samples. Indoor air samples are collected from predetermined locations within buildings and structures and are typically analyzed for volatile organic compounds (VOCs) using U.S. Environmental Protection Agency Method TO-15. Ambient air samples are collected at the same time, and for the approximate same duration, as the indoor air sample(s).

2.0 Method Summary

This method uses an evacuated 6-liter SUMMA® passivated stainless-steel canister for sample collection. A flow regulator with vacuum gauge is attached to the canister in order to collect a volume of sample over a pre-determined time span. Location(s) for the placement of the canisters within the building(s) or structure(s) are also pre-determined in order to focus sampling efforts on potential receptors within the building(s)/structure(s). The outdoor, ambient sample must be collected at approximately the same time and for the same time interval as the indoor air samples (see section 8.0). Oral interviews and a written questionnaire for building inhabitants are required prior to the sampling event (this step is necessary to reduce and/or eliminate the impact of inhabitant activities on the analytical results – see Indoor Air Sampling Form). Once the flow regulator is attached to the canister, the valve on the regulator is opened. Notes are made regarding the project, building, location (address of building and placement of canisters), canister ID number, flow regulator ID number, sample start time, canister pressure (inches of Hg), and the samplers performing the sampling event (see Attachment 2 “Canister Sampling Data Sheet”).

Ambient air sample locations should be in an area that has unobstructed airflow, especially in the direction of any recognized sources of the materials being sampled. Locations should be avoided that will potentially have a negative effect on the sample collection activities. Additionally, avoid locations where reactive surfaces may cause chemical changes in the air sampled, directly above contaminated soil, or locations what may influence the ability to collect a representative sample (such as nearby hills, structures, bodies of water, etc.).

Intake probes for the ambient air sample(s) should be placed at a representative height, such as breathing zone height, or between 6 to 8 feet (3 to 15 meters) above the ground. Locations near the structures should extend at least 3 to 4 feet (1 to 2 meters) away from the structure. If located on a building, the sample equipment should be mounted on the windward side. Additional considerations for the collection of ambient air sample(s) are located in section 8.0.

Sample collection times may vary depending on the scope of the project. It is important to return to the sample location at least 30 to 60 minutes prior to the end of the sample collection time. Sampling stops when the flow regulator valve is turned off. Final notes are made regarding the sample stop time and final vacuum pressure.

3.0 Sample Preservation, Containers, Handling and Storage

3.1 SUMMA® Canister Sampling

After the indoor air/soil gas sample is collected, the canister valve is closed, an identification tag is attached to the canister and the canister is transported to a laboratory under chain of custody for analysis. Upon receipt at the laboratory, the data documented on the canister tag is recorded. Sample holding times are compound dependent, consult with the laboratory for holding times.

4.0 Interferences and Potential Problems

Sampling personnel should not handle hazardous substances (such as gasoline), permanent marking pens, wear/apply fragrances, or smoke cigarettes/cigars before and/or during the sampling event.

Care should be taken to ensure that the flow regulator is pre-calibrated to the proper sample collection time (confirm with laboratory). Correctly connecting the flow regulator to the sample canister is vital to eliminate the potential for leaks. Sample integrity is maintained if the sampling time is slightly shorter than the planned sampling time. In other words, if the SUMMA® canister is allowed to completely fill such that there is no pressure/vacuum left in the canister then it may be very difficult for the laboratory technician to extract a sample aliquot for analysis. Sample integrity can also be compromised if the sample event is extended to a point where the canister reaches atmospheric pressure.

Certain activities within the building(s)/structure(s) can interfere with the collection of a representative indoor air sample. For example, storage of paints, varnish, adhesives, gasoline, and/or oils may create false-positive results during sample collection. Smoking, certain hobbies, and/or equipment maintenance are examples of activities which may impact the ability to collect a representative sample. Conducting a pre-sampling on-site survey and completing a written questionnaire is important to address such potential inferences.

Ambient air sample location(s) should be pre-selected with the aforementioned site selection criteria taken into consideration.

5.0 Equipment/Apparatus

- Stainless steel SUMMA® canister(s) (request at least one additional canister as a backup, if possible and make sure that the canisters are labeled with the decontamination information);
- Appropriate flow regulator (properly calibrated for the specified sample collection duration *e.g.*, 30 minutes, 8 hours, 24 hours) with in-line particulate filters and vacuum gauges (request at least one additional gauge, if possible).
- Appropriately-sized open-end wrench, typically 9/16-inch (may want two wrenches so that you can tighten the fitting in two directions at the same time);
- Copy of building survey and resident questionnaire(s);
- PID;
- Sample collection log (Canister Sampling Data Sheet);
- Chain-of-custody (COC) form;
- Field notebook;
- Digital camera.

6.0 Reagents

- N/A

6.0 Reagents

- N/A

7.0 Procedures

7.1 Sample Location Determination

7.1.1 Indoor Air - conduct a building/structure survey **(Appendix F)** to determine potential target receptors and identify potential interferences to sample collection. A pre-sampling inhabitant/worker questionnaire should also be completed at this time. It is important to recognize and eliminate potential interferences to the sample collection process. This should be done at least 48 to 72 hours prior to sample collection.

Ambient Air – survey the exterior area outside the structure and/or equipment. Sample location should be on the windward side of the structure with the intake probe set to an appropriate, representative height and without the potential for interference and/or biased by vapor flux from contaminated soil surface(s).

Discretion to avoid potential equipment theft or vandalism should also be taken into consideration when determining sample location/placement.

7.1.2 Sample canisters should be placed at appropriate breathing-zone heights

7.1.3 Special consideration must be given to dirt basements and crawl spaces within the structures.

7.1.4 Indoor Air sampling should be conducted in the lowest indoor areas or areas that are likely to capture highest concentrations.

7.2 Sampling Set-Up

7.2.1 Document appropriate information on field log sheet (“Canister Sampling Data Sheet”).

7.2.2 Remove brass plug from the SUMMA® canister and connect the flow regulator with in-line particulate filter and vacuum gauge to the SUMMA® canister. Use the open-end 9/16” wrench to gently tighten the connection between the flow regulator and the canister. Do not over-tighten this connection. Do not open the valve on the SUMMA® canister (if one is present). Record both the SUMMA® canister number and the flow regulator number on the “Canister Sampling Data Sheet”. The canister number can be used for sample identification on the COC form (refer to Attachment 1 “Sampling Instructions for Canisters with Pneumatic Flow Controllers”)

7.2.3 Open the canister/regulator valve. Record the sample start time and the canister pressure.

7.2.4 Take a photograph of the canister and surrounding area.

7.3 Termination of Sample Collection

7.3.1 Arrive at the sample location approximately 10 to 15 minutes prior to the end of the sampling interval. An examination of the flow regulator should show a slight vacuum left on the gauge (preferably between 2 to 10 inches of Hg on the regulator flow dial). Document this final vacuum pressure and stop sample collection by closing the flow regulator valve.

SUMMA® canister with flow regulator attached and placed at appropriate breathing zone height - ready for sampling.

7.3.2 Complete the documentation by recording the stop time on the Canister Sampling Data Sheet as well as any additional field logs.

7.3.3 Remove the flow regulator from the SUMMA® canister using the 9/16 open-end wrench. Place the flow regulator into the proper shipping container provided by the lab. Re-install the brass plug on the canister fitting, and tighten with the open-ended wrench.

7.3.4 Package the canister and the flow regulator into the shipping container provided by the lab. Note: the SUMMA® canister does not require preservation.

7.3.5 Complete the appropriate forms and sample labels as directed by the laboratory. Use the sample start time when completing the laboratory COC and double check canister identification numbers for accuracy.

7.3.6 Ship the canisters to the laboratory for analysis.

8.0 Quality Assurance/Quality Control

Most ambient and indoor air sample analysis will be performed using U.S. EPA TO-15 methodology. Canisters used for sample collection are typically 6-liters and thoroughly cleaned by the laboratory prior to use. Flow regulators will also be thoroughly cleaned by the laboratory. An additional co-located indoor air sample is recommended at a frequency of 10% (1 in 10) or as specified in the site-specific Quality Assurance Project Plan (QAPP). The outdoor, ambient sample must be collected at approximately the same time and for the same time interval as the indoor air samples. The following general Quality Assurance (QA) procedures apply:

8.1 A rough sketch of the area is drawn where the samples are collected, with the major areas noted on the sketch.

8.2 A global positioning system (GPS) unit may be used to document coordinates outside of a structure as a reference point.

8.3 Proper completion of associated data sheets, log books and COC is vital to the overall success of the sampling effort.

8.4 Photographs showing proper function of the flow regulators at the start and end of the sample time period are recommended. Additional photos of the surrounding area where the samplers are placed are also recommended.

9.0 Health & Safety

When working with potentially hazardous materials, follow site specific health and safety procedures. All site activities should be documented in the site-specific Health and Safety Plan (HASP).

Attachment 1
for DERR SOP 2.5.3

Sampling Instructions for Canisters With Pneumatic Flow Controllers

1. Inspect your canister shipment once received from the lab and/or equipment provider. Compare contents with the packing slip and notify the lab/supplier of any discrepancy or damage.

2. Familiarize yourself with the diagram located on this page and the equipment you received for sampling. The flow controller/regulator will be set for the appropriate sampling rate in the lab and should not require adjustment.

3. Remove the brass caps from the flow controller/regulator and canister. Connect the flow controller to the canister by inserting the “canister connection” into the “canister inlet” and hand tighten the Swagelok® nut being careful not to cross the threads. Using two open end wrenches (1/2” & 9/16”) tighten the nut no more than 1/8 turn past finger tight. DO NOT use adjustable wrenches or pliers.

4. The fittings are swage lock compression fittings. Do not use Teflon tape or other sealants, they are not necessary. DO NOT over-tighten any connection. Over-tightening may potentially cause leaks.

5. The canister and controller are now ready for sampling. If you intend to sample a source location, you will need to attach a sampling line. This should be ¼” outer diameter tubing (virgin Teflon® recommended) or cleaned stainless steel.

6. If possible, coordinate with the lab to supply a Swagelok® nut and set of nylon ferrules for connecting line. Slide the nut, the back ferrule, then the front ferrule onto the tubing. Insert the tubing into the sample inlet and slide the ferrules into the fitting. Secure the nut being careful not to cross the threads. Note: when using nylon ferrules, a snug finger-tight should be sufficient for a leak-free connection.

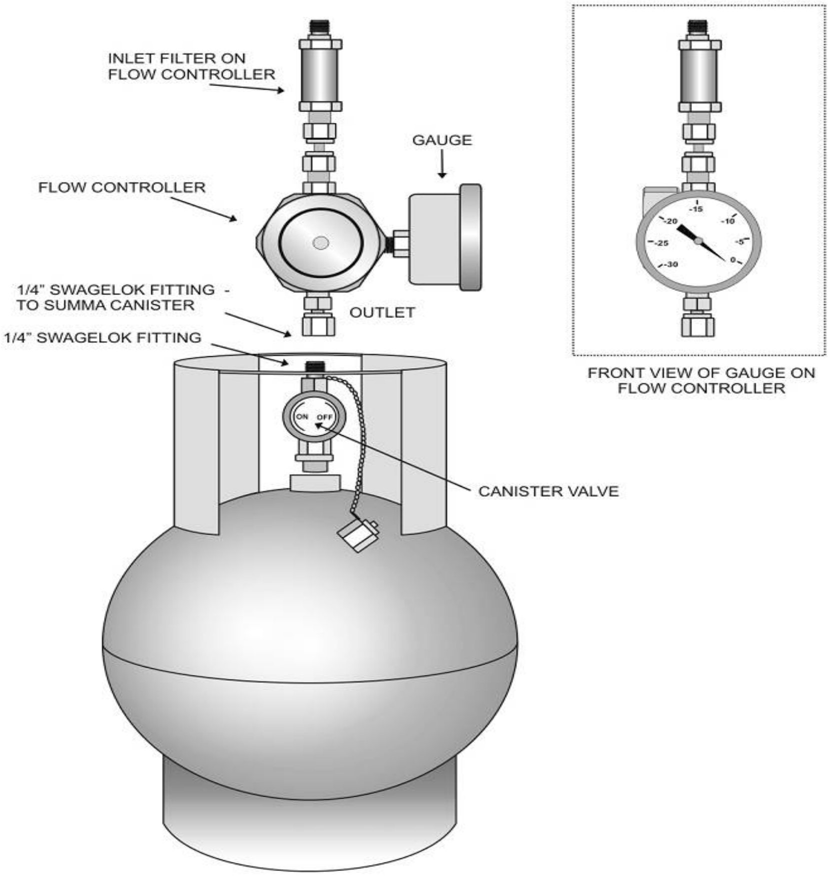
7. To begin sampling, open the canister valve by turning counter-clockwise. One full turn is sufficient. Observe and note the vacuum gauge reading on your field log form. Take photos of the sample location and close-up of the properly functioning sampling equipment.

8. Observe the decline in the vacuum to gauge the sampling rate. This is especially significant for grab samples. In a one hour sample duration the gauge should drop in vacuum at a rate of 0.5” Hg per minute (*i.e.* 30”/60 min). Note that is condition is a rough estimate and may not necessarily be reflective of your particular equipment. Sampling rate(s) are established before sampling and are set by the laboratory supplying the equipment. Contact the lab immediately for assistance if your equipment demonstrates any malfunctioning. As a consequence for the potential for a malfunction, it is advisable to request one or two back-up/additional canisters and flow regulators when coordinating with the lab.

9. After sampling is complete, note the time and final vacuum gauge reading on your field log sheet. Close the canister valve by turning clockwise until finger tight. DO NOT over-tighten as this will damage the valve. .

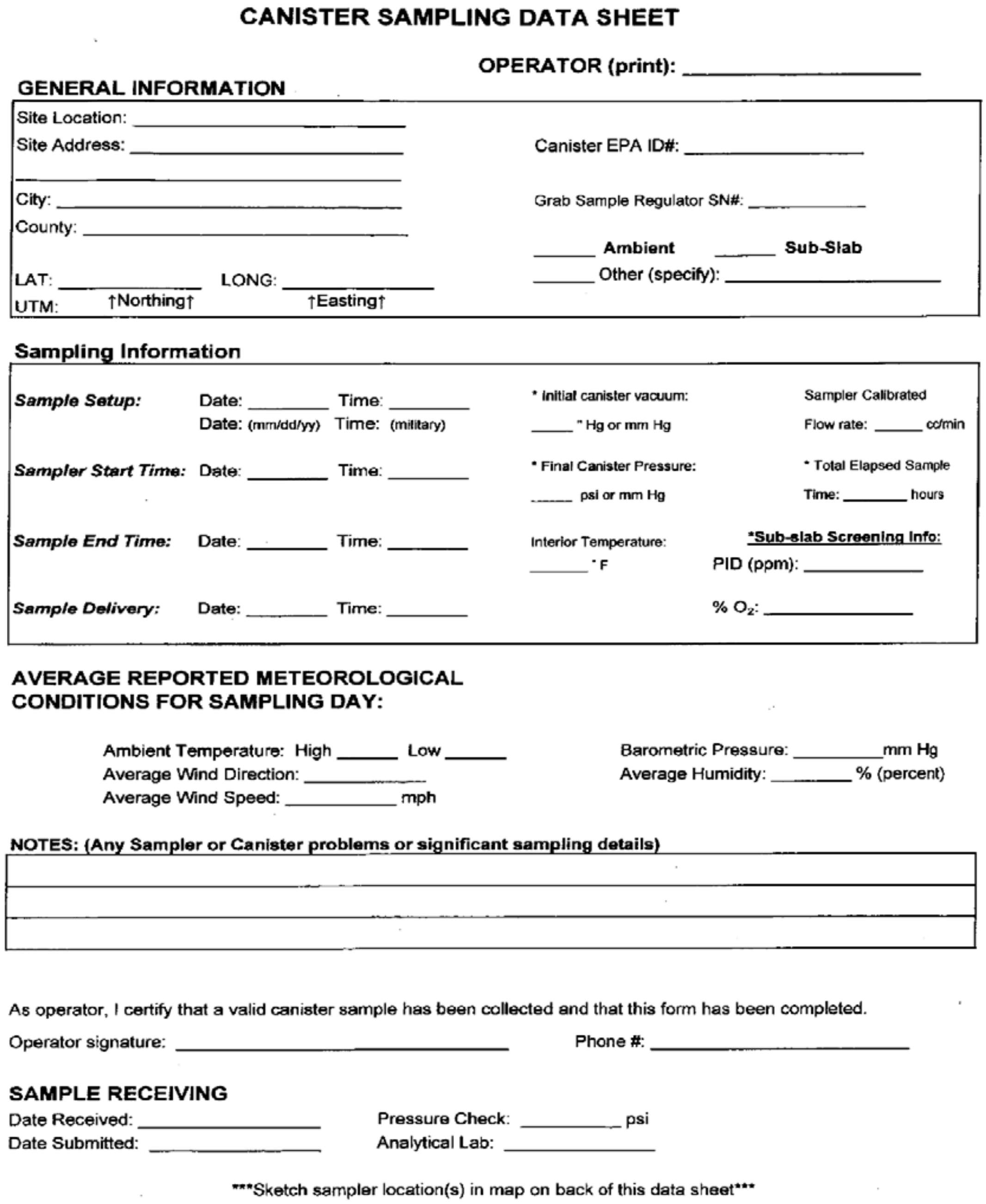
10. Disassemble the components in reverse order of the above assembly instructions. Return all components to the original shipping containers and package them as received. Verify that all parts are packed for return by referencing the packing slip.

11. Review and complete the field sampling log form. Complete the appropriate Chain-of-Custody record (as supplied to you by the lab) and return the sample to the laboratory for analysis.



Schematic of Summa Canister

Attachment 2
For DERR SOP 2.5.3



CANISTER SAMPLING DATA SHEET

OPERATOR (print): ____________________

GENERAL INFORMATION

Site Location: ____________________

Site Address: ____________________

____

City: ____________________

County: ____________________

LAT: ____________ LONG: ____________

UTM: ↑Northing↑ ↑Easting↑

Canister EPA ID#: ________________

Grab Sample Regulator SN#: ____________

______ **Ambient** ______ **Sub-Slab**

______ Other (specify): ____________________

Sampling Information

Sample Setup: Date: ________ Time: ________

Date: (mm/dd/yy) Time: (military)

Sampler Start Time: Date: ________ Time: ________

Sample End Time: Date: ________ Time: ________

Sample Delivery: Date: ________ Time: ________

* Initial canister vacuum: _____ " Hg or mm Hg

* Final Canister Pressure: ______ psi or mm Hg

Interior Temperature: _______ ° F

Sampler Calibrated Flow rate: ______ cc/min

* Total Elapsed Sample Time: ________ hours

***Sub-slab Screening Info:**

PID (ppm): ____________

% O_2: ______________

AVERAGE REPORTED METEOROLOGICAL CONDITIONS FOR SAMPLING DAY:

Ambient Temperature: High ______ Low ______

Average Wind Direction: ____________

Average Wind Speed: ___________ mph

Barometric Pressure: _________mm Hg

Average Humidity: ________ % (percent)

NOTES: (Any Sampler or Canister problems or significant sampling details)

As operator, I certify that a valid canister sample has been collected and that this form has been completed.

Operator signature: ______________________________ Phone #: __________________________

SAMPLE RECEIVING

Date Received: __________________ Pressure Check: __________ psi

Date Submitted: _________________ Analytical Lab: _______________

Sketch sampler location(s) in map on back of this data sheet

APPENDIX E
Ohio Environmental Protection Agency
Division of Emergency and Remedial Response

Soil Gas Probe Field Data Report Form

Soil Gas Probe Field Data Report								
Site:								
Date:								
Instrument(s) used:								
Tracer used:								
Weather:								
Technician:								
Soil Gas Probe Number	Probe Depth (ft.)	Probe Volume (l)	Purge Rate (lpm)	Volume Purged (l)	Tracer Field Analysis (ppmv or ppbv)	%CO_2	%O_2	Other indicators

ND=Non Detect
NM=Not measured

APPENDIX F
Ohio Environmental Protection Agency
Division of Emergency and Remedial Response

Indoor Air/Sub Slab Sampling Form

OHIO EPA DERR Site #__________________

Site Name____

Address____

____

Occupant Information

Name____

Address____

____

Telephone No (H) (____)____

(W) (____)____

Number and Age of Occupant(s) ____

Does anyone smoke inside the building?_____________________________________

Building Characteristics

Type of building: (circle) Residential / Industrial / School / Commercial / Multi-use / Other?

If residential, what type (circle) Single family / Condo / Multi-family / Other? __________

If commercial, what is the business?____

How many floors does the building have? ____________________________________

Does the building have a (circle) Basement / Crawl space / Slab-on-grade / Other?____

Is the basement used as a living / work space area?_____________________________

What type of foundation does the building have (circle) Field stone / Poured concrete / Concrete block / Other?_____________

Describe the heating system and type of fuel used._____________________________

Is there an attached garage? ____

Spill / Contaminant Source Information

Type of petroleum / VOC release?____

When did the release occur? ____

What areas of the building have been impacted by the release?___________________

Are there any odors? ___________ If so describe the odors:___________________

Where are the release odors found? _______________________________________

Sampling Information

Sampling Date ________________________

Sampler Type Sorbent Canister Tedlar® Other__________ (Please circle one)

Analysis Method ___________________

Consulting Firm ____

Contact Person ____

Telephone No (____) ___________________

Laboratory Name ________________________

Telephone No (____) ___________________

Table 1: Sorbent Tube Sample Information

Sample ID#	Floor	Room	Tube ID #	Pump ID #	Volume (liters)	Duration (minutes)	Comments

Table 2: Canister Sample Information

Sample ID #	Floor	Room	Canister ID #	Initial On-site Pressure*	Pressure* On-site Following Sample Collection	Pressure Received at the Laboratory

* Indicate pressure in units of inches of mercury.

Please provide a sketch of area and location of sampler unit(s), include all pertinent structures.

Pre-Sampling Inspection and Product Inventory

List products or items which may be considered potential sources of VOCs such as paint cans, gasoline cans, gasoline powered equipment, cleaning solvents, furniture polish, moth balls, fuel tank, woodstove, fireplace, etc.

Date and time of pre-sampling inspection ____________________________________

Table 3: Pre-sampling Inspection Product Inventory

Potential VOC Source	Present (Y / N)	Location	Field screening Results (ppm)	Product Condition
Paints or paint thinners				
Gas powered equipment				
Gasoline storage cans				
Potential VOC source	Present (Y / N)	Location	Field screening Results (ppm)	Product Condition
Furniture polish				
Moth balls				
Fuel tank				
Wood stove				
Fireplace				
Perfumes/colognes				
Other:				
Other:				
Other:				

Table 4: Potential vapor migration entry point information

Potential Vapor entry points	Present (Y/N)	Field screening results (ppm)	Comments
Foundation penetrations in floor or walls			
Cracks in foundation floor or walls			
Sump			
Floor drain			
Other			
Other			

Was the building aired out prior to sample collection? ___________________________

How long was the airing out process? _______________________________________

Were vapor control methods in effect while the samples were being collected?

Windows open? Yes / No Ventilation fans? Yes / No
Vapor barriers? Yes / No
Vapor phase carbon treatment system? Yes / No
Other site control measures_________________________________

Weather Conditions during Sampling

Outside temperature (^{o}F) __________ Inside temperature (^{o}F)_____________

Prevailing wind speed and direction_________

Describe the general weather conditions (*e.g.* sunny, cloudy, rain) ________________

Significant precipitation (0.1 inches or more) within 12 hours of the sampling event? ___

General Comments

Is there any information you feel is important related to this site and the samples collected which would facilitate an accurate interpretation of the indoor air quality?

APPENDIX G
Comparison of Tubing Type to Vapor Absorption

Researcher / Tubing	Ouellette (2004)	Hayes, et. al. (2006)	Nicholson, et. al. (2007)	Hartman (2008)
LDPE	Sorption of hexane and pentane	Sorption of numerous compounds	N/A*	Sorption of TCE and PCE
Tygon	Sorption of hexane, butane, and pentane	N/A	N/A	Acceptable for TCE
Nylaflow	Acceptable	Sorption of naphthalene and 1,2,4-TCB	Sorption of aromatic hydrocarbons	Acceptable for TCE
Teflon	Acceptable	Acceptable	N/A	Acceptable for TCE
Vinyl	Sorption of hexane and pentane	N/A	N/A	N/A
PEEK	N/A	Acceptable	N/A	Acceptable for TCE
Copper	N/A	N/A	N/A	Sorption of TCE and PCE

*N/A – not analyzed