United States Environmental Protection Agency

Region 5

Superfund and Emergency Management Division

Vapor Intrusion Handbook

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LIST OF ACRONYMS

µg/L	Micrograms per liter
µg/m^3	Micrograms per cubic meter
%	Percent
°C	Degrees Celsius
°F	Degrees Fahrenheit
ACM	Asbestos-containing material
ADT	Active depressurization technology
AER	Air exchange rate
AF	Attenuation factor
ANSI	American National Standards Institute
AOC	Administrative Order on Consent
AOE	Area of Observed Exposure
APU	Air purification unit
ARAR	Applicable or relevant and appropriate requirement
ASAP	As soon as possible
ASC	Area of Subsurface Contamination
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
ASTM	ASTM International
ATSDR	Agency for Toxic Substances and Disease Registry
BPM	Brownfields Project Manager
bgs	Below ground surface
CAG	Community Advisory Group
CalEPA	California Environmental Protection Agency
CD	Consent Decree
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
CIC	Community Involvement Coordinator
CIP	Community Involvement Plan
CLU-IN	Contaminated Site Clean-Up Information
COC	Chemical of concern
COR	Contract Officer Representative
CR	Carcinogenic risk
CSM	Conceptual site model
DCE	Dichloroethene
DMP	Data management plan
DQO	Data quality objective
DOD	U.S. Department of Defense
EDD	Electronic data deliverable
EMEG	Environmental Media Evaluation Guide
EPA	U.S. Environmental Protection Agency
ERT	Emergency Response Team
ESTCP	Environmental Security Technology Certification Program
FID	Flame ionization detector

FS	Feasibility Study
GC/MS	Gas chromatograph/mass spectrometer
GIS	Geographic information system
HDPE	High-density polyethylene
HEPA	High-efficiency particulate air
Hg	Mercury
HI	Hazard Index
HQ	Hazard Quotient
HRS	Hazard Ranking System
HRV	Heat recovery ventilation
HVAC	Heating, ventilation, and air conditioning
IA	Indoor air
IC	Institutional control
ID	Identification
IDEM	Indiana Department of Environmental Management
IRIS	Integrated Risk Information System
ITRC	Interstate Technology and Regulatory Council
LEL	Lower explosive limit
MIP	Membrane interface probe
MMOA	Mutagenic mode of action
NAPL	Non-aqueous-phase liquid
NAVFAC	Naval Facilities Engineering Command
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
O&M	Operation and maintenance
OEPA	Ohio Environmental Protection Agency
OLEM	Office of Land and Emergency Management
OSC	On-Scene Coordinator
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
PCE	Tetrachloroethene
PDT	Passive Depressurization Technology
PFE	Pressure field extension
PID	Photoionization detector
PII	Personally identifiable information
ppb	Parts per billion
ppbv	Parts per billion by volume
PRP	Potentially responsible party
PRSC	Post-Removal Site Control
PVC	Polyvinyl chloride

QA	Quality assurance
QAPP	Quality Assurance Project Plan
QC	Quality control
RCRA	Resource Conservation and Recovery Act
RfC	Reference concentration
RI	Remedial Investigation
RML	Removal management level
ROD	Record of Decision
RPM	Remedial Project Manager
SA	Site Assessment
SAM	Site Assessment Manager
SAP	Sampling and analysis plan
SEMD	Superfund and Emergency Management Division
SEMS	Superfund Enterprise Management System
SERAS	Scientific, Engineering, Response & Analytical Services Contract
SIM	Selective Ion Monitoring
SMDS	Sub-membrane depressurization system
SOP	Standard operating procedure
SORN	System of Records Notice
SPP	Superfund Profile Page
sq ft	Square feet
SS	Sub-slab
SSDS	Sub-slab depressurization system
SsI	Subsurface intrusion
START	Superfund Technical Assessment and Response Team
TAGA	Trace Atmospheric Gas Analyzer
TCA	Trichloroethane
TCE	Trichloroethene
TO	Toxic Organics
UAO	Unilateral Administrative Order
UST	Underground storage tank
VI	Vapor intrusion
VISL	Vapor intrusion screening level
VOC	Volatile organic compound
WC	Water column

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1.0 INTRODUCTION

The United States Environmental Protection Agency (EPA) Region 5 Vapor Intrusion (VI) Policy Workgroup prepared this document for assessing and mitigating VI sites. EPA typically addresses VI sites that include homes and apartment buildings. This document updates and replaces the Region 5 Vapor Intrusion Guidebook originally published in October 2010 (EPA 2010).

The VI Policy Workgroup prepared this handbook for the Superfund and Emergency Management Division (SEMD), particularly On-Scene Coordinators (OSC) and Remedial Project Managers (RPM). Other programs, agencies, and individuals, such as Brownfields Project Managers (BPM) and state environmental programs, may find this document useful.

The body of knowledge regarding vapor intrusion has grown immensely since publication of the original Region 5 guidebook. This document provides technical updates, identifies lessons learned from Region 5 sites, and reflects changes in regional VI policies. However, this document is not intended to provide a comprehensive examination of VI. Instead, the authors intend for it to be a road map for project managers.

This document outlines EPA's roles, responsibilities, and authorities under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to investigate and mitigate VI. CERCLA 101(14) excludes petroleum, including crude oil or any fraction thereof which is not otherwise specifically listed or designated as a hazardous substance. As such, this document focuses on non-petroleum VI. However, the concepts discussed in this document may be useful for project managers of petroleum VI sites.

The Region 5 VI Handbook is organized into the following sections:

Section 1.0 introduces the document.

Section 2.0 overviews VI, including conceptual site models (CSM), statutory authorities, and the multiple lines of evidence approach.

Section 3.0 discusses site identification and cross-program coordination, including an approach to determine how and when sites should be transferred among Region 5 programs. This section focuses on ensuring consistency between the Removal and Remedial Programs. The section also provides limited guidance on scoring sites for the National Priorities List (NPL).

Section 4.0 discusses community engagement, including methods to obtain access and available tools and resources for meaningful community involvement.

Section 5.0 provides information on developing CSMs, sampling strategies, and data quality objectives (DQO).

Section 6.0 discusses sampling methodology and procedures for various media, including groundwater, exterior soil gas (outside of a building footprint), sub-slab soil gas (beneath a building footprint), indoor air, and ambient air.

Section 7.0 conveys information on communicating sampling results to property owners and tenants. It also addresses privacy concerns and data management.

Section 8.0 discusses decision making at VI sites, including types of actions taken at sites and factors to consider when choosing among mitigation options. This section also presents a simplified decision matrix developed by the Region 5 VI Workgroup.

Section 9.0 explores mitigation options and discusses policy issues that may influence mitigation.

Section 10.0 addresses post-mitigation issues, including proficiency sampling, operation and maintenance (O&M) manuals, annual inspections, and use of institutional controls (IC).

Section 11.0 reviews coordination with state programs.

Section 12.0 lists sources referenced during preparation of this document.

2.0 KEY CONCEPTS OF VI

This section overviews VI, including a definition of VI, a CSM for VI, using multiple lines of evidence to document the occurrence of VI, and EPA's authorities under CERCLA to investigate and mitigate VI.

2.1 OVERVIEW

VI is the migration of hazardous vapors from a subsurface source into overlying buildings. Vapors can migrate through subsurface soils, groundwater, and utility corridors into the indoor air of buildings via cracks in basements and foundations, as well as through conduits and other openings. VI migration occurs in ways similar to that of radon gas seeping into homes. VI is a potential human exposure pathway and may pose an unacceptable risk to human health due to exposure to hazardous vapors.

Figure 2-1 below shows a simplified CSM of intrusion of vapors into a home from contaminated groundwater (Agency for Toxic Substances and Disease Registry [ATSDR] 2017). The CSM shows dissolved contamination from a groundwater plume entering the home through cracks in the foundation, utility lines, and the crawl space.

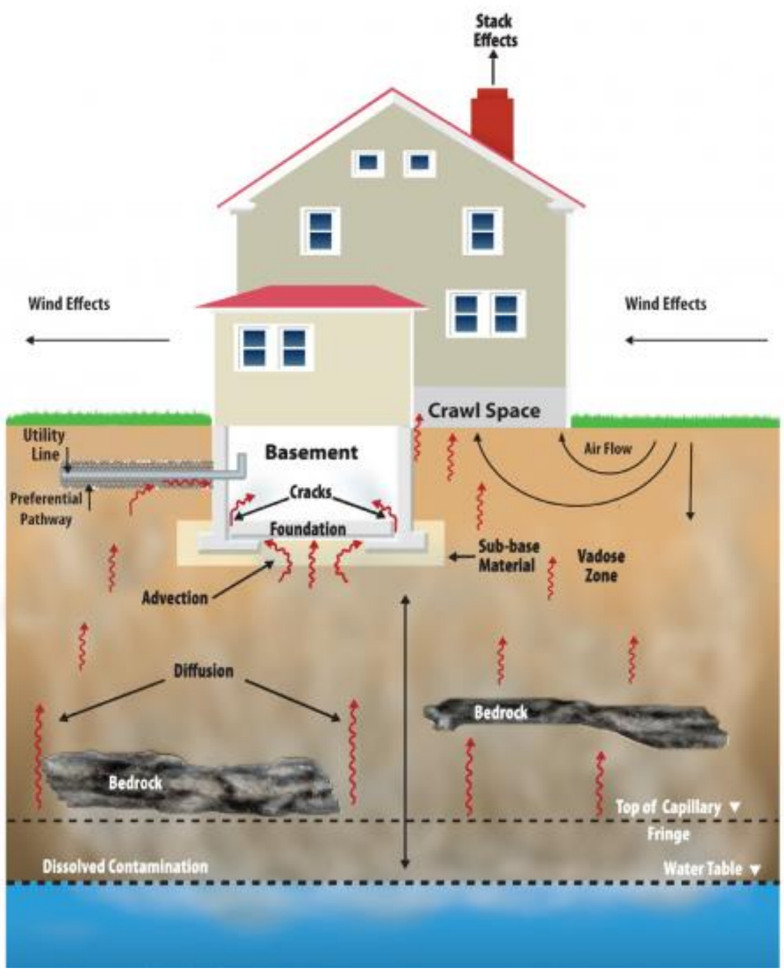


Figure 2-1. Vapor Intrusion into a Home (ATSDR 2017)

Typically, the VI pathway is considered complete if the following conditions are met:

- A subsurface source of vapor-forming chemicals is present within 100 feet vertically or horizontally of occupied structures.
- Shallow soil gas or utility conduit samples within 100 feet of structures contain the same compounds and/or breakdown products detected in contaminated soil or groundwater.
- Crawl space or sub-slab samples from underneath an occupied structure contain the same chemicals and/or breakdown products detected in soil gas samples.
- One or more vapor-forming chemicals identified in sub-slab/crawl space samples are present in indoor air at concentrations exceeding VI screening levels (VISL).

If one or more of the above conditions is absent, the VI pathway may be "incomplete." Region 5 recommends supporting an incomplete VI pathway determination with multiple rounds of sampling in different seasons to demonstrate that the pathway does not change from incomplete to complete.

A completed VI pathway can pose safety and/or health risks to residents, workers, and other building occupants. Building occupants inhaling chemical vapors from VI may experience acute and/or chronic health effects, thereby posing unacceptable risk. Under extreme circumstances, vapors may accumulate in occupied buildings to levels that may pose explosion hazards.

Vapor-forming chemicals generally meet a threshold for volatility and may also exhibit hazardous characteristics. High partial pressures and Henry's Law constants generally indicate high volatility, with general acceptance that vapor-forming chemicals have Henry's Law constants exceeding 10^{-5} atmosphere-cubic-meters per mole. VI chemicals of concern (COC) can exhibit flammability (e.g., methane) or acute toxicity (e.g., hydrogen sulfide).

Non-petroleum vapor-forming chemicals may include:

- Volatile organic compounds (VOC), such as trichloroethene (TCE) and benzene
- Semivolatile organic compounds, such as naphthalene
- Polychlorinated biphenyls
- Pesticides
- Elemental mercury
- Methane
- Hydrogen sulfide

VI COCs include breakdown products of other vapor-forming chemicals. The tetrachloroethene (PCE) degradation pathway is one that has been well-documented. PCE undergoes reductive dechlorination to TCE. TCE in turn breaks down to dichloroethene (DCE), either *cis*-1,2-DCE or *trans*-1,2-DCE, both of which further dechlorinate to vinyl chloride. Any VI investigation of PCE or TCE must include assessment of the degradation products.

Typical sources of vapor-forming chemicals may include dry cleaners, industrial facilities, landfills, buried waste, automotive shops, and other sources. Subsurface contamination from these sources can include contaminated soil, non-aqueous-phase liquids (NAPL), dissolved-phase contaminants, and contaminated soil gas—any of which can cause VI.

VI is a potential concern at any building, existing or planned, near soil or groundwater contaminated with toxic chemicals that can volatilize (Interstate Technology and Regulatory Council [ITRC] 2007). Relatively low chemical concentrations in soil or groundwater may pose a VI risk. According to EPA's VISL calculator, TCE contamination as low as 5.2 micrograms per liter (µg/L) in shallow groundwater can present a VI risk.

The VI pathway can present challenges different from those of other exposure pathways. Many variables may affect the migration of hazardous vapors and subsequent investigations, including current or potential site land use, contaminant concentrations, soil type and degree of heterogeneity, building construction and condition, depth of contamination, and seasonal variations.

Most other exposure pathways involve contamination in the outdoor environment. Cleanups involving other pathways typically are not invasive to personal lives of nearby residents and workers. Furthermore, simple engineering controls often can prevent adverse exposure of nearby populations to contaminated media. Addressing VI, on the other hand, may require collection of environmental samples inside or immediately outside of occupied buildings. Investigating the VI pathway can be intrusive and disruptive to the general public. In addition, products present inside of buildings can release COCs and may therefore complicate the assessment of VI sampling results.

2.2 CONCEPTUAL SITE MODEL

Once COCs are introduced into the subsurface, a complex series of fate and transport mechanisms act upon them, potentially moving them away from the source area.

VOCs may be transported beneath buildings as a NAPL, dissolved in groundwater, present as a vapor in soil gas, or present as vapors in utility corridors. Vapors typically move from areas of high concentration to areas of low concentration and from areas of high pressure to areas of low pressure.

Volatile contaminants present near or beneath buildings migrate upward as vapors through soil gas and may accumulate beneath buildings, asphalt, concrete slabs, or basements. The vapors migrate through cracks or openings in walls or foundations of buildings. Vapors can also migrate laterally along a preferential pathway, such as a utility corridor, beneath concrete or asphalt, or within other confined passageways.

Many factors can affect vapor transport, including source concentration, source depth, distance from source, depth to groundwater, soil type, seasonal fluctuations, etc. For more information on CSMs for VI, refer to Conceptual Model Scenarios for the VI Pathway (EPA 2012a).

Figure 2-2 below is a CSM illustrating a release from a primary source (i.e., aboveground storage tank) into soil. NAPL migrates downward through the vadose zone and into groundwater or the saturated zone. NAPL and dissolved-phase product migrate downgradient with groundwater flow. Nearby properties are affected by migration of contamination through a preferential pathway (e.g., the elevator sump), soil gas from the primary source or contaminants diffused from a groundwater plume.

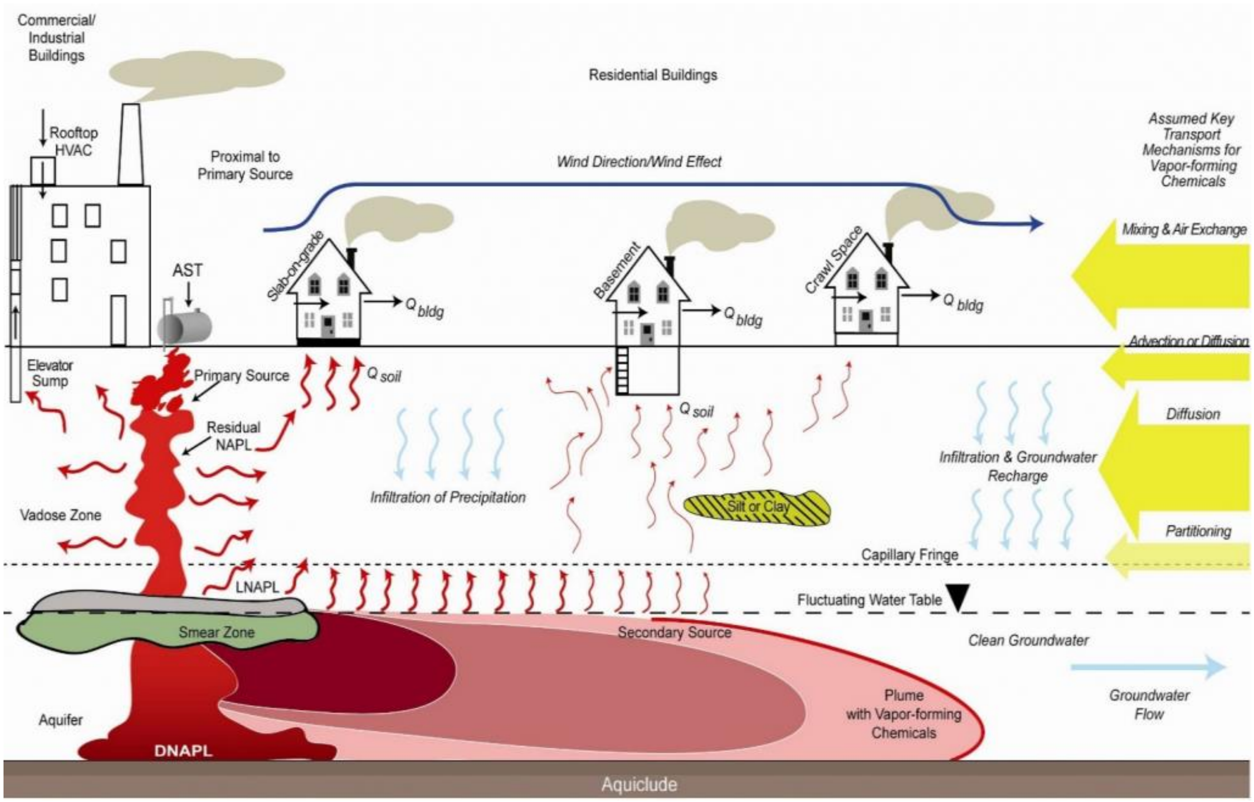


Figure 2-2. Conceptual Site Model of Vapor Intrusion from Contaminated Groundwater (EPA 2015a)

2.3 MULTIPLE LINES OF EVIDENCE APPROACH

Investigation of no single medium (groundwater, soil, sub-slab soil gas, or indoor air) is sufficient to determine completeness of the VI pathway and potential for risks from VI. Many variables can affect transport of vapors from the subsurface into indoor air. As such, Region 5 recommends gathering and evaluating lines of evidence from various media to support a need for action. These lines of evidence may include, but are not limited to:

- Groundwater data, including vertical and spatial profiling as appropriate;
- Soil gas data, including vertical and spatial profiling if warranted;
- Sub-slab soil gas or crawl-space air data;
- Indoor air data;
- Sewer gas data;
- Concurrent ambient air data;
- Geology; and
- Tracer data.

By following the multiple lines of evidence approach, OSCs and RPMs can determine if the VI exposure pathway is complete and if elevated contaminant concentrations in indoor air are caused by subsurface vapors, an indoor source (such as a consumer product), or an outdoor source. Generally, site conditions determine the lines of evidence that OSCs and RPM should gather to provide sufficient information for decision-making. For example, when groundwater and soil gas concentrations are low and sub-slab results are non-detect, OSCs or RPMs could determine that the VI pathway is incomplete based on relatively few lines of evidence. Coordination with a risk assessor and hydrogeologist can generally be helpful in evaluating multiple lines of evidence.

2.4 STATUTORY AUTHORITIES

Sections 104 and 106 of CERCLA authorize EPA to take response action(s) to address a release or threatened release of hazardous substances that "may present" a human health risk. This includes the authority to assess and mitigate VI at sites with subsurface contamination by vapor-forming chemicals, except vapors caused by petroleum products.

EPA can implement vapor intrusion investigation and mitigation through enforcement or fund-lead actions. EPA's stated preference is that potentially responsible parties (PRP) perform removal or remedial actions when appropriate. PRPs can agree to perform removal or remedial actions through a Consent Decree (CD) or Administrative Order on Consent (AOC), or EPA can order the PRPS to complete work under a Unilateral Administrative Order (UAO). If the PRPs are doing work under an AOC or UAO, those documents must include an imminent and substantial endangerment finding. The Order or CD should also address the work to be performed, schedules, cost recovery, and other deliverables. PRPs should follow VI standard operating procedures (SOP), such as EPA Emergency Response Team (ERT) sub-slab port installation and indoor air sampling procedures.

2.4.1 Removal Actions

EPA may use its removal authority under CERCLA to mitigate VI threats. The Removal Program can address VI sites as emergency responses or time-critical removal actions. The type of action implemented depends directly on severity of the threat. Additional information on the choice of implementing an emergency action or a time-critical removal action is in Section 8.

The decision to take an action, whether emergency or time-critical, must be documented in an action memorandum. Section 104(c) under CERCLA limits a federal response action to 12 months, unless the response action meets emergency and/or consistency exemptions outlined in the Superfund Removal Guidance for Preparing Action Memoranda (EPA 2009). Post-installation proficiency sampling for VI usually extends beyond 12 months. OSCs, in consultation with management, should consider requesting an exemption from the 12-month statutory limit for a VI site in the action memorandum, based on the emergency and/or consistency exemptions.

2.4.2 Remedial Actions

EPA added a subsurface intrusion (SsI) component to the Hazard Ranking System (HRS) on December 7, 2016 in a proposed rulemaking that was published in the *Federal Register* on January 9, 2017, and which was effective on May 22, 2017.

The HRS is the principal mechanism EPA uses to place sites on the NPL. The HRS is Appendix A to the National Contingency Plan (NCP), which EPA promulgated on July 16, 1982 (47 FR 31180) pursuant to Section 105(a)(8)(A) of CERCLA. Addition of the SsI component to the HRS is another way EPA meets the congressional mandate in CERCLA to identify releases of hazardous substances at sites that warrant further investigation. The investigation of SsI along with the other releases of hazardous substances will determine if Superfund remedial authority is necessary to address unacceptable risks. With this addition, EPA can now consider human exposure to hazardous substances or pollutants and contaminants that enter regularly occupied structures via SsI as it evaluates whether a site should be included on the NPL.

SEMD may use its remedial or removal authority under CERCLA to undertake early action at NPL sites to ensure protection of human health that could be affected by VI.

EPA can also address VI issues when it completes its five-year reviews under Section 121 of CERCLA. Section 121 requires re-evaluation every five years of remedial actions that leave any hazardous substances, pollutants, or contaminants at a site, to determine if the remedy remains and will continue to remain protective of human health and the environment. Office of Solid Waste and Emergency Response (OSWER) Directive 9200.2-84, “Assessing Protectiveness at Sites for VI,” provides a recommended framework for assessing VI in the context of the Superfund five-year review process (EPA 2012b).

2.5 CASE STUDY: MULTIPLE LINES OF EVIDENCE APPROACH

Keystone Corridor Site, Indianapolis, Indiana

The Keystone Corridor Ground Water Contamination Site is approximately six miles northeast of downtown Indianapolis, in an area that is both commercial and residential. A contaminated groundwater plume exists at the site. Within the site are the municipal Fall Creek Station Well Field and multiple, independent, potential sources of groundwater contamination, some of which are commingled. Groundwater at the site is contaminated with chlorinated VOCs, including PCE; TCE; *cis*-1,2- DCE; and vinyl chloride.

EPA and the Indiana Department of Environmental Management (IDEM) conducted investigations to identify sources of the contamination. More than 40 known users or handlers of solvents in the area have been identified as possible sources, one of which—the former Tuchman Cleaners—operated as a dry-cleaning business at its Keystone location from 1953 to 2008. After the Tuchman Cleaners’ parent company declared bankruptcy in 2008 and the Fall Creek municipal drinking water well field was found to be contaminated, IDEM requested EPA's assistance with a removal action at Tuchman Cleaners.

From September 2012 to December 2014, EPA conducted a time-critical removal action at the former Tuchman Cleaners property. EPA excavated more than 2,550 tons of contaminated soil and two underground storage tanks (UST) from the property. Because of historical presence of NAPL, recovery of which was discontinued in July 2008, EPA also sampled soil gas in the downgradient residential neighborhood to the east and performed testing at more than 40 residential properties to determine if VI was occurring. During the removal action, EPA installed sub-slab depressurization systems (SSDS) at 22 residential properties where the OSC had determined that the VI pathway was complete. EPA recognized that chlorinated VOCs would continue to threaten the Fall Creek municipal well field, and that a long-term response action was necessary. In December 2013, EPA finalized the site on the NPL, thus allowing use of federal Superfund funding for investigation and remedial action cleanup work at this site, which had no PRPs willing to undertake the investigation and remediation.

From December 2015 to March 2017, EPA collected groundwater, soil gas, sub-slab soil gas, and indoor air (including crawl space) samples to characterize site conditions and determine the nature and extent of contamination. Analytical results and multiple lines of evidence demonstrated completed VI pathways from PCE and TCE in groundwater at several additional properties.

After the VI sampling in March 2017, EPA identified three additional residential buildings that met the criteria for a time-critical removal action as specified in the NCP. In May 2017, EPA initiated a second time-critical removal action that included installation of vapor mitigation systems at the three residential buildings.

Regarding the VI pathway, analytical results were compared to residential and commercial/industrial VISLs and removal management levels (RML). VISLs were determined based on a carcinogenic risk (CR) of 1E-05 and/or a non-cancer hazard quotient (HQ) of 1, while RMLs were based on a CR of 1E-04 and/or a non-cancer HQ of one for TCE or three for PCE. These screening levels were established to ensure that long-term exposures at these concentrations would be safe for even the most sensitive populations, such as children or pregnant women.

The four steps summarized below describe application of the multiple lines of evidence approach to the Keystone Corridor Site:

First Step – Shallow Groundwater Sampling

Groundwater sampling occurred to (1) determine the nature and extent of chlorinated solvent contamination in groundwater, and (2) assess potential for presence of a VI pathway.

During the Tuchman Cleaners removal assessment, EPA collected groundwater samples from nine existing groundwater monitoring wells both on site and downgradient. Five of the nine samples were collected from shallow aquifer monitoring wells (sampling depth 20 feet below ground surface [bgs] or less), three were collected from intermediate aquifer monitoring wells (sampling depth 37 to 39 feet bgs), and one was collected from a deep aquifer monitoring well (sampling depth 65 feet bgs). EPA detected high concentrations of chlorinated solvents in six of the nine monitoring wells, including PCE, TCE, vinyl chloride, and VOCs associated with Stoddard solvent. PCE concentrations were as high as 49,000 µg/L, and TCE concentrations were as high as 2,300 µg/L.

EPA conducted additional groundwater sampling between February and June 2016 as part of the Remedial Investigation/Feasibility Study (RI/FS). Forty-two monitoring well samples and 44 groundwater grab samples were collected within the shallow interval. Seven chemicals were detected in shallow groundwater at concentrations above residential VISLs: PCE, TCE, vinyl chloride, 1,1,2-trichloroethane (TCA), benzene, bromodichloromethane, and chloroform. PCE was most extensively found in groundwater. PCE concentrations at 29 locations exceeded the 58 µg/L residential VISL, with a maximum concentration of 8,900 µg/L. TCE exceeded the 5.2 µg/L residential VISL at 31 locations, with a maximum concentration of 640 µg/L. At three locations, vinyl chloride was detected, all concentrations exceeding the residential VISL of 1.9 µg/L, with a maximum concentration of 78 µg/L. However, vinyl chloride was not detected in soil gas, sub-slab soil gas, or indoor air samples at a concentration above its respective VISLs, and, therefore, was not identified as a COC for VI. Although 1,1,2-TCA, benzene, bromodichloromethane, and chloroform were detected at concentrations above VISLs in shallow groundwater, in most cases, these chemicals were not detected in sub-slab soil gas samples at concentrations above VISLs, and thus was not considered COCs for VI. Chloroform was detected in the sub-slab at concentration above the VISL at one property, but this finding likely was related to industrial use of VOCs at this property, not site-related contamination.

Second Step – Soil Gas Sampling

As part of the removal assessment, EPA collected soil gas samples in the neighborhood downgradient of the Tuchman Cleaners Site within public rights-of-way. Soil gas probes were set in borings at approximately one to two feet above the static water level. EPA detected high concentrations of chloroform, propylbenzene, PCE, and TCE. PCE was detected at maximum concentration of 36,000 parts per billion by volume (ppbv), and TCE at 210 ppbv. TCE was detected in seven of the nine samples collected.

EPA sampled soil gas from late September to early October 2016 in the residential and commercial/industrial area immediately west (and downgradient) of the former Tuchman Cleaners facility, and to a limited extent to the south near the former S&K Laundry property. A summary of soil gas results is as follows:

TCE was present in soil gas at concentrations between 0.113 and 2,023 ppbv, compared to the TCE soil gas VISLs of 13 ppbv (residential) and 54 ppbv (commercial/industrial). Of the 73 samples collected, 25 samples had TCE concentrations above 13 ppbv, and 20 had TCE concentrations above 54 ppbv.

PCE was detected in soil gas at concentrations between one and 50,895 ppbv, compared to the PCE soil gas VISLs of 206 ppbv (residential) and 855 ppbv (commercial/industrial). Of the 73 samples collected, 32 samples had PCE concentrations above 206 ppbv, and 20 had PCE concentrations above 855 ppbv.

Third Step – Building Sampling

During the removal, EPA sampled 41 properties, including 29 residential and 12 commercial properties. Sub-slab soil gas (or crawl space air) samples were collected concurrently with indoor air samples to eliminate temporal variation in sample results. In sub-slab soil samples, PCE was detected at maximum concentration of 55,300 ppbv, and TCE was detected at maximum concentration of 700 ppbv. In indoor air, PCE was detected at maximum concentration of 22 ppbv, and TCE was detected at maximum concentration of 62.6 ppbv. Based on sample results, EPA installed sub-slab depressurization systems at 22 residential properties.

During the RI/FS, to sample for potential VI, EPA prioritized residential and commercial/industrial buildings within 100 feet of a soil gas sample found to contain concentrations exceeding EPA's RMLs for TCE and PCE, unless those buildings had been previously sampled or mitigated by an EPA removal action. EPA then collected sub-slab and indoor air samples for VOCs analysis at 18 commercial/industrial and six residential properties where property owners granted access.

EPA evaluated the data from the 24 buildings sampled and determined that the VI pathway was complete for only TCE and PCE, and that concentrations of TCE and PCE exceeded both VISLs and RMLs at 11 buildings, including three residential and eight commercial/industrial multi-unit buildings. Some chemicals, such as 1,2-dibromoethane, bromodichloromethane, and chloroform, were detected in some indoor air or crawl space air samples at concentrations above screening levels, but not in sub-slab soil gas samples collected at the same property (except for chloroform at one property, discussed under *Groundwater Sampling* above). Indoor air concentrations of chemicals other than TCE and PCE are therefore considered derived from indoor air sources, and thus are not attributed to VI from the site. Additionally, during surveys of the buildings where these indoor air and crawl space air detections occurred, EPA identified potential indoor sources of those chemicals.

Summary

EPA conducted two time-critical removal actions at the site, as described above. The first, from 2012-2014, involved excavation of more than 2,550 tons of contaminated soil and two USTs at the former Tuchman Cleaners property, and installation of vapor mitigation systems at 22 residential properties where VI had been detected. The second, in 2017, involved installation of vapor mitigation systems at three additional residential properties based on VI data acquired during the RI/FS.

Based on multiple lines of evidence, site-related contaminants at concentrations that posed a potential threat to human health could migrate into the indoor air of buildings from sub-slab soil gas originating in groundwater or in some other subsurface source of contamination. A potential VI area of concern was identified based on a conservative estimate by use of soil gas sample results exceeding residential soil gas VISLs.

The response action in the Record of Decision (ROD) for Interim Action, dated September 2018, addressed residential and industrial/commercial buildings within the VI area of concern that hosted sub-slab and/or indoor air concentrations of site-related COCs which exceeded remedial action levels. Based on sampling to date, eight known commercial/industrial buildings pose VI risks that should be addressed. EPA estimates that as many as 88 additional buildings (44 residential and 44 commercial/industrial) not yet tested are within the potential VI area of concern. Some portion of these additional properties may also be under VI risks that should be addressed. Additional sampling is necessary to assess those additional buildings.

3.0 SITE IDENTIFICATION AND CROSS-PROGRAM COORDINATION

Region 5 identified a need to coordinate among Superfund programs, particularly where there is a need for removal actions at NPL sites or for removal sites that could score for the NPL using the SsI pathway. To ensure consistency, effective communications among SEMD programs is important.

This section discusses VI site identification and cross-program coordination regarding VI sites, including Superfund Removal, Remedial, Site Assessment (SA), and Brownfields Programs.

3.1 SITE IDENTIFICATION

This section discusses VI site identification programs and recommendations.

3.1.1 Site Identification Programs

Potential for unacceptable VI risks may bring a site to EPA's attention through the following programs:

SA Program – SA Managers (SAM) and NPL Coordinators may identify a possible VI issue at a site based on analytical results, general environmental program experience, and familiarity with VI guidance documents. As discussed in Section 2.4, EPA revised the HRS in 2017 to include SsI. This revision provided a means to score VI sites for inclusion on the NPL, which would primarily apply to large vapor plume sites not eligible for the NPL by means of another pathway, such as groundwater migration.

The SA Program's primary purpose is to evaluate sites for inclusion on the NPL. However, the SA Program may identify sites that pose an imminent and substantial threat to public health. A site may be referred to the Removal Program if the SAM, NPL Coordinator, or the referring state believes that timelier VI investigative work and an emergency or time-critical response is necessary.

Region 5 acknowledges the need for assistance to SA staff in identifying potential VI sites for inclusion on the NPL and performing relatively inexpensive investigative activities (such as direct push sampling, testing with a portable monitor, or passive sorbent sampling). Most SA work in Region 5 occurs via state cooperative agreements, and capacities of states to conduct VI screening vary.

Remedial Program – The identification of potential VI threats can occur during the NPL listing, RI/FS, or five-year review. If the potential for VI is identified after the ROD, follow-up usually occurs during the 5-year review process. Some sites are investigated earlier if groundwater or soil gas monitoring results suggest necessity for more expedited VI activities. The RPM and support staff may identify a need to perform a VI investigation and proceed as necessary. Bases for a decision to proceed are professional knowledge and experience, this document, familiarity with the OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air (EPA 2015a), and review of supporting technical documents.

Removal Program – Removal sites are identified in various ways including referral by other Region 5 programs, state environmental agencies, or local agencies. Additionally, the Remedial Program may request assistance with potential time-critical aspects of VI issues at an NPL site discovered during a remedial investigation or the five-year review process. The OSC and/or the Removal Manager evaluate each request for assistance and determine the necessity for follow-up. For example, Ohio EPA (OEPA) collects groundwater and soil gas data at sites, and subsequently requests Removal Program assistance in conducting an independent analysis of sub-slab and indoor air to determine if a completed exposure pathway exists. Based on the results, a site may be assigned to an OSC, and in discussion with Removal Program management, a general course of action is determined. After site investigation, the site may also be transferred from the Removal Program to the SA Program, or to the Remedial Program if the site is listed on the NPL, for follow up. Contaminant levels may not justify a removal action, but an existing health hazard could be addressed under the Remedial Program for sites on the NPL.

Brownfields Program – Brownfields Program personnel may identify a potential VI issue based on experience and familiarity with VI guidance. If a VI concern is identified, the BPM may bring the site to the attention of the local entity administering the Brownfields grant. By raising awareness, the Project Manager may be able to identify potential VI sites and actively work with Brownfields Program grant recipients to address the problem through the grant assessment process.

Brownfields Program staff review of selected guidance documents may be advisable. EPA's "Brownfields Technology Primer: VI Considerations for Brownfields Redevelopment" (EPA 2008a) provides a useful introduction to VI issues.

Generally, Brownfields Program staff should notify the SA or Removal Program when they are made aware of a VOC groundwater plume that extends to residential areas beyond the boundaries of a Brownfields development site.

State Program – State agencies may request EPA assistance with VI sites that they have identified. In Ohio, for example, OEPA will evaluate groundwater and deep soil gas to initiate a VI investigation. If residential sub-slab and indoor air sampling is warranted, OEPA will request assistance from the EPA removal program to further evaluate the need for a time critical removal action and potential mitigation.

3.1.2 Site Identification Recommendations

Many factors may complicate a decision to investigate VI at a site. These factors can include expenditure of time and resources, land use scenarios, difficulties with property access, and questions about the relative contribution of consumer product sources to indoor air concentrations of volatile chemicals (such as dry-cleaned clothes, nail polish remover, model glue, or presence of gas or paint cans in the garage or basement). Despite these complicating factors, Region 5 staff must decide how to evaluate the potential exposure threat, which may be significant at some sites.

The general recommendations discussed below apply to identification of VI sites in Region 5. OSCs, RPMs, NPL coordinators, and SAMs are encouraged to review these recommendations and familiarize themselves with the OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air (EPA 2015a). General recommendations reflecting regional policies or currently accepted opinions about investigative methods and approaches appear later in this document.

1. **Project managers should follow a conservative approach when determining if a VI investigation is warranted at a site.** In general, a VI investigation should always be considered if (1) a site has soil or groundwater contamination with vapor-forming chemicals, (2) buildings are present above or within 100 feet laterally from the surface footprint of the contaminant plume exceeding the groundwater VISL, or within applicable programmatic soil or soil gas action levels within 100 feet of a contaminated utility corridor, and (3) subsurface soil contamination sources are present near buildings. For example, several southwest Ohio VI sites are over sand-and-gravel aquifers with shallow (less than 20 feet bgs) groundwater containing VOCs at concentrations exceeding 200 µg/L, and a completed exposure pathway for nearby residences.

   Note: Homes with existing radon mitigation systems may not require additional VI mitigation. OSCs and RPMs should consider sampling these properties to ensure that the systems are working effectively. Additionally, OSCs and RPMs should consider if continued operation of the system should be included in the site remedy. If the systems are to be modified, OSCs and RPMs should consider inclusion of before and after sampling for radon and VI contaminant(s).

2. **Project managers should consult a regional risk assessor or ATSDR for the latest groundwater, sub-slab, and indoor air site-specific screening levels.** State health departments, in consultation with ATSDR, can also be a source of site-specific screening levels. The EPA VISL

Calculator provides generic screening values for determining need for a VI investigation based on concentrations of specific chemicals in soil gas and groundwater (EPA 2019a).

Site-specific factors such as soil type, soil moisture content, subsurface or geologic conduits, building construction, pressure differentials, and other variables can increase or decrease likelihood of vapor migration and affect appropriateness of screening values. Geologic factors (such as presence of a sand-and-gravel aquifer or a shallow water table) tend to further reduce confidence in generic screening values. The project manager should evaluate these factors and seek assistance of hydrogeologists, geologists, soil scientists, or other specialists experienced in VI investigations.

3. **Project managers may consult with members of the VI Workgroup**. The Region 5 VI Workgroup can offer suggestions based on experience and knowledge gained from efforts to keep up to date on VI practices and current ideas. The Workgroup can also reach out to experts to assist with specific issues.

3.2 REMOVAL ACTIONS

This section discusses removal actions at VI sites, including removal action triggers for VI sites and RPM and OSC removal action roles.

3.2.1 Removal Action Triggers for VI Sites

An OSC or RPM can recommend the agency begin a removal action (such as installation of a mitigation system) based on site-specific conditions in accordance with the NCP. Typically, sub-slab and indoor air results trigger a removal action, as summarized below.

- **Site-related contaminants are identified in sub-slab and indoor air that pose an unacceptable threat to human health**. Removal actions are generally initiated as a response to a high level of risk or concern about acute health risks, defined as a CR exceeding 10^{-4}, non-cancer hazards exceeding a hazard index (HI) or HQ of 3.0 (except for the screening level for TCE, which is based on an HQ of 1.0), exceedance of an ATSDR acute (short-term) risk or screening level, or existence of a fire or explosion hazard. EPA RMLs are applied to screen site data in order to determine if the level of risk supports a Removal Action.
- **Multiple lines of evidence indicate that indoor air contaminants are from VI**. Multiple lines of evidence can include groundwater, soil gas data, and historical site information linked to sub-slab and indoor air contamination. Concentrations of site-related contaminants in indoor air must result from VI at and from the site and not from indoor sources or ambient air.

Documenting groundwater, soil gas, sub-slab, outdoor ambient air, and indoor air contamination is important. Not “connecting the dots” may lead to a conclusion that VI risks exist when actually a residential indoor air contaminant (such as recently dry-cleaned clothes in the basement, nail polish remover, model glue, or presence of gas or paint cans in the garage) is the source. Preferential pathways (such as utility corridors) may also complicate this connection by allowing the horizontal movement of contaminants from sources outside the structure being evaluated.

In addition, the Removal Program routinely requests sub-slab and indoor air screening levels from state health departments in consultations with ATSDR. For example, in 2009 at the Behr Dayton VOC Removal Site, the residential TCE sub-slab screening level was set at 4.0 ppbv (21.5 micrograms per cubic meter [$\mu g/m^3$]), and the TCE indoor air screening level was set at 0.4 ppbv (2.15 $\mu g/m^3$). Exceedance of the sub-slab TCE screening level triggered collection of an indoor air sample. Exceedance of the residential TCE indoor air screening level and detection of TCE in soil gas and shallow groundwater indicated a need for mitigation.

3.2.2 RPM and OSC Removal Action Roles

This section discusses the roles of the RPM and OSC in VI site removal actions.

Role of the RPM

RPMs have the authority to implement removal actions in accordance with the NCP. An RPM may conclude that a threat to public health exists because of actual or potential exposure of nearby human populations to hazardous substances based on site-specific information such as groundwater, soil gas, sub-slab, and indoor air data; site historical information (location of contamination source areas); and other information.

If an RPM, in consultation with the technical support team, concludes that a removal action to address VI is warranted at a site, the RPM should request a consultation with the Removal Program through his or her manager about the site-specific situation and recommendations. If the Removal Program concurs that a removal action is warranted, the RPM should coordinate follow-up along either the enforcement or fund-lead pathways described in Section 2.0.

Role of the OSC

The role of an OSC during implementation of removal actions at a site with ongoing remedial response varies based on the site and action. Depending on project needs, the OSC's role may be central (such as direct coordination of a large VI removal action at a non-NPL Fund-lead site or implementation of an emergency response) or minimal (such as when an RPM acts as the "EPA Project Coordinator" at an NPL site for a PRP-lead removal action addressing VI pursuant to an AOC). The OSC has unique and valuable experience with the removal process, including mitigation of time-critical threats posed to human health from hazardous substances, and oversight of response contractors in the field. Therefore, RPMs may find it beneficial to partner and coordinate with an OSC for removal actions to address VI, even though the RPM may directly coordinate the response. Section 3.3.2 discusses coordination between RPMs and OSCs in more detail.

The role of an OSC at a site of ongoing remedial response should be outlined early in the process in coordination with EPA Remedial and Removal Program management staff. Remedial and Removal Program management staff should periodically and collectively meet with their respective staffs to discuss work efforts and work allocations at VI sites where both the Removal and Remedial Programs are actively involved.

3.3 CROSS-PROGRAM COORDINATION

Site-specific coordination between Region 5 programs has long been standard practice and should continue for VI sites. However, some general guidelines are advisable considering the expected increase in the number of VI sites, potential resource issues, and the different health threat criteria applied by the various programs for implementing mitigation actions.

This section discusses cross-program transfers of VI sites and recommendations pertaining to cross-program coordination.

3.3.1 Cross-Program Transfers of VI Sites

Numerous NPL sites have been referred from the Remedial Program to the Removal Program because VI was identified as a potential exposure pathway. These referrals generally occurred after Remedial Program staff performed groundwater, soil gas, or sub-slab sampling for VOCs during remedial investigations. The sites generally were referred to the Removal Program because sampling results indicated levels that presented a high level of risk or concern about acute health risks warranting indoor air sampling or mitigation actions by OSCs. At these sites, in the absence of established guidelines or policy, the involved

RPMs, OSCs, and respective management staff determined how work activities would be apportioned among them on a site-by-site basis.

Additionally, some Region 5 removal sites (such as the Behr Dayton VOC Removal Site and the East Troy Aquifer Site) have been listed or were to be listed on the NPL after the OSC had conducted extensive residential sub-slab and indoor air sampling, and after installation of residential VI mitigation systems. Although these removal activities protected public health in the short term (as long as the VI mitigation systems function properly), Remedial or State Program assistance was necessary to address the VI source (i.e., groundwater contamination).

The SA Program has recognized potential VI issues at a few sites and has brought these issues to the attention of the Removal Program. In addition, the 2017 revision to the HRS model, used to screen sites to evaluate eligibility for the NPL, added SsI, including VI.

3.3.2 Cross-Program Coordination Recommendations

This section provides recommendations for coordination among various personnel in different programs. Figure 3-1 below illustrates how communication flows between OSCs, RPMs, SAMs, and BPMs.

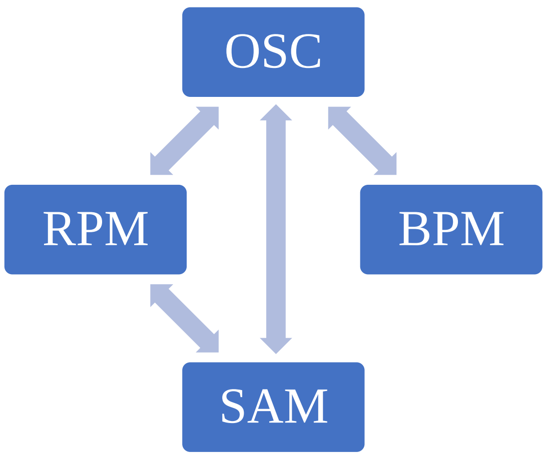


Figure 3-1. Communication Flows Between Programs

Coordination Between RPMs and OSCs

As discussed in Section 3.2.2, an RPM may benefit from partnership and coordination with an OSC regarding removal actions to address VI, even though the RPM may directly coordinate the response. During use of a Removal Program contractor for response work, the OSC's involvement may be essential for specific contract purposes, although the RPM can coordinate much of the work as a Contract Officer Representative (COR). In all cases, the VI site removal approach followed (PRP or Fund-lead) should first be weighed against the urgency of the threat posed. If the RPM believes that a situation is an emergency, the RPM should immediately consult with the Removal Program to expedite a potential emergency response or time-critical removal action.

Coordination Between SAMs and OSCs

The process of requesting Removal Program assistance at a site should follow normal procedures pertaining to any site where SAMs believe a removal assessment or action is warranted.

Generally, the SAM should discuss the need for Removal Program involvement with the state program and the SA Program Manager, who in turn will approach the appropriate Removal Program Manager. The Removal Program Manager likely will review available information with an OSC and the state program and assess the necessity for Removal Program follow-up.

When an OSC closes out a VI site after a SA investigation or removal action, the site cannot then be referred back to the SA Program for NPL consideration solely based on the VI pathway. Unlike cases of removal sites with more traditional exposure pathways (soil and water ingestion or dermal contact and outside air inhalation), the Remedial Program will have little chance to conduct follow-up at a VI site to address residual contamination that could pose longer-term health risk if VI is the only pathway of concern. The OSC should consider this limitation when evaluating health risk criteria at a removal site and the need for mitigation.

If a site may be considered for inclusion on the NPL through the VI pathway, the OSC should coordinate the removal action with the SAM because the actions taken may affect factors utilized in the HRS evaluation.

Scores for SsI can be calculated in an Area of Observed Exposure (AOE), where documented indoor air contamination meets HRS observed exposure criteria, and in an Area of Subsurface Contamination (ASC), where documented subsurface contamination (i.e., crawl space, sub-slab, groundwater) meets HRS observed release criteria. Determining whether the SsI pathway is complete with indoor air exposures is important when scoring SsI, because targets within an AOE can be scored as Level I or Level II under HRS, whereas targets within an ASC are weighted similar to potential targets in other HRS pathways, based on factor values for structure containment, depth to contamination, vertical migration, and vapor migration potential. Other key factors to consider when determining HRS scores for SsI include building size, number of occupants, and structure type. Installation of mitigation systems without prior indoor air sampling also affects scoring.

Without a completed exposure pathway documenting an AOE, the ASC of a vapor plume would likely have to encompass multiple residential blocks, or high-density housing industrial/commercial, to score sufficiently for further site assessment activity.

Coordination Between SAMs and RPMs

Evaluation of the SsI pathway during NPL consideration is not an indicator of whether VI is an issue at any site. For sites identified because of issues other than VI, the SAM may be aware of a potential VI problem and wish to bring the problem to the attention of the Remedial Response Sections. In such cases, the SAM can alert the RPM about the possibility of VI when the site is listed, which the RPM can incorporate into investigative planning for the site.

Coordination Between BPMs and OSCs

A BPM should discuss the need for Removal Program involvement at a potential VI site with the Brownfields Program supervisor. Upon deciding to investigate VI issues, the process should closely follow the normal process between SA and Removal Program staff. The Removal Program generally should align coordination of Brownfields staff in any field work with partnerships developed by the BPM with local governments, and consider the possible stigma that Removal Program involvement could bring upon a site. Moreover, the BPM may independently consult with the Region 5 VI Workgroup, EPA risk assessors, or ATSDR for technical advice when evaluating a potential VI site.

4.0 COMMUNITY ENGAGEMENT

Region 5 should proactively engage in dialogue and collaborate with communities affected by a VI site. This proactive engagement is especially important in communities historically underrepresented in the environmental decision-making process.

VI site teams must be aware of effective methods to handle community concerns. Informing residents or business owners that hazardous vapors may have entered their buildings is a delicate task. Often, people are just learning that the groundwater or soil near their properties has been contaminated by releases from a nearby site. Communities may be skeptical or unsure of what will happen next. They will wonder how vapors will affect their health and the health of their coworkers and families. It is important to learn from the experience of other personnel who have faced similar challenges, and to become familiar with risk communication tools that promote dialogue, identify solutions, and respond to public concerns.

Good communication is an essential component of any community engagement program. EPA should inform building occupants about a VI investigation prior to knocking on the door asking permission to drill holes in their floor or requesting information about their personal activities (such as smoking and dry-cleaning of clothes).

When addressing VI concerns, it is important to convey to community members the risk of soil gas migration from the subsurface into buildings, and to explain what types of background sources are common in buildings.

4.1 INFORMING A COMMUNITY ABOUT VI CONCERNS

Community engagement activities should begin as soon as possible after determination that VI concerns potentially exist at a site. Informing the community about VI concerns and plans to conduct sampling can be resource-intensive. The RPM or OSC should work with a Community Involvement Coordinator (CIC) to develop a community engagement strategy that ensures the most appropriate means of communication throughout the process. Region 5 recommends developing fact sheets, online questions and answers, and public availability sessions or community meetings to share information with the public and facilitate communication. Staff should also consider EPA's previous involvement at the site, existence of community or neighborhood groups, and the phase of the regulatory process under which EPA is addressing VI when choosing effective communication strategies.

Region 5 recommends conducting individual, one-on-one communication with each property owner or tenant whenever possible. The one-on-one approach establishes trust and provides an opportunity for the individual to ask questions that may not otherwise happen in a public setting. This communication can occur after meetings with a larger audience to introduce the overall issue of VI. Before a community meeting, each home and building owner and tenant should receive a letter explaining EPA's plans to conduct sampling and EPA's intent to contact the owners and tenants soon. EPA can then begin to contact individual home or building owners, and tenants, and schedule in-person visits. Building-by-building contact and communication is probably the most effective means of educating the community about VI issues and obtaining access to properties. Personal contact is recommended to establish a good working relationship with owners and tenants, and to build the trust needed for continued access necessary for sampling activities.

The initial visit can serve to explain EPA's plans in detail and answer questions, obtain signed access agreements, identify sample locations, and provide instructions for the home or building owner or tenant (such as keeping doors and windows closed during sampling, avoiding entry of dry-cleaned clothing indoors during sampling, etc.). The initial visit could include a building survey to identify likely sources of consumer and industrial products. Personnel conducting this initial visit should also schedule a sampling date and time.

Communicating New VI Concerns at a Legacy Site

From time to time, EPA investigates new potential VI pathways on legacy sites, such as NPL sites. These new VI investigations generally begin as the result of monitoring, assessing, or reviewing conditions at these legacy sites.

Community engagement at legacy sites can be challenging for several reasons, including the possibility that a remedy for the site may have already been selected, and property owners, community members, or local officials have changed.

To mitigate some of these difficulties, the site team should reassess the community and the site, reintroduce the team to local officials, reconnect with community groups and members, and update mailing lists and fact sheets.

4.2 ACCESS AGREEMENTS

For EPA staff or contractors to enter private property to perform work, EPA must have either consent of the owner/occupant or judicial approval of a warrant. CERCLA grants designated representatives of EPA the authority to access properties, with owner/occupant approval, for purposes including response actions and determination whether a response to address hazardous substances would be necessary.

Region 5's policy is to obtain consent from building owners, at a minimum, and, ideally, from tenants as well, if applicable. Region 5 recommends obtaining permission to access properties in writing. Region 5 also recommends attempting multiple times to obtain voluntary access to properties before seeking a warrant. EPA can acquire signed access agreements in several ways—mailing out request letters which include access agreements, convening public meetings and availability sessions, referring the public to EPA websites, conducting door-to-door visits, and calling property owners and occupants. Each of these methods has resulted in positive community responses in Region 5 and is described later in this section. Appendix A includes an example EPA access agreement.

There are many resources available for developing mailing lists and obtaining access. Many local utility departments have phone numbers of property owners and occupants. Many local governments maintain parcel ownership information in a geographic information system (GIS). Additionally, local health departments also often assist with outreach to hard-to-reach/recalcitrant property occupants.

4.2.1 EPA Sample Request Letters

Appendix A includes an example of a packet containing a letter sent to residents requesting access for VI sampling. The letter describes why EPA is conducting the investigation. The packet includes fact sheets related to VI and COCs at the site, an access agreement, and contact information. The request letter is accompanied by a postage-paid envelope for the property owner/resident to return the signed access agreement. Some OSCs have been most successful in obtaining completed access agreements by sending the letters with return receipts which require signatures using commercial mailing services. During past projects, EPA has also used CICs to send out request letters. EPA has successfully used request letters and packets in numerous VI investigations, including the Behr Dayton VOC Removal Site in Dayton, Ohio, where EPA obtained more than 400 signed access agreements.

Sending out a second or third mailer may be necessary to generate additional positive responses. Tracking to whom and how many times letters have been sent is important in case the property owner subsequently questions whether he or she had ever been contacted to request sampling, and to document EPA's attempts to acquire access if the property owner never grants access.

Upon receipt of an access agreement, the OSC, RPM, or CIC should call the resident to schedule a sampling appointment.

4.2.2 Public Meetings and Availability Sessions

The OSC or RPM can conduct a public meeting or availability session to gain access to properties for sampling, explain the site's history, and share EPA's plans. During the meeting or availability session, the OSC or RPM can explain VI, the sampling strategy, and how results will be presented to the public. This also allows residents to "sign up" for sampling. These meetings also present an opportunity for the public to ask health-related questions of invited representatives of local or state health departments and ATSDR.

Figure 4-1. EPA Conducting Public Meeting

At public meetings like the one pictured in Figure 4-1 above, Region 5 has placed contractors and EPA personnel at the back of the room with access agreements for property owners to sign after the meeting, and to schedule sampling times. At some public meetings, EPA has gained access to more than 50 sampling locations using this method.

4.2.3 Door-to-Door Visits

In addition to holding public meetings, Region 5 also recommends visiting residences or businesses to obtain signed access agreements. This is more labor intensive, and results can vary based on the time of day the visits take place Typically, CICs, OSCs, Superfund Technical Assessment and Response Team (START) contractors, or local health department representatives walk door-to-door throughout an area of concern to obtain signed access agreements. If residents are not home at the time of the door-to-door canvassing, EPA recommends leaving a blank access agreement and a fact sheet on the site in a door hanger.

4.2.4 Telephone Contact

Another useful method CICs, START contractors, and OSCs use to obtain signed access agreements and communicate about site activities is to call property owners and tenants (if applicable). Many local utility departments maintain lists of telephone numbers of property owners and occupants.

4.3 TOOLS AND RESOURCES

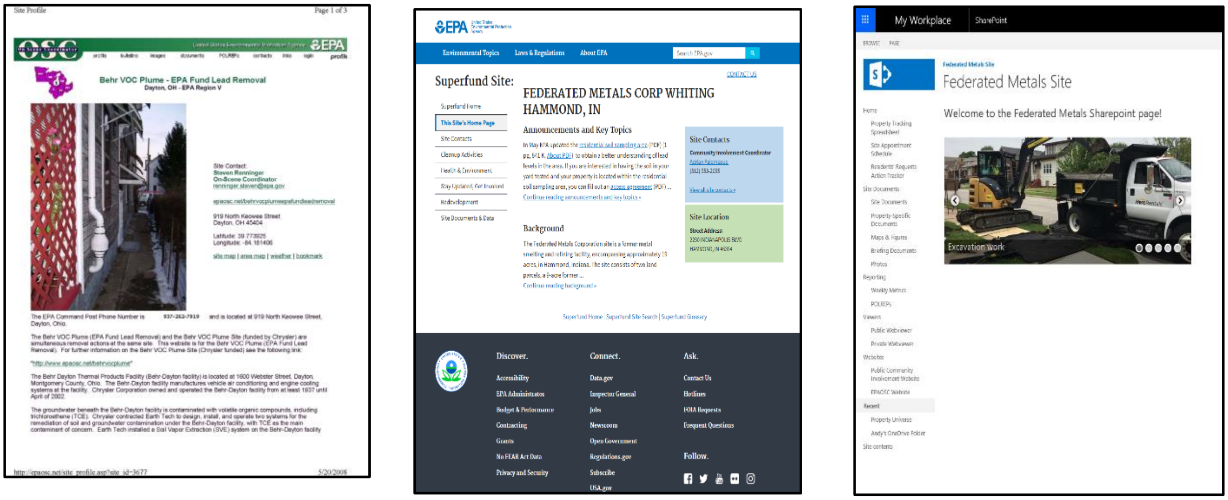
Additional tools and resources have proven helpful in Region 5 in communicating with communities affected by a VI investigation. This sub-section describes some of the most effective and widely utilized resources.

4.3.1 EPA Websites

Two types of public EPA websites are useful to share information with communities affected by VI concerns. On the EPA OSC website (https://response.epa.gov), OSCs can post site-specific VI information, updates, site photographs, and blank access agreements for sampling for people to sign and return to EPA. Although this website is traditionally for OSC use, RPMs may also utilize this resource. The second website option is a Superfund Profile Page (SPP). OSCs and RPMs can work with a CIC to create an SPP that has more flexibility and provides more options to share information than the EPA OSC website. See example displays of these public EPA websites on Figure 4-2 below.

EPA public websites can be linked to public web-viewers and Story Maps that can visually display site data that does not contain personally identifiable information (PII) effectively and interestingly. Public web-viewers are normally used for larger sites, as they are resource intensive. For more information on developing public web-viewers or Story Maps, contact a CIC or the Regional GIS Support team.

An internal online tool for a VI investigation team is to create an EPA SharePoint site (Figure 4-2 below) where team members can access the same data and update files as a group. SharePoint sites have proven useful to organize large amounts of information about complex sites and investigations. SharePoint sites are not meant for public access.



EPA OSC Website **SPP Site** **SharePoint Site**

Figure 4-2. Websites

4.3.2 Community Involvement Plan and Fact Sheets

A Community Involvement Plan (CIP) is a site-specific document and strategy created to enable meaningful community involvement. CIPs specify EPA-planned activities to address community needs, concerns, and expectations that have been identified through community interviews and other means. A CIP conveys information about the geographical location of the site, historical background, COCs, community groups, and local officials. A CIP can be an excellent tool to determine the best ways to engage a community affected by a VI investigation. CIPs are required for sites with removal actions that exceed 120 days (e.g., most VI removals).

Fact sheets are brief documents written in plain language to help residents understand technical laws, concepts, and information (Appendix A). This traditional communication tool remains an effective way to provide site-related information and inform the public about VI investigations. CICs can assist with translating fact sheets into various languages for communities with non-English speakers.

4.3.3 Community Advisory Groups

A Community Advisory Group (CAG) is a small group of residents, committee, or task force that meets regularly with agencies and/or PRPs. A CAG provides opportunities for the public to gain understanding of the complexities of a VI investigation. This group enhances public participation by providing a public forum where representatives of diverse community interests can discuss their concerns and learn from each other. If a CAG already exists in an area where VI is under investigation, the VI team should regularly update the CAG about progress of the investigation. If a CAG is not present in the area and the local community is interested in obtaining more information about these groups, a CIC should be contacted.

4.3.4 Community Involvement Resources

CICs routinely use the three additional tools listed below to engage the community.

- The *Community Involvement Handbook* (EPA 2016a), which provides guidance to EPA staff on how EPA typically plans and implements community involvement activities. https://semspub.epa.gov/work/HQ/100000070.pdf.
- The *Superfund Community Involvement Toolkit*, which provides practical, easy-to-use aids for designing and enhancing community involvement activities. https://www.epa.gov/superfund/superfund-community-involvement-tools-and-resources.
- The *Superfund Community Involvement SharePoint Site*, set up by EPA Headquarters and providing useful resources for EPA staff. https://usepa.sharepoint.com/sites/OLEM_Community/superfundcieveryone/SitePages/Home%20-%20Superfund%20CI%20Everyone.aspx.

4.4 ADDRESSING RELUCTANT PROPERTY OWNERS

Property owners allowing EPA to sample and install mitigation systems is a voluntary action. Some property owners may be reluctant to grant access or refuse to give access outright. EPA can request assistance from the local health department to meet with owners and occupants to explain the need for sampling or installation of a mitigation system. However, EPA should not continue to pressure reluctant homeowners once sufficient information has been communicated regarding health risks and the benefits of mitigation. Property owners should be advised that if they decline an offer for installation of a vapor mitigation system and change their minds in the future, they may be responsible for the costs of installing and maintaining their own systems.

Property owners are responsible for granting access for sampling and for installation of mitigation measures, but logistics may be coordinated with tenants. EPA recommends apprising both the owner and tenants of human health risk that may be posed by VI, which includes providing building-specific sampling results to both parties when available. If the owner of a rental property refuses access, EPA may request the assistance from the local health department in the form of a letter to the property owner describing why sampling is necessary and informing the owner of his or her obligation to ensure that the rental property is safe for occupancy (EPA 2015a). As a last resort, if the owner of a rental property still refuses access, the OSC or RPM may consult with their section chief and attorney to see if it is appropriate to seek a warrant for access.

Obtaining access to non-residential buildings such as schools, libraries, hospitals, hotels, and stores is similar to gaining access to rental properties. If the owner of a non-residential building refuses access, EPA may request assistance of the local health department. If the owner of a non-residential building still refuses access, the OSC or RPM may consult with their section chief and attorney to see if it is appropriate to seek a warrant for access.

The site team should document attempts to obtain access. The site team should also inform the local health department if it did not obtain access for VI sampling after multiple attempts.

4.5 SAMPLING APPOINTMENTS

Once the access agreement is signed, EPA should schedule a date and time for the sampling with the property owner. Appendix B provides an example of the Residential Sample Reminder Form. This form should be filled out and either hand delivered or mailed to residents to remind them when the sampling team will visit. Many homeowners like this form because they can place it on their refrigerators as a reminder. The form specifies the number of samples to be collected, where the samples will be collected, instructions to ensure integrity of air samples, and contact information in case the sampling time must be rescheduled. Some residents may prefer to receive sampling appointment reminders through other means of communication in addition to or instead of the Residential Sample Reminder Form. These sampling reminders can be provided through telephone calls or text messages before the sampling date. It's a good practice to ask residents if they would like to be reminded of the sampling appointments by receiving the Residential Sampling Form or by other means of communication.

4.6 TRACKING OWNERSHIP CHANGES

OSCs and RPMs should make reasonable attempts to track ownership changes for homes and buildings where access was not granted for assessment sampling or installation of a mitigation system. Often, a state, tribal, or local agency or PRP may be in a better position to track this information. These attempts could include annual contact, drive-by visits, communication with community representatives, and other approaches. Reasonable attempts could also include an annual site inspection during which nearby homes and buildings for sale are noted. If ownership changes are identified, appropriate follow-up with the new home or building owner should occur (EPA 2015a).

4.7 PRE-SAMPLING INFORMATION

Before sampling occurs, fact sheets can be used to inform property owners and tenants about potential household sources of indoor air contamination. The fact sheets should also describe steps the home or building owner can take to minimize such sources, and steps EPA will take to minimize risks.

Occupants of the property should be informed of the following guidelines contained in Appendix B:

- Do not smoke near the SUMMA canisters.
- Leave doors and windows closed during sampling.
- Try not to enter the room where sampling is occurring.
- If possible, do not bring home dry-cleaned items during the sample period.
- Do not touch the SUMMA canisters during sampling.

Some common household sources can interfere with sample results. These indoor air sources include nail polish remover, paints and paint thinner, dry-cleaned items, scented candles, and cleaning fluids. The site team should develop a plan to remove consumer and household sources of indoor air contamination before sampling occurs. The plan could include providing the homeowner or tenant plastic containers into which to place household products. These plastic containers can be issued to the owner or tenant a few days before the sampling takes place. A useful practice is to tape on the lid of the plastic container a list of items that the owner or tenant should place inside the plastic container. The list of household items contained in Appendix C can be used for this purpose.

4.8 ADDITIONAL INFORMATION ABOUT CONSUMER AND HOUSEHOLD SOURCES OF INDOOR AIR CONTAMINATION

The home or building owner should be notified that once a VI mitigation system is installed in the property, the system will only protect the home or building from chemicals coming from the ground, and will not protect the home against continuing indoor sources because VI mitigation systems are not indoor air filtration systems. Owners and tenants should also be informed that minimizing consumer and household sources of indoor air contamination is in their best interest—not just during sampling events but over the long term as well.

5.0 VI SITE CHARACTERIZATION

A CSM is developed to form a general VI sampling strategy and develop DQOs. Various VI sampling strategies are possible, depending on access, location, complexity of the site, and presence of preferential pathways and receptors. Sampling strategies discussed in this section are not meant to be comprehensive but are limited to more frequently encountered situations or considerations based on regional policy.

5.1 CONCEPTUAL SITE MODEL

OSCs, RPMs, and their site teams should develop a CSM to help create sampling strategies by use of valid analytical data or historical records to determine type and source of the contamination, potential migration route(s)/exposure pathways, and the receptor. Section 2.0 provides general information about a CSM and describes a typical VI CSM (aided by an accompanying figure). A CSM may be modified throughout a project after acquisition of additional data to assess data gaps and/or to determine if additional sampling is necessary.

The multiple lines of evidence approach (as described in Section 2.3) should be followed during development of the CSM to assess completeness of the VI pathway and the VI threat. Section 5.2 discusses these approaches for each medium in further detail. Section 5.4 conveys several strategies to interpret data and provide reasonable assumptions about the VI threat. However, Region 5 recommends evaluating each medium before deciding to respond.

OSCs or RPMs should refer to *Conceptual Model Scenarios for the Vapor Intrusion Pathway* (EPA 2012a) for additional information on developing a CSM for a VI site.

5.2 GENERAL VI SAMPLING STRATEGY

Region 5 recommends that the site team develop a site-specific VI sampling strategy. In developing the strategy, the OSC or RPM may consult with risk assessors, ERT, chemists, hydrogeologists, and/or geologists, as well as with laboratory personnel. Consulting with laboratory personnel is important to ensure that (1) appropriate sampling and analytical methods are selected, and (2) laboratory reporting limits will allow comparisons of sample results to VI screening levels. This approach ensures that team is using the CSM to develop the sampling strategy and incorporate DQOs (see Section 5.3 regarding DQOs).

The general VI sampling strategy typically follows the approach outlined in the multiple lines of evidence case study provided in Section 2.5. Parts of the Keystone Corridor case study are used below to illustrate the general VI sampling strategy. The general VI sampling strategy typically proceeds from identification of the source area, determination of migration pathways, and confirmation of exposure. In the case of the Keystone Corridor Site, Region 5 performed groundwater, soil, soil vapor, and building sampling (sub-slab, crawlspace, indoor air, and ambient air) to determine the source area, migration pathways, and receptors. Below is a generalized summary of how Region 5 used multiple lines of evidence to determine the VI threat.

Step 1, Soil Investigation: Region 5 identified seven properties as potential sources based on historical investigations and product use. Region 5 collected soil samples near these properties to determine if source areas existed.

Step 2, Groundwater Investigation: The site team collected groundwater samples from the existing monitoring well network. The team supplemented areas with data gaps by collecting grab groundwater samples to determine the flow direction and concentration of VOCs throughout the water column. The monitoring wells and grab samples were placed inside of the known plume and around the plume perimeter in a residential area. The sample team used the groundwater data to determine where VI issues would likely be present based on the groundwater flow direction and VOC concentration in the uppermost portion of the aquifer. The team used the groundwater data to determine where soil gas samples should be collected.

Step 3, Soil Gas Sampling: Region 5 collected soil gas samples within and around the perimeter of groundwater plume to establish a connection between groundwater contamination migrating to the vapor phase. The team collected soil gas samples within 100 feet of residential properties. The investigation team utilized a HAPSITE portable gas chromatograph/mass spectrometer (GC/MS) for real-time analytical data. This allowed the team to determine concentrations of selected VOCs in real-time and decide if they needed to step-out from the footprint of the groundwater plume. The team collected a number of real-time samples for laboratory analysis to confirm the results. Region 5 used the soil gas results to determine which properties required sampling.

Step 4, Building Sampling: The team collected sub-slab, crawlspace, indoor air samples at properties located within 100 feet of soil gas samples that exceeded RMLs. Building surveys were performed prior to sample collection to identify indoor chemical sources that could interfere with the VI analysis. Some property owners did not grant access and, therefore, those properties were not sampled. The team also collected ambient air samples to evaluate contribution from nearby sources.

At some sites, hazardous vapors do not migrate along the conventional VI CSM, i.e. groundwater to soil gas to sub-slab or crawl space. Instead, vapors may move along sewer lines and may even enter buildings through utility openings. At these sites, the site team should consider investigating utility conduits or other preferential pathways. Region 5 recommends consulting Environmental Security Technology Certification Program (ESTCP) Project ER-201505 (ESTCP 2018) for guidance on assessing sites for preferential pathway migration.

VI sampling strategies can include other types of samples or methodologies. Geophysical surveys can be useful for identifying contamination sources (such as buried drums, tanks, or dry wells) or preferential pathways (such as utilities or buried pipes). High-resolution site characterization, such as use of a membrane interface probe (MIP) can aid with identifying source areas in soil or contaminant migration in groundwater.

A detailed discussion of sampling strategies and technologies is outside the scope of this document. However, EPA, states, and industry groups have written various documents and SOPs that may be helpful in developing a sampling strategy. EPA's Contaminated Site Clean-Up Information (CLU-IN) website offers more information on technologies, strategies, and tools useful for VI investigations.

5.3 DATA QUALITY OBJECTIVES

DQOs are documented and executable laboratory and sampling requirements to ensure achievement of target COC concentrations and screening levels. DQOs include specifications for COC screening levels, laboratory reporting limits, sample duration, sample containers, sample collection techniques, quality assurance/quality control (QA/QC) samples, and other objectives to be followed/used to assess the threat to human health and the environment. DQOs are discussed before sampling and documented in a sampling and analysis plan (SAP) or Quality Assurance Project Plan (QAPP). The main DQO elements are discussed in greater detail in the remaining portions of this section.

The site team establishes laboratory and sample requirements by first identifying COCs based on site history and previous investigations. Many OSCs and RPMs choose a targeted subset of VOCs that directly relates to the site. For example, the analytical suite for a dry cleaner site with PCE contamination should include degradation products of PCE, such as TCE; *cis*-1,2-DCE; *trans*-1,2-DCE; and vinyl chloride. In this example, the site team may choose to exclude benzene, despite elevated background readings from petroleum products such as gas cans, gas-fueled power equipment, paints, etc., because benzene was not used at the site.

The team establishes screening levels in consultation with agency risk assessors or partners (i.e., state health departments, ATSDR, etc.). Screening levels are applied based on building use, i.e. residential or commercial. Once screening levels are established, the team should consult the laboratory to verify that reporting limits are lower than the screening levels. For example, if the indoor air screening level for TCE is 0.4 ppbv (2.15 $\mu g/m^3$), the laboratory's reporting limit for TCE should be equal to or less than this value. Laboratory reporting limits are determined by reference to the laboratory analytical method and capabilities of sample containers.

Collection of QA/QC samples should be based on DQOs. QA/QC samples may include trip blanks, field blanks, media blanks (i.e., lot blanks), duplicates, and spikes. QA/QC samples are collected to identify errors of contamination in sample collection and analysis. Types and frequencies of QA/QC samplings should be discussed with the laboratory or chemist, and documented in a QAPP or SAP prior to sampling.

5.4 VISL CALCULATOR

EPA's VISL calculator identifies chemicals that are sufficiently volatile and toxic to warrant an investigation of the VI intrusion pathway when present as subsurface contaminants (EPA 2019a). VISLs are screening level concentrations for groundwater, soil gas (target sub-slab and near-source), and indoor air. These screening levels are determined based on exposure scenarios, attenuation factors (AF), groundwater temperature in addition to other variables.

Region 5's policy relies on actual sample data consistent with the multiple lines of evidence approach to determine whether to take an action. For example, if groundwater concentrations are above VISLs do not provide enough data to take further action, but instead may indicate the need for collection of soil gas, sub-slab, or indoor air samples. Therefore, the VISL calculator is a tool to evaluate sample results. Additional details on using the VISL calculator and determining screening levels are provided in Section 8.0. Use of the VISL calculator should be accompanied by consultation with a risk assessor to verify that the exposure scenario, CR levels, and HQs are correct/appropriate. To determine correct inputs, the user of a VISL calculator should be knowledgeable about groundwater temperature and attenuation factors.

5.5 SAMPLING STRATEGY CONSIDERATIONS

This section addresses site-specific situations such as sampling at large sites; building types and property use, including those sites without buildings. This section also includes a discussion of the VISL calculator. These strategy considerations do not include all scenarios that may be encountered during a VI investigation, but are limited to frequent issues or issues stemming from regional policy.

5.5.1 Large Sites

Large VI sites are those with a great number of potentially-affected properties. Sampling every potentially-impacted building at a large site may not be possible. For example, EPA may not be able to obtain access for all properties. The multiple lines of evidence approach as discussed in Sections 2.3 and

5.2 should still be followed but on a broader scale and with an emphasis on delineating the boundaries of contamination. Once the site team has defined the contaminant boundaries, the team should prioritize sampling buildings closest to the source. The next priority would be given to properties within 100 feet of a groundwater plume.

5.5.2 Building Types

Buildings completed below grade with basements or partial basements may be prone to VI for several reasons. Floors and walls may have small voids and cracks that allow soil gas to enter the building. Basements with earthen floors are especially susceptible to VI because of the large surface area for soil gas migration into the overlying structure, especially if ventilation is not present to dilute significant vapors. Finished basements (with living spaces) also can be of concern because of a combination of insufficient ventilation and frequent use. Other “red flag” buildings include those with basement sumps, walls with moisture barriers, and walls that are wet during the rainy season. Drywells, cisterns, or other voids below basements can be preferential pathways for VI.

There are generally five types of buildings with four types of basement and/or crawl space arrangements. When sampling a crawl space, the sampler should determine if it meets the requirements of a confined space and adjust sampling according to health and safety guidelines.

- Concrete floor – Basements with concrete floors can be finished or unfinished. Initially, at least one sub-slab and one indoor air sample should be collected at a concrete-floor basement, preferably near the middle of the basement.
- Concrete floor with dirt crawl space – Sometimes a section of the basement has a concrete floor and is next to a crawl space lined with dirt or rock. Initially, at least one sub-slab sample should be collected within the concrete-floor section of the basement, and one indoor air sample should be collected within the crawl space area.
- Dirt floor – At a basement with an all-dirt floor, the sample team should collect only one indoor air sample. There is no need to collect a sub-slab sample. Some basements may have a partial slab large enough to allow vapors to accumulate under the slab and to allow installation of a sampling port. Rock outcrops in basements can provide routes for seepage of contaminated groundwater and vapors, and in these cases, indoor air sampling should occur.
- Dirt crawl space only – Structures with only a dirt floor crawl space beneath the living space should have a sample collected in the crawl space and in the living space.
- Slab foundation (no basement) – Initially, at least one sub-slab and one indoor air sample should be collected at the main floor. The sample should be collected near the middle of the structure. The sample team should place the sub-slab port where it will not damage finished flooring.

Residential Buildings

Region 5 defines residential properties as those properties that contain single and multi-family dwellings, including apartment complexes. The OSC or RPM should use residential screening levels for these properties.

Schools, day care centers, and nursing homes may also be considered residential properties in some circumstances. These facilities often contain sensitive populations that may be adversely affected by exposure to hazardous vapors. Region 5 recommends consulting with a risk assessor to develop screening levels for these properties.

Industrial or Commercial Buildings

Industrial and commercial buildings may present challenges during a VI investigation stemming from variations in population that could occupy the buildings, ownership (private versus municipality), use of site-related COCs, and ability of the owner or tenant to fund the investigation/mitigation. For these reasons, the OSC or RPM should consult management whenever industrial or commercial buildings are part of a VI investigation. Below are general sampling strategy considerations to assist the OSC or RPM in determining if an action is required at industrial or commercial buildings.

Typically, OSCs and RPMs should investigate VI at commercial and public-use buildings where the public may be present. Industrial or commercial non-residential settings should have low priority if the public or sensitive populations are not expected to be present or if site COCs are used by the facility. Under some scenarios, the Region's policy may be to investigate the building but allow the building owner or tenant to provide the remedy.

Screening levels for industrial and commercial structures differ from those for residential structures. For most industrial and commercial buildings (except hospitals), the screening levels should be based on an eight-hour-per-day building occupation time. Screening levels may also change based on occupants. For example, hospitals tend to have sensitive populations, which may change the screening strategy.

The building configuration may result in a different sampling strategy due to larger or changing ventilation systems and types of work performed throughout the building, along with many other variables. Ventilation poses an issue because of zones of influence, potential for negative pressure (depending on activities), or chemicals used in adjacent rooms. Discussion of sampling strategy with the building maintenance person before initiation of the investigation is recommended to identify these conditions and any subsurface utilities. It may be difficult to remove household/industrial VOC sources from commercial buildings prior to collection of indoor air samples due to the quantities of products maintained and the natures of the businesses.

5.5.3 Sites Without Buildings

Multiple lines of evidence should go into an assessment of VI into future buildings or structures to be constructed at a site—including site history, planned future site use, groundwater data, groundwater depth, soil-gas data, soil concentrations, soil characteristics, subsurface geology, and modeling results (i.e., via the VISL calculator). After obtaining several lines of evidence, the OSC or RPM can determine need for ICs or other mechanisms as administrative tools to limit potential for VI into future buildings.

6.0 SAMPLING METHODOLOGY AND PROCEDURES

This section presents information on sampling methodology and procedures for the VI sampling strategy outlined in Section 5.2. This section includes discussions of sample containers, sampling procedures and methodology, and data management. Topics include a broad range of sampling methodologies that may be applied based on DQOs, site-specific conditions, and potential environmental or human health receptor(s). RPMs and OSCs should prepare and document the sampling methodology in a SAP before initiating a VI investigation. Typically, multiple sampling locations and multiple sampling events are necessary to characterize VI conditions.

Prior to some sampling (e.g., soil gas and sub-slab soil gas), equilibrium time, leak testing, and purging may be necessary. This section includes subsections that address sampling methodologies for sampling of groundwater, soil gas, sub-slab air, indoor air, ambient air, and multiple media. Each of these subsections includes a discussion of sampling design, best practices, and unique considerations for performing a VI investigation of that medium.

6.1 GROUNDWATER SAMPLING

Groundwater sampling or characterization is helpful to delineate the nature and extent of a contamination plume and to determine soil gas sampling locations. Groundwater characterization may be conducted through a monitoring well, groundwater grab samples, or through use of high-resolution groundwater characterization tools, such as the MIP. The site team should select groundwater locations to assess sensitive areas (i.e., residential neighborhoods, schools, etc.) for potential VI issues. Data such as groundwater flow direction and concentrations of volatile chemicals may indicate areas where additional investigation is necessary.

Assessing groundwater in a VI investigation involves special considerations that differ from a traditional groundwater assessment. For example, the position of the monitoring well screen should be targeted to a narrow interval (a few feet or less) within the uppermost portion of the shallowest aquifer. The objective is to assess groundwater contamination that may volatilize and become a source for VI. In some cases, it may also be necessary to determine which aquifers are affected by VI-producing contaminants, and whether these contaminants have migrated below any confining geological layers. RPMs and OSCs should consult established guidance documents pertaining to the installation of monitoring wells (ERT SOP 2048), sampling of groundwater (ERT SOP 2007), and arrangement for chemical analysis (Scientific, Engineering, Response, and Analytical Services Contract [SERAS] 2018 and 2017b).

6.2 AIR SAMPLING

Air sampling is critical for decision-making at VI sites. Samplers must make decisions regarding sample duration, type, location, and QA/QC protocols prior to sample collection. This subsection presents information to ensure that air samples are collected in a way that fulfills project DQOs.

6.2.1 Sample Containers and Laboratory Analysis

Region 5 most frequently uses evacuated canisters as sample containers for soil gas, sub-slab, and indoor air sampling; however, air sample bags and passive or active sorbent sampling also may be appropriate. In this section, the generic sample container name will be used instead of the colloquially known name (i.e., "SUMMA" being an evacuated canister and a "Tedlar® bag" being a gas sample bag). This change in semantics acknowledges the variety of products available and avoids endorsement of any manufacturer. Sample containers are generally divided into two classes for laboratory analysis: (1) evacuated canisters and gas sample bags that collect "whole air" samples, and (2) sorbent samplers that collect specific chemicals based on the adsorbent. The main advantage of whole air samples is ability to analyze multiple sub-samples from one container. Table 6-1 below presents a matrix of air sample container options. A more thorough discussion of sampler options, overview of deployment, and examples of available laboratory analyses is presented after Table 6-1.

Table 6-1. Air Sample Container Matrix

Container Type	Description	Pros	Cons
Evacuated canister	Typically, a stainless-steel vacuum device with a regulator that controls flow at a constant rate over time	• Can be used for time-weighted and grab samples • Widely available from most laboratories • Well studied for certain methods • Reusable with cleaning and lab certification	• Not suitable for all COCs, e.g. PCBs • Connections may leak if the sampler is inexperienced in set up • Expensive to rent, clean, and ship
Sample bag	Sealed, inert bag fitted with a valve that allows air to enter by placing the bag into a vacuum bag sampler connected to an air pump	• Works well for grab samples • Cost effective	• Short holding time (less than 24 hours) • Not appropriate for time-weighted samples • Some COCs may react or diffuse through the bag
Sorbent sampler	Hollow containers with adsorbent media that binds chemicals in vapors; can be used actively (with a pump) or passively	• Can be deployed for longer time periods • Available for a wide variety of COCs	• COC specific • Uptake rates have not been established for some compounds • Some sorbents retain moisture, biasing reported concentrations • Care must be taken to avoid potential cross-contamination
Real-time analysis	Typically, a GC/MS unit that may be paired with another detector	• Works well for quickly collecting screening data • Some units are field portable	• May require specialized training to operate • May not be suitable for collecting laboratory-quality data

Evacuated Canisters

Evacuated canisters are typically stainless-steel canisters of various shapes—polished and/or coated with an inert, sometimes proprietary material. Under sub-atmospheric pressure these containers passively draw air into the canister. An evacuated canister may also be a glass bottle that is inert, clean, and under sub-atmospheric pressure; however, this type is mainly used to collect a grab sample. For time-weighted average sampling, a regulator controls flow by allowing entry of air into the canister at a constant rate over time. Evacuated canisters are typically one, six, or 15 liters, with regulators calibrated to collect a sample over a 24- or eight-hour period. Grab sampling does not usually involve use of a regulator, as collection occurs by opening the valve to the evacuated canister.

The laboratory will clean and test the canisters for leaks prior to deployment. Laboratories typically use two types of procedures to certify cleanliness—batch (or lot) and individual. During batch testing, the laboratory tests a subset of cleaned canisters (typically one out of every 10 or 20 canisters) for VOC constituents. The laboratory then "certifies" the batch as clean if no or low concentrations of VOCs are present. Through extrapolation, the entire batch is then "batch-certified" clean. Alternatively, the laboratory may test each canister for "individually-certified" clean. The purpose of individually certifying each canister is to lower the uncertainty that VOCs may be present and, in some cases, lower detection limits. However, individually-certified clean canisters are more expensive than batch-certified clean canisters.

Batch-certified clean evacuated canisters are typically used for subsurface air sampling because screening levels are higher and, therefore, reporting limits may be higher. Individually-certified clean evacuated canisters are used for indoor air or ambient air sampling. Sampling staff should be aware that both batch-certified and individually-certified clean evacuated canisters may be shipped concurrently, and thus the staff should ensure placement of an appropriately-certified canister at each sampling location.

Once a canister is deployed, sample team should collect a pressure gauge vacuum reading and record the value. An initial vacuum reading typically is less than -28 inches of mercury (Hg). Typically, the sample team should turn off flow to the canister when the pressure reading is between -1 and -10 inches of Hg. The slight negative pressure ensures that the canister fills over the entire planned sampling period. If the canister flow controller shows 0-inches Hg (atmospheric pressure), samplers have no way of knowing if the canister filled over the planned sampling duration or over a shorter timeframe. At the end of the sampling period, the sample team should read and record the pressure gauge vacuum. Region 5 recommends an ending vacuum reading between -1 and -10 inches of Hg to indicate collection of a valid sample. If the final vacuum reading exceeds -10 inches of Hg or is less than -1 inch of Hg, another sample should be collected.

The most common laboratory analytical method for evacuated canisters is EPA Method Toxic Organics 15 (TO-15) in full scan mode. EPA Method TO-15 can detect VOC concentrations at and above their screening levels in soil gas, sub-slab soil, or indoor air. For sites that require lower laboratory reporting limits, the sample team should request EPA Method TO-15 in Selective Ion Monitoring (SIM) mode. Reporting limits for TO-15 SIM can be an order of magnitude lower than those of application of TO-15. The sample team may use other analytical methods, depending on targeted COCs, sample methodology, and sorbent samplers. The team should consult with a chemist before initiating sampling to ensure that laboratory reporting limits are at or below screening levels.

Air Sample Bags

Air sample bags are sealed, inert, and fitted with a valve that allows air to enter the bag. Sample bags vary in thickness and are manufactured using various blends of proprietary material(s) (e.g., Tedlar®, Kynar®, etc.) that help prevent air from reacting and diffusing through the bag material. Due to the material limitations, sample teams should use sample bags for collection of grab samples and not for collection of time-weighted samples (eight-hour, 24-hour, etc.). Sample bags are usually used for determination of the VI pathway.

Figure 6-1. Air Sample Bag Sampling Setup

A sampler collects a sample by placing the sample bag inside a vacuum bag sampler, attaching the sample tubing into the vacuum bag sampler, then into the sample bag, and finally attaching a pump to the vacuum bag sampler (Figure 6-1). The pump removes the air inside the vacuum bag sampler, thus creating differential pressure between the sample bag and the location of the sample (i.e., subsurface air), thereby filling the sample bag. Region 5 recommends that the sample team does not fill the sample bag directly by use of the air sample pump because of the possibility of cross contamination with the sampling pump.

The holding time for a sample bag is typically 24 hours, which may limit use of off-site laboratory analysis. Samples shipped by air must be transported in an air-tight container or within a container of reduced volume to avoid rupture of the sample bags due to pressure changes. Analytes may diffuse out of or into sample bags, resulting in samples with lower or higher analyte concentrations than present immediately after collection. Region 5 does not recommend shipping sample bags off-site for these reasons.

Methods for laboratory analysis of sample bags include EPA Method TO-3, EPA Method TO-18, and, in some cases, EPA Method TO-15. Concentrations of VOCs collected in sample bags may be present in parts per trillion. The sample team should consult a chemist before initiating sampling to ensure that laboratory reporting limits are below screening levels.

Sorbent Samplers

Sorbent sampling devices are hollow containers that hold one or more adsorbent media that can bind with chemicals in vapors. A sorbent sample may be collected by allowing the air to diffuse into the adsorbent medium (passive sorbent sampling) or actively moving the air through the adsorbent medium/media (active sorbent sampling). Each type of sorbent sampling is described below.

Passive Sorbent Sample Device

Passive sorbent samplers come in many forms that include badges, glass tubes, or various types of other containers. These collection devices operate by exposing the sorbent material to the investigation area (indoor air, sub-slab, etc.) for a duration of time, after which samplers seal the device for shipment to a laboratory for analysis. The laboratory calculates the concentration based on sampling duration, mass of COC adsorbed, and the uptake rate (expressed in milliliters per minute). Uptake rates vary based on many factors that may include design of the device, sorbent used, COC under investigation, and meteorological conditions (e.g., humidity, temperature, etc.), among others. However, because no mechanism delivers air through the sorbent material, sample duration can be extended to greater than the 24 hours typical for collection via evacuated canisters and air sample bags.

Site COCs and the deployment location determine the type of sorbent material and design for use at a site. Uptake rates of some COCs by some sorbent materials have not been established, and thus these materials may not be used for a VI investigation. Certain sorbent materials are better at retaining weakly sorbed compounds (e.g., vinyl chloride, chloromethane), and some are better at retaining strongly sorbed compounds (e.g., naphthalene). Device design may be important depending on the deployment location because some sorbents retain moisture, thus biasing reported COC concentrations. Moreover, some sorbent devices are designed with the option of multiple uptake rates to facilitate a longer or shorter sampling duration. Because of the complexities involved in choosing sorbents and sample containers, the sample team should consult with a chemist with expertise in VI sampling during development of the SAP.

Personnel deploying passive sorbent devices should be aware of potential cross contamination that may occur inadvertently during sampling. Use of a solvent-based marker, exposure from nearby traffic, certain sun-tan lotions, or improper sealing of the sample may adversely affect reported chemical concentrations. Other potential biases during passive sorbent sampling include starvation (device withdraws target compound faster than it is replenished, associated more with soil gas sampling) and advective uptake (wind causing a higher uptake) (Naval Facilities Engineering Command [NAVFAC] 2015). Other biases, such as poor retention and recovery, relate more to sorbent selection than sample placement during a VI investigation.

Manufacturers or laboratories may provide certification of quality and associated uptake rate for the target COC. Additional QC checks of the sorbent sampling devices must occur, such as use of trip blanks (to assess contamination during shipping) or media blanks (to identify contamination introduced during manufacturing) based on requirements in the SAP. Laboratory analysis of the sorbent material may proceed via carbon disulfide extraction and GC/MS, or via EPA Method TO-17, depending on the type of sorbent deployed.

Passive sorbent samplers have been developed and tested over several decades for industrial hygiene monitoring, and more recently have been tested for use in VI investigations. In a study funded by the U.S Department of Defense (DOD), five passive samplers were deployed in various VI investigations (indoor air, ambient air, sub-slab, and deeper soil vapor) and compared to data from evacuated canister sampling (McAlary 2014). Results of the study indicated comparable reported concentrations in the passive sorbent samples and the evacuated canisters. The study also identified conditions causing poor results and suggested recommendations that sample teams should consider during development of a sampling plan. Sample teams should consult with persons with expertise in passive sorbent sampling for advice on each project until best practices and SOPs are developed by government, industries, or academia.

Active Sorbent Sample Device

An active sorbent sample device is typically cylindrical and contains sorbent material. The main difference between passive and active sorbent sampling is use of a mechanical pump during active sampling to pull air through the device at a known flow rate. The laboratory's ability to detect a result comparable to the screening level for a COC depends on the flow rate and concentration of that COC on the sorbent. Sample duration is limited by the amount of time the mechanical pump can operate and the volume of air the sorbent material can take before "breakthrough" occurs, i.e. a detectable level of the COC eluting from the non-sampling end.

Active sorbent sampling is more common than passive sorbent sampling and, therefore, sorbent devices have been incorporated into certain EPA laboratory methods. Several sorbent devices for VOC analysis can be used in EPA Method TO-17. Therefore, selection of sorbent material for active sorbent sampling is less uncertain than for passive sorbent sampling. However, additional precautions are necessary to avoid issues with the mechanical pump and breakthrough. EPA ERT has established protocols to calibrate certain mechanical pumps (EPA ERT SOP 2130). To prevent breakthrough, flow rate should conform to that recommended by the laboratory analytical method. Certain precautions in sampling follow those discussed in the passive sorbent sampler section, such as preventing exposure to moisture and to non-investigatory VOCs, sealing sample containers during shipment, and shipping sample containers on ice or at reduced temperatures. To ensure a non-biased sample, the laboratory should provide certification of cleanliness of the sample containers, and the sampler should follow protocols established in the site SAP regarding media and/or trip blanks.

Real-time Analysis

Real-time analysis can be useful during VI investigations for quickly assessing contaminant pathways and identifying potential sources, receptors, and pathways. Depending on DQOs, quality of real-time data may not be at the level necessary for human health exposure determinations but may narrow the investigation area to allow better allocation of resources. The RPM or OSC should consult with a chemist or risk assessor to determine DQOs and whether real-time analysis is appropriate for a site.

The main device used to perform real-time analysis is a GC/MS unit. Sampling tubes or air sample bags are connected to the GC/MS unit to screen a variety of areas where VI may occur (i.e., cracks in basements, utility conduits, indoor air, etc.). EPA's Trace Atmospheric Gas Analyzer (TAGA) provides GC/MS capabilities, which can also be provided by other commercially available products. Personnel knowledgeable about the real-time analytical system should aid in operation of the equipment until field staff become capable. Brief discussions of the EPA/ERT TAGA and other commercially available portable GC/MS units follow.

EPA TAGA Bus

The EPA TAGA bus is a National Environmental Laboratory Accreditation Program accredited to apply modified TO-15 Method, EPA Method 8021B Modified, or EPA Method 8260 Modified (Figure 6-2). A mobile laboratory, such as the TAGA bus, can expedite site characterization in VI investigations. Mobile laboratories can be cost effective for a large number of samples. However, mobile laboratories may be more operator-dependent than analyses of samples completed at a fixed laboratory.

Figure 6-2. EPA TAGA Bus

Region 5 has used ERT's TAGA to analyze soil gas and indoor air samples at VI sites. ERT's SERAS contractor operates the TAGA. At the Highway Seven and Wooddale Avenue Project in St. Louis Park, Minnesota, the SERAS contractor installed approximately 268 sub-slab sample ports at residential and commercial/industrial properties. The TAGA unit analyzed sub-slab air samples via a modified EPA Method TO-15 analysis. The sample team compared results to screening levels established by the state health department.

The TAGA unit is self-contained and capable of real-time monitoring (at the parts-per-trillion-by-volume level) of outdoor air, indoor air, and emissions from various environmental sources. Each TAGA unit is equipped with the TAGA triple-quadruple mass spectrometer and an Agilent GC/MS for VOC analysis (Figure 6-3). Three TAGA systems are available. One TAGA bus is in Edison, New Jersey; one TAGA bus is in Las Vegas, Nevada; and a TAGA truck is located in Research Triangle Park, North Carolina. More information concerning the TAGA laboratories, their capabilities, and their schedule is available from ERT.

Figure 6-3. Instrumentation in a TAGA Bus

Commercially Available Real-Time Analytical Equipment

Various portable, real-time analytical systems are available for use in a VI investigation (Figure 6-4 below). Most of these systems are small, portable, GC/MS units or general detector systems, and can fit into a standard sport utility vehicle. Users should follow the appropriate SOPs for calibration and operation of the portable GC/MS units. Sample teams should consult with a chemist to determine if the analysis would meet DQOs for a site. Advantages of these commercially available, real-time analytical systems over the EPA TAGA bus are their convenience, as they are easily portable, and able to be rented from multiple sources, with training usually included with the rental.

Figure 6-4. Commercially Available GC/MS System

6.2.2 Air Pre-Sampling and Sampling

To establish a traditional vapor intrusion pathway, samplers show COCs present in groundwater and exterior soil gas prior to concurrently sampling sub-slab and indoor air at individual buildings (Figure 6-5 below). Air sampling involves pre-sampling activities, which may include leak testing to ensure absence of leaks in the sample assembly and purging of air. Both activities depend on the medium collected (e.g., ambient air sampling does not require purging while soil gas may). Because sample collection techniques vary based on the medium, sampling guidance will be limited to a broad discussion of sample collection, nomenclature, and documentation.

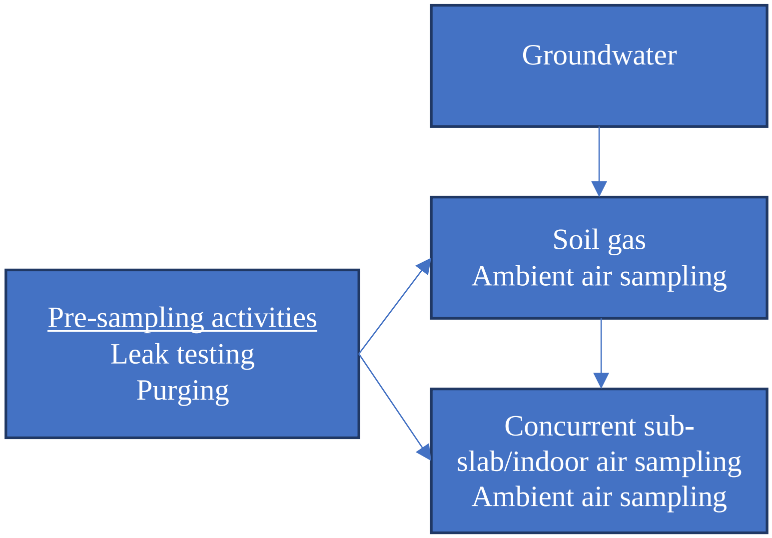


Figure 6-5. Traditional Pathway Sampling Flowchart

Leak Testing

Region 5 recommends leak testing to assess the integrity of the sampling assembly by providing quantitative proof that breakthrough of air is not occurring into the sub-slab sampling port, sampling train, or sampling medium (e.g., evacuated canister). Region 5 samplers should conduct leak testing each time a soil gas or sub-slab sample is collected. The variety of methods for leak testing include one or more of the following: (1) shut-in leak test (depressurize the sampling train to determine if pressure increases over time); (2) shroud leak test (inject gas [e.g., helium or other inert gas] into a shroud containing the sampling port, sampling train, and sampler, and then sample air from the sampling train to determine if gas is present) (Figure 6-6); (3) laboratory leak tracer test (apply tracer compound [e.g., isopropyl alcohol] near connections in the sampling train and analyze for the tracer compound when analyzing the sample); and (4) water dam test (place water dam around sampling port to determine if water leaks into the foundation). Type and frequency of leak testing will be determined according to use of permanent or semi-permanent sampling ports, sampling medium (SUMMA canister, adsorbent tubes, passive sampler, etc.), and location of the sampling port. All leak testing should follow SOPs or best practices developed by federal or state agencies, common industry practices, or published research. The appropriate types of gas or tracer compounds are discussed in Section D.4.7 of the 2007 ITRC guidance, and in other federal or state guidance that should be consulted prior to usage (ITRC 2007).

Figure 6-6. Helium Leak Test Using Shroud

Exercise caution when performing leak testing that could interfere with the laboratory analysis. For example, placing 99 percent (%) isopropyl alcohol near a sample port or sample train connections could interfere with the laboratory analysis of the target compound (if a substantial leak occurs). Similarly, a water dam test could introduce water into the subsurface and into the sampling device, interfering with the analysis and damaging the SUMMA canister. Most federal, state, and industry SOPs or guidance allows for a set amount of leakage during testing. The acceptable range of leakage should be documented in the SAP and communicated to field staff prior to site activities.

Purging

Samplers should purge the sampling assembly before collection of a sample. Ambient air may infiltrate the sampling port during the drilling and installation process, and infiltrate sample tubing during preparation of the sampling assembly. Purging the sampling assembly could help reduce infiltration of ambient air that may occur during assembly of the connection between the sampling port and the sampler. The amount of purged air should be the same as in the sample tubing and the area immediately surrounding the soil gas probe. The sampler should follow SOPs or best practices developed by federal or state agencies, common industry practices, or published research when determining methods to remove ambient air, flow rate, and amount to purge. In some cases, SOPs or best practices may specify purge of air from the sampling assembly but not from the sampling port.

Sample Collection

Sample collection combines all aspects of a VI investigation described above to achieve DQOs and fulfill the requirements of the sampling event specified in the SAP. There are a large number of sampling approaches and options for analytical testing. This section describes sample collection in general terms.

In construction of the sampling train, extend inert flexible tubing (e.g., polyvinyl chloride [PVC], high-density polyethylene [HDPE], Teflon, etc.), unreactive with the COC analytes, from the sampling port or location to the sample container. Collection of ambient air and indoor air samples may not require a sampling train, depending on the sample container used. Leak testing or purging may be necessary after completion of the connection, based on DQOs. To collect a sample, the user should follow container-specific sampling SOPs such as ERT SOP 2103 for Charcoal Tube sampling in ambient air (i.e., sorbent sampling), ERT SOP 2102 for Tedlar Bag sampling (i.e., air sample bag), ERT SOP 1704 for SUMMA Canister sampling (i.e., evacuated canister), or other industry-accepted SOPs approved by an RPM, OSC, or chemist in the SAP (SERAS 2017c, 2017d, and 2015).

The sample team should use a unique sample designation number for each sample. For example, include the Site identification (ID) or Property ID-Matrix-Sublocation-Sample ID-Date, e.g. C54X-RP036-AIR-AA-01-121718. Region 5 recommends using a unique coded identification number for residential samples to protect PII. Residential sample IDs should not include any part of the address or parcel number. Additionally, the sample team should avoid using permanent markers emitting VOCs because VOCs from the marker could interference with sample analysis.

Information pertaining to each sample should be recorded on the Air Sampling Field Form (Appendix D), in the logbook, or on an electronic data collection form. At a minimum, this information should include the sampler’s name, sample ID, start and end vacuum or flow rate and time, and location of the sample. Other information may include temperatures at start and end of the sampling period, atmospheric pressure, basement depth, equipment serial numbers, sample type (such as baseline, post-mitigation, etc.), and any comments. Samplers should take photographs of the sampling event, including the inside and outside of the property where the sampling occurred. Location of the sample should be described as the type of room and distance from nearby walls.

6.2.3 Soil Gas Sampling

Soil gas sampling is used to locate and characterize subsurface vapor sources and migration routes. Soil gas sampling generally involves installing a probe into the ground, drawing gas out of the probe, and collecting the gas for analysis. The following sections discuss temporal, spatial, and special considerations for soil gas probe locations.

Temporal Considerations

Temporal considerations for soil gas sampling include rain events and barometric pressure, which may affect sampling results at certain depths. Infiltration from rain events generally affects samples collected within three to five feet bgs or less in areas with porous cover (i.e., no vegetation or sandy soils). Sample depths exceeding three to five feet bgs tend not to be affected unless the groundwater table rises because of infiltration of precipitation. Soil gas samples should not be collected during rain events because of potential for water to infiltrate parts of the sample container or sampling train, thus compromising the sample. The 2007 ITRC guidance provides a more robust discussion on temporal considerations for soil gas sampling (ITRC 2007).

Spatial Considerations

Region 5 generally recommends collection of soil gas samples at multiple locations and depth intervals between the vapor source and building(s) (potential "receptors") due to spatial variability caused by a variety of factors—site geology, temporal considerations, and other factors discussed in this and other sections. The soil gas survey may include sampling immediately outside the building ("exterior soil gas") at various depths, and immediately beneath the building (sub-slab soil gas sampling). The soil gas survey should include collection of a "near-source" soil gas sample immediately above each source of contamination to help characterize the subsurface vapor source. Region 5 recommends that shallow soil gas samples be collected as close as possible to receptors (building) and at depths below the building foundation. Shallow soil gas samples should be collected no deeper than five feet bgs, depending on site-specific conditions (EPA 2015a). But be aware that soil gas samples collected shallower than five feet bgs may be diluted as a result of ambient air interference.

Special Considerations

Region 5 recommends collecting soil gas samples from the coarsest and driest medium in the vadose zone. Soil type may be determined via collection of soil samples during the investigation phase. Other possible areas of coarse and dry material may be within a utility corridor. However, it is not advisable to sample near utilities unless the location of the utility is known. Soil gas probes should be placed two to three feet above the water table.

Soil Gas Probe Installation and Abandonment

EPA ERT developed an SOP for soil gas sampling that includes procedures for construction and installation of sampling probes (ERT SOP 2042) (SERAS 2001). The 2015 OSWER Guidance provided best practices but did not include a revised SOP (EPA 2015a). This section builds upon the ERT SOP with best practices from the 2015 OSWER Guidance, commonly accepted industry standards, and state guidance. Before any subsurface work occurs, the site team should follow health and safety procedures, including development of a health and safety plan, a call to a utility locate service, etc.).

Soil gas probes may use hand or mechanical methods to set an inert probe at a desired depth. Several methods for installing soil gas probes include hand auger, slam bar, slide hammer, or direct-push. Installation methods vary based on site conditions. For example, maneuvering a direct-push drill rig next to a structure may not be possible during installation of a soil gas probe. Hand auger or direct-push methods may be used to recover soil to log soil type and/or collect and analyze oil samples if needed.

During soil gas probe installation, the screen may be advanced at the end of the drive rod or placed in a vacated borehole. Certain direct-push methods allow for sampling through the hollow drive rod via a retractable screen or connection of the sample tubing to the end of the hollow rod (i.e., post-run tubing). In all circumstances, the probe should be composed of an inert material, most commonly VOC-free stainless steel. Completion of the soil gas probe is similar to that of a groundwater monitoring well, whereby coarse material is placed surrounding the screen followed by a sealant (i.e., bentonite) to the surface (see Figure 6-7 for an example). When sampling through a hollow drive rod, the rod should be sealed to prevent penetration of aboveground ambient air from the subsurface.

Region 5 recommends that samplers allow time (equilibrium time) after soil gas probe installation before a leak test to allow subsurface conditions to equilibrate. This amount of time will depend on the installation method of the soil gas probe. For example, the California Environmental Protection Agency (CalEPA) recommends an equilibrium time of at least two hours for direct-push methods, and up to 48 hours for installation methods in fine-grained material, opened hole, or depths less than five feet bgs (CalEPA 2015). The SAP should include the method of soil gas probe installation and equilibrium time. Following equilibrium time, the probe is connected to the container, leak tested, purged (if applicable), and sampled.

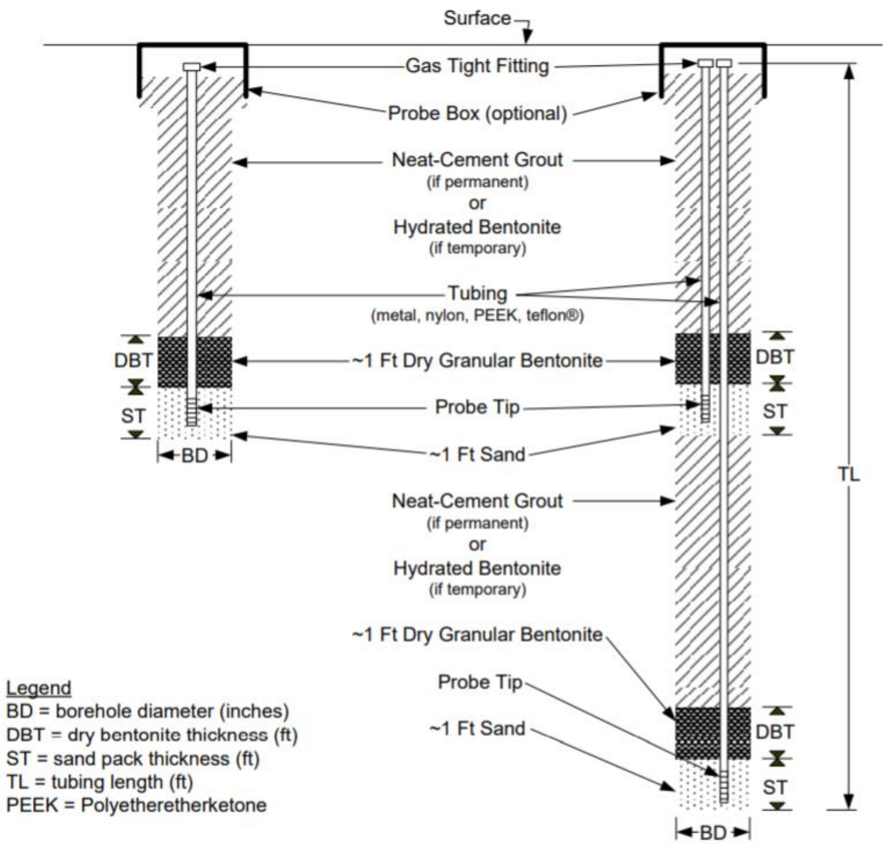


Figure 6-7. Example Soil Gas Probe Profile (CalEPA 2015)

Soil probe abandonment should be performed following the last anticipated sampling event. Abandonment should result in the sampling location being as close as possible to the original condition of the area. At a minimum, tubing should be removed to a depth where it will not interfere with the property's ascetics, the hole should be filled with bentonite, and the surface should be graded and filled to match the surrounding area (i.e. topsoil with grass seed, asphalt, concrete, etc.). The property owner should be consulted to determine if the completed abandonment is satisfactory.

6.2.4 Building Sampling

The OSWER guidance recommends sampling buildings within 100 feet of a source area or elevated soil gas sampling locations (EPA 2015a). Building sampling includes collecting air samples from sub-slab, crawl spaces, and/or indoor air. The following sections discuss each type of building sampling in greater detail.

Sub-Slab Sampling

Sub-slab samples are collected to characterize the air space immediately beneath the foundation of a building. Sub-slab air space is sampled by drilling or coring through the lowest floor (or slab) and inserting a probe. The following sections discuss methods for installation of the sub-slab probe, as well as temporal, spatial, and special considerations.

Temporal Considerations

Some temporal factors affecting sub-slab sampling include: (1) seasonal changes in building depressurization stemming from use of fireplaces, heaters, or air conditioners; open windows; barometric pressure; and/or wind; (2) movement of subsurface soil gas induced by pressure gradients caused by diurnal and longer-term atmospheric pressure changes; and (3) effects of temperature on contaminant partitioning. Ideally, these factors should be considered when developing a SAP and evaluating data. The 2015 OSWER guidance recommends collecting samples in multiple seasons (EPA 2015a).

Spatial Considerations

The site team should consider spatial variability in sub-slab soil gas when selecting sampling locations. Sampling results may indicate variation in contaminant levels measured in sub-slab soil gas even when COC concentrations at the source are consistent and the subsurface material is relatively homogenous. Therefore, at least one sub-slab soil gas sample should be collected at each property of concern. If a single sampling location is used, this should be at the lowest point of the property (such as the basement) and approximately in the middle of the room, where concentrations are expected to be highest and to represent the greatest radius of influence of sub-slab soil gas across the footprint of the basement. However, the selected sampling location may be dictated by availability of locations for sampling and owner approval. Some buildings do not have slabs or basements. For those, buildings, the site team should collect a crawl space sample in lieu of a sub-slab sample, assuming that the crawl space is present and accessible. Crawlspace sampling is described later in this section.

If more than one sub-slab soil gas sample is collected, sampling locations should be spaced to adequately cover the floor space of the basement or lowermost floor. Region 5 recommends collecting multiple sub-slab samples at schools and multi-family homes, basements divided into sections by a concrete footer, and basements or slabs with areas exceeding 1,500 square feet (sq ft).

Collection of several sub-slab samples at a building may not be practical because of (1) construction considerations (such as the presence of utilities, floor condition, floor materials, finished basements, post-stressed concrete, etc.), (2) reluctance of the owner to grant permission to install multiple sampling ports, and (3) cost/time considerations. However, wherever possible, the site team may consider installing multiple ports at approximately 10 percent of sampled buildings to evaluate variability across or slab or foundation.

Certain situations trigger the need for additional (or possibly fewer) sub-slab sampling locations other than those recommended above. These situations include very large or small homes or buildings, buildings with more than one slab floor type, subsurface structures or conditions that could facilitate or mitigate VI, multi-use buildings with sensitive populations in segmented areas (such as day care facilities), and areas of buildings directly above the subsurface with constant occupancy (rather than occasional occupancy). Regarding larger structures, a statistician can help determine numbers and placements of sampling ports to ensure attainment of DQOs.

Special Considerations

Considerations for sub-slab sampling are listed in Section D.6 of Appendix D to the 2007 ITRC Guidance, and in Section 6.4.3 of the 2015 OSWER Guidance. These are summarized as follows (ITRC 2007, EPA 2015a):

- Avoid sub-slab sampling in areas where groundwater could intersect the slab.
- Locate and avoid underground utilities and structures (such as electric, gas, water, tension rods, in-floor or radiant heating, and sewer lines).
- If a vapor barrier is in place under the slab, sub-slab sampling could puncture the barrier and thus should not occur.
- In basements, primary entry points for vapors could be through sidewalls rather than through the floor slab, especially where a building is near the contamination source area; in this case, additional sampling may be necessary via collection of samples through basement walls. Consider the type of sidewall (concrete, brick, cinder block, etc.) before installing sampling ports in basement walls.
- Utility penetrations and sumps may also be entry points for vapors and could checked using a photoionization detector (PID) or other real-time VOC detection equipment. The sub-slab investigation may be modified based on the results.
- Consult with property owner if installing a sub-slab sampling port in a finished basement to avoid disturbing finished floors or walls. The property owner may also have knowledge of the location of the utilities.

Sub-Slab Port Installation and Abandonment

This section builds upon the ERT SOP by combining best practices from the 2015 OSWER Guidance, commonly accepted industry standards, and state guidance (EPA 2015a).

Sub-slab sampling ports may be installed for permanent or semi-permanent use depending on the sampling strategy and access to the property. Samplers install permanent and semi-permanent sampling ports by drilling a hole through the building foundation into the underlying porous material (Figure 6-8). If the port is to be permanent, the sampler inserts a brass or stainless-steel probe into the vacated hole and completed with cement grout or a non-reacting sealant. Alternatively, the sample team may complete the vacated hole with hydrated bentonite to be semi-permanent (Figure 6-9). Another semi-permanent option includes using the brass or stainless-steel probe inserted into the vacated hole and surrounded by a pre-manufactured silicon sleeve to form a seal. Both types of installation require an air-tight seal. However, sample teams should seal a semi-permanent port immediately after installation, however, permanent ports require time for the grout or sealant to cure.

EPA ERT SOP 2082 describes procedures to install permanent or semi-permanent sub-slab sampling ports (SERAS 2017a). Commonly acceptable procedures also have been established by federal or state agencies (e.g., DOD, OEPA, etc.), industry (e.g., ASTM International [ASTM], ITRC, etc.), or in published research (e.g., in *Environmental Science and Technology*, etc.). These SOPs and guidance include recommended supplies and equipment for installation of sampling ports. At a minimum, a vacuum equipped with a high-efficiency particulate air (HEPA) filter should be used during installation activities to minimize effects of concrete dust on the property and the sampler.

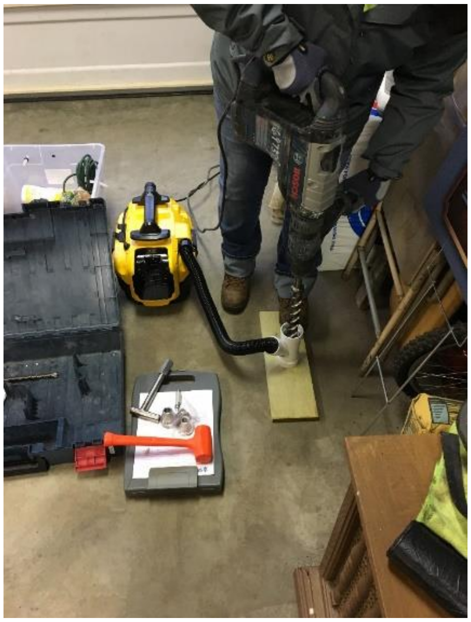


Figure 6-8. Installation of Sub-Slab Probe

Sampling teams can use flush-mounted or covered sub-grade sampling ports left in place during a long duration or a multi-sampling event. Samplers should not install sub-grade ports in areas that can fill with oil, water, or other liquids that can interfere with sampling the port. At buildings with thin foundations, sampling ports may have to be above grade, which poses potential trip hazards, which, in turn may affect the integrity of port sealing. If sampling team install sampling ports above grade, owners or occupants should be notified, and the sampling ports marked or blocked to prevent tripping or breakage. Following port installation, equilibrium time is necessary; discussion of equilibrium time appears above in the soil gas sampling section. Following equilibrium time, the sampler connects the probe to the sample train, conducts leak testing, purges (if applicable), and then collects a sample.

Sample teams should abandon sub-slab ports following the last anticipated sampling event. Abandonment should result in the sampling location being as close as possible to the original condition of the area. Permanent ports should be freed using cold chisels or by drilling small holes surrounding the port. Alternatively, the port could be permanently capped or sealed. A semi-permanent probe should be removed, and the port hole repaired to match surrounding areas. The team should consult with the property owner to determine if the abandonment method and result is satisfactory.

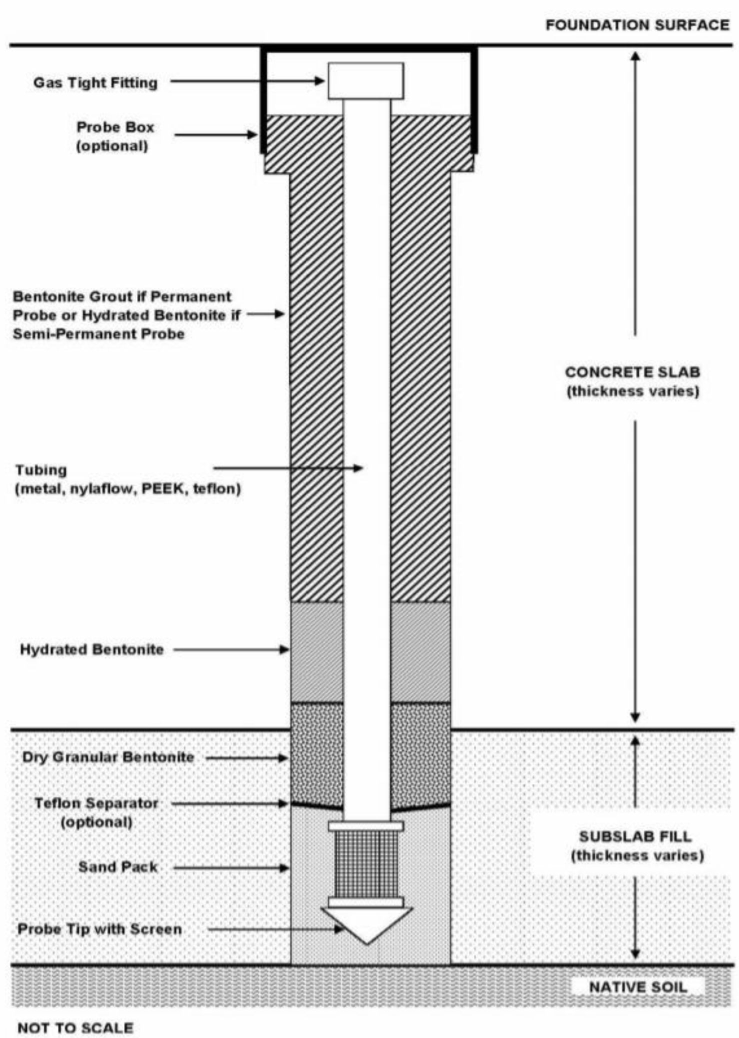


Figure 6-9. Sub-slab Probe Typical Diagram (CalEPA 2015)

Crawl Space Sampling

Crawl spaces represent the air under a building's living space. They typically constructed with dirt floors. As such, they do not impede vapor migration the same way that concrete slabs do (EPA 2015a). EPA Region 5 collects samples from crawl spaces where they are present. Some buildings have crawl spaces in conjunction with basements. In these cases, EPA Region 5 recommends collecting a sub-slab sample from beneath the basement and a sample from the crawl space.

Mobile homes with skirting around the bottom are enclosed spaces similar to crawl spaces. EPA Region 5 recommends sampling the air inside mobile home skirts in the same way crawl space samples are collected.

EPA conducts crawl space sampling using the same procedures as indoor air sampling, which is described later in this section. The sample team should place the sampling device inside the crawl space away from the center and sides, if possible. EPA Region 5 recommends locating sample containers away from the direct influence of forced air from air conditioning units, central air conditioning vents, furnaces, or heaters, if present in the crawl space.

Indoor Air Sampling

EPA collects indoor air samples to confirm presence or absence of a site-related COCs in the indoor environment and to measure concentration levels. The following sections discuss completion of the VI Resident Questionnaire, indoor air sampling prescreening, and indoor air sample collection.

VI Resident Questionnaire

The property owner or site team should fill out the VI Resident Questionnaire in Appendix E before collection of indoor air samples. The form records information about sources of chemicals within the residence that could be detected in indoor air samples. The form also captures property-specific information about household features that can aid interpretation of analytical data. The VI Resident Questionnaire form in Appendix E includes questions related to indoor air quality and building construction.

Many consumer products contain chemicals that can interfere with VI testing. Potential indoor air sources include household and consumer product chemicals such as paints, gasoline, dry-cleaned items, and nail polish remover. A secure location for storing the removed products should be identified (for example, an outside shed). Alternately, the items could be triple-bagged or placed in plastic bins in the garage or outside. An inventory of household or other products in the building that could be sources of volatile chemicals is particularly important if potential sources cannot be removed. Such an inventory often is useful even if the sources can be removed. The inventory should document all sources of volatile chemicals present (or formerly present) in the structure. Section 1.6.1 of the 2007 ITRC Guidance provides greater detail about this issue (ITRC 2007).

Therefore, the questionnaire should account for the variety of household products and building construction materials present in each household. The property owner, tenant, or sampling team should remove any products that may contain target compounds from residences and attached garages at least 24 hours before initiation of sampling. An example list of common household products that can cause indoor air contamination is provided in Appendix F.

Indoor Air Sampling Prescreening

Indoor air sampling prescreening includes a physical survey of the structure, the purpose of which is to obtain data for a qualitative assessment of factors that could influence indoor air quality. The physical survey is intended to collect information on the building construction, configuration, attached structures, utility entrances into the building, ventilation system design, foundation conditions, presence of a foundation sump, building material types (including recent carpeting or linoleum installation and painting), presence of fireplaces, location of laundry facilities, and other information.

The physical survey also includes acquisition of data related to indoor air quality, such as use of cleaning products, presence of dry-cleaned items, use of carpet-cleaning services, indoor storage of paints, use of aerosol products, presence of smokers, occupant hobbies, and other information.

The sample team can conduct a building real-time monitoring or sampling. Options for real-time air monitoring include direct reading instruments such as EPA ERT's TAGA mobile laboratory, commercially available portable GC/MS, PID, and/or flame ionization detector (FID). Section 6.2.1 describes the benefits and limitations of TAGA and other direct reading equipment.

PIDs and FIDs detect total VOC concentrations if the unit has low-level concentration sensitivity (i.e., parts per billion [ppb]); however, these instruments are often not sensitive enough to detect low levels of chlorinated compounds in indoor air that exceed action levels. General air monitoring guidelines appear in ERT SOP 2008. Refer to the instrument-specific manual for calibration procedures, general maintenance, and instrument limitations when using direct reading instruments.

The Uniform Federal Policy for QAPPs governs the types of decisions appropriate at EPA sites based on real-time monitoring data. This policy specifies that:

- **Screening data** can support an intermediate or preliminary decision but should eventually be supported by definitive data before completion of a project.
- **Definitive data** should be suitable for final decision-making (at the appropriate level of precision and accuracy, as well as legally defensible).

Either data type can be effective for various decisions. The major differences in QA/QC activities for the consolidated QA matrix are largely between definitive data and screening data, rather than between CERCLA phases or data uses.

Indoor Air Sample Collection

Sample teams should collect at least one indoor air sample at each floor of the property, including the basement and the first floor. At larger residential or commercial properties with sensitive populations, collection of more indoor air samples often is necessary. Samplers should collect indoor air samples at the lowest point on the property with potential for frequent use (such as the basement). Teams should place sample containers approximately in the middle of the room and close to the breathing level of a seated person (two to three feet above the floor). However, the sampling location may change depending on the situation (e.g., a toddler crawls on the floor), and should represent the worst-case scenario for the occupants. If the sampling team collects more than one indoor air sample, the locations should be spread out to adequately cover the floor space of the basement. If the property does not have a basement or the basement is infrequently used, the team should place the sampling device in the bedroom of the most sensitive receptor.

Region 5 recommends locating sample containers away from the direct influence of forced air from air conditioning units, central air conditioning vents, furnaces, or heaters. Also, sample teams should advise building occupants to keep exterior doors and windows closed for 24 hours before and during the sampling period. Building occupants can operate heating, ventilation, and air conditioning (HVAC) systems to be representative of actual living conditions. The sample team should note and consider HVAC operation when determining if additional tests are required. Indoor air concentrations due to VI vary over time and are often higher during the winter season, so additional testing should be considered if initial testing occurred during a mild season when windows are open. Teams should deploy sample containers in areas not subject to disturbances, and away from locations that could interfere with the occupants' normal activities.

Indoor air sampling duration is contingent on building usage (i.e., residential or commercial). Typically, these are as follows: 24-hour period for residential settings, eight-hour period for commercial or industrial settings, and less than five minutes for collection of grab samples (implemented mainly to determine if a COC is present). Sample duration may be extended over several days to weeks if the laboratory method and sample container allow.

Concurrent Sampling

Many VI investigation approaches recommend collection of sub-slab samples first to determine if indoor air sampling is required. However, Region 5 recommends concurrent sub-slab and indoor air sampling; samplers should follow proper indoor air screening techniques. Concurrent collection is advantageous because: (1) sub-slab and indoor air sampling results can provide a paired set of data, increasing understanding of the relationship between sub-slab and indoor air concentrations; (2) environmental sampling contractor re-mobilization costs are reduced or eliminated; and (3) disturbance of property owners and residents is minimized.

Collocated Sampling

One way to check the integrity of laboratory data is to collocate a pair of indoor air samples or a pair of sub-slab samples, with collection of the sub-slab samples through a "T" in the line to the port in the slab (Figure 6-10 below). The paired sampling containers should be placed side by side during the sampling period. Also, EPA may collect collocated samples during PRP oversight activities to check the integrity of the PRP's laboratory results.

Figure 6-10. Collocated Indoor Air Samples (Left) and Sub-slab Soil Gas Samples (Right)

6.2.5 Ambient Air Sampling

At least one outside ambient air sample should be collected on days that indoor air samples are collected for comparison of data from the outside ambient air sample to indoor air sampling results. Sample teams should collect an outdoor ambient air sample at a representative location, preferably upwind and away from any wind obstructions such as trees and buildings (Figure 6-11).

Results from the ambient air sample allow the OSC or RPM to determine if outside COC concentrations are contributing to the indoor air sample results. The sample team should consider nearby commercial or industrial facilities with air emissions as potential interferences or sources.

Samplers should lock the air sampler and/or sample to a secure location to avoid theft. It may also be beneficial to provide signage to inform observers of the container ownership, contact information, and purpose of the sample. Most laboratories discourage placing stickers on the sampler (i.e. specifically evacuated canisters). Teams can use premade signage attached with tie wraps or other mechanisms.

Figure 6-11. Ambient Air Sampling

Sample teams should document relevant meteorological data (such as barometric pressure, temperature, precipitation, wind direction and speed) during ambient air sampling.

Outdoor ambient sampling should begin at least one hour and preferably two hours before indoor air sampling begins and should continue until at least 30 minutes before completion of indoor sampling. Region 5 recommends this practice because most buildings have an hourly air exchange rate (AER) in the range of 0.25 to 1.0, which means that air entering a building before indoor sampling can remain in the building for a long time (ITRC 2007).

6.3 SEWER AND UTILITY TUNNEL SAMPLING

Sewers and utility tunnels may act as preferential pathways into buildings and, therefore, may require assessment as part of the VI investigation. The DOD outlined an approach to a sewer and utility tunnel VI investigation in an ESTCP report (ESTCP 2018). The DOD approach includes: 1) initial screening, 2) field investigation of sewers and utility tunnels, and 3) building testing (Figure 6-12). The initial screening process will identify the location and depth of the sewers and utility tunnels within or near a source area. Based on the initial screening, the site team may need to conduct real-time air monitoring or air sampling to confirm the presence of COCs in the sewers and utility tunnels. If COCs are confirmed in utility conduits, the site team should conduct building testing including sampling or screening sewer or utility openings in a building and collecting indoor air samples. Further details on sampling methodology and investigation strategies can be found in the above-referenced document.

The sewer and utility tunnel sampling approached outlined above follows a similar strategy to the general VI sampling strategy, in which the OSC or RPM uses multiple lines of evidence to confirm the source of COCs and document the pathway to the receptor. Collecting VI data in sewers or utility tunnels requires additional scrutiny as a nearby facility may have discharged small amounts of materials that may interfere with the VI investigation. Therefore, the sampling team should also note potential nearby sources to compare with VI data when revising the CSM.

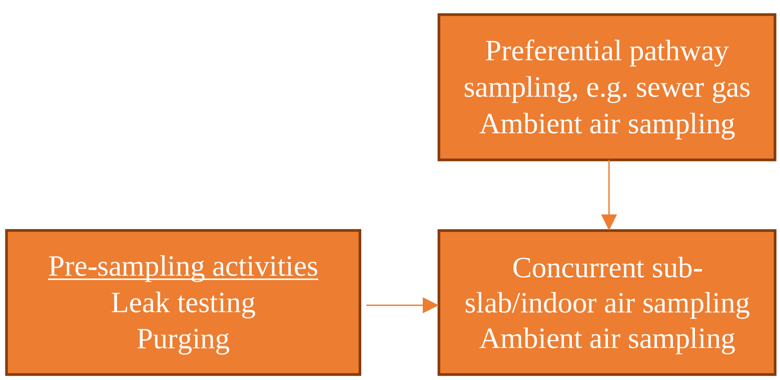


Figure 6-12. Preferential Pathway Sampling Flowchart

7.0 COMMUNICATING AND MANAGING SAMPLE RESULTS

Region 5 is committed to communicating results to residents and owners as soon as information is available, particularly in situations of immediate endangerment, i.e. exceedances of RMLs, acute health hazard criteria, or the possibility of explosion. Region 5 expects the site team to communicate those results to owners and occupants as soon as validated results are received. Where an immediate health threat is present, EPA may communicate unvalidated results but should indicate the data is not validated. Delivering results as soon as possible is especially important when addressing residential VI.

Meeting this commitment requires effort from RPMs, OSCs, toxicologists, contractors, and CICs to monitor data production, quickly evaluate results, and develop a message to residents and owners. It also necessitates close coordination with ATSDR, public health departments, and local partner agencies from the beginning of the project. The site team must address the issue of data communication during the enforcement and planning phases. The team also must actively monitor data flow from sample collection through data processing, thus enabling early communications with residents and owners regarding results and minimizing their possible anxieties as they wait for results. In setting these expectations, Region 5 recognizes that every site poses unique challenges associated with data communication, and site teams must use their best judgment to determine when and how to communicate with the community.

7.1 SAMPLE COMMUNICATION STRATEGY

OSCs and RPMs should work with their CICs to develop a data communication strategy (see Section 4). The communication strategy should provide for release of sample results within the timeframes specified in Table 7-1.

Table 7-1. Expectations for Data Communication

Results	Expected Communication Timeframe
Results above levels that pose immediate health threat	Within 24 to 48 hours from EPA's receipt of data regardless of data validation status
All validated data	Within 15 calendar days of EPA's receipt of validated data packages

The sample communication strategy should identify how data will be communicated to residents/owners (by letter, phone call, email, etc.), and may include a contact list of residential property owners and lessors who should receive data communications. The strategy should also include plans for development, communication, and implementation of possible interim measures by residents and/or EPA to mitigate threats until implementation of final cleanup strategies. OSCs, RPMs, and CICs can use the data communication strategy to manage expectations within the community regarding EPA's management and release of data. The data communication strategy could be extended to inform residents about the efficiency of the mitigation system and to demonstrate achievement of safe levels of hazardous constituents in indoor air in cases of interim measures followed by final cleanup actions, such as installation of sub-slab depressurization systems.

The Plain Writing Act of 2010 requires federal agencies to write "clear Government communication that the public can understand and use." Region 5 is committed to communicating sample results in plain language, using the Federal Plain Language Guidelines. EPA's plain language guidelines are located at https://plainlanguage.gov/guidelines/.

Appendix G includes an example sample results letter. The letter includes a brief description of what EPA did, the sample results evaluated against the appropriate screening levels, an interpretation of the results, and information on next steps.

7.2 EARLY SCREENING

OSCs and RPMs must work closely with their laboratories and/or contractors to ensure data are screened as early as possible to identify any parameters that exceed RMLs or other health-based levels, or that otherwise indicate immediate endangerment. Generally, site teams should not release unvalidated data to the public. However, when an immediate endangerment is indicated, the site team shall release the results to residents and owners as soon as that information is available.

OSCs and RPMs shall actively monitor EPA's and/or the contractor's receipt of analytical results and follow up with the resident/owner when necessary if delays occur. If results are not available within the timeframe originally communicated to the property owner/resident, the team shall notify the owner/resident of the delay, specify a revised delivery date, and continue to communicate until results become available.

7.3 RELEASE OF DATA: VALIDATED VERSUS UNVALIDATED DATA

Region 5's policy is to release to the public data only of known quality (i.e., validated data); thus, preliminary data should not be released to the community. However, EPA policy does not preclude release of preliminary data as "information," especially to owners and occupants of the subject property if the data are above RMLs. The results letters should state that the results are "preliminary" if a site team releases unvalidated data to an owner or occupant. Any discussion or release of preliminary information should clarify that EPA is still reviewing the data and will make final results available as soon as possible but emphasize that EPA is discussing the information preliminarily out of an abundance of caution. Uncertainties associated with preliminary information should be clearly explained to the resident or owner, and the site team should state that the results may change based upon further review. To be clear, a site team should take steps to inform residents and property owners if preliminary or unvalidated data indicate a situation that may pose an immediate endangerment to the public. In this case, the site team should seek prioritization of data validation of the packages in question and take immediate emergency response action if warranted.

When validated data are received, the OSC, RPM, or CIC should send a letter resident or owner communicating results, explaining the results in plain language, and providing other opportunities to discuss the results.

7.4 PERSONALLY IDENTIFIABLE INFORMATION

The Privacy Act of 1974 establishes a Code of Fair Information Practices that governs collection, maintenance, use, and dissemination of PII about individuals maintained in systems of records by federal agencies. EPA's Privacy Policy 2151.1 establishes EPA requirements for safeguarding PII and Privacy Act Information. PII is any information about an individual maintained by an agency that can be used to distinguish, trace, or identify an individual's identity—including personal information linked or linkable to an individual (e.g., name, date of birth, address). Privacy Act Information, a subset of PII, is information about an individual retrieved by name or other personal identifier, including name, address, email address or telephone number assigned to the individual. Privacy Act Information is subject to special requirements under the Privacy Act and EPA's Privacy Policy. PII and Privacy Act Information must be protected from unauthorized access during collection, access, use, dissemination, and storage. Section 6.2.2 addresses methods for sample identification that protect PII and confidentiality.

Region 5 cannot share data with anyone outside of the Agency except ATSDR unless an information sharing agreement is in place with the state or local agency it intends to share the data with. RPMs and OSCs should work with the Office of Regional Counsel and partner agencies on information sharing agreements well in advance of the need to share unredacted versions of the data. Data that is not associated with PII or a personal identifier can always be shared. Site-specific information sharing agreements may be necessary unless a global information sharing agreement is in place with state partners. To share data outside of EPA, those data must be stored in a system of records compliant with EPA's System of Records Notices (SORN). Scribe and EQuIS are considered SORN-compliant under the Environmental Assessments for Residential Properties SORN (EPA-74), which allows for the collection of residential data for certain purposes. The Superfund Enterprise Management System (SEMS), which has a separate SORN (EPA-69), also allows data sharing for certain purposes under an information sharing agreement. However, this is a currently developing issue, and the site attorney should be consulted before data are shared.

7.5 PROPERTY VALUE AND DISCLOSURE CONCERNS

Region 5 staff should avoid discussing property value and disclosure issues. Generally, EPA staff should recommend that prospective buyers or sellers speak to real estate professionals and local-area lenders about questions related to these subjects. If asked at a public meeting, EPA can indicate that a mitigation system is present to reduce exposure to chemicals in indoor air. It can be helpful to explain that active VI mitigation systems are very similar to radon mitigation systems, which have been widely used and accepted by the public. Moreover, EPA staff can inform homeowners and prospective property owners that the VI mitigation system also addresses potential radon problems.

Property disclosure requirements vary depending on location. In general, Region 5 staff should advise property owners to consult with a local real estate professional for information on the property disclosure requirements applicable to their property.

7.6 DATA MANAGEMENT

Data management is necessary to maintain data organization and tracking. The regional data management plan sets forth methods to store and retrieve data compatible with EPA policy. A single person should be tasked with maintaining a spreadsheet or database that organizes sampling location data, contact information, access agreement status, sampling dates, sample identification numbers, sample result mapping, status summary mapping, and all other sample-related information.

The site team can manage laboratory analytical results in different ways. If the number of COCs is small, a spreadsheet can serve to manage the data. If the number of COCs is large and sampling occurs at many locations, a database may be more useful in managing data. Once a database is used, and the information can be retrieved by a name or address, the data must be stored consistent with the appropriate SORN, and shared only pursuant to an information sharing agreement. See Section 7.4 above.

Acquisition and management of sampling and analytical data should be documented in a site-specific Data Management Plan (DMP). The DMP should specify who will screen the data, what screening levels to use, how results of the screening will be communicated to the OSC or RPM, and steps that may be taken if acquired data exceed screening levels. The DMP also should include a process for development, communication, and implementation of possible interim measures by residents and/or EPA to mitigate threats before finalization of data or implementation of final cleanup strategies.

During work planning stages, the site team should discuss which data management tools to apply to the site and should incorporate those decisions into the DMP. The conversations should consider tools available through EPA, its contractors, or laboratories, and identify those that have worked at other similar sites. For example, the site team may want to consider a tool such as the Data Viewer, developed for and deployed at the East Chicago and Flint responses. Please consult with regional GIS staff for more information on using a Data Viewer. All data should be uploaded to a database such as Scribe or EQuIS in the regional Electronic Data Deliverable (EDD) format accessible at https://www.epa.gov/superfund/epa-superfund-electronic-data-submission-multi-regions-edd.

EPA Removal Program staff are required to input project data into Scribe. Scribe is an EPA data management tool (database) that allows users to import laboratory EDDs into the program. Scribe also allows users to record property-specific information and query specific data values for efficient data management. EPA adopted Scribe as its database for sampling and analytical data in its "Site Operations Information Management Implementation Memorandum," dated October 2015 (EPA 2015b). Scribe was designated as the official database for sampling and analytical data during a national response in "Scribe – Exclusive Agency Database during a National Response Memorandum," dated March 2016 (EPA 2016b). More information about Scribe is available online at http://www.ertsupport.org/scribe_home.htm and at https://response.epa.gov/site/site_profile.aspx?site_id=ScribeGIS.

EQuIS is commercially developed software, currently used by six EPA Regions and managed through a contract in Region 2. Information on EQuIS is available at https://earthsoft.com/.

7.7 ENFORCEMENT LEAD

The preceding discussion largely pertains to work by EPA and/or its contractors; however, much of EPA's workload involves its role as enforcement lead. That work should also meet the same goals as fund-lead work. Data analysis and validation performed by PRPs are largely out of EPA's direct control, adding a level of complexity to communication and management of data in residential projects. In many cases, PRPs may be hesitant or unwilling to pay for expedited analytical services, or to share information with EPA or residents/owners until completion of data validation and review. Until language is added to model enforcement agreements to require expedited data generation and validation, and to facilitate early communication of data at residential projects, OSCs and RPMs should discuss the issue with their PRPs and seek commitments minimally for timely communication of results that might pose immediate endangerment. The site team should also consider negotiating language into site work plans to address this issue if appropriate language is not included in the governing enforcement document. If PRPs are unwilling to cooperate on this issue, OSCs and RPMs may want to consider collection of split samples to generate data for early communications with residents.

8.0 DECISION MAKING AT VAPOR INTRUSION SITES

This section focuses on evaluation of site data to determine the level of health risks, consideration of appropriate actions, and development of a defensible management strategy to address any risks. The OSWER VI guidebook provides the general technical basis for fulfilling those responsibilities to address VI sites (EPA 2015a). This Region 5 handbook is designed to provide OSCs, RPMs, and SAMs a stepwise, practical guidance to support their decisions based on a "multiple lines of evidence" approach to trace contamination from groundwater to soil gas to sub-slab to indoor air or through a preferential pathway.

This section discusses generic guidelines for the Remedial, Removal, and Site Assessment Programs, including the following: application of risk-based decision criteria for prioritization of properties for a range of actions, evaluation of both subsurface (e.g., sub-slab or exterior soil gas) and indoor air measurements, specifications/comparisons of commercial and residential screening values, and consideration of proactive mitigation as a response option.

Region 5 strongly recommends that the project manager form a site team with a broad range of technical expertise to ensure acquisition of high-quality data. The team should also include a toxicologist or risk assessor with experience in VI investigations to support evaluation of those site data for decision-making. Decision-makers assuredly should consider the influence of risk-based policy criteria applied by any state agencies involved in the investigation.

To provide documentation for risk-based assessments and recommendations, OSCs, RPMs, and SAMs may request a site-specific health consultation document or Technical Assistance letter from the ATSDR health assessors, EPA toxicologists, or state health departments.

8.1 RISK-BASED GUIDELINES

The Superfund Program is responsible for evaluating potential risks and hazards at contaminated sites, and for decisions regarding the need for remedial or removal cleanups to protect human health and the environment. CERCLA and the NCP outline the Superfund Program's core responsibilities. The following is a summary of general risk criteria applied by Superfund programs to make decisions regarding response at a VI site.

A removal action generally is a response to a high level of risk or concern about acute health risks, defined as a CR exceeding 10^{-4}, non-cancer hazards exceeding a hazard index (HI) or HQ of 3.0 (except for the screening level for TCE, which is based on an HQ of 1.0, as discussed in a later section), exceedance of an ATSDR acute (short-term) risk or screening level, or existence of a fire or explosion hazard. EPA RMLs (https://www.epa.gov/risk/regional-removal-management-levels-chemicals-rmls) are applied to screen site data in order to determine if the level of risk supports a removal action.

Short-term exposure levels typically are derived from ATSDR's Acute or Intermediate Environmental Media Evaluation Guides (EMEG). Acute EMEGs apply for up to two weeks of exposure, with intermediate EMEGs applying to exposure durations of longer than two weeks but less than one year. Exposure levels exceeding levels derived based on the EMEG will not necessarily result in adverse health effects but should prompt further evaluation of potential public health threats.

Remedial Actions generally are to address long-term or chronic risk, with the general policies described in CERCLA and the NCP as the acceptable exposure levels represented as an excess, upper-bound lifetime CR level to an individual of between 10^{-4} and 10^{-6}. The 10^{-6} CR level should be used as a point of departure for determining remediation goals (NCP Section 300.430[e][2][A][2]). As a matter of policy, Region 5 recommends a trigger level of 10^{-5} CR for combined carcinogens to undertake remedial action, which is consistent with the risk criterion used by all Region 5 state agencies. Site-specific decision levels can be developed by use of the EPA VISL calculator (https://www.epa.gov/vaporintrusion/vapor-intrusion-screening-level-calculator).

OSCs and RPMs should request sub-slab soil gas and indoor air screening levels from Superfund risk assessors or ATSDR. Screening levels may differ from state to state, so OSCs, RPMs, and risk assessors should consult with state health departments when developing screening levels. Additionally, OSCs and RPMs should request screening levels specific to the type of property (e.g., residential, commercial, schools) and the air space to undergo sampling (such as sub-slab soil gas, indoor air, exterior soil gas, soil, and groundwater).

Long-term screening or risk levels can be developed by use of the EPA OSWER Technical VI Guide (EPA 2015a) and the VISL calculator (EPA 2019a); exceedance of a screening value indicates increased potential for health effects from exposure, and need to consider mitigation options.

8.2 VI DATA USED FOR RISK ASSESSMENT AND MITIGATION DECISIONS

After receiving site-specific screening levels, OSCs and RPMs should use existing groundwater and soil gas data, if available, to identify buildings most likely to be impacted by VI at levels that may pose a health hazard. The site team collects sub-slab samples to determine if vapors have migrated to and accumulated at levels of concern below a building foundation. As discussed in Section 6.8, Region 5 recommends the collection of concurrent sub-slab and indoor air samples to facilitate the collection of data to make a decision for that property and to minimize the disturbance of the property owners and residents.

A discussion of CSMs and the steps to verify a completed exposure pathway are presented in Section 2.2. If the OSC or RPM documents the migration of contaminants from groundwater (or soil) to soil gas to sub-slab to indoor air, the VI pathway is considered a completed exposure pathway. Based on that determination, the assessment can then move forward to evaluate the risk of exposure to site contaminants and the appropriate decisions to address those risks.

Evaluation of indoor air data for a risk assessment and decisions regarding mitigation must account for several complicating factors, such as: (1) frequent use of products containing VOCs in indoor environments, (2) contributions from ambient air, and (3) site-specific parameters that control contaminant migration from the subsurface to indoor air, such as preferential pathways (e.g., sump pumps, floor drain, utility lines, foundation cracks).

The Region 5 approach recommends that OSCs and RPMs use both sub-slab and indoor air data before deciding on VI mitigation options for an individual residence. Figure 8-1 shows a Decision Flowchart to guide evaluation of both subsurface and indoor air data to categorize the property for possible response actions. Mitigation should be considered if indoor air screening levels are exceeded, and those levels are not attributable to consumer products. The evaluation of explosive conditions in either the sub-slab or indoor air sampling should be the initial step in the screening process. A determination of an explosive potential would trigger an immediate management consultation to decide the next steps in the assessment.

The removal action memorandum should present results from at least one sub-slab sample exceeding sub-slab screening levels, and results from the corresponding indoor air sample also exceeding indoor air screening levels to document a health threat for VI removal actions in Region 5. The OSC should prepare appropriate documentation that presents the basis for his/her site-specific decisions, to be submitted for review and concurrence by program management staff. In an emergency situation, the OSC's may use his or her delegated warrant authority to initiate a removal action.

Based on discussion with removal management staff, OSCs should be aware that they are generally expected to acquire or evaluate existing indoor air analytical data, and to document determination of a completed exposure pathway and the level of health threat. Rationales for this approach are the Removal Program's focus on addressing exposures at the higher end of the acceptable risk range, and preference for taking mitigation action when a release or threat of release is imminent. Exceptions likely will occur, for example, during emergencies when dangerous indoor air readings are recorded by use of hand-held instruments, extremely high sub-slab readings are measured, or contaminated water or liquid is observed seeping through walls or floors.

The Superfund Program must address only contamination determined to be site-related. Use of VOC-containing products in residences may contribute to detection of elevated air concentrations during an investigation. Therefore, cleanup decisions should not be based on measured indoor air concentrations alone. A VI investigation should begin outside a residence first, with collection of groundwater, soil gas, utility conduit, or sub-slab vapor samples before proceeding to indoor air sampling.

This document does not specify a required approach, but the OSC should be aware that a decision to take mitigation action at a residence without collection of indoor air samples will require a well-documented rationale to support that decision. It should be recognized that the decision to take "pre-emptive" mitigation actions requires Superfund management approval. In addition, the OSC or RPM should consult with VI experts, such as EPA ERT, to support a decision for implementing mitigation based solely on sub-slab data, or if a sub-slab to indoor air AF other than the standard default factor of 33 is used (discussed in a later section).

Considering the Remedial Program's responsibility and authority to address chronic health risks (in contrast to the more time-critical risks addressed under the Removal Program), RPMs may have greater leeway in decisions regarding mitigation based on sub-slab data without indoor air data; but again, Region 5 recommends that RPMs consult with VI experts and management.

8.3 SITE CATEGORIES

The objective of this section of the guidance is to provide a framework to support site-specific decisions about appropriate response to potential for VI at individual properties. This decision tool allows for use of available data (e.g., soil gas, sub-slab, indoor air) to prioritize individual properties and to guide determination of the appropriate level of response, based on the level of health risk. Included in this guidance are: (1) a flowchart (Figure 8-1) showing the general scheme of how site data are triaged to assign a category for each property, and (2) a summary of the recommended response based on the assigned category (Tables 8-1 and 8-2).

EPA's VISL Calculator User's Guide (EPA 2019b) is a valuable resource to support decisions at VI sites. It provides descriptions, equations, and default exposure parameters used to calculate risk-based VISLs. It calculates screening level concentrations for groundwater, sub-surface (sub-slab and soil gas near source), and indoor air. OSCs, RPMs, and SAMs should become familiar with the VISL Calculator.

Under most circumstances, short-term exposure levels exceeding levels based on EMEGs should result in a recommendation to take actions to reduce exposure. The greater the exceedance of levels derived based on the EMEG, the greater the need for a rapid mitigation response and possible relocation of residents. Rapid mitigation may also be appropriate if sub-slab soil gas sample results exceed 10% of the lower explosive limit (LEL) or if indoor air sample results exceed 1% of the LEL.

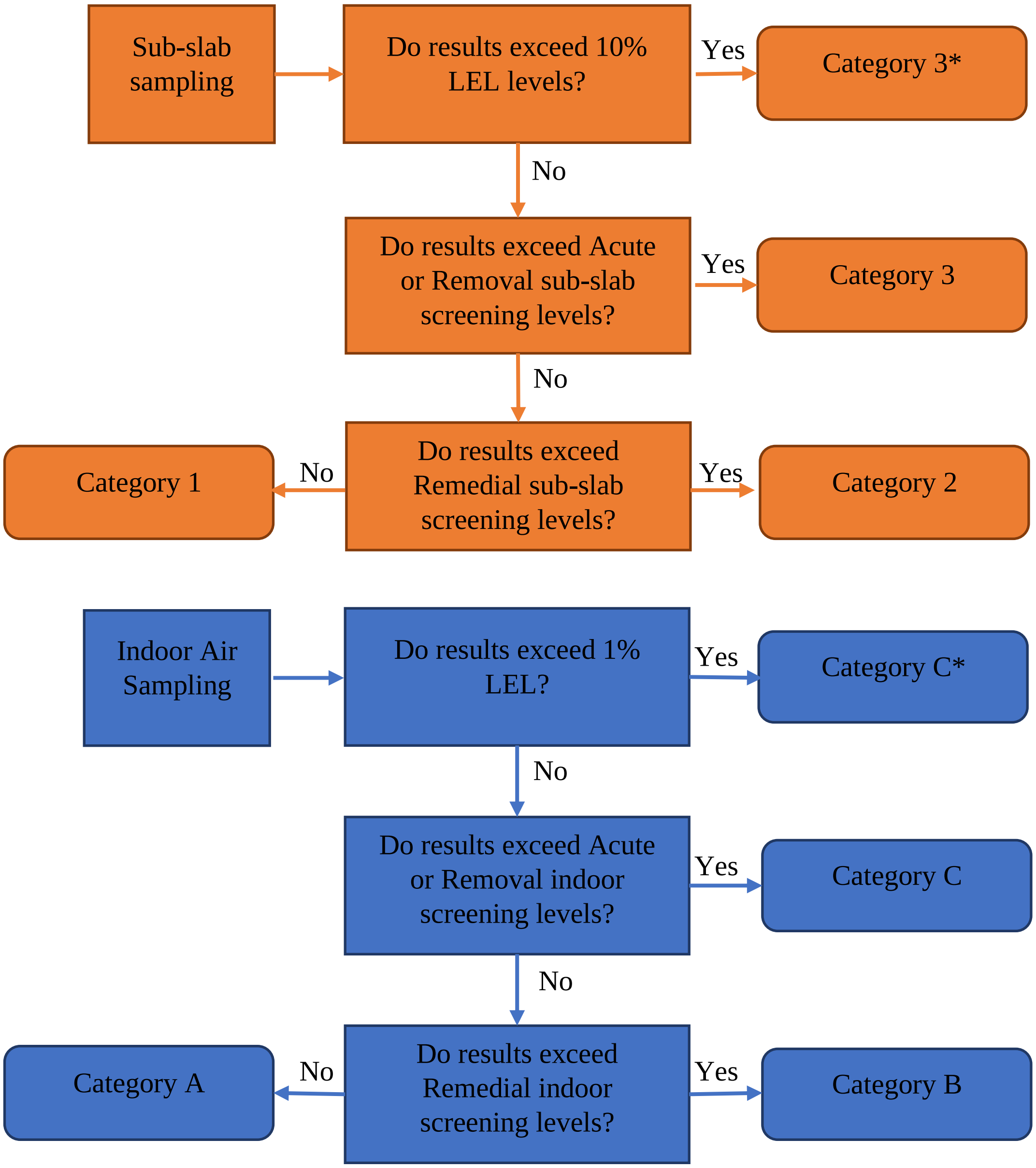
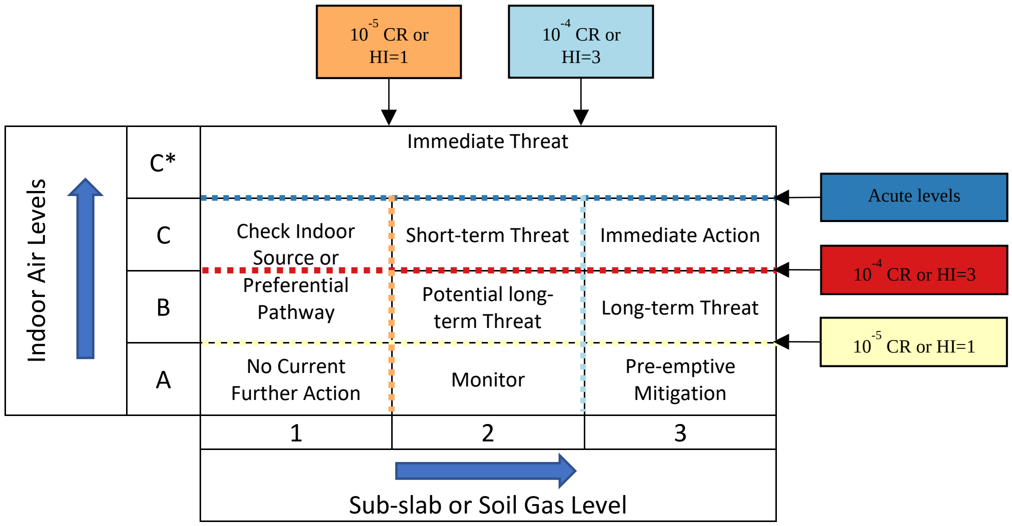


Figure 8-1: Decision Flowchart for Evaluation of Vapor Intrusion Sampling Data

Table 8-1. Risk-Based Decision Matrix for VI Sites



Notes:

CR Carcinogenic risk
HI Hazard Index

Table 8-2. Decisions Associated with Vapor Intrusion Categories

Category	Air Results: Indoor	Air Results: Sub-slab	Decision
C1	>Acute or RML	<RSL	Likely indoor source; warn homeowner of hazard
C2	>Acute or RML	>RSL, <RML	Concern about acute exposure; plan for remediation within weeks
C3	>Acute or RML	>Acute or RML	Concern about acute exposure; plan for remediation ASAP; consider APUs
C3*	>1% LEL	>10% LEL	Immediate action; consider relocation depending on conditions
B1	>RSL, <RML	<RSL	Check potential for indoor source; notify homeowner of potential concern
B2	>RSL, <RML	>RSL, <RML	Concern about long term-exposure; develop strategy for inclusion in site
B3	>RSL, <RML	>Acute or RML	Concern about long-term exposure; more rapid remediation plan
A1	<RSL	<RSL	No further action at this time, pending new data
A2	<RSL	>RSL, <RML	Continue monitoring subsurface conditions
A3	<RSL	>Acute or RML	Consider pre-emptive mitigation to prevent future indoor air impact

Notes:

APU Air purification unit
ASAP As soon as possible
IA Indoor air
SS Sub-slab soil gas

8.3.1 Category A Properties

Properties in Category A are those where measured levels in indoor air are below action levels. However, recommended actions for those properties may be influenced by levels of contamination found via sub-slab or soil gas sampling. To distinguish these conditions, Category A properties are segregated into A1, A2, or A3, based on results from sub-slab or soil gas sampling:

A1 Criteria: low indoor air, low sub-slab contamination
indoor air data: CR < 10^{-5} and HI < 1.0
sub-slab data: CR < 10^{-5} and HI < 1.0

Action to be taken: No further action at this time

A2 Criteria: low indoor air, moderate sub-slab contamination
indoor air data: CR < 10^{-5} and HI < 1.0
sub-slab data: CR > 10^{-5} and HI > 1.0

Action to be taken: Continue to monitor to determine if contaminant concentrations change significantly.

A3 Criteria: low indoor air, high sub-slab contamination
indoor air data: CR < 10^{-5} and HI < 1.0
sub-slab data: CR > 10^{-4} and HI > 3.0

Action to be taken: Consider pre-emptive mitigation to prevent future indoor air impacts or conduct more frequent monitoring.

8.3.2 Category B properties

Properties in Category B are those where measured levels in indoor air are above long-term or chronic screening levels, but below EPA RMLs that would indicate need for more immediate actions. However, recommended actions at those properties may be influenced by levels of contamination found via sub-slab or soil gas sampling. To distinguish these conditions, Category B properties are segregated into B1, B2, or B3 based on results from sub-slab or soil gas sampling:

B1 Criteria: moderate indoor air, low sub-slab contamination
indoor air data: CR > 10^{-5} and HI > 1.0
sub-slab data: CR < 10^{-5} and HI < 1.0

Action to be taken: Evaluate a preferential vapor migration pathway or possible indoor chemical sources.

B2 Criteria: moderate indoor air, moderate sub-slab contamination

indoor air data: CR < 10^{-5} and HI < 1.0
sub-slab data: CR > 10^{-5} and HI > 1.0

Action to be taken: Consider implementation of a strategy to reduce vapor migration.

B3 Criteria: moderate indoor air, high sub-slab contamination
indoor air data: CR < 10^{-5} and HI < 1.0
sub-slab data: CR > 10^{-4} and HI > 3.0

Action to be taken: Consider a more rapid response to reduce vapor migration, or possible referral to Removal Program for an evaluation of a time-critical response.

8.3.3 Category C properties

Properties in Category C are those where measured levels in indoor air are above short-term risk levels because they exceed EPA RMLs. However, recommended actions at those properties may be influenced by results from sub-slab or soil gas sampling. To distinguish these conditions, Category C properties are segregated into C1, C2, or C3, based on results from sub-slab or soil gas sampling:

C1 Criteria: high indoor air, low sub-slab contamination
indoor air data: CR > 10^{-4} and HI > 3.0
sub-slab data: CR < 10^{-5} and HI < 1.0

Action to be taken: Evaluate possible indoor chemical sources, and recommend resident take appropriate actions to remove those sources.

C2 Criteria: high indoor air, moderate sub-slab contamination
indoor air data: CR > 10^{-4} and HI > 3.0
sub-slab data: CR > 10^{-5} and HI > 1.0

Action to be taken: Take actions to reduce vapor migration into indoor air space.

C3 Criteria: high indoor air, high sub-slab contamination
indoor air data: CR >10^{-4} and HI > 3.0
sub-slab data: CR > 10^{-4} and HI > 3.0

Action to be taken: Take actions to reduce vapor migration into indoor air space.

C* Criteria: very high indoor air concentrations
indoor air data: HI > 10, exceeds acute screening levels, or >1% LEL

Action to be taken: If the indoor contamination is attributable to a subsurface source, an immediate removal action is recommended to reduce exposure, including relocation if the LEL or acute levels are exceeded. If the indoor contamination is determined not attributable to a subsurface source, local or state health agencies should be engaged immediately with the homeowner to address the indoor sources.

8.4 COMMERCIAL VERSUS RESIDENTIAL SCREENING LEVELS

When determining whether to use residential or commercial screening or action levels for comparisons to sampling results, OSCs and RPMs should ask, "Is someone currently living or will live at the property?" If the answer is "yes," sample results should be compared to residential screening or action levels.

If a site has a commercial business on the first floor and an apartment on the second floor, the OSC or RPM must use the most conservative action or screening level (residential level) for comparison. Occupational Safety and Health Administration (OSHA) values for COCs are not appropriate for commercial or industrial facilities when VI is determined to be the source of contamination.

For locations with sensitive populations, such as schools, the residential chronic screening or action levels may be adjusted to account for the length of the school day and the number of months the school is in session. Based on site conditions and possible year-round utilization of the school, it is also acceptable to use residential criteria only. However, acute screening levels would be applied for schools without adjustment for occupancy duration.

8.5 VI SITE-SPECIFIC CONSIDERATIONS

Hazardous vapor migration into buildings may vary greatly, not only from site to site, but also from building to building within a site, and even between sections within the same building. These differences may be due to site-specific parameters, such as soil type, building foundation type and condition, preferential pathways such as fractures in underlying rock or underground utilities, and differential building pressures. Within a neighborhood, differences in basement types (such as poured concrete, crawl spaces, cracked concrete, and dirt floors) are most significant in evaluating residences. These characteristics render extrapolation of VI scenarios between sites and properties extremely difficult. For that reason, site decision-making must be based on multiple lines of evidence, including data from more than one environmental medium (such as groundwater, sub-slab vapor, utility conduits, or indoor air). To address these many variables, the site team should carefully design sampling plans to gather data that can best be used to evaluate human exposure. Acquired data should then be used to make informed decisions regarding need for mitigation.

8.6 VAPOR ATTENUATION FACTOR (AF)

The vapor AF is a unitless empirical ratio of indoor air contaminant concentration to subsurface (sub-slab) contaminant concentration. It is defined as the indoor air contaminant concentration divided by the contaminant concentration in either soil gas or sub-slab. The soil gas equation is as follows:

$$AF = C_{\text{indoor air}} \div C_{\text{subsurface}}$$

For example, a site with a soil gas TCE concentration of 2.0 $\mu g/m^3$ in indoor air and a soil gas concentration of 2,000 $\mu g/m^3$ would have an AF of (2 ÷ 2,000) or 0.001.

The default AF value in current EPA VI guidance is 0.03, updated from the previous default AF value of 0.1 based on more extensive field data. This default AF value is used to calculate subsurface (sub-slab or soil gas) screening levels, as presented in the VISL tables.

For air data acquired in crawl space areas, a default value of 1.0 is recommended.

OSCs and RPMs may need to consider AFs based on other migration pathways, such as vapors migrating through conduits. ESTCP recommends 0.03 (33× attenuation) as a reasonable upper-bound for the migration of chemical vapors from sewers/utility tunnels into buildings, for use in the calculation of sewer-to-indoor-air screening values (McHugh 2018).

8.7 MITIGATION DECISIONS BASED ON SUB-SLAB SOIL GAS DATA / PRE-EMPTIVE MITIGATION

This section provides guidance to assist OSCs and RPMs in making reasonably consistent cleanup decisions, recognizing that site-specific factors and innovative approaches may result in modifications. As discussed previously, to initiate a VI response action, the OSC or RPM must document a completed VI exposure pathway that is based on multiple lines of evidence. If a completed exposure pathway is demonstrated, with levels of contamination that indicate a public health threat consistent with the NCP, the OSC or RPM may consider applying a proactive mitigation strategy based on sub-slab data and multiple lines of evidence. Region 5 recommends that OSCs and RPMs discuss proactive mitigation with management prior to implementation.

One approach to mitigation decision-making for VI sites involves use of the default AFs discussed above or site-specific AFs. In such cases, the OSC or RPM should have sub-slab data pertaining to individual homes. If the default of site-specific, sub-slab-to-indoor air AF value predicts indoor air levels above acceptable health criteria, mitigation actions can be considered even if indoor air levels have not been measured at those properties. This concept has been termed "pre-emptive (or proactive) mitigation" and could apply to other nearby residences over a groundwater plume. Region 5 strongly recommends basing decisions on actual indoor air results. OSCs and RPMs must provide a strong case for proceeding with proactive mitigation in lieu of indoor air sample collection.

There are several benefits of pre-emptive mitigation. Pre-emptive mitigation can save time and resources by not having to conduct several rounds of indoor air sampling at individual residences. Indoor air sampling can be time-consuming for staff and disruptive for residents, especially when multiple residences are to be sampled. In many cases, preemptive mitigation at residences predicted to have elevated indoor air readings based on sub-slab results may actually save money when costs of multiple sampling events and contractor and EPA personnel labor are considered. Another advantage to preemptive mitigation is that the sub-slab environment generally is believed to be more stable than indoor air, with lower levels of fluctuations in contaminant concentrations over time. If sub-slab samples are collected properly, results should not be influenced by presence of extraneous household chemicals, which can significantly influence results from indoor air samples.

If the OSC or RPM is confident in the predictive capability of the AF approach to identify conditions indicating potential for indoor air values to reach unacceptable levels, risk managers could justify a decision to implement proactive mitigation action even if a one- or two-time indoor air sampling event revealed results below levels of concern. This approach would be justified based on the presumption that conditions could change over time, leading to levels of indoor air contamination that could pose a future health threat. The decision to implement pre-emptive mitigation is made on a case-by-case basis and must receive Superfund management approval.

8.8 TOXICOLOGY AND RISK ASSESSMENT ISSUES

This section addresses toxicology and risk assessment issues related to VI. OSCs and RPMs should consult with EPA risk assessors or ATSDR for recommended site-specific, sub-slab and indoor air screening levels. It is important that the risk assessor and risk manager consider both cancer and non-cancer endpoints when evaluating risk and the need to take an action at a site.

8.8.1 Approach for Assessing Risk for Screening Levels of TCE

TCE is one of the most prevalent contaminants at Superfund sites. The OSWER Memorandum dated August 27, 2014, titled "Compilation of Information Relating to Early/Interim Actions at Superfund Sites and the TCE IRIS Assessment" (https://clu-in.org/download/contaminantfocus/tce/TCE-compilation-final-2014.pdf) cites the conclusion of a TCE Integrated Risk Information System (IRIS) assessment that TCE poses a potential human health hazard (noncancer toxicity) to the central nervous system, kidney, liver, immune system, male reproductive system, and a developing fetus, and is "carcinogenic to humans" by all routes of exposure (EPA 2014). The reference concentration (RfC) for noncancer effects of TCE (2 $\mu g/m^3$) is based in part on the developmental toxicity endpoint of increased incidence of fetal cardiac malformations. The memorandum also states that "existing guidance provides that responders should consider early or interim action(s) where appropriate to eliminate, reduce, or control the hazards posed by a site." Applying the conservative ratio approach described above, concentration of the RfC (2 $\mu g/m^3$) corresponds to an estimated HQ of 1. Because the critical stage for cardiac development in the human fetus occurs during a three-week period in the first trimester, the RfC applies to even short-term exposure (i.e., several weeks of exposure).

8.8.2 Evaluation of Risk from Chemicals with No Inhalation Toxicity Values

When evaluating indoor air data and data from other media sampled as part of a VI investigation, risk assessors should quantitatively evaluate risk from chemicals for which inhalation toxicity values (RfC for non-cancer effects or Inhalation Unit Risk for cancer effects) are available, as stated in EPA's Toxicity Hierarchy memorandum (https://www.epa.gov/sites/production/files/2015-11/documents/hhmemo.pdf) (EPA 2003). In addition, consultations with ATSDR should occur as appropriate. If actionable risk has been estimated, risk managers can take appropriate actions to address the risk. If actionable risk has not been estimated, uncertainty associated with chemicals for which no inhalation toxicity values are available should be discussed as a potential underestimation of risk and communicated to the risk managers.

8.8.3 Evaluation of Specific Risks for Children

If site-related chemicals are known to act through a mutagenic mode of action (MMOA) for carcinogenic effects, it is appropriate to apply age-dependent adjustment factors to the appropriate age ranges for children. No other adjustments to inhalation toxicity values are recommended for assessing risk to children.

8.8.4 Applicability of OSHA Standards to Evaluate Worker VI Risk

OSHA standards should *NOT* be used to evaluate risk from VI or to establish appropriate indoor air target levels. OSHA standards are not fully risk-based and are applicable to situations where exposure to workplace chemicals can be controlled through process engineering and protective equipment. Such exposure controls would not apply to situations where COCs in a particular workplace are not in use in that workplace. Furthermore, at sites subject to CERCLA, cleanup levels are determined based on applicable or relevant and appropriate requirements (ARAR) or via risk assessments.

9.0 MITIGATION

This section discusses mitigation options to reduce indoor air levels of COCs in existing buildings if and where there is a completed exposure pathway. Additional information regarding mitigation options for VI is available in the documents cited in Section 12.0.

9.1 BACKGROUND POLICY INFORMATION

This section describes techniques frequently applied to mitigate buildings where VI is occurring or is likely to occur in the future.

Region 5 considers building mitigation an interim action that can provide effective human health protection and may become part of a final cleanup plan; but mitigation of VI in specific buildings generally is not a substitute for remediation of subsurface vapor sources. Thus, Region 5 recommends conducting building mitigation in conjunction with vapor source remediation where possible.

9.1.1 Types of Properties Typically Mitigated by the Superfund Program

Each site is evaluated individually, and decisions may vary based on individual site factors.

- The Removal Program generally remediates non-commercial properties with existing buildings—including schools, day-care centers, and other buildings with sensitive populations.
- The Remedial Program generally mitigates commercial buildings in addition to the other types of properties listed above when approved in the ROD or interim decision document. If VI is not addressed in the ROD, the RPM will need to consult with management regarding next steps.
- The types of buildings remediated by either program may vary based on site-specific factors.

9.1.2 Mitigation Costs

EPA generally pays costs associated with design and installation of mitigation systems for Fund-lead removal and remedial actions. EPA, the PRP, or another entity may pay for electrical costs associated with short-term or emergency mitigation actions in some situations. OSCs and RPMs should consult with management and/or ORC in these situations. Mitigation systems may be connected to separate electrical meters to facilitate division of electrical costs for the property.

9.1.3 Notification and Community Outreach

Upon determination of need for mitigation, EPA must obtain consent from the property owner/occupant for mitigation. EPA should also obtain an agreement from the state or local government to maintain the systems over the long term, until the systems are no longer necessary. Section 4.0 addresses community outreach.

Mitigation Agreement

EPA cannot install mitigation against the wishes of property owners. It is very important that property owners understand the types of mitigation proposed for their properties, and that EPA staff obtain the specific written agreement of property owners prior to installation of building mitigation systems. This agreement is in addition to the access agreement obtained for sampling/assessing the property. An example agreement is included in Appendix H.

EPA staff should make property owners aware of and encourage their agreement to the type of mitigation work planned, how the mitigation system will work, general maintenance requirements, and any costs that they may incur from the system, such as increased electrical costs associated with active SSDS. Alternative approaches to active SSDSs can be considered when property owners state that electrical costs to run this type of system would be too burdensome. Property owners can decline EPA offers to install mitigation systems. Local and state health departments may follow up in cases where properties are tenant-occupied and owners have declined mitigation offers. ICs can be used to track properties where mitigation offers have been declined (see Section 11.8).

Post-Removal Site Control (PRSC)

EPA's OSWER (renamed Office of Land and Emergency Management [OLEM]) Directive 9360.2-02, "Policy on Management of PRSC" (hereafter "PRSC Policy") requires that EPA generally establish agreements regarding post-removal site controls before initiating a removal action (EPA 1990).

PRSC refers to those response activities necessary to sustain the integrity of a Fund-lead removal action following its conclusion. PRSC activities, such as ensuring mitigation systems continue to function or replacing filters, are necessary to ensure continued effectiveness of a removal action after completion of Fund-lead removal activities.

Before commencing a Fund-lead removal action where PRSC is anticipated, EPA should obtain commitment from the state government or local government to agree to perform and fund the actions necessary to sustain the integrity of the removal action. PRSC Policy includes an example agreement letter. If the Region does not have an agreement to assume O&M the OSC should consider other measures to address emergencies and some time-critical responses. Once there is a commitment for O&M, installation of mitigation systems may proceed.

Region 5 states have requested that, where possible, EPA provide the states with O&M recommendations prior to states assuming responsibility for VI mitigation systems. Standard and example EPA O&M recommendations, manuals, and agreements are included in the O&M Section of this document (Sections 10.1.1 and 10.1.2).

For PRP-lead removal actions, EPA should secure a PRSC agreement from a PRP through an administrative order on consent or unilateral administrative order.

Per PRSC policy, at a site where no private or governmental entity is willing or able to assume responsibility for PRSC, EPA should avoid taking any action that requires continuing site control activities if other reasonable response options are available. In the absence of other options, EPA will respond only to the initial threat, ensuring that the emergency created by the release or threat of release is mitigated.

Remedial O&M

Prior to a Fund-lead remedial action, the state must provide assurance in accordance with CERCLA Section 104(c)(3)(A) to assume responsibility for O&M of the implemented remedial action for the expected life of such action. This assurance is typically in the form of a State Superfund Contract and cooperative agreement. These documents must include a statement that, following completion of the remedial action, the state and EPA will inspect the site to determine that the remedy is functioning as designed (40 *Code of Federal Regulations* [CFR] §35.6805(q) and 40 CFR 300.435(f)(2) of the NCP).

For VI mitigation systems installed under a Fund-lead remedial action the state assumes responsibility for O&M once the implemented remedy has been determined to be operational and functional, up to one year after completion of construction (40 CFR 300.435(f)(1)), unless the mitigation systems are deemed part of a long-term remedial action for groundwater restoration. This transfer of O&M responsibility can occur even if all remedial action objectives are not yet met. VI investigations often continue after installation of mitigation systems, and the state is also responsible for any mitigation systems installed at the same site after the operational and functional determination.

For mitigation systems installed under a Fund-lead remedial action and operated as part of a long-term response action for groundwater restoration, EPA will maintain responsibility for O&M of the systems as part of the remedial action (often with the state covering a portion of the costs) for 10 years after the operational and functional determination. After the 10-year period, the state assumes responsibility for O&M of any mitigation systems still necessary.

For PRP-lead remedial actions, the PRP is responsible for O&M of the remedial action for the duration of its operation.

PRSC may be considered part of a remedial action at a site; therefore, if a state incurs PRSC expenditures for eligible response activities at a site currently or eventually listed on the NPL, the state may submit a claim for credit under Section 104(c)(5)(B) of CERCLA. Further details are provided in the PRSC policy.

9.2 IMMEDIATE MITIGATION ACTIONS

Several techniques have been found effective to quickly improve air quality at properties where levels of indoor air contamination necessitate immediate action. ATSDR recommends immediate action at Category C* properties (See Section 8.3.3). Category C* properties are ones where indoor air meets at least one of the following conditions: a HI greater than 10, exceeds acute screening levels, or greater than 1% LEL

When applying these immediate action techniques, residents must be advised that modifying the system as set up by EPA may result in decreased effectiveness. The site team should assess effectiveness of any immediate actions by collecting and analyzing indoor air samples.

9.2.1 Evacuate

If indoor air concentrations warrant evacuation, the OSC or RPM must work with the local or state health department. **EPA does not have the authority to evacuate buildings and should never issue evacuation orders.** Health departments may decide to evacuate buildings due to elevated levels of contaminants in indoor air from VI. OSCs and RPMs should work closely with local and state health departments and ATSDR during all VI responses to ensure that health agencies have the information they need to protect building occupants and determine circumstances under which buildings can be reoccupied after evacuation. If the site team identifies potential explosion and fire hazards, staff should exit the building, immediately notify the local fire department, and subsequently follow up with the health agencies.

9.2.2 Increase Fresh Air Input into the Building

Opening windows and adding fans can improve air quality quickly by exchanging air and removing contaminated air from the building. These actions should occur initially throughout the entire structure and continue to at least the basement level (EPA 2015a). The site team can modify settings on the HVAC system and run it 24 hours a day to increase input of outdoor air. However, this approach is rarely cost effective over the long term, especially in older, leakier buildings (EPA 2008b). Industrial engineers are available via the START contract to help with calculation of the number of air exchanges achieved through various ventilation configurations, and assist with air flow configurations. It is important to increase air input as much as output to avoid under-pressurization of the building, which can increase soil gas flow into the building (EPA 2008b). Region 5 does not recommend exceeding AERs of four changes per hour because it can make conditions uncomfortable for occupants. Increasing fresh air input is a short-term technique to address indoor air contamination.

9.2.3 Treat Indoor Air

Portable or whole house/in-duct air treatment is another way to remove contaminated air from a building. Available air cleaners include both in-duct models and portable air cleaners. These devices operate according to various principles including zeolite or carbon sorption, ozone oxidation, and photocatalytic oxidation (see EPA [2008b and 2017]) for discussion of options). For TCE, the most effective adsorption medium for air filtration is activated carbon (EPA 2017). Air treatment can achieve 80% reduction in TCE concentrations in indoor air.

In the HVAC-mounted filtration system, a portion of the HVAC system's return air is routed through an air filtration unit before it reaches the air handler. The rerouted air is typically processed in three stages: foam large particulate pre-filter; 0.3-micron HEPA filtration for dust, pollen, bacteria, animal dander, and attached viruses; and a filter with sorbent media designed to remove the contaminant of concern. Filtered air is then fed back into the home's air supply via the HVAC duct work. The add-on filtration unit has its own fan and is designed to run continuously.

Region 5 and the Massachusetts Department of Environmental Protection (MADEP 2016a) have utilized portable air purification units (APU) that operate using carbon sorption to successfully reduce vapor concentrations in numerous buildings at a number of VI sites; however, the units are not always able to fully mitigate high levels of contamination under conditions of continuous contaminant inputs and/or influence of other environmental factors. These APUs filter air from up to 1,500 square feet per unit and provide an AER of 400 cubic feet per minute on the high setting. AERs exceeding four changes per hour are not recommended, as these can be uncomfortable for residents. Flow rates for APUs can be obtained from the manufacturer and used to calculate the AER. In emergency situations, maximizing the number of air exchanges on the lowest building level up to four per hour is recommended. Multiple portable APUs may be needed to achieve this AER, depending on size of the building undergoing treatment. The number of units required to successfully treat contaminated indoor air may also increase with increasing concentrations of contaminants in indoor air (EPA 2017). Portable APUs may also be deployed at higher levels of the building, as needed and determined on a case-by-case basis. Region 5 recommends air purification as a short-term technique to address indoor air contamination.

Other considerations:

- Treatment effectiveness is impacted by high humidity, high temperature, particulates, concentrations of non-target VOCs, and acid gases.
- Treatment effectiveness is potentially affected by impeded air circulation (i.e., closed door).
- Monitoring is necessary to evaluate system effectiveness and potential for contaminant breakthrough.
- Desorption occurs under various conditions.
- Constant fan activity is necessary, increasing electrical costs.

- Sorptive capacity of activated carbon filter is greater for large chain organic compounds, including several common indoor air contaminants, increasing potential of breakthrough of smaller chain carbon compounds (e.g., TCE).

Region 5 owns portable air filtration units that may be available to check out for deployment as needed. Because exact sorption rates of COCs and other indoor air contaminants during a given deployment and other environmental factors are unknown, the filters must be replaced after each deployment. The site team must make a waste determination for disposal of used filters as listed waste (if applicable to contamination source) or characteristically-hazardous waste for each site and property (MADEP 2016b).

9.2.4 Eliminate Significant Openings

High concentrations of contaminants may continue to flow into a property where significant openings for soil gas intrusion (i.e., vapor entry) are present in the basement floor or on the slab of a property (see Figure 9-1 below). Sealing major openings usually helps improve indoor air quality and performance of other mitigation methods (e.g., sub-slab depressurization) (EPA 2015a).

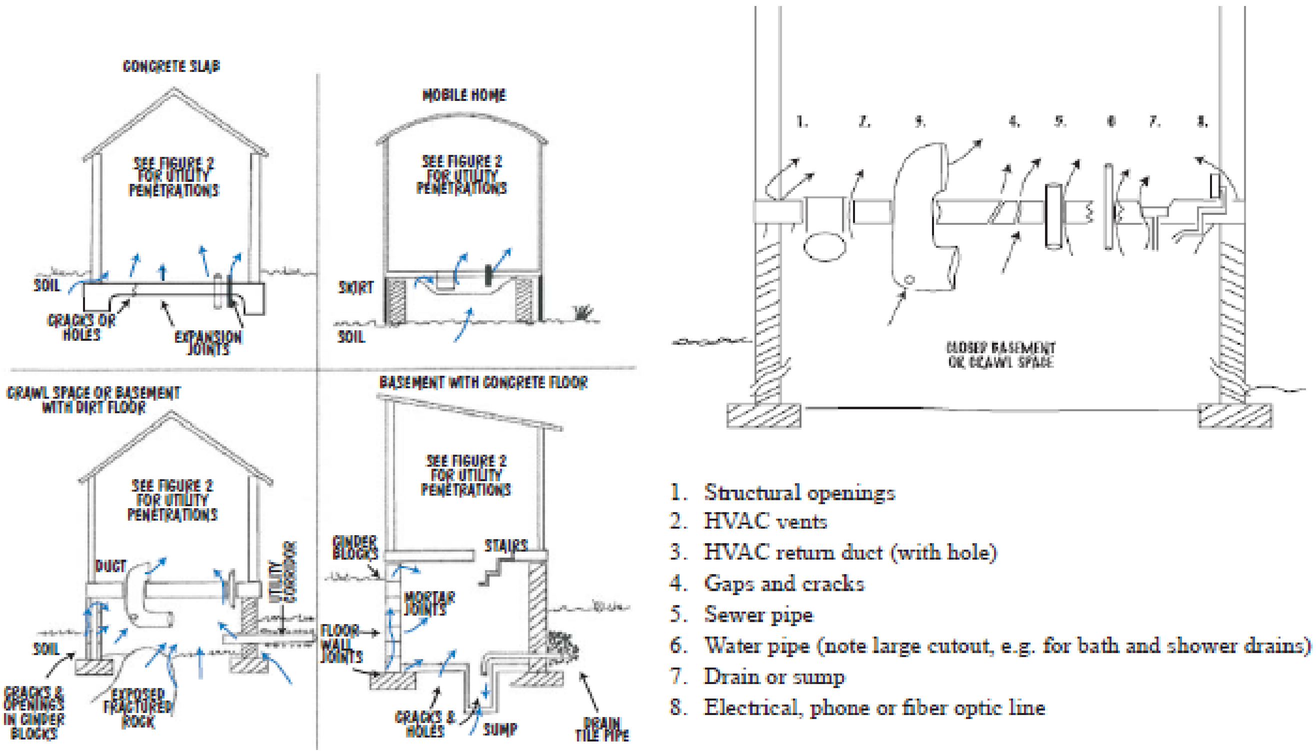


Figure 9-1. Vapor Intrusion Potential in Various Residential Structure Types

Effective sealants must:

- Have good adherence to building materials;
- Be workable at the installation temperature;
- Have high elasticity and compressibility to resist foundation movements;
- Not shrink after curing;
- Be compatible with the COCs;

- Have good recovery after stretching or compression;
- Be durable and water resistant; and
- Emit no or low concentrations of hazardous VOCs.

Sealing materials include synthetic rubbers, acrylics, oil-based sealants, asphaltic/bituminous products, swelling cement, silicon, and elastomeric polymers. Sealants are sometimes supplemented with fillers or backup materials, including filler rods, tapes, tubing, and foams (EPA 2008b). The site team must be careful in reviewing the ingredients of any materials prior to application to ensure that they do not contain vapor-forming chemicals targeted in the cleanup.

9.2.5 Seal Cracks and Holes

During the immediate action phase of a response, Region 5 recommends evaluating the basement floor/slab surface to identify holes around utility inlets, cracks, or other areas of compromised concrete that can be patched. Cracks and holes can be sealed by use of a tube of concrete filler or hydraulic cement (see Figures 9-2 and 9-3 below). The site team may also consider using basement waterproofing products such as masonry paint or epoxy-based floor sealers to cover large surface areas and to cover caulked materials previously placed in concrete wall or floor cracks.

Figure 9-2. Cracks in Floor Sealed with Hydraulic Cement

Figure 9-3. Holes in Floor Sealed with Hydraulic Cement

9.2.6 Seal Utility Openings

Utility corridors often contain permeable backfill, which may allow vapors and even free product to migrate away from source areas in a different manner than through native undisturbed soils. In this situation, utility penetrations through building floors or walls can provide a direct pathway for vapors to enter buildings. If possible, it is a good practice to seal gaps around utility penetrations into basements and/or crawl spaces early in the response (EPA 2008a).

9.2.7 Maintain Vapor Traps

A site team can reduce or eliminate VI into a building through sewer and drain lines via installation, repair, and maintenance of vapor traps (EPA 2015a). Traps that create a water seal at potential points of entry typically restrict entry of sewer gas into buildings. These traps can dry out over time if not maintained, allowing sewer gas to migrate into a home. Also, infrequently used plumbing fixtures may allow sewer gas to enter a home due to evaporation of water in the trap, especially in warm weather. This can be resolved by regular use of the fixtures or addition of water to the drains/traps (https://www.dhs.wisconsin.gov/air/sewergas.htm). Traps and plumbing fixtures should be checked to verify that water is present in drains/traps.

9.2.8 Seal Sumps

Dry and wet sumps have proven to be significant sources of VI at several Region 5 sites. ASTM recommends sealing sumps at VI sites (ASTM 2013). If a sump is not in use, and not required by local building code, filling it with concrete has been shown to reduce VI into properties within the Region (Figures 9-4 and 9-5 below).

Figure 9-4. Dry Sump Prior to Filling with Concrete

Figure 9-5. Dry Sump After Filling with Concrete

If a sump is used for water control and/or contains a sump pump, the site team may instead initially cover the sump with plastic and tape to eliminate some vapors in indoor air. A permanent sump cover subsequently can replace the plastic to seal over the sump and around sump pump piping. Installation of J-tubes with ball valves can allow entry of water to the sump but block vapors from migrating out of the sump (see Figures 9-6, 9-7, and 9-8 below). ASTM (2013) recommends sump pit covers of durable plastic, designed to permit air-tight sealing. Sealing with silicone or other nonpermanent caulk will allow removal of the lid for pump servicing. Installing a lid with a viewing panel or a clear, see-through lid (e.g., plexiglass) will also facilitate inspection of the pump (ASTM 2013).

Sump lids should be labeled in a manner similar to recommended labels for SSDSs (see Section 9.4.6).

Region 5 does not recommend connecting a sump, which is in contact with soil gas, to a depressurization system unless other options are determined to be inadequate. Concerns include increased system noise, air leakage, and compromised accessibility to sump pumps (American National Standards Institute [ANSI] 2017).

Figure 9-6. Sump Temporarily Sealed with Plastic and Tape

Figure 9-7. Sump More Permanently Sealed with Plexiglass Cover and J-Valve

Figure 9-8. J-Drain Tube with Ball Valve

9.2.9 Evaluate Effectiveness of Immediate Actions

Where possible, when exposure threats exist and protection of occupants over several days or weeks has required immediate action, Region 5 recommends a round of indoor air sampling to verify sufficient improvement in air quality resulting from that immediate action. Regional staff should coordinate with ATSDR and state and/or local health departments regarding actions to be taken and necessary/recommended follow-up sampling.

9.2.10 Immediate Action Final Notes

None of the immediate action options cited above reduces the level of vapor-forming contamination in the subsurface. Region 5 recommends supplementing these response options, if feasible, by installing, operating, and maintaining an engineered exposure control that reduces or eliminates vapor entry into the building(s) (see Section 9.3) until remediation of subsurface vapor sources is complete. In some cases, actions such as sealing floors or sumps may suffice to prevent migration of high concentrations of vapors into buildings, but relying on seals alone to remain effective over the long term at sites with known subsurface contamination is potentially risky. Region 5 does not recommend sealing as the only action to address VI because field experience has shown this to be unreliable (ANSI 2017).

9.3 LONGER-TERM MITIGATION OPTIONS FOR BUILDINGS

Most buildings are presumed to have openings for soil gas entry. Susceptibility to vapor intrusion will vary with conditions specific to each building and exterior conditions. Buildings with significant openings in the slab—including dirt floors, skim-coated floors, sumps, and cracks and gaps in concrete floors—may be more vulnerable to soil gas intrusion. Buildings with basements have more surface area in contact with soil than buildings with slab or crawlspace foundations, increasing opportunities for vapors to migrate into the buildings. A general overview of the typical mitigation selection process appears below, with general descriptions of some common building mitigation techniques.

Several mitigation methods have successfully reduced indoor concentrations of soil gas contaminants. Most of the research relates to the reduction of indoor radon levels. Fewer residences have undergone mitigation of chlorinated solvent VI, but the body of research is growing. The extent to which each mitigation method has been studied varies widely. A matrix of typical mitigation techniques is presented in Table 9-1 below (EPA 2008b, EPA 2013, MRR 2019, NACHI 2019, NJDEP 2008). This section also provides additional details regarding several of the most commonly used techniques in Region 5. The References list (Section 12.0) includes sources of additional information about each type of mitigation system.

Table 9-1. Mitigation Technique Matrix

Remedy	Remedy Type	Description	Pros	Precautions
Sub-slab depressurization system	Active	Consists of PVC piping installed through the floor with a fan connected to the piping to remove sub-slab vapors	• Works best in buildings with slab floors • Commercially available as radon systems • Requires low maintenance	• Does not work well in buildings with earthen floors or crawl spaces • Ensure an adequate amount of excavated materials have been removed from the extraction points • Ensure that sub-slab communication testing is completed and integrated into system design prior to installation
Sub-membrane depressurization system	Active	Consists of PVC piping installed under and through an impermeable membrane placed over earthen or gravel area with a fan connected to the piping to remove vapors	• Works best in buildings with crawl spaces • Can be used in buildings with earthen or compromised floors but membrane must be protected from puncture • Commercially available as radon systems • Uses little electricity • Requires low maintenance	• Not appropriate for use on slab floors • Tears in the membrane and gaps in seals can render the system ineffective • Inspect for seams that are lapped less than 12 inches and edges not sealed to walls, posts, or other penetrations

Remedy	Remedy Type	Description	Pros	Precautions
Wall depressurization	Active	Includes PVC piping installed into the walls with a fan connected to the piping to apply suction	• Works well in homes where vapors are migrating through the walls, or through gaps in walls such a compromised mortar	• Walls may need to be sealed to prevent vapor migration through walls in conjunction with wall depressurization • May require concurrent use of a SSDS or a sub-membrane depressurization system (SMDS) • Inspect for cracks, opening, and open-top courses
Drain tile depressurization	Active	Requires perforated pipes or drain tiles that move water away from the foundation of the house; suction is applied to remove vapors	• Most effective where the drain tile extends entirely around the building	• Inspect daylighted drainpipes for missing devices, such as one-way flow valves or water traps
Sump depressurization	Active	Involves capping an existing sump and installing a fan to remove vapors	• Works best if air can easily move in sub-slab material	• Ensure that the sump pit has an airtight seal
Crawl space depressurization	Active	Involves drawing air from the crawl space with a fan; a membrane is often used in conjunction with the fan	• Can effectively reduce concentrations in crawl spaces	• Inspect crawl spaces for the presence of asbestos-containing materials (ACM) and combustible fuel appliances
Indoor air treatment	Active	Includes portable and in-duct units to purify air with zeolite or carbon sorption, ozone oxidation, and photocatalytic oxidation	• Can be rapidly deployed, i.e. APUs	• Affected by high humidity, high temperature, particulates, other COCs • May be affected by impeded air circulation • Desorption may occur • Need to evaluate number of units to deploy considering AERs and COC levels to ensure adequate filtration of contamination
HRV Systems	Active	Increases AERs by introducing outdoor air while using heated or cooled air being exhausted to warm or cool incoming air	• May result in reduced energy costs because the environment is fairly constant • Reduces humidity and condensation	• Not effective at heating air at temperatures below 18°F • Requires frequent filter changes and cleaning • Inspect for ACM

Remedy	Remedy Type	Description	Pros	Precautions
Indoor ventilation	Active or passive	Various methods to increase AER; methods may include opening windows, door, and vents; HVAC modification; fans; or HRV (described above) for active supplemental ventilation	• Can be used to quickly and easily reduce indoor air concentrations	• May result in increased energy costs for the building • May not be effective at adequately reducing indoor air COCs • May not be appropriate at certain times of year, i.e. opening doors and windows in the winter
Vapor barriers	Passive	Impermeable covering or coating that prevents vapors from entering through floors or walls engineered into new building or retrofit into existing building	• Can be used for existing buildings with dirt or compromised floor basements or walls • Works wells in new construction when placed beneath the building	• More challenging to install leak-free in existing structures • For retrofits, limit foot traffic to protect the integrity of the barrier, or protect barrier by topping with coatings, concrete or overlying flooring materials
Passive depressurization technologies	Passive	Uses natural driving forces to intercept sub-slab contamination; may include wind-driven turbines, solar-powered fans, certain piping configurations	• Works well when paired with other technologies, such as vapor barriers	• Dependent on meteorological and site conditions • Lack of available long-term performance results
Sealing	Passive	Consists of sealing cracks and other openings in foundations, walls, or sumps	• May completely eliminate intrusion pathway in some circumstances • Often works well when paired with other technologies, such as SSDS	• Requires regular maintenance • Can be difficult to find and seal all openings • Must ensure that sealants do not contain COCs

9.3.1 Active Depressurization Technologies (ADT)

ADTs are the most thoroughly studied approach to mitigate VI. ADT systems are widely considered the most practical VI mitigation strategy for most existing buildings, including those with basements, crawl spaces, or slab-on-grade foundations. ADT systems are generally recommended for VI mitigation because of their demonstrated ability to achieve significant concentration reductions in a wide variety of buildings at a moderate cost. ADT systems involve a group of methods, customized for the different construction features of buildings, to intercept vapors before they enter the indoor air which exhausts the vapors to the outside. This is an active approach to mitigation because it integrates one or more fans into the system design to actively draw vapors away from structures. The group of ADTs primarily consist of SSDSs, wall depressurization, drain tile depressurization, sump depressurization, and sub-membrane depressurization. Sub-slab and sub-membrane depressurization are described in more detail below. For additional guidance on ADT methods, see EPA (1993 and 2015), ANSI (2017), and ASTM (2013).

9.3.2 Indoor Air Treatment

Treatment of indoor air can proceed via use of portable and whole house commercially-available air cleaners. Portable units are described above in the immediate action option section of this document (Section 9.2.3). In certain circumstances, air filtration units can serve as a longer-term technique to address indoor air contamination; however, EPA recommends pairing this technology with another method that reduces or eliminates vapor entry into the building (EPA 2015a). Air treatment technology utilized over a longer term is recommended as a "polishing" technique. Periodic replacement of filters is necessary. Filter breakthrough time can be estimated by use of equations such as the Wheeler-Jonas equation that accounts for air concentration, flow rate, and adsorption rates. The system manufacturers can convey chemical isotherms to facilitate these calculations. Additional information is available in MADEP (2016b) and EPA (2017).

9.3.3 Positive Indoor Pressurization

Application of this method occurs most often in commercial and industrial buildings where HVAC systems bring in outdoor ventilation air, and systems can be modified to increase indoor air pressure. Under certain conditions, this technique can effectively stop soil gas entry (ANSI 2017); however, it is generally not cost effective in older, more leaky buildings (EPA 2008b). Existing or new mechanical systems can add enough uncontaminated air at a sufficient rate to result in a positively-pressured airspace. A qualified individual, such as an industrial engineer, should vet the design, and a ventilation professional should install the system (ANSI 2017). Monitoring pressure and other indicators (e.g., indoor air monitoring) is important to ensure maintenance of adequate pressurization throughout areas of the building that could be subject to VI (EPA 2015a).

9.3.4 Crawl Space Depressurization/Pressurization/Ventilation

Crawl space depressurization involves sealing off the area and depressurizing the entire ambient airspace. EPA Region 5 does not generally recommend this technique, as it can lead to significantly increased contaminant levels in the crawl space, adding to exposure risk (EPA 2008a). The site team should consider crawl space depressurization as a last resort where SMDS or SSDS cannot be installed in the crawl space (EPA 2008a, design info in EPA 1993, ANSI 2017). The site team may also consider other methods when sub-membrane depressurization will not work, including crawl space ventilation and positive pressure increased ventilation. See EPA (2008a) for design information.

9.3.5 Indoor Ventilation (with or without heat recovery)

General building ventilation is discussed above in the emergency response section. In addition to application of this technique as an emergency response strategy, active or passive ventilation may sometimes serve as a longer-term remediation strategy. However, passive ventilation may not work in many climates. Ventilation strategies and design options are discussed in EPA (2008a) and ANSI (2017).

Heat Recovery Ventilation (HRV) systems (see Figure 9-9 below) and Energy Ventilation Recovery systems can be good sources of supplementary ventilation (https://www.energy.gov/energysaver/weatherize/ventilation/whole-house-ventilation). These systems bring fresh air into a building, heat/cool it, and then vent indoor air out of the basement/crawl space. HRV systems typically consist of two ducts—one bringing fresh air from the outside and one venting air to the outside. The air is brought into the building through one duct, filtered, and then dispersed throughout the building. A separate exhaust fan is installed on another duct to remove an equal volume of air and exhaust it outside the building. Heat is exchanged between the inside air and the outside air, thereby heating or cooling it. HRV heats the incoming air in winter, preventing "cold basements," which helps discourage building occupants from turning off the system. HRVs have been utilized to effectively reduce indoor air VOC and radon concentrations to acceptable levels where the required reduction was less than 50% (Rudd and Bergey 2014, EPA 1993).

In OEPA's experience, HRV systems provide one to four air exchanges per hour depending on size of the blower, creating potential to greatly increase the amount of fresh air into basements/crawl spaces. Residential-sized units typically provide one air exchange per hour. The heat exchange is approximately 85% efficient. During winter, HRV systems effectively heat outdoor air as cold as approximately 18 degrees Fahrenheit (°F). HRV systems are not effective at heating air when outside temperatures are below 18 degrees. HRV systems for most residential-size units typically cost $1200-$2200. These add $10 to $20 a month in electrical costs (Hagen 2018). Design tips are included in ASTM (2013). Residential building ventilation rate standards are specified in American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Standard 62.2-2016 (ASHRAE 2016).

Additional considerations are as follows:

- HRV can induce low humidity conditions indoors during the heating season; system modifications may be necessary seasonally.
- HRV can increase window condensation when temperatures are below one degree Celsius (°C); modifications may be needed seasonally.
- Air-to-air heat exchangers provide reductions no greater than 25 to 75%.
- No practical limits restrict the amount of "clean" dilution air that can be exchanged to achieve VOC reductions without adversely affecting space conditioning requirements and occupant comfort.
- Required maintenance (model-dependent) includes cleaning or replacing filters every one to three months, cleaning the heat exchanger core every six months, cleaning the condensate pan and hood/fan every six months, and arranging for an annual inspection by a professional that may include an air balance check and rebalancing, if needed.
- Dust and dirt buildup can reduce airflow and reduce system efficiency.
- OEPA has used HRV in residential structures. Most of these homes had basements or crawl spaces (usually both) that could not be fully isolated by use of a typical sub-slab mitigation system or a geomembrane. One drawback that OEPA has observed is that the units tend to channelize air flow, preventing complete mixing of basement air (Hagen 2018).

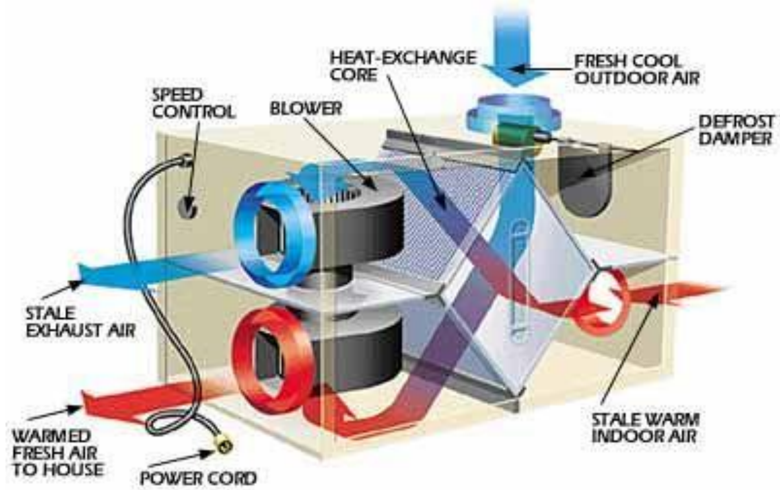


Figure 9-9. HRV System (from Klenck 2000)

9.3.6 Vapor Barriers (impermeable membranes, coatings, or coverings)

Vapor barriers are impermeable coverings or coatings frequently and effectively engineered into the design of new buildings or retrofitted into existing buildings (a more challenging task) to cover building floors and/or walls to reduce or eliminate vapor entry into the buildings (see Figure 9-10 below). Chemical resistivity data are available for some types of barriers, described in more detail below. Region 5 has effectively retrofitted buildings with several types of vapor barriers, but typically pairs vapor barriers with active SSDSs, as recommended in EPA's national guidance (EPA 2015a).

Figure 9-10. Vapor barrier being installed over deteriorated slab of building

9.3.7 Passive Depressurization Technologies (PDT)

Traditional passive depressurization systems are similar to active SSDSs except they exploit natural driving forces to intercept sub-slab contamination and vent it outside above the roofline (EPA 2008a) (see Figure 9-11 below). These systems rely primarily on the buoyancy of air warmed by passing through the heated indoor space; they do not contain active fans. Their effectiveness depends on meteorological and site conditions. Few systems have been tested for long-term performance. In Region 5, some existing PDT systems have been tested and found inadequate for protecting indoor air from VI.

ANSI (2017) includes an advisory about passive systems in its guidance that states: "Achieving a complete and comprehensive break in the connection between soil air and living spaces is not truly possible or sustainable and efforts to counter natural forces that drive soil gas entry using passive means are often unreliable or unsustainable."

A wide variety of mechanisms or configurations have been studied and implemented to counter the natural energy forces that drive soil gas into a building. These PDT include wind-driven turbines, solar-powered fans, and piping configurations that seek to enhance the effect of wind in generating negative pressure within depressurization system piping. These technologies have not demonstrated that they can consistently and sustainably deter vapor from entering buildings (ANSI 2017). If these types of systems are utilized, great care must be taken to ensure that indoor air remains safe across multiple seasons and conditions.

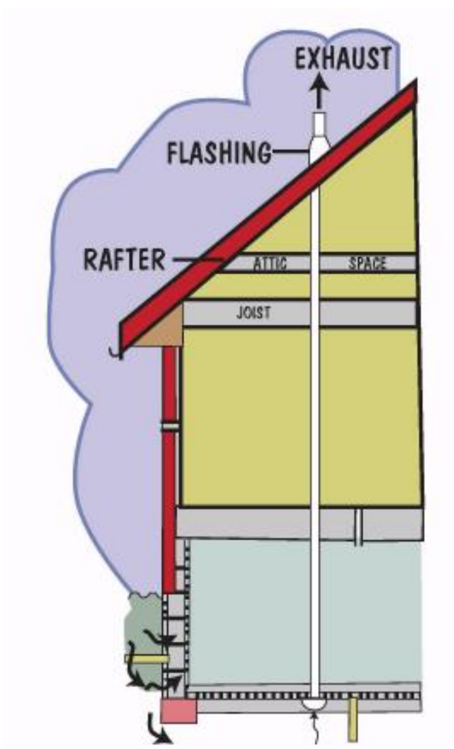


Figure 9-11. Passive Depressurization Example (EPA 2008b)

9.4 SELECT A MITIGATION SYSTEM

The general mitigation selection process flow laid out in Figure 9-12 below was adapted from the radon mitigation process flow chart included in EPA's radon mitigation design document (EPA 1993).

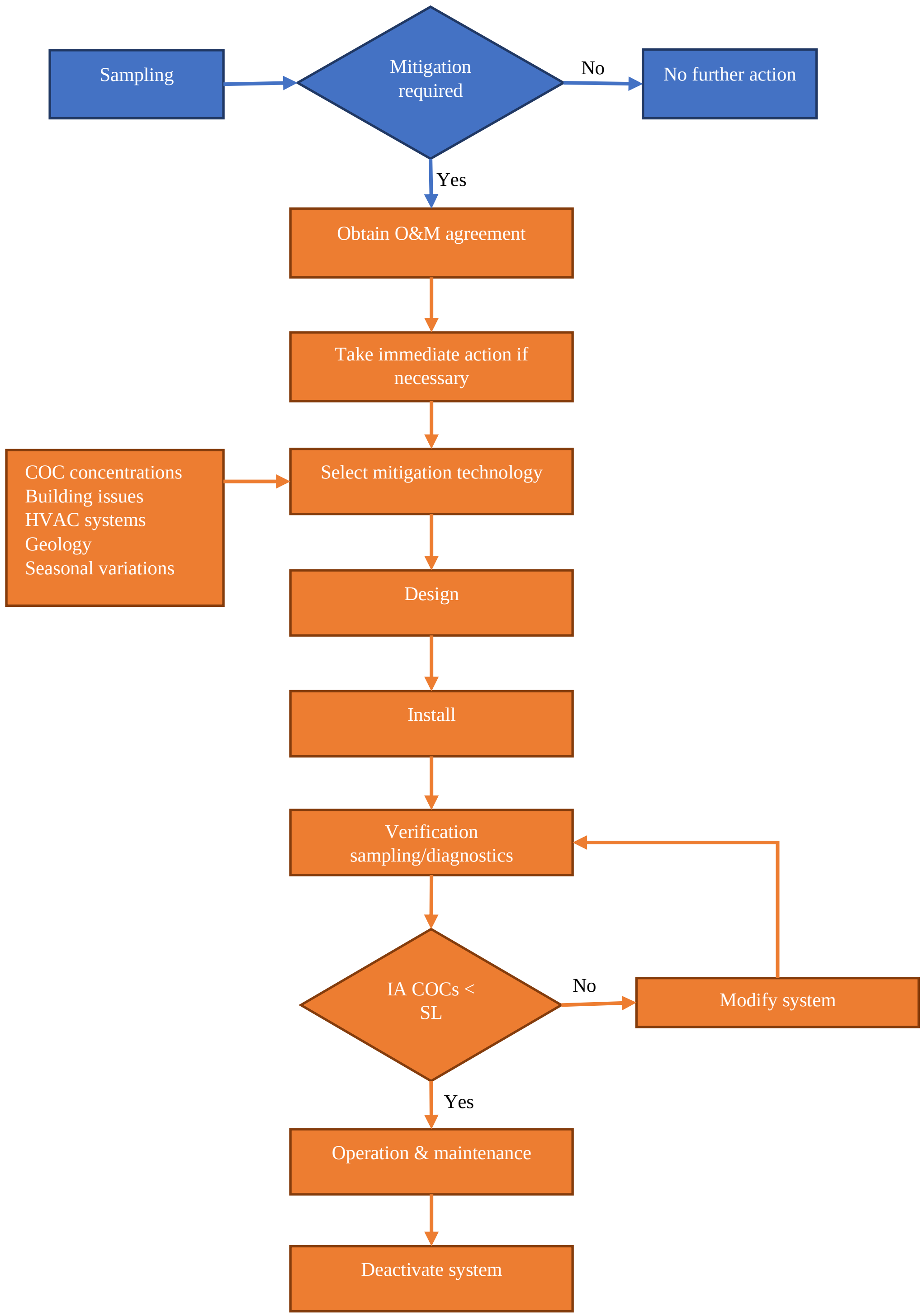


Figure 9-12. Mitigation System Installation Flowchart

9.4.1 Conduct a Building Survey

Building features largely dictate applicable mitigation methods in existing buildings. Some such features are discussed in Section 5.4. Appendix E includes a questionnaire that captures information on building construction. Additionally, Minnesota Pollution Control Agency has an example building survey form on its website, included as Attachment D to its VI Guidance document (https://www.pca.state.mn.us/sites/default/files/c-rem3-01a.doc). Typically, assessments of the following items occur during a building survey:

- Type of building foundation: basement, slab-on-grade, slab-below-grade, or crawl space
- Type of heating and air conditioning system
- Tightness of the building
- Size and layout of building floors
- Age, condition, and construction materials of the basement/slab/crawl space floor and exterior walls
- Level of contaminant reduction required
- Extent of dirt floors and walls in the basement/slab/crawl space
- Nature of soil under and around the building
- Proximity of building to contamination source area
- Presence of openings in basement/slab floor surface
- Presence of dry or wet sump pits and sump pumps
- Groundwater intrusion/flooding issues
- Presence of perimeter drain tile
- Presence of other potential VOC sources
- Occupant use of each building floor.

Building survey information can then aid an initial determination of types of mitigation to consider for the building.

9.4.2 Active Sub-Slab Depressurization Detail

Details regarding design of SSDSs are beyond the scope of this document, and numerous other references are available. Recommended sources include EPA's 1993 Technical Guidance for Active Soil Depressurization Systems that addresses chlorinated compounds, as well as radon, and is now stewarded by the Consortium on Radon Standards (ANSI 2017). In addition, installation of mitigation systems in low-rise residential buildings should conform to the ASTM standard (ASTM 2013). These documents cover design and installation of combinations of the following types of systems: passive SSDS, active SSDS in basements with concrete floors, sub-membrane depressurization, hollow block wall depressurization, and drain tile and sump depressurization. Compliance with local building codes is necessary during installation of the SSDS.

9.4.3 Identify a Qualified Contractor to Design and Install

It is important to use contractors with experience, applicable technical knowledge, and licensing (if required) for installation of SSDSs. Many states have radon licensing or certification programs that can help identify an experienced local contractor. Radon Professionals are also certified by the National Radon Proficiency Program or the National Radon Safety Board. Contractors under consideration should be able to furnish references. Region 5 maintains a running list of contractors within the Region that conduct vapor mitigation (available on the R5 VI toolbox site: response.epa.gov/vaporintrusiontoolbox). However, EPA is does not endorse or recommend any particular contractor.

9.4.4 Active SSDS for Basements or Partial Basement/Partial Crawl Spaces with Concrete Floors/Slabs, and Buildings on Slabs

This section provides a brief description of how to design and install an active SSDS in a basement with a concrete floor.

Depressurization involves installation of one or more extraction point(s) in a basement, crawl space, or slab floor connected to a high-static extraction fan using the steps below

1. Drill one or more holes in the existing slab.
2. Remove soil from beneath the slab to create a “suction pit” (6- to 18-inch radius).
3. Place vertical suction pipes into the holes.
4. Seal openings around the pipes.
5. Connect pipes to a fan.
6. Turn on fan and draw soil gas from the sub-slab area through the piping and vented to the exterior of the building.

Figure 9-13 shows a typical active SSDS layout.

An active SSDS generally functions best when an intact, uniform floor is in place and communication (air flow) is good below the slab. Skim/wash coat and dirt floors may need sub-membrane depressurization. Active SSDS does not tend to work well in buildings with complex sub-structures, where the suspected source is groundwater infiltration or building materials, or where significant vapor entry points are in the floor and remain after system installation. An active SSDS also functions best in buildings where basement/crawl space walls are hollow block or poured concrete. Another technique may be necessary to supplement application of an active SSDS to a fieldstone wall if the wall is a major vapor entry route. Occasionally, this is an issue with hollow block walls as well. Low sub-slab communication can complicate design. Sub-slab communication/air flow may be obstructed by factors such as footings supporting load bearing walls, beams, air ducts, and sunken rooms; however, with good communication, these types of obstacles may not hinder results. Designs can also be complicated at buildings with part basement/part crawl space or adjoining wings/additions. In several Region 5 projects, EPA has been able to successfully address indoor air contamination by treating the basement portion of the building alone, without depressurizing an adjacent crawl space or addition on a slab.

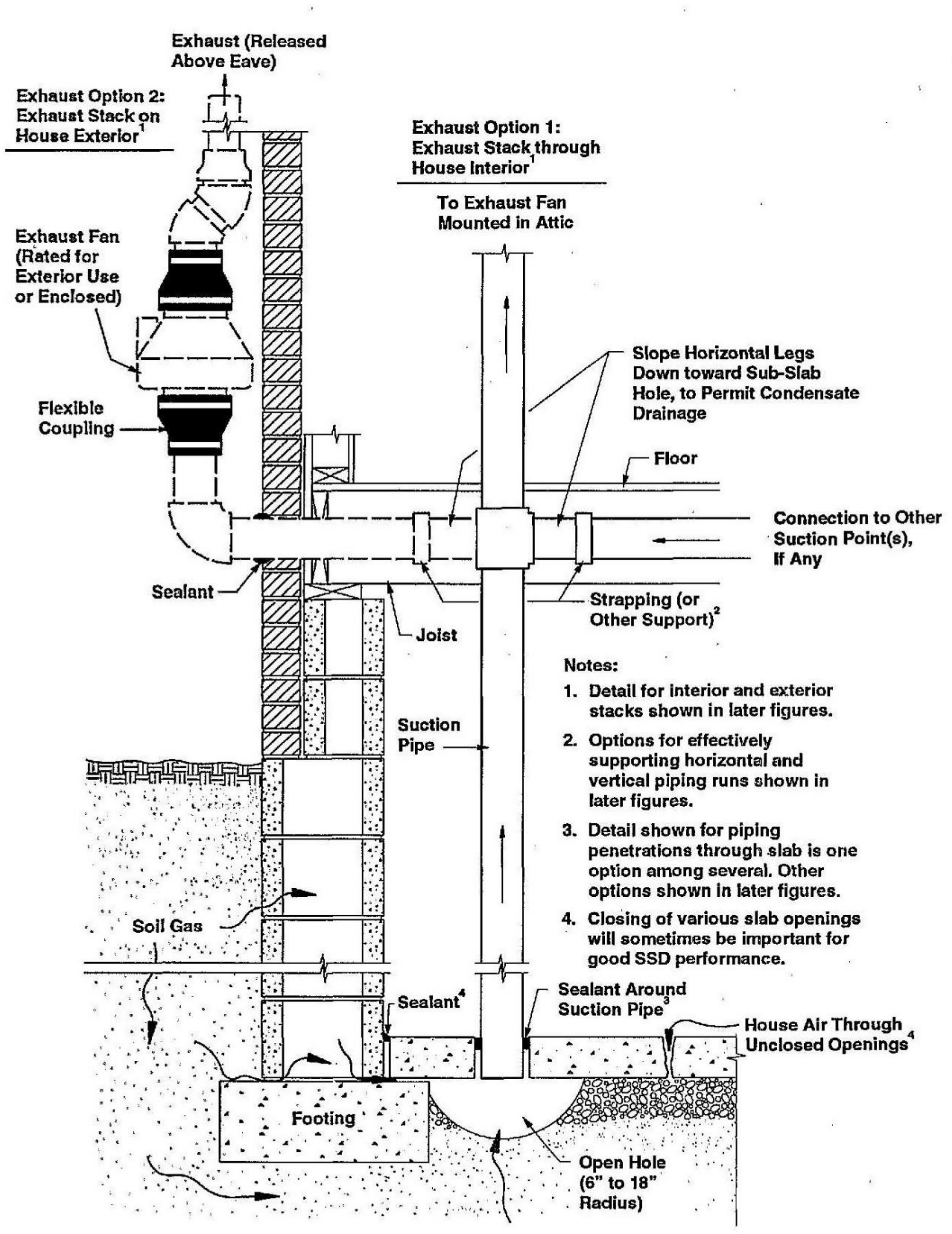


Figure 9-13. Typical Active SSDS Design (EPA 1993)

9.4.5 Communication/Pressure Field Extension Testing

Pressure field extension testing must occur prior to installation of an active SSDS (ANSI 2017). Necessary procedures and equipment are detailed in EPA (1993) and ANSI (2017). Generally, this includes the following:

- Initiating testing by application of a qualitative method
- Installing test holes and inspecting for aggregate (one per corner, no less than three holes per residential building, and at least one hole per slab)
- Applying suction (vacuum cleaner or SSDS fan mounted on pole)
- Measuring baseline pressurization at each test hole by use of a micromanometer (vacuum off)
- Measuring pressurization at each test hole by use of a micromanometer (vacuum on)
- Continuing testing with quantitative results if qualitative tests indicate poor communication.

Communication is likely adequate and uniform if distinct measurement of induced sub-slab depressurizations can occur via the micromanometer at each test hole with the vacuum cleaner operating. If this is the case, just one or two SSDS pipes will likely suffice in the active SSDS (up to 2,700 sq ft), and selection of locations of pipes will be flexible (EPA 1993).

Marginal sub-slab depressurization and high flow rates could indicate that communication is adequate, but the relatively low-flow vacuum cleaner is overwhelmed by available flow. In this case, an active SSDS (with perhaps double or triple the flow capacity of the vacuum) might perform well. Marginal depressurizations and high flow could also suggest a leak through the slab near the vacuum cleaner. With marginal communication, one extraction pipe per 350 to 750 sq ft (two to four per property) is often used, but more could be needed (EPA 1993).

Inconclusive results, with distinct depressurizations in some test holes but with no (or marginal) depressurization in other holes, may suggest nonuniform communication or failure of the suction field to extend to the more remote portion of the slab. In this case, the site team should determine next steps based upon the mitigator’s experience with other houses in the area (EPA 1993).

If results suggest poor suction field extension, with no (or only marginal) depressurizations observed in most or all test holes, assume poor communication. Further quantitative testing can verify this. The site team can try to increase communication by increasing the number of extraction points or consider other remediation techniques (EPA 1993).

With marginal or poor communication, more centrally-located suction points may be necessary (use radius of influence from testing to obtain overlapping circles to cover the entire slab). Additional fans may be needed, or it may be necessary to increase in the fan to suction point ratio. This may also necessitate use of specialty fans (high suction) (EPA 1993).

Results may vary seasonally. Pressure field extension (PFE) test data obtained when outdoor temperatures are within 10 °F of the average coldest local temperature will typically characterize worst-case PFE (ANSI 2017).

9.4.6 Additional System Aspects

Design

The design should specify:

- Number and locations of suction points;
- Locations and sizes of piping, suction fan, piping network, pipe cap, manometer, alarm, labels, and exhaust system; and

- The sealing.

System Piping

Rigid schedule-40 PVC is the industry standard. Piping should be small enough to be inconspicuous but large enough to avoid suction loss and excessive noise; 4-inch piping is the most common size used and it represents a good compromise between the two factors. Generally, the site team should design system piping runs as straight as possible to avoid suction loss. Piping should drain back to the suction point with no “sumps” or low spots, if possible, to help avoid condensation (EPA 1993). System installation should proceed in a manner that prevents water from escaping the piping at any location other than as designed (e.g., to the ground beneath the slab or soil-gas retardant membrane). Water will form consistently within piping during colder seasons as vapor condensates. This water can contain COCs (ANSI 2017). Insulation can help prevent condensation (ASTM 2013).

The PVC pipe is connected to an extraction fan, and the exhaust piping is routed to the roof-line. The stack should be designed to prevent the following:

- Re-entrainment of exhausted air into the structure or any adjoining or adjacent structure;
- Exposure of individuals outside the building to soil gas constituents in the exhaust air; and
- Damage to building components (ANSI 2017).

Positively-pressurized piping (exhaust from fan) should not pass through or under occupied spaces in the building—it should run completely outside of the building or within an attic (ANSI 2017).

Piping may be subject to general height restrictions and height specifications related to discharge emissions. For example, Michigan requires that stacks discharge 12 inches above the eaves or surface of the roof. Stacks may require bracing. Also, it is important to position discharge away from any air intakes for the building, away from any windows, and above the highest roofline and ridge if practical. Details on design of stacks and piping selection and installation appear in ANSI (2017) and ASTM (2013).

As shown on Figure 9-14 below, flow adjustment valves can be installed on piping if depressurization needs may vary over time or if multiple extraction points are installed. Region 5 also recommends installing sampling ports on piping to facilitate analysis of vapor extraction over time.

Figure 9-14. Installations of Flow Adjustment Valves (Left) and Sampling Ports (Right) on Piping

Fans

Inline radial blower fans are most common. They typically operate within a range of 95 to 140 watts. They are reasonably priced, quiet, and generate good suction (2 to 4 inches water column [WC]) at flows typical of active SSDS applications. The site team should select specific models based on expected suction and flow rates determined during testing that optimize the fan power curve. The installer should place fans outside or in the attic (in cold climates) and not in living spaces or basements, as they may leak. Outside fans should be outdoor rated or enclosed. See Figure 9-15 below. Extensive discussion of fan selection is in ASTM (2013) and ANSI (2017).

Radon mitigation fans are not typically rated as explosion proof. An explosion-proof fan may be necessary when evidence indicates that gases passing through the fan could result in a fire or explosion (ANSI 2017).

Figure 9-15. SSDS Extraction Fan

Turbines/Pipe Caps

The site team should install pipe caps at the top of the system discharge. Caps prevent most precipitation from entering the system. Several different styles of pipe caps are available. Figure 9-16 shows, from left to right, a semi-circle style cap with guard, a turbine style cap, and a circular style cap. The turbine in the turbine style cap will turn in the wind, potentially allowing the system to continue operating during a power outage.

Figure 9-16. Three Cap Style Options

Wiring/Electrical

An electrician should install the wiring for the active SSDS. Where possible, Region 5 recommends hardwiring the system into the electrical panel (i.e., not including a system on/off switch), or, if a switch is included, equipping it with a lock (Figure 9-17). The OSC or RPM should provide a key to residents allowing them to turn off power for maintenance purposes. These methods will help prevent inadvertent system shutoffs. The extraction fan should operate continuously to vent the subsurface air from beneath the basement slab.

Region 5 tested the use of solar power to power the SSDS at a property in Indianapolis, utilizing a combination of solar panels and a marine battery. Based on results of this limited test, Region 5 does not encourage use of solar power at this time (Lam 2017). Moreover, ANSI states that technologies such as solar-powered fans have not yet demonstrated they are reliable for consistent and sustainable mitigation (ANSI 2017). Additional testing of these components is necessary to ensure that they operate continuously so that indoor air remains safe across multiple seasons and under multiple conditions.

Figure 9-17. Electrical Box with Switch, Equipped with a Lock

Manometers

The installer should place a permanent vacuum gauge ("U-tube" manometer) on each system on the extraction side of the fan. Manometers are open tubes and must remain upright to avoid liquid loss (Figure 9-18). The system should operate such that the manometer reads between a minimum vacuum of 1 inch WC and a maximum vacuum of 2.5 inches WC. An SSDS vacuum exceeding 4 inches WC may pull "make-up" air (from below the house) and draw contaminant vapors from the subsurface plume into the building. The goal is to achieve vacuum across the entire sub-slab, with minimal vacuum draw from the extraction fan. A standard U-tube manometer reads zero to 4.5 inches WC vacuum at 0.1-inch increments. For high suction fans (30 inches WC +), "mini-helic" dial manometers are more appropriate.

Figure 9-18. U-Tube Manometer

Alarms

Region 5 recommends equipping systems with alarms, in-line on the system piping, between the extraction point and the fan (Figure 9-19). There should be one alarm for every fan installed. Several styles of alarms are available from radon mitigation companies. The alarms typically make an audible noise and flash a red light if the fan stops operating. Region 5 has used both battery-powered and hard-wired alarms, and recommends the hard-wired models, where possible. However, this alarm must be labeled with a warning not to unplug and noting its association with a soil gas control system.

Figure 9-19. Installed Alarm

Labels

The site team should label primary components of the system, including piping, fans, electrical boxes, sump covers, membranes, and other accessories. Labels should be placed at eye level and convey the information in Figure 9-20. Place the system O&M manual or overview sheet next to the system label.

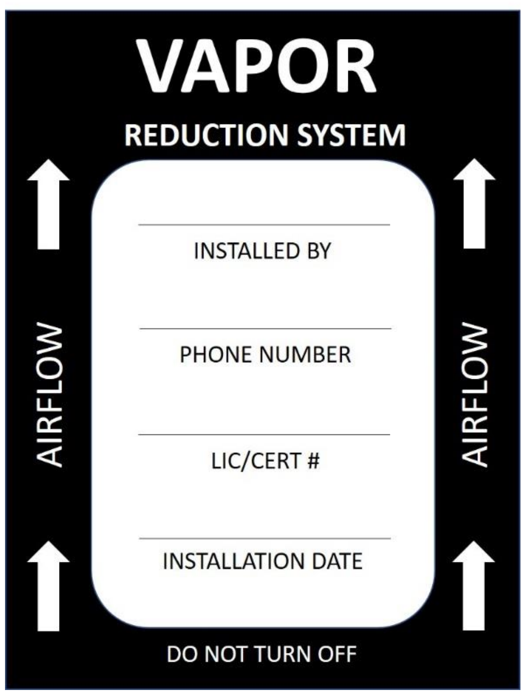


Figure 9-20. Example Label

Remote System Monitoring

Remote monitoring technology for active SSDSs is available. Some products transmit airflow, pressure (vacuum), power, and device temperature measurements continuously via cellular or Wi-Fi communication networks, allowing interested parties to recognize immediately that a system is not operating. One system EPA has used transmits airflow, pressure (vacuum), power, and device temperature measurements continuously via cellular or Wi-Fi communication networks.

9.4.7 Active Sub-Slab Depressurization in Areas with High Water Tables

High water tables can compromise sub-slab communication seasonally or all the time. Traditional sub-slab depressurization may be ineffective for areas with high water tables. Alternative techniques are available, including tile drain depressurization, installation of a false floor with vapor capture below, groundwater infiltration management techniques, or the options described in the additional mitigation options section. Sub-slab depressurization may still work if groundwater is not directly below the slab and/or the water level does not fluctuate frequently.

9.4.8 Active Sub-Membrane/Sub-Slab Depressurization in Properties with Dirt Floors and/or full Crawl Spaces

Inhalation exposure can be reduced in structures with dirt floors, significantly compromised concrete floors, or full dirt bottom crawl spaces by installing a SMDS. SMDS involves installing line-slotted PVC piping under a polyethylene (poly) membrane (6-mil [0.15-millimeter] thickness or greater over the dirt floor or dirt crawl space (ASTM 2013). The slotted PVC pipe should be routed to an in-line fan and then exhausted, as for a typical SSDS installation. Alternatively, suction points could be installed below the membrane, routed to the in-line fan, and exhausted outside. The poly membrane should cover the entire floor and be completely sealed to the walls and all penetrations to ensure maintenance of negative pressure below the poly membrane. The installer should ensure that there are no obstructions to airflow below the membrane and prevent breaches of the membrane. The site team should evaluate the integrity of the membrane after installation. Design tips are available from EPA (2008a), ANSI (2017), and ASTM (2013). This option is typically more expensive than a traditional SSDS.

Another option for mitigation of buildings with dirt floors or compromised concrete floors to is to install a vapor barrier on the floor and pour “flowable fill” concrete over the membrane, forming a new concrete floor (Figures 9-21, 9-22, and 9-23). This option is expensive because concrete pouring and forming are labor intensive. In addition, the installer must raise water heaters and furnaces a few inches and reconfigure all piping to account for thickness of the new concrete flooring. The OSC or RPM also must coordinate with the owners or occupants to move all belongings out of the basement. After removal of these items and pouring and curing of the concrete, the site team should install a regular SSDS.

Figure 9-21. Piping Beneath Membrane

Figure 9-22. Piping in Crawl Space

Figure 9-23. Basement with New Concrete Floor and SSDS

9.5 ASSESSING EFFECTIVENESS OF BUILDING MITIGATION EFFORTS

Region 5 recommends conducting a series of simple tests to establish that the system is working as designed. The following are a few performance testing tips based on Region 5's experience.

- For soil depressurization systems, it is important to repeat some parts of the sub-slab communication test to establish that the fan delivers the pressure field extension under the slab as designed. Also, the site team should check the pressure head established in the exhaust pipe to ensure that it achieves the design value. Measurements of sufficient pressure differentials (e.g., five Pascals) at a variety of grid locations across the slab can be a strong indication of reduction of VI.
- Measurement of adequate pressure differentials in the system's exit pipe (for example, 1 inch WC or 250 Pascals) can indicate that the system is operating as intended, but these are not measurements of system performance.
- Regarding positive pressurization systems, the site team should monitor the positive pressure in the lowest zones of the building over an extended period (at least several days) to establish that the system can maintain adequate pressure over time. Evaluating the increase in energy consumption necessary to maintain adequate pressure is also important.

- The site team may attempt to balance flows properly for air-to-air heat exchange ventilation systems (this can be very difficult).

Although the intent of the procedures listed above is to establish that the system is operating as designed, implementing these procedures does not ensure proper system operation. These procedures do not allow prediction of indoor air concentrations because of uncertainties related to many properties of soil, buildings, and environmental driving factors. The only way to unequivocally prove that the system is performing adequately is to measure indoor air concentrations of COCs.

Initial Post- Mitigation Clearance Sampling

The primary indicator of successful mitigation system performance is post-mitigation indoor air sampling results that fall below action levels (EPA 2008a). Indoor air sampling should occur after determining that the system is performing as designed (via tests such as those described in the previous section). Region 5 recommends collecting multiple rounds of 24-hour, post-mitigation indoor and sub-slab air samples shortly after installation of the mitigation system to initially clear the building. In Section 6.8, Region 5 recommends collection of concurrent sub-slab and indoor air samples for the purposes of evaluating and interpreting data.

The site team should collect samples within the breathing zone at the lowest level of the building. On a case-by-case basis, the OSC or RPM may also consider subsequent sampling and/or sampling at other locations (see Section 6.6). For example, if a building previously had high levels of indoor air contamination on the first floor, collecting clearance samples on the first floor may help verify that COC concentrations in the indoor air no longer exceed action levels. The OSC or RPM should consider more than one round of clearance sampling in buildings where there are concerns of possibly unstable conditions such as staff suspecting additional VI through building walls, unsealed points in the floor, unsealed crawl spaces, diffusion from groundwater intrusion, or similar scenarios. After completion of clearance sampling and verification that the mitigation techniques utilized are working effectively, the OSC or RPM should transition the building into a post-mitigation system evaluation program (Section 10.0). The site team should communicate clearance sampling results to property owners/occupants and to the federal, state, and local health and environmental agencies collaborating on the response.

9.5.1 Additional Building Mitigation Options That May Be Helpful

If the VI mitigation system is not adequately controlling COC concentrations in indoor air, the site team can apply the immediate response techniques detailed above to stabilize the situation. In addition, Region 5 recommends considering the following techniques only after the more traditional techniques, such as sub-slab or sub-membrane depressurization, have been attempted and have been demonstrated not to adequately control VI.

Revisit Installed Mitigation System and Original Assessment of Contamination Source

The OSC or RPM should consider taking the following steps if VI into indoor air remains inadequately controlled after system installation:

- Ensure that the system was designed and installed appropriately and is functioning as designed.
- Check to be sure that the designer completed pressure field testing, and that the results support the installed system. For example, pressure field testing may show that sub-slab communication is very poor, but only one extraction point was installed, and that extraction point is unable to extract vapors from beneath the entire slab.
- Ensure that condensation is not adversely affecting the system.

- Confirm that a high water table is not impacting depressurization.
- Ensure that all openings in the floor are sealed.
- Verify that no other source of contamination exists (e.g., ambient air, household products, or a product introduced during the response action).
- Try to determine the pathway by which vapors may be continuing to intrude. Real-time field screening tools such as EPA's TAGA bus or portable GC/MS instrumentation may help in identifying vapor inflow points. (Note: reviewing agency QA/QC policies for decision making associated with use of field screening tools like a portable GC/MS unit is important.) Smoke testing may also provide valuable information. A consulting engineer may be needed to assist with this work. If unable to determine any reason why the system is not adequately controlling VI, consider adding some of the techniques listed below as system supplements.

Add a Retrofitted Vapor Barrier

Some slabs cannot be sealed successfully. The slab may be too thin or composed of materials not conducive to sealing. Alternatively, there may be evidence indicating that hazardous vapors are intruding through basement/crawl space walls and impacting indoor air quality. In these situations, the site team should consider the addition of vapor barriers to seal walls and/or floors Sealing building floors should close openings in the foundation for soil gas contaminants to enter, and reduce the driving forces for VI by minimizing the stack effect and effects of wind on the building. Building codes and several manuals address these issues.

Two primary types of vapor barriers are used to retrofit existing buildings—sheet membranes and fluid-applied membranes. Region 5 has retrofitted existing buildings with both types of vapor barriers, installed in conjunction with SSDSs.

In Region 5's experience, vapor barrier retrofitting is a developing field. OSCs and RPMs should not assume that a building with a vapor barrier is no longer undergoing VI. Smoke testing can be useful in identifying gaps in installed vapor barriers. (Note: smoke may trigger fire alarms in buildings.) The OSC or RPM should review all product contents carefully before use to ensure they do not contain chemicals that are targets of the response action. Also, the OSC or RPM should carefully review product specifications. Some products are approved only for horizontal use or only for vertical use. The OSC or RPM can request chemical resistivity data for products under consideration to learn whether the product has been shown to block the COCs targeted in the response action. The manufacturer can provide cure times, as well as odors or vapor emissions that may arise while the product cures. If possible, the site team should verify the integrity of the membrane after installation. Finally, Region 5 recommends clearing any products planned for use with the local fire department. Some products may increase fire hazard and may require thermal barriers if installed.

Typically, Region 5 recommends supplementing vapor barriers with an engineered exposure control (e.g., an active depressurization technology) that further reduces or eliminates vapor entry into the building.

Evaluate Wall Depressurization

If the building is near or in the contaminant source area or contaminated soil, contaminated vapors may migrate through sub-surface building walls, especially if the walls are porous, such as fieldstone walls (EPA 2008a). Farther away from the source area, vapors typically migrate from impacted groundwater vertically and intersect with basement/slab/crawl space floors first, and VI through walls is less of an issue and wall treatment is not needed.

Assessing the condition of subsurface walls and concentrations of contaminants in soil gas next to the building will help determine if VI into the building is occurring. If treatment of walls is necessary, seal the walls with various vapor barrier products, and/or install systems to depressurize areas behind the walls. Adding depressurization of walls by drawing air from voids in the wall and venting it outside may improve performance of the overall system.

Sealing walls may also be necessary for successful depressurization if walls are made of concrete block. Sub-slab depressurization may not suffice to effectively mitigate buildings with block wall construction. Block wall depressurization is discussed in detail in EPA (1993) and ANSI (2017).

Address Groundwater Intrusion

OSCs and RPMs may need to assess contaminated groundwater infiltrating a building. Groundwater infiltration can be a very significant risk pathway (EPA 2008a). The potential impact of infiltrating groundwater on indoor air contaminant concentrations can be modeled by use of Henry's Law. EPA's ERT can assist with generating these models. Suggestions for addressing groundwater infiltration are in EPA (2008a).

Consider Adding "Permanent" Indoor Air Treatment/Air Polishing

The site team can add the portable APUs described above to buildings as a temporary measure to facilitate removal of chlorinated compounds from indoor air. The OSC or RPM may consider "permanent" air purification if the source of intruding vapors either cannot be identified or cannot be successfully addressed after installation of mitigation systems and further investigation and testing. "Permanent" refers to the status prior to remediation of the source of VI and before the need for elimination of mitigation to protect indoor air quality. Portable and whole house options are available. In an HVAC-mounted filtration system, a portion of the HVAC system's return air is routed through an air filtration unit before it reaches the air handler. The rerouted air is typically processed in three stages: (1) large particulate pre-filtering, (2) HEPA filtration of smaller particulates (dust, pollen, bacteria, animal dander, and attached viruses), and (3) filtration with sorbent media designed to remove the COC(s). Filtered air is then ducted into the home's HVAC system. The add-on filtration unit typically has its own fan and is designed to run continuously. These filtration systems require maintenance to continue to reduce indoor air contaminant levels (ANSI 2017). EPA (2017) extensively discuss temporary and permanent indoor air treatment options.

9.5.2 Mitigating Source Areas

Numerous techniques are available to mitigate contaminant source areas, thereby reducing or eliminating ongoing migration of contamination to groundwater and source area soil gas, and eventually reducing or eliminating need for continued mitigation of existing buildings. Unfortunately, it can take many years to reduce groundwater contamination before potential VI threats are eliminated (EPA 2008a). These techniques, which typically require complex designs, include soil vapor extraction, air sparging, thermal treatment, chemical and biological in situ remediation, source removal, electric resistive heating, and others. Guidance on source area treatment is beyond the scope of this document. Moreover, mitigation of source areas is generally beyond the scope of the Removal Program. However, each site is evaluated individually, and decisions may vary based on individual site factors. EPA (2008a) and EPA (2015a) provide some reference information about source area mitigation.

9.5.3 Other Considerations/Issues

The following sections discuss other considerations and issues the OSC or RPM should take into account.

Mitigation System Emissions and other ARARs

During removal actions, EPA has the responsibility to request ARARs from federal and state agencies, and to comply with these ARARs to the extent practicable.

Air emissions control requirements may be ARARs that apply to building mitigation projects. The Clean Air Act and/or state regulations governing air pollution emissions may apply to vapor mitigation systems, and compliance with these should occur if practical. These regulations limit annual amounts of discharge of certain pollutants to the air, as well as regulate locations of discharges (e.g., at least 12 inches above the roofline). Many state agencies typically require that EPA demonstrate that potential air emissions from the mitigation systems are below levels requiring permits. Many states have guidance available to facilitate compliance with these regulations. Discharge air can be routed through carbon systems to reduce emissions. EPA can evaluate (calculate) emissions from a sub-slab depressurization system by collecting a sample from a port installed on the exhaust pipe of the mitigation system.

It is important to ensure that installed systems also comply with local building codes, although they are not ARARs.

Radon Mitigation

The site team may encounter active radon mitigation systems during a VI investigation. Sampling results may indicate that active radon mitigation is not effectively controlling the migration of COCs. The site team should evaluate the existing mitigation system to determine if it can be modified or upgraded to address VI. The site team may need to incorporate supplemental mitigation methods if modifications are not possible or do not address intruding vapors.

Power Outages

In areas where frequent power outages occur, active vapor mitigation systems will shut down while power is out. Short power outages do not pose a threat to public health of building occupants. OSCs and/or RPMs should advise occupants that, if power outages occur, they can take the following actions to reduce exposure to organic vapors during a power outage:

1. Limit time in the basement or lowest floor of the building as much as possible.

2. If the power outage continues for many days, create cross ventilation in the basement or lowest floor if outdoor temperatures are tolerable. Cross ventilation draws outdoor air in one window and exhausts it out another window. This process does not have to occur continuously; it can occur periodically.

3. Do not just open windows or turn on ventilation fans, as this may draw organic vapors from the subsurface into the building (New Jersey Department of Environmental Protection [NJDEP] 2012). ATSDR can assist with determining risks from extended power outages, communicating those risks, and requesting EPA assistance to address indoor air quality issues that may arise. This information should be included in the O&M plan.

Battery backup systems, such as 1000-Watt uninterruptible power supply systems, are available and can be installed at properties where frequent, extended power outages occur and health vulnerability is high. Licensed electricians should install battery backup systems.

Turbine-style vent caps, described above, will facilitate passive operation of SSDSs under certain environmental conditions as well.

Avoid Products that may Contain COCs

COCs are present in millions of household and remediation products. The site team should remove any household products that may contain COCs from the property prior to post-mitigation sampling, and air out the property after removal if possible. Importantly, the site team should review constituents of any products planned for use in remediation before installation in a house. If a product containing a COC, e.g. TCE, is accidently installed in a building, the OSC or RPM should follow up with the manufacturer for advice about how to mitigate the situation and how long the chemical is likely to remain in the environment. Ventilation can often facilitate curing of products (as can space heaters if the installation occurs during colder weather) (ANSI 2017).

Ambient Air Sources

At some sites in Region 5, the primary source of indoor air contamination in residential buildings has been ambient air. Region 5 recommends always testing ambient air when conducting air sampling to rule it out as a source (Section 6.7).

Communications about Mitigation to Stakeholders Team

The OSC or RPM should update local and state health departments and environmental agency stakeholders on project status, current conditions, and sampling results (where data sharing agreements have been established) when remediating buildings impacted by VI. Local and state agencies cannot take appropriate response action or assume responsibility for O&M of installed mitigation systems unless they are kept abreast of site information. All stakeholders, other than ATSDR, that EPA shares information with regarding mitigation systems at specific addresses must have signed information sharing agreements in place before EPA can share the information. See Section 7.4 above.

10.0 POST-MITIGATION

This section discusses post-mitigation actions, including documentation of O&M manuals, O&M plans, proficiency air sampling, mitigation system inspections, and ICs. O&M generically refers to "periodic inspections, component maintenance or replacements, repairs, and related activities necessary to ensure continued operation and effectiveness of engineered exposure controls used to mitigate VI" (EPA 2015a).

10.1 MITIGATION DOCUMENTATION

EPA recommends providing documentation of mitigation to property owners, occupants, and state and local regulatory agencies. At minimum, this documentation should include an O&M manual and a summary of the agreement with a state or local government agency (or PRP if applicable) for long-term O&M oversight (i.e., post-removal site control) of the system (i.e., an O&M Plan) (EPA 2015a).

10.1.1 O&M Manual

An O&M manual is a user's guide for informing lay persons about the system. It provides a reference to answer questions or offer resolutions to issues that may arise regarding the system.

The manual should include a summary of why a VI mitigation system was installed at a property and how the system works. The O&M manual should also include, but not be limited to, the following information or items:

- Cover letter;
- Brief description of each major component of the system (i.e., active SSDS, sub-membrane depressurization system, sealants, air treatment systems, sump management systems, vapor barriers, etc.) and the system's proper range of operation;
- Instructions about O&M of each system component;
- Pictures of key system components;
- Description and diagram of final as-built system layout with components labeled;
- Copies of any building permits for the mitigation system;
- Summary of pre- and post-mitigation diagnostic test data;
- Copies of contracts and warranties (i.e., active SSDS fan warranty);
- Name(s) of system installer(s);
- Contact information pertaining to the party responsible for responding to malfunctions and ensuring the system performs properly, and for answering any general questions; and
- Inspection and maintenance guidelines.
- What to do to eliminate risk if there is a prolonged power outage affecting the mitigation system.

Region 5 also recommends including copies of the following administrative documents as appendices to the O&M manual:

- Signed access agreement;
- Mitigation agreement;
- Pre-mitigation sample result letter(s); and
- Post-mitigation sample result letter(s).

In addition, the OSC or RPM should provide the property owner or occupant with keys to the lock for the SSDS switch, if installed.

Example O&M manual templates that Region 5 has used at removal sites are posted on the EPA regional VI toolbox site (https://Response.epa.gov/vitoolbox).

Region 5 recommends placing an O&M manual near the mitigation system for quick access and easy reference. An easy-to-read O&M manual may be especially helpful at rental properties because the guide informs each new tenant about the system and why it was installed.

10.1.2 O&M Plan and Referral to other Programs

Region 5 typically conducts post-mitigation system inspections and sampling for a period of time after installation to verify that the system is functioning effectively. O&M plans are to be implemented by the state, PRP, or homeowner. These plans go into effect *after* EPA's initial system evaluation period. The intent of these plans is to ensure that a qualified entity periodically verifies effective functioning of the systems to protect indoor air quality after EPA's system evaluation period.

The length of EPA's initial system evaluation period varies by program and funding source:

- At Fund-lead sites within the Removal Program, Region 5 typically samples building mitigation systems for one year after installation, as removal actions are not to exceed one year. The Removal Program will conduct periodic O&M during routine sampling. The Removal Program does not perform O&M after the initial year of sampling demonstrates that the system is operating as designed. EPA expects that a PRP, state, or local agency will implement a post-removal site control plan (i.e., O&M Plan), whereby that entity agrees to conduct periodic inspections of the installed mitigation system until the source of VI has been permanently addressed, or the stakeholder agencies determine that mitigation is no longer necessary.

- At Fund-lead remedial sites where EPA installs VI mitigation systems, upon determination that the implemented remedy is operational and functional, the state must assume responsibility for O&M and for inspections of these systems up to one year after completion of construction (40 CFR 300.435(f)(1)). An exception to this is for mitigation systems deemed part of long-term remedial actions for groundwater restoration.

- At PRP-lead removal and remedial sites, PRPs will be required to monitor installed systems as long as the systems are determined necessary to protect indoor air quality.

Installation of a mitigation system is NOT the preferred long-term remedy to solve the VI problem. Installation of a mitigation system is a "temporary fix" to the problem. Mitigation measures reduce exposure of building occupants to hazardous chemicals. The solution for solving the VI problem is to remediate groundwater contamination. Groundwater remediation often requires many years and outlasts the life expectancy of a mitigation system. Therefore, yearly system inspections should occur to ensure proper operation.

O&M plans take effect after the building mitigation systems have passed EPA's system evaluation process and have been proven to adequately reduce indoor air contamination. Annual inspection and maintenance is generally acceptable after the one-year evaluation process, although the O&M Plan should establish triggers for unscheduled inspections. These thresholds may include additional unscheduled inspections following alarms (from warning devices), floods, earthquakes, building modifications (EPA 2015a), construction blasting, or formation of nearby sinkholes (ANSI 2017). Region 5 requests that agencies taking over O&M commit in the O&M plan to annual inspections of the building mitigation systems until the systems are no longer needed and more frequently if triggers occur. Staff should use best professional judgment to determine whether regular inspections should occur more frequently than annually, based on site-specific factors.

The inspecting entity should complete system inspections as detailed in the System Inspection and Maintenance section below (Section 10.2.1), and take prompt action to correct any identified issues. Inspectors should evaluate all installed systems (active or passive SSDS, sub-membrane depressurization system, sealant system, air treatment system, ventilation system, sump management system, vapor barriers, etc.). The inspecting entity may also perform periodic indoor air sampling to reconfirm that the system continues to operate effectively.

O&M plans should describe the transition of system oversight from EPA to a state or local agency. These plans should document where mitigation has been conducted, the entity that will conduct long-term inspections and O&M of the systems, inspection/maintenance frequency, inspection methodology, and any triggers that may induce more frequent inspections. Both Region 5 and the state or local agency assuming inspection responsibility should agree to O&M plans. Region 5 also recommends that the OSC or RPM issue letters to the state or local agency at conclusion of EPA's involvement in the site, referring the site to the state or local program, as additional evaluation and remediation may be needed. An example referral letter is in Appendix I.

10.2 PERIODIC RE-EVALUATION OF REMEDIATION SYSTEM PERFORMANCE

Mitigation monitoring will generally occur in two phases: (1) an initial post-construction phase, which is more intensive; and (2) a subsequent phase that may involve fewer diagnostic tests conducted periodically. After installation of a mitigation system and demonstration via initial clearance sampling that the mitigation is working effectively (see Section 9.0), the building should be transitioned over to a longer-term mitigation evaluation program. These programs are described in further detail below.

10.2.1 System Monitoring Within the First Year After Mitigation

Regarding Fund-lead actions, EPA's Removal and Remedial Programs will typically monitor a mitigation system during routine sampling events within one year of system installation; then, after the system has been deemed operational and functional, EPA will turn oversight of the system over to the PRP or state or local government, per the Post-Removal Site Control Policy described above.

10.2.2 Indoor Air Sampling

Within that first year of system monitoring, Region 5 recommends seasonal 24-hour post-mitigation indoor air sampling, especially during the heating season (EPA 2008a), and/or at roughly 30, 90, 180, 270, and 365 days post-mitigation, to ensure that the system still functions effectively. Sampling may occur more or less frequently to address issues at specific properties on a case-by-case basis. For example, Region 5 recommends increasing the post-mitigation indoor air sampling schedule to address concerns that VI may not be fully controlled by the installed mitigation system. Additionally, more frequent sampling may be necessary if triggers occur (alarms, floods, earthquakes, building modifications [EPA 2015a], construction blasting, or formation of nearby sinkholes [ANSI 2017]). After the first year of system monitoring, Region 5 recommends annual indoor air sampling, where possible, to verify that the system still functions effectively. If annual indoor air sampling is not possible, at least annual inspections of mitigation systems should occur, as described in Section 10.2.3.

Sample collection should occur within the breathing zone at the lowest level of the property—at the basement level, if applicable, or at the first floor if no basement is present. On a case-by-case basis, the OSC or RPM may also consider collecting subsequent samples and/or samples at other locations.

Within Region 5, the Chicago Regional Lab may be available to provide air sampling equipment and analyze air samples at no cost to the project. Staff should contact the lab as early as possible to determine whether it is able to accommodate anticipated post-mitigation samples.

The OSC or RPM should transmit sampling results to property owners/occupants and to the federal, state, and local health and environmental agencies collaborating on the response—complying, , with Agency PII policies. Examples of post-mitigation indoor air sample result letters specifying either that sampling results exceed or do not exceed site-specific action levels are accessible on the Region 5 VI toolbox site (https://Response.epa.gov/vitoolbox). For additional information, refer to Section 8.0.

Staff should consult with ATSDR and the local and state health departments to discuss options if indoor air sampling results indicate that concentrations exceed site-specific action levels. Additional mitigation actions may be necessary to ensure that mitigation is adequately controlling VI (see Section 9.4 above).

10.2.3 Remediation System Inspection

During follow-up sampling by EPA, the site team should also conduct inspections of systems that have been installed and follow up promptly on any identified issues during visits to properties that have been mitigated.

Until the source of VI has been permanently addressed, Region 5 recommends annual inspections as part of O&M of remediation systems, and also during any additional visits to the properties, to ensure proper operation of the systems. More frequent inspections may be necessary if triggers (listed above in Section 10.2.2) occur. One of the following should perform inspections: (1) the OSC or RPM overseeing the remediation; (2) the state or local entity that has agreed to conduct post-removal site control, as documented in the O&M plan; or (3) the PRP, if applicable.

Inspectors should evaluate all installed systems (active or passive SSDS, sub-membrane depressurization system, sealant system, air treatment system, ventilation system, sump management system, vapor barriers, etc.), and ensure that they are present and in good working condition. Per EPA (2015a) and ANSI (2017), typical inspection activities pertaining to either passive or active building mitigation systems may include, but are not limited to:

- Visual inspection of all visible components of the VI mitigation system inside and outside for signs of degradation or blockage—including fans, piping, piping discharge points, seals, membranes, and collection points. A crawl space membrane or vapor barrier, for example, may warrant repair or replacement if its integrity is compromised.

- Comparison of on-site system to as-built drawings for the VI mitigation system to verify the system configuration has not been modified.

- Visual inspection of the building to identify any significant alterations (such as remodeled basement, new furnace, heating/cooling system altered such that it affects air distribution or pressure, extensive changes in building weatherization) that would affect the design of the VI mitigation system or the general environment in which it operates.

- Visual inspection of the area of concern (including basement floor and wall seals, floors generally, sumps, floor drains, utility penetrations, groundwater or slab surface water management systems added or altered) to identify significant changes in conditions that would warrant modification of the system design. Look for any sizable openings to soil in floor surface possibly caused by settling. Integrity of lower level floors is critical to prevent vapor migration into structures.

- Comparisons of current and prior vacuum readings for active SSDS, assurance that manometers are still in place and filled, and confirmation that manometers read at least 1 inch of WC.

- Evaluation of pressure readings for both active and passive depressurization systems, as well as positive pressurization systems (e.g., periodic verification of measurable pressure differences across the slab).

- Confirmation that the extraction fan is operating. Feel the piping to ensure air is flowing through.

  - Inspection of the fan(s) is important throughout the operating period but may be particularly important near the end of its expected lifespan. Noisy fans typically indicate problems with ball bearings and should be replaced.

  - Active SSDS system fans generally can function well over prolonged periods without maintenance; however, Region 5 recommends replacement of fans periodically throughout the operating life of the system (e.g., every four to 10 years) to avoid breakdowns and associated problems.

- Monitoring of vent risers for flow rates and pressures generated by the fan to confirm the system is working and moisture is draining correctly.

- Completion of routine maintenance, calibration, and testing of functioning components of the venting system consistent with manufacturers' specifications.

- Inspection of external electrical components to identify undesirable conditions, such as excessive noise, vibration, moisture, or corrosion, and to verify that the fan cut-off switch is operable.

- Confirmation of adequate operation of the warning device or indicator (alarm), and presence of system labels.

- Confirmation that building owner/occupants are knowledgeable about how to operate the system, determine whether they have altered or repaired the system, and confirm that they have been operating the system, if applicable.

- Discuss any questions or concerns about the system with building owner/occupants.

- Confirmation that a copy of the O&M manual is present.

- Determine whether owner and/or occupant has changed. If so, Region 5 recommends that the OSC or RPM brief the new owner/occupant on the building mitigation systems.

The site team or the party responsible for O&M should correct any deficiencies as soon as possible. Deficiencies may include an inoperable fan, power switch in the "off" position, damaged PVC piping, punctured membrane or vapor barrier, new cracks in basement floors, etc. Post-correction indoor air sampling may be necessary to ensure that the system is operating effectively. The site team should collect post-correction samples approximately 30 days after completion of the modification.

An example inspection checklist is in Appendix J.

10.3 INSTITUTIONAL CONTROLS

ICs, such as non-engineered instruments (administrative or legal controls), may be necessary to ensure long-term protectiveness of remedies.

In some situations, ICs can be required to restrict access to a property, to facilitate response activities by a responsible party or EPA (e.g., installation or maintenance of VI mitigation systems), or help insure the integrity of vapor mitigation systems. ICs may also be required at sites where vapor-forming waste remains in place to ensure VI mitigation systems are protected if there is future construction.

ICs that may be helpful include, but are not limited to, government controls such as zoning laws, public health and safety ordinances, and building permits and codes; proprietary controls such as environmental covenants; enforcement controls within UAOs and CDs; and informational devices such as deed notices or public advisories. In some cases, state or local laws or regulations establishing or requiring certain ICs may also be considered ARARs.

Deed notices or environmental covenants may be even more necessary but also may be more difficult to obtain when the person or entity involved with day-to-day O&M of a VI remedy is not a liable party. For a non-NPL site addressed by the Removal Program, the OSC should work with state or local agencies to incorporate ICs into the O&M requirements to insure long-term protectiveness of the remedy.

Guidance on ICs is beyond the scope of this document; however, EPA policies and recommendations regarding ICs are addressed extensively in EPA (2015a).

11.0 STATE PROGRAM OVERVIEW - REGION 5 VI POLICY GROUP

The six Region 5 states have active programs to address both chlorinated and petroleum VI. This section focuses on their chlorinated VI programs. Various state environmental programs address chlorinated VI, including state Superfund, remediation, cleanup, voluntary remediation, or Resource Conservation and Recovery Act (RCRA) programs. These state programs address public health exposures, health-related questions, and relocation of building occupants, among other issues. Most states have issued their own VI guidance documents (see links below), and all have established, for environmental media, numeric action levels and response timeframes for chlorinated compounds typically associated with VI. Typical triggers for immediate response action, potentially including evacuation, are indoor air sampling results that exceed immediate action levels, and in some states, also exceedances of action levels in sub-slab air. State environmental programs discover VI sites primarily through regulatory interaction with current facilities, review of records related to previously operating facilities, or investigations associated with property redevelopment or re-use. PRPs or parties interested in re-using/redeveloping a site often complete investigatory work. Most states have programs to address chlorinated VI sites associated with no viable/liable responsible parties, but resources for these programs are often limited.

11.1 INITIAL SITE ASSESSMENT

State involvement in potential VI sites often follows discovery or reporting of a release of VOCs to soil, with initial follow-up investigation often targeting groundwater and soil gas. State programs work to determine if there are off-site impacts, affected media, the extent of contamination, and whether completed exposure pathways are likely to exist.

11.2 SITE ACCESS

All Region 5 states have access policies and template documents. Most states utilize legal processes to compel access if a significant threat is present where a property owner denies access for sampling or mitigation. Wisconsin has the authority to assign the status of PRP to off-site properties that deny access. Some local health agencies have the authority to compel access, evacuation, or condemnation of a building if warranted.

11.3 SITE ASSESSMENT

Most states utilize groundwater and soil gas sampling to help delineate VI areas of concern. State guidance documents detail state sampling recommendations/requirements.

About half the Region 5 states currently base most mitigation decisions on sub-slab air sampling results, and do not sample indoor air prior to mitigation or requiring mitigation. Most states require completion of multiple rounds of sub-slab sampling during assessments, including at least one round during the winter heating season. Some states that utilize indoor air sampling in assessment typically recommend or require several rounds of indoor sampling during different seasons with removal of potential VOC sources prior to sampling. Several states prefer paired indoor air/sub-slab sampling. Collection of ambient outdoor air samples typically occurs during indoor air sampling. As noted, decisions about whether to mitigate may be based on sub-slab air sampling results. If sub-slab results are above state action levels and mitigation is not completed based on those results, an indoor air contamination investigation is typically required. Most states assess both residential and commercial properties

Radon mitigation, via sub-slab depressurization, is required in many new residential developments within Region 5. Most Region 5 states have established sampling protocols that include procedures for assessment of VI threat at properties with active radon mitigation, often requiring that mitigation cease prior to sampling, or requiring sampling during the mitigation but conducting verification diagnostics based on results.

Building surveys are required or recommended before sampling within buildings. Many states have standard building survey forms available on their websites or within their guidance documents. Each state has established procedures to communicate sampling results to property owners and occupants, and many have template letters available.

11.4 MITIGATION OF PROPERTIES AFFECTED BY VI

Most states have integrated into their programs timeframes within which mitigation must be performed. Timeframes vary based on media, levels of contamination, and type of contaminants. Most states permit pre-emptive mitigation.

Mitigation agreements often occur between property owners and responsible parties, or between property owners and the state if the state is the lead on mitigation.

States most frequently use active sub-slab depressurization at existing residential buildings, and vapor barriers for new construction in areas with potential for VI. States typically require pressure field testing to ensure adequate sub-slab air flow during installation of SSDS. After systems are installed, most state programs require one or more of the following to verify that mitigation is effectively controlling indoor air contamination: indoor air sampling, sub-slab air sampling, smoke (or similar) testing, or verification of pressure field extension across the entire slab under different atmospheric and temperature conditions.

Most states also use short-term/emergency remediation techniques including air filtration and ventilation.

11.5 SYSTEM O&M

Most states have established programs to verify that mitigation remains effective until the mitigation is no longer needed. These programs include combinations of O&M plan development and dissemination, follow-up indoor air sampling, inspections of installed systems, verification that electrical charges are still occurring for installed systems, soil gas sampling, and pressure field testing.

11.6 TURNING OFF PROPERTY MITIGATION SYSTEMS

Several states have established protocols to determine when mitigation systems can be turned off, and several states are in the process of developing these protocols. Protocols include verification that sub-slab vapor conditions no longer exceed action levels, or verification that a building has been removed or land use or current conditions have changed such that VI no longer threatens occupants.

11.7 MITIGATION OF SOURCE AREAS

Cleanup of source areas is not always required by state programs if not practical, or if risks can be otherwise mitigated. However, remediation of source areas is a long-term goal for most state programs, completion of which is required by most states as part of the site close-out process for VI pathways.

11.8 INSTITUTIONAL CONTROLS

Several states require ICs for properties currently impacted by VI, or that could be impacted with changes in land use. ICs include required use of various building control technologies, implementation of environmental covenants for properties where active mitigation is ongoing, and requirements to reevaluate risk from land use of a property in an impacted area.

11.9 REASSESSMENT OF SITES OVER LONG TERM

Most states are developing programs for long-term reassessment of plumes not believed to be stable.

11.10 SITE CLOSURE

All states have protocols for closing chlorinated VI sites with VI pathways. Sites can be closed if soil gas contaminant concentrations demonstrably have fallen below action levels, mitigation systems are no longer needed, and/or cleanup of the source has been completed and mitigation is in place at all impacted properties that allow access.

11.11 ROLE OF PUBLIC HEALTH AGENCIES

Most states have partnered with their state and local public health agencies for health risk communication support. These health agencies respond to requests regarding urgency and appropriateness of actions needed to protect health, including relocation of building occupants. They may provide toxicology and risk assessment support for development of VI action criteria. Public health agency staff often furnish communication support such as health information sheets, webpages, site-specific messaging, and availability at public meetings. They also often answer health questions in one-on-one discussions with concerned individuals. Public health staff may also promote radon awareness and education.

11.12 CONCLUSION

All Region 5 states actively implement VI programs. Most states continue to refine these programs, so acquisition of the most recent programmatic information directly from the states is recommended.

Table 11-1. Links to State Vapor Intrusion Programs/Documents

State	Link to Chlorinated Vapor Intrusion Website / Guidance
Illinois	https://www2.illinois.gov/epa/topics/cleanup-programs/taco/vapor-intrusion/Pages/default.aspx
Indiana	https://www.in.gov/idem/cleanups/files/remediation_closure_guide.pdf https://www.in.gov/idem/cleanups/2344.htm
Michigan	https://www.michigan.gov/deq/0,4561,7-135-3311_4109_66336---,00.html
Minnesota	https://www.pca.state.mn.us/waste/vapor-intrusion
Ohio	http://www.epa.ohio.gov/portals/30/rules/vapor%20intrusion%20to%20indoor%20air.pdf
Wisconsin	https://dnr.wi.gov/files/PDF/pubs/rr/RR800.pdf https://dnr.wi.gov/topic/brownfields/vaporpublic.html

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APPENDIX A
VI INFORMATION PACKET

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 W. JACKSON BLVD.
CHICAGO, IL 60604

February 28, 2019

Dear Resident or Property Owner:

The U.S. Environmental Protection Agency (EPA) is testing the air in homes and buildings in your neighborhood as part of an environmental investigation. We would like to test the air in your residence. We are trying to find out if vapors from contaminated groundwater or soil are entering homes and contaminating the indoor air. Please note that your drinking water is ***not*** contaminated. The drinking water for your area is treated by the City and is safe to drink.

This air sampling will be performed at no cost to you. If you would like to have your property tested, please complete and return the attached *Consent for Access to Property*. If the house is a rental property, the access agreement must be signed by both the property owner and the tenant(s).

Please sign and return the access form before the deadline of March 31, 2019. You can return the form in the enclosed *postage-paid* reply envelope or you can send it by email to smith.john@epa.gov. If you have any questions, please contact me, at (800) 621-8431.

Sincerely,

John Smith
On-Scene Coordinator

Enclosures: Consent for Access to Property
Postage-paid envelope
Vapor intrusion fact sheet

United States Environmental Protection Agency

What You Should Know About the Problem of Vapor Intrusion

EPA Superfund Division

Chicago, Illinois

January 2012

What you can do to improve indoor air quality

- Don't buy more chemicals than you need.
- Store unused chemicals in appropriate tightly sealed containers.
- Don't make your home too air-tight. Fresh air helps prevent chemical build-up and mold growth.
- Fix leaks promptly, as well as other moisture problems that encourage mold.
- Check all appliances and fireplaces annually.
- Test your home for radon. Test kits are available at hardware and home improvement stores or you can call the Radon Hotline at 800-767-7236 (800-SOSRADON).
- Install carbon monoxide detectors in your home. They are available at hardware and home improvement stores.

For more information

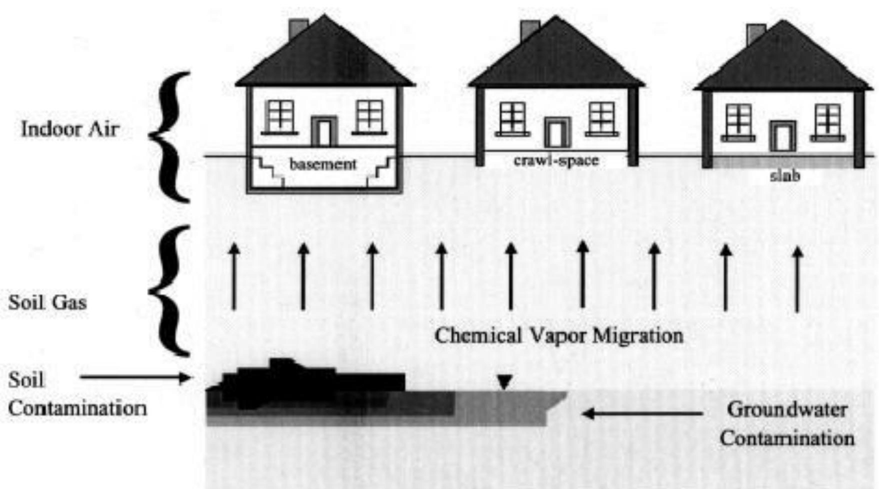
For questions on how vapor intrusion affects your health, contact your local health department or the federal Agency for Toxic Substances and Disease Registry at 888-422-8737, or visit www.atsdr.cdc.gov.

For detailed EPA information on vapor intrusion, visit www.epa.gov/oswer/vaporintrusion.

For more information on indoor air quality, visit www.epa.gov/iaq.

You may also call EPA Region 5 at 800-621-8431, 8:30 a.m. to 4:30 p.m. (Central), weekdays.

Vapor Intrusion into Indoor Air



This diagram shows how vapors can rise up through the soil and into your home.

Vapors and gases from contaminated ground water and soil have the potential to seep into indoor spaces and cause health problems. The U.S. Environmental Protection Agency wants you to know how to deal with vapor intrusion in your home.

What is vapor intrusion?

When chemicals or petroleum products are spilled or leak from underground storage tanks, they can give off gases or vapors that can get inside buildings. Common products that can cause vapor intrusion are gasoline or diesel fuel, dry cleaning solvents and industrial degreasers. The vapors can move through the soil and seep through cracks in basements, foundations, sewer lines and other openings.

Vapor intrusion is a concern because vapors can build up to a point where the health of residents or workers in those buildings could be at risk. Some vapors from petroleum products have a gasoline odor, others are odor-free.

Common household items can give off vapors

Common household products can be a source of indoor air problems. Vapors and gases can come from paint, paint strippers or thinners, moth balls, new carpeting and furniture, stored fuel, air fresheners, cleaning products, dry-cleaned clothing and cigarette smoke.

Vapor intrusion may affect your health

Health risks vary based on the type and amount of chemicals. How healthy you are and how long you are exposed are also factors. Some people may experience eye and respiratory irritation, headaches or nausea. These symptoms are temporary and should go away when the vapors are vented. Low-level chemical exposures over many years, however, may raise your lifetime risk of cancer or chronic disease.

Steps in the study of vapor intrusion

EPA first takes samples of gas in the soil and ground water near a site with known contamination. If we don't find the type of contamination that can turn into a gas – known as "volatile" – then vapor intrusion should not be a problem.

If we find volatile contamination, we may widen the search to include sampling closer to or on individual properties. The next step is to take vapor samples from the soil under building foundations. These are called "sub-slab soil" gas samples.

The results of these samples will tell EPA if indoor air samples are needed. The indoor air samples will tell us if there are vapors in the indoor air. The samples will also show if the vapors pose a health risk, or if they are at levels normally present in most buildings.

One way to keep harmful vapors out of your home is to make sure common household products, especially chemical- and petroleum-based products, are tightly sealed and properly stored in a well-ventilated area.

An example of a system that draws radon and other vapors out of the soil and vents them outside. It's known as a "sub-slab mitigation system."

EPA does not generally recommend indoor air sampling before sub-slab sampling because indoor air quality varies widely day to day. Also, household products may interfere with sampling results.

Finally, we will determine if there is enough of a problem to take action. Environmental law and EPA regulations tell us when we need to do something to protect your family's health.

If EPA finds a problem

The most common solution is to install systems often used to reduce naturally occurring radon that seeps into homes in some geographic areas. These systems remove soil vapors from below basements or foundations before they enter homes.

Vapors are vented into the outside air where they become dispersed and harmless. These systems use minimal electricity and do not affect heating and cooling efficiency. Once the source of the vapors is eliminated, the systems should no longer be needed.

Investigating Vapor Intrusion

What is vapor intrusion?

Vapor intrusion is a way that volatile chemicals (see text box) in soil and groundwater can enter and build up inside buildings.

When chemicals spill or leak into the ground, they can contaminate the soil and the groundwater. Depending on the type and amount, these chemical vapors can possibly affect your health if you breathe them in indoor air.[1]

If scientists suspect that people are being exposed to chemicals through vapor intrusion, they may conduct a **vapor intrusion investigation**.

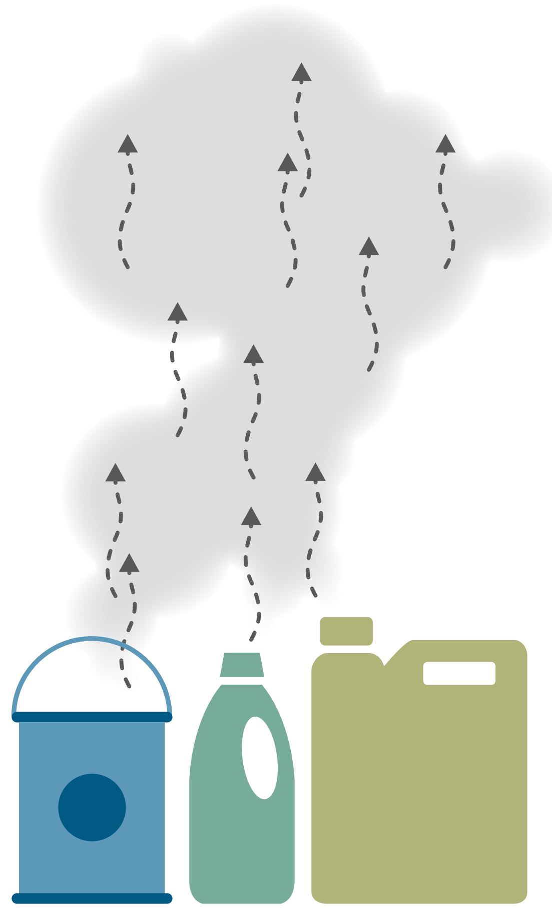
What can I expect during a vapor intrusion investigation?

If scientists suspect vapor intrusion in a community, they first gather information about the type, amount, and location of contamination in soil, groundwater, and indoor air. If this information shows that vapor intrusion is a concern, scientists collect additional samples to confirm it.

- Scientists collect samples from indoor air, from beneath the building (sub-slab gas samples), and sometimes from outdoor air as well. Samples are usually collected from people's homes over a 24 hour period.
- If weather can affect the test results, scientists may collect samples during different times of the year.
- Scientists then send the air samples to a laboratory where they are tested for various chemicals. The results will then be shared with the occupants and/or owners of each home.

Can chemicals in household products affect vapor intrusion investigations?

- Many of the chemicals found in vapor intrusion investigations are also found in common household products such as paints, air fresheners, and cleaning supplies.
- To focus on just the chemicals that may be coming from vapor intrusion, scientists may identify household products containing chemicals and remove them (whenever possible) before collecting indoor air samples.



Volatile chemicals are a class of chemicals that are volatile (evaporate easily) and form a vapor in the air. Some common volatile chemicals include the dry cleaning chemical tetrachloroethylene and benzene which is a component of automotive gasoline.

Chemicals detected during a sampling event that are not entirely the result of underground contamination are referred to as "background contamination."

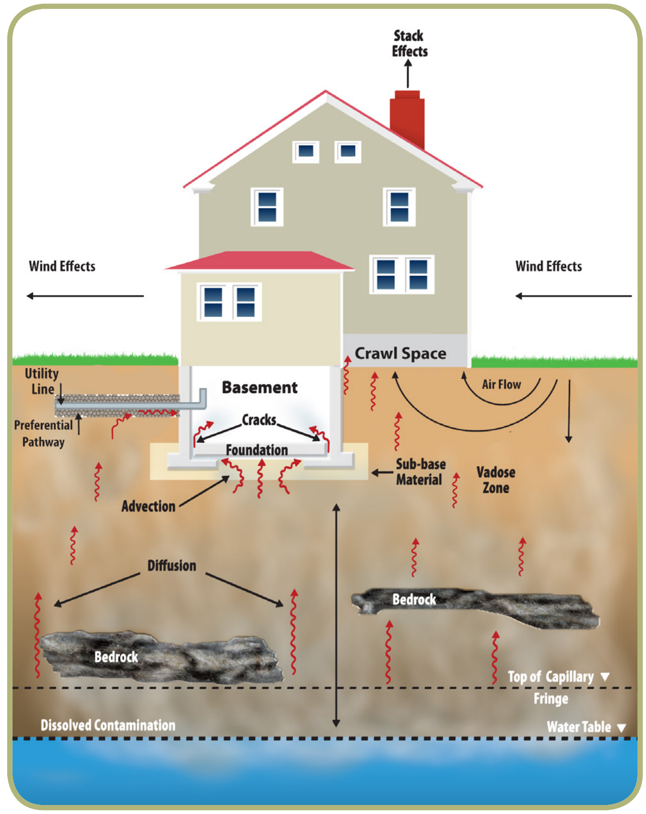
[1]ATSDR's Toxic Substances Portal provides information about chemical health effects and is located at http://www.atsdr.cdc.gov/substances/index.asp

Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations

ATSDR

CS263709-B

How can I reduce the levels of volatile chemicals in my home?



You can take these steps to help improve your home's indoor air quality:

1. Get more fresh air into your homes. Ventilation can keep any volatile chemicals in your home from building up to unsafe levels.[2]
   - Open windows and use fans to bring in fresh air directly – unless you have asthma triggered by outdoor air pollution or pollen in your area.
   - If your ventilation, heating, and air conditioning systems have filters, you may be able to adjust the fresh-air intakes to increase air exchange while removing pollen, dust, or other asthma irritants brought in from outdoors.
2. Seal cracks or holes in the floor or foundation to keep any volatile chemicals under your home from coming in.
3. Use and store fewer products that contain volatile chemicals (such as fuels, certain paints, paint thinners, and products that remove glue and adhesives).
   - When you use such products, follow the product recommendations carefully.
   - Open windows and run a fan to reduce the amount of the chemical in indoor air.
   - Avoid smoking tobacco products indoors.

What can environmental health scientists do to remove chemical contamination caused by vapor intrusion from your home?

- If scientists find that vapor intrusion could harm your health, they may install a **mitigation system** to keep volatile chemicals from entering your home.[3] Mitigation systems are usually made up of a fan and a system of pipes that draw the soil gases from beneath your home and release them outside so they can scatter and break down naturally.
- Scientists may recommend adjusting heating, ventilation and air conditioning systems in larger commercial buildings to regulate indoor air pressure and keep vapors from being pulled inside.
- Sealing openings and installing a vapor barrier (made of plastic sheeting) may also reduce vapor intrusion.

Where can I learn more about vapor intrusion?

U.S. Environmental Protection Agency

- Vapor intrusion website, visit: http://www2.epa.gov/vaporintrusion

Interstate Technology & Regulatory Council

- Vapor intrusion website, visit: http://www.itrcweb.org/Team/Public?teamID=22

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[2]Unless a significant source of outdoor air contamination has been identified.
[3]For more detailed information, see US EPA's Engineering Issue: Indoor Air Vapor Intrusion Mitigation Approaches https://clu-in.org/download/char/600r08115.pdf

Trichloroethylene - ToxFAQs™

CAS # 79-01-6

This fact sheet answers the most frequently asked health questions (FAQs) about trichloroethylene. For more information, call the CDC Information Center at 1-800-232-4636. This fact sheet is one in a series of summaries about hazardous substances and their health effects. It's important you understand this information because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.

HIGHLIGHTS: Trichloroethylene is used as a solvent for cleaning metal parts. Exposure to very high concentrations of trichloroethylene can cause dizziness, headaches, sleepiness, incoordination, confusion, nausea, unconsciousness, and even death. The Environmental Protection Agency (EPA) and the International Agency for Research on Cancer (IARC) classify trichloroethylene as a human carcinogen. Trichloroethylene has been found in at least 1,045 of the 1,699 National Priorities List sites identified by the EPA.

What is trichloroethylene?

Trichloroethylene is a colorless, volatile liquid. Liquid trichloroethylene evaporates quickly into the air. It is nonflammable and has a sweet odor.

The two major uses of trichloroethylene are as a solvent to remove grease from metal parts and as a chemical that is used to make other chemicals, especially the refrigerant, HFC-134a. Trichloroethylene was once used as an anesthetic for surgery.

What happens to trichloroethylene when it enters the environment?

- Trichloroethylene can be released to air, water, and soil at places where it is produced or used.
- Trichloroethylene is broken down quickly in air.
- Trichloroethylene breaks down very slowly in soil and water and is removed mostly through evaporation to air.
- It is expected to remain in groundwater for long time since it is not able to evaporate.
- Trichloroethylene does not build up significantly in plants or animals.

How might I be exposed to trichloroethylene?

- Breathing trichloroethylene in contaminated air.
- Drinking contaminated water.
- Workers at facilities using this substance for metal degreasing are exposed to higher levels of trichloroethylene.
- If you live near such a facility or near a hazardous waste site containing trichloroethylene, you may also have higher exposure to this substance.

How can trichloroethylene affect my health?

Exposure to moderate amounts of trichloroethylene may cause headaches, dizziness, and sleepiness; large amounts may cause coma and even death. Eating or breathing high levels of trichloroethylene may damage some of the nerves in the face. Exposure to high levels can also result in changes in the rhythm of the heartbeat, liver damage, and evidence of kidney damage. Skin contact with concentrated solutions of trichloroethylene can cause skin rashes.

There is some evidence exposure to trichloroethylene in the work place may cause scleroderma (a systemic autoimmune disease) in some people. Some men occupationally-exposed to trichloroethylene and other chemicals showed decreases in sex drive, sperm quality, and reproductive hormone levels.

How likely is trichloroethylene to cause cancer?

There is strong evidence that trichloroethylene can cause kidney cancer in people and some evidence for trichloroethylene-induced liver cancer and malignant lymphoma. Lifetime exposure to trichloroethylene resulted in increased liver cancer in mice and increased kidney cancer and testicular cancer in rats.

The National Toxicology Program (NTP) has determined that trichloroethylene is a "known human carcinogen". The EPA and the International Agency for Research on Cancer (IARC) have determined that trichloroethylene is "carcinogenic to humans."

Trichloroethylene

CAS # 79-01-6

How can trichloroethylene affect children?

It is not known whether children are more susceptible than adults to the effects of trichloroethylene.

Some human studies indicate that trichloroethylene may cause developmental effects such as spontaneous abortion, congenital heart defects, central nervous system defects, and small birth weight. However, these people were exposed to other chemicals as well.

In some animal studies, exposure to trichloroethylene during development caused decreases in body weight, increases in heart defects, changes to the developing nervous system, and effects on the immune system.

How can families reduce the risk of exposure to trichloroethylene?

- Avoid drinking water from sources that are known to be contaminated with trichloroethylene. Use bottled water if you have concerns about the presence of chemicals in your tap water. You may also contact local drinking water authorities and follow their advice.
- Discourage your children from putting objects in their mouths. Make sure that they wash their hands frequently and before eating.
- Prevent children from playing in dirt or eating dirt if you live near a waste site that has trichloroethylene.
- Trichloroethylene is used in many industrial products. Follow instructions on product labels to minimize exposure to trichloroethylene.

Is there a medical test to show whether I've been exposed to trichloroethylene?

Trichloroethylene and its breakdown products (metabolites) can be measured in blood and urine. However, the detection of trichloroethylene or its metabolites cannot predict the kind of health effects that might develop from that exposure. Because trichloroethylene and its metabolites leave the body fairly rapidly, the tests need to be conducted within days after exposure.

Has the federal government made recommendations to protect human health?

The EPA set a maximum contaminant goal (MCL) of 0.005 milligrams per liter (mg/L; 5 ppb) as a national primary drinking standard for trichloroethylene.

The Occupational Safety and Health Administration (OSHA) set a permissible exposure limit (PEL) of 100 ppm for trichloroethylene in air averaged over an 8-hour work day, an acceptable ceiling concentration of 200 ppm provided the 8 hour PEL is not exceeded, and an acceptable maximum peak of 300 ppm for a maximum duration of 5 minutes in any 2 hours.

The National Institute for Occupational Safety and Health (NIOSH) considers trichloroethylene to be a potential occupational carcinogen and established a recommended exposure limit (REL) of 2 ppm (as a 60-minute ceiling) during its use as an anesthetic agent and 25 ppm (as a 10-hour TWA) during all other exposures.

References

This ToxFAQs™ information is taken from the 2014 Toxicological Profile for Trichloroethylene (Draft for Public Comment) produced by the Agency for Toxic Substances and Disease Registry, Public Health Service, U.S. Department of Health and Human Services.

Where can I get more information?

For more information, contact the Agency for Toxic Substances and Disease Registry, Division of Toxicology and human Health Sciences, 1600 Clifton Road NE, Mailstop F-57, Atlanta, GA 30329-4027.

Phone: 1-800-232-4636.

ToxFAQs™ Ion the web: www.atsdr.cdc.gov/toxFAQs.

ATSDR can tell you where to find occupational and environmental health clinics. Their specialists can recognize, evaluate, and treat illnesses resulting from exposure to hazardous substances. You can also contact your community or state health or environmental quality department if you have any more questions or concerns.

United States Environmental Protection Agency

Consent for Access to Property

Name (please print): ____

Property Address: ____

Phone #: ______________________ **E-mail:** ______________________________

Contact Preference: Phone call ☐ Text message ☐ E-mail ☐

I consent to officers, employees, contractors, and authorized representatives of the United States Environmental Protection Agency (U.S. EPA) entering and having continued access to this property for conducting monitoring and sampling activities.

I realize that these actions taken by U.S. EPA are undertaken pursuant to its response and enforcement responsibilities under the Comprehensive Environmental Response, Compensation and Liability Act of 1980, as amended, 42 U.S.C. Section 9601 et seq.

This written permission is given by me voluntarily, on behalf of myself and all other co-owners of this property, with knowledge of my right to refuse and without threats or promises of any kind.

Signature: ______________________________ **Date:** ____________________

Questions about property:

Does the building have a basement? Yes ☐ No ☐

If yes, does the basement have a concrete slab? Yes ☐ No ☐

If no, does the basement have a dirt floor? Yes☐ No ☐ Partial ☐

Does the building have a crawl space? Yes ☐ No ☐

Are there are children living or cared for at this property? Yes ☐ No ☐

Are there are pregnant women living or working at this property? Yes ☐ No ☐

For tenant-occupied properties:

Are you the owner ☐ or the tenant ☐ of the building?

Owner's Information (if different from above)	**Tenant's Information**
Name: ______________________	Name: ______________________
Address: ______________________	Address: ______________________
City, State, Zip: ______________________	City, State, Zip: ______________________
Phone #: ______________________	Phone #: ______________________
E-mail: ______________________	E-mail: ______________________

Return to:
John Smith
U.S. EPA Region 5
77 W. Jackson Blvd
Chicago, IL 60604

APPENDIX B
RESIDENTIAL SAMPLE REMINDER FORM

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 W. JACKSON BLVD.
CHICAGO, IL 60604

Residential Sample Reminder Form

SAMPLE TIME:

Date: ___________________
Time: ___________________

PICK-UP TIME:

Date: ___________________
Time: ___________________

Location: _________________________________

Sampling Notes and Reminders:

1) EPA will collect at least one sub-slab and one indoor air sample from your property. The duration of the test is approximately 24 hours.
2) EPA will collect the samples in stainless steel SUMMA canisters. The canister is made of clean stainless steel and does not contain any moving parts or chemicals. Please do not handle or move the canister during the testing.
3) If your basement has a concrete floor or if you have a slab foundation, EPA will install one sample probe in the house foundation and collect an air sample. The location of the sample probe will be placed in a location that is not that noticeable. This sample is called a sub-slab sample and will test the soil gas beneath your home.
4) If you have a basement with a dirt floor, no sub-slab sample will be collected. Only an indoor air sample will be collected from the basement area.
5) The indoor air sample will be collected in the basement of the house. If there is no basement, the indoor air sample will be collected in the living area of the home.
6) Please do not smoke around the canister and to the extent possible, please leave doors and windows closed during testing.
7) During sampling, do not enter the room where the air samples are being collected. Activity in the room has the potential to alter the air sample results.
8) If possible, do not bring dry cleaning home during the testing.
9) If you have any aggressive pets, please lock them up or place them into a separate room prior to the sample team arriving at your property.
10) EPA will send analytical results to the owner (and tenant(s), if applicable) approximately 4-6 weeks after sampling is completed.
11) EPA will offer to meet with each owner (and tenant(s), if applicable) to discuss the air sample results.
12) As a courtesy, please be on time for your appointment.
13) If you must reschedule your appointment, please contact ______________________________ as soon as possible at ____________________.

APPENDIX C
HOUSEHOLD PRODUCTS INFORMATION

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 W. JACKSON BLVD.
CHICAGO, IL 60604

Plastic Container Information for Household Products

Common household products can interfere with our sample results. If you have any of the items in the list below stored in your home, we ask that you place them into the storage containers we provided prior to our appointment. The storage containers should be placed outside in a shed or garage while we are sampling.

- ✓ Paint or oil-based stains
- ✓ Liquid insect pest products
- ✓ Mineral spirits
- ✓ Furniture polish (particularly those containing orange oil or pine oil)
- ✓ Paint stripper
- ✓ Paint thinner
- ✓ Glues and adhesives
- ✓ Solvents
- ✓ Fuels (gasoline, heating oil, kerosene)
- ✓ Aerosol sprays
- ✓ Mothballs
- ✓ Air fresheners
- ✓ Sealing caulks
- ✓ Varnishes
- ✓ Nail polish
- ✓ Nail polish remover
- ✓ Spot removers
- ✓ PVC cement and primer

We will collect the empty storage containers from you on the final day of sampling.

Thank you!

APPENDIX D
SAMPLE LOG SHEET

SAMPLE LOG

SITE: ____

Address: ____

Owner's Name: ____________________ Occupant's Name: ____________________

Telephone No: ____________________ Telephone No: ____________________

Is resident living in basement? YES ☐ NO ☐

Sub-slab Sample:

Start Date/Time	Barometric Pressure	Outside Temp	Vacuum at Start	Sample ID#	ppbRAE VOC Conc.	SUMMA Canister ID	Regulator ID

End Date/Time	Vacuum at End	Location of sub-slab sample

Indoor Air Sample:

Start Date/Time	Barometric Pressure	Outside Temp	Vacuum at Start	Sample ID#	ppbRAE VOC Conc.	SUMMA Canister ID	Regulator ID

End Date/Time	Vacuum at End	Location of indoor sample

PICTURES TO BE TAKEN:

Inside basement (all four directions) YES ☐ NO ☐

Sub-slab sample YES ☐ NO ☐

Indoor air sample YES ☐ NO ☐

Outside of residence (all four directions) YES ☐ NO ☐

IF HOUSE HAS A VAPOR MITIGATION SYSTEM

U-Tube Manometer (inches water column) ________ (ideal >1)

Vacuum reading (inches water column) ________ At location ____________________

Vacuum reading (inches water column) ________ At location ____________________

Vacuum reading (inches water column) ________ At location ____________________

TYPE OF AIR SAMPLING: ☐ Initial ☐ _____-day post mitigation ☐ Quarterly sample ☐ Other ______________________________

COMMENTS ____

____

____

APPENDIX E
RESIDENTIAL QUESTIONNAIRE

VAPOR INTRUSION RESIDENT QUESTIONNAIRE

Preparer's Name: ___________________________________ Date Prepared: ____________________

Preparer's Affiliation: ____

OCCUPANT

Interviewed: Yes ☐ No ☐

Last Name: ________________________________ First Name: ________________________________

Address: ____

City: ___________________________ County: ________________________ State: _______________

Phone No: ____________________________________

Number of occupants/persons at this location: ________________ Age of occupants: _______________

OWNER OR LANDLORD (☐ Same as occupant)

Interviewed: Yes ☐ No ☐

Last Name: ________________________________ First Name: ________________________________

Address: ____

City: ___________________________ County: ________________________ State: _______________

Phone No: ____________________________________

PROPERTY TYPE

☐ Residence ☐ School ☐ Commercial

☐ Industrial ☐ Church ☐ Day care

☐ Other ____

BUILDING TYPE

Residential

☐ Single family ☐ Two family ☐ Multi-family

☐ Mobile home ☐ Apartment ☐ Townhouse/Condo

☐ Group housing (dorm, nursing home, retirement home)

Commercial

☐ Office ______ floors ☐ Retail ☐ Other _________________________

Industrial

☐ Manufacturing ☐ Warehouse ☐Other ___________________________

If multiple units, how many? _______________

Number of floors ______________ Building age ______________

CONSTRUCTION CHARACTERISTICS (check all that apply)

Above-grade construction: ☐ Wood frame ☐ Concrete ☐ Stone ☐ Brick

Foundation type: ☐ Basement ☐ Crawl space ☐ Slab

Basement type: ☐ Full ☐ Partial

Basement floor: ☐ Concrete ☐ Dirt ☐ Other ___________________

Foundation walls: ☐ Poured ☐ Block ☐ Stone

☐ Dirt ☐ Other

Integrity of foundation walls: ☐ Good ☐ Fair ☐ Poor

The basement is: ☐ Wet ☐ Damp ☐ Dry ☐ Moldy

The basement is: ☐ Finished ☐ Unfinished ☐ Partially finished

Integrity of basement floors: ☐ Good ☐ Fair ☐ Poor

Sump present: ☐ Yes ☐ No

Does anyone live in the basement? ☐ Yes ☐ No

If yes, how many people? ____________ What age(s)? ________________

Approximate square foot of structure footprint: __________________ ft^2

Basement/lowest level depth below grade: __________________ ft

Identify potential soil vapor entry points and approximate size (e.g., cracks, utility ports, drains)

____

____

____

FACTORS THAT MAY INFLUENCE INDOOR AIR QUALITY

Is there an attached garage? ☐ Yes ☐ No

Does the garage have a separate heating unit? ☐ Yes ☐ No

Are petroleum-powered machines or vehicles stored in the garage? Please specify. ____ ☐ Yes ☐ No

Has the building ever had a fire? ☐ Yes ☐ No

Is kerosene or unvented gas space heater present? ☐ Yes ☐ No

Is there a workshop or hobby/craft area? ☐ Yes ☐ No
Where and type? ____

Is there smoking in the building? ☐ Yes ☐ No

Are chemicals, paints, etc. stored in the basement? ☐ Yes ☐ No
Types? ____

COMMENTS

____

____

____

SKETCH

APPENDIX F
COMMON HOUSEHOLD SOURCES OF INDOOR AIR CONTAMINATION

Common Household Sources of Background Indoor Air Contamination

Acetone	rubber cement, cleaning fluids, scented candles and nail polish remover
Benzene	automobile exhaust, gasoline, cigarette smoke, scented candles, scatter rugs and carpet glue
Bromomethane	soil or space fumigant
1, 3-Butadiene	automobile exhaust and residential wood combustion
2-Butanone (MEK)	automobile exhaust, printing inks, fragrance/flavoring agent in candy and perfume, paint, glue, cleaning agents and cigarette smoke
Chlorobenzene	scented candles, plastic foam insulation and paint products
Chloroethane	refrigerant
Chloroform	generated from chlorinated water (showers)
Cyclohexane	gasoline, paint thinner, paint and varnish remover
1,4-Dichlorobenzene	moth balls, general insecticide in farming, air deodorant and toilet disinfectant
Dichlorodifluoromethane	refrigerant (CFCs) and cleaning solvent
1, 1-Dichloroethane	plastic products (food and other packaging material) and flame retardant fabrics
1,2-Dichloroethane	polyresin molded decorations (particularly from China)
1, 1-Dichloroethene	plastic products (food and other packaging material), adhesives and flame retardant fabrics
1, 3-Dichloropropene	fungicides
Ethylbenzene	paint, paint thinners, insecticides, wood office furniture, scented candles and gasoline
Formaldehyde	building materials (particle board), furniture, insulation and cigarette smoke

n-Heptane	gasoline, nail polishes, wood office furniture and petroleum products
n- Hexane	gasoline, rubber cement, typing correction fluid and aerosols in perfumes
Methylene chloride	hairspray, paint stripper, rug cleaners, insecticides and furniture polish
Methyl isobutyl ketone (MIBK)	paints, varnishes, dry cleaning preparations, naturally found in oranges, grapes and vinegar
Methyl *tert* butyl ether (MTBE)	gasoline (oxygenating agent)
Naphthalene	cigarette smoke, automobile exhaust, residential wood combustion, insecticides and moth balls
Styrene	cigarette smoke, automobile exhaust, fiberglass, rubber and epoxy adhesives, occurs naturally in various fruits, vegetables, nuts and meats
Tertiary butyl alcohol (TBA)	gasoline (oxygenating agent)
1, 1 , 2 ,2-Tetrachloroethane	solvent, paint and rust removers, varnishes and lacquers
Tetrachloroethene (PCE)	dry cleaning, metal degreasing, adhesives and glues, insecticides, scented candles and rug cleaner
Toluene	gasoline, automobile exhaust, polishes, nail polish, synthetic fragrances, paint, scented candles, paint thinner, adhesives and cigarette smoke
1, 1, 1-Trichloroethane	spot cleaner, glues, insecticides, drain cleaners, shoe polish
Trichloroethene (TCE)	glues, adhesives, paint removers, spot removers, rug cleaning fluids, paints, metal cleaners, typewriter correction fluid, and automotive cleaning and degreasing products
1, 2, 4-Trimethylbenzene	gasoline and automobile exhaust
1, 3, 5–Trimethylbenzene	gasoline and automobile exhaust
2 ,2, 4-Trimethylpentane	gasoline and automobile exhaust
Xylenes, total	water sealer, gasoline, automobile exhaust, markers, paint, floor polish and cigarette smoke

APPENDIX G
SAMPLE RESULTS LETTER

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 W. JACKSON BLVD.
CHICAGO, IL 60604

August 25, 2017

Brad Pitt
123 Main Street
Indianapolis, IN 46205

Dear Mr. Pitt:

The U.S. Environmental Protection Agency (EPA) received the results of the air sample we collected at your property at 123 Main Street on August 4, 2017.

We sampled the air inside your home (indoor air) and the air underneath your home (sub-slab) to determine if the sub-slab depressurization system (system) we installed is working properly to reduce indoor air concentrations.

What did we find in your air sample?
Your air results are in the table below. The indoor air results were compared to EPA's vapor intrusion screening levels. The results are in units of micrograms per cubic meter (μg/m^3). The laboratory report is attached to this letter.

Chemical	Indoor Air Screening Level (μg/m3)	Your Indoor Air (μg/m3)		Your Sub-Slab Air (μg/m3)
		IARP039-0817	IARP039-0817D	SSRP039-0817
1,2,4-Trimethylbenzene	22	0.92 J	0.69 J	1.6 J
Chloroform	12	1.1 J	0.89 J	0.90 J
cis-1,2-Dichloroethene	No value	<1.1	<1.2	<1.2
m,p-Xylene	310	1.2 J	<1.0	2.0 J
o-Xylene	310	<1.3	<1.4	<1.4
Tetrachloroethene	130	<1.7	1.8 J	2.0 J
Trichloroethene	2.1	<1.4	<1.4	<1.4
Vinyl chloride	17	<0.57	<0.60	<0.59

J – Estimated value
< - Less than

What do these results mean?
Your indoor air is below the screening levels. These results mean that the system is reducing or eliminating these chemicals in your indoor air.

What happens next?
EPA will resample your property in December 2017. I will call you to schedule a sampling appointment.

If you have any questions, please call me at (800) 621-8431.

Sincerely,

John Smith
Federal On-Scene Coordinator

APPENDIX H
VAPOR MITIGATION AGREEMENT

UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY

VAPOR MITIGATION AGREEMENT

Name: ____

Address: ____

____

The U.S. Environmental Protection Agency (EPA) proposes to install a vapor mitigation system at the above property to reduce elevated concentrations of trichloroethene in indoor air. By your signature below, you agree to the following terms and conditions.

- EPA will purchase the vapor abatement system and pay for the basic costs of installation. The U.S. EPA has arranged for Environmental Restoration and its subcontractors to install a vapor mitigation system at your property. The vapor mitigation system includes PVC piping and an inline fan to vent vapors from below the foundation to above the roofline.

- EPA will conduct performance sampling to ensure that the system is working properly and indoor air quality is below screening levels. EPA will conduct performance sampling approximately 30 days, six months, and one year after system installation.

- Operation of the system is your responsibility. Operations includes the cost of electricity to power the system's fan.

- Following successful performance sampling, inspection and maintenance of the system is also your responsibility. EPA will provide you with a system manual that includes instructions for routine inspection.

This written permission is given voluntarily by owners and operators of the property with knowledge of the right to refuse and without threats or promises of any kind.

Date: ____

Signature: ____

Printed Name: ____

APPENDIX I
STATE REFERRAL LETTER

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 W. JACKSON BLVD.
CHICAGO, IL 60604

June 6, 2019

Ms. Julia Roberts
Ohio Environmental Protection Agency
347 N. Dunbridge Road
Bowling Green, Ohio 43402

Dear Ms. Roberts:

The U.S. Environmental Protection Agency (EPA) recently completed a time-critical removal action at the Shadeland Avenue Groundwater Contamination Site. The Site is a groundwater plume that has contaminated the municipal well field for the City of Bowling Green. The plume consists of chlorinated solvents, specifically tetrachloroethene (PCE), trichloroethene (TCE), vinyl chloride, and cis-1, 2-dichloroethene (DCE) from multiple sources. The plume impacted nearby residential properties through the vapor intrusion pathway.

During the removal action, EPA addressed hazardous substances, pollutants and contaminants that presented an imminent and substantial threat to the public health, or welfare, and the environment and met the criteria for a time-critical removal action as provided for in the National Contingency Plan, 40 C.F.R. § 300.415(b)(2). The Pollution Reports documenting site actions are available at https://response.epa.gov/ .

During the removal action, EPA conducted the following activities.

1. Performed vapor mitigation at residential properties where relevant indoor air action levels were exceeded in accordance with current EPA guidance. EPA installed sub-slab depressurization systems at the three residential properties listed below.
   456 Forest Avenue
   458 Forest Avenue
   135 Maple Street

2. Performed post-installation proficiency sampling 30 days, six months, and one year after mitigation system installation.

3. Took any other response actions to address any release or threatened release of a hazardous substance, pollutant or contaminant that the EPA OSC determined posed an imminent and substantial endangerment to the public health or the environment.

EPA addressed the imminent and substantial threats to human health and the environment. However, PCE and its degradation products remain in groundwater, soil, and soil vapor. The contaminant concentrations and locations in groundwater could change over time, resulting in the threat of vapor intrusion at additional properties.

EPA is referring the site to the Ohio EPA for long-term monitoring and remediation. If you have any questions regarding the site, please contact me at 317-417-0980.

Sincerely,

John Smith
Federal On-Scene Coordinator

cc: File

APPENDIX J
INSPECTION CHECKLIST

MITIGATION SYSTEM
ANNUAL O&M INSPECTION FORM

Property Address:	______________________	Temperature (ambient):	________ °F
Tenant's Name:	______________________	Temperature (house):	________ °F
Owner's Name:	______________________	Barometric pressure:	________ ″Hg
Owner's Address (if different from property):	______________________	Weather conditions:	______________________
Inspector Name:	______________________		______________________
Date:	______________________		______________________
Time:	______________________		______________________

Exterior System Inspection

Is fan intact and operational?	☐ Yes	☐ No
Any unusual fan vibrations?	☐ Yes	☐ No
Is vent piping/downspout intact?	☐ Yes	☐ No
Any caulking required around fan and piping connections?	☐ Yes	☐ No

Interior System Inspection

Any heaving or subsidence at suction point?	☐ Yes	☐ No
Any whistling noise noted?	☐ Yes	☐ No
Caulk seals inspected?	☐ Yes	☐ No
Is alarm on and operational?	☐ Yes	☐ No

Owner/Tenant Observations

Any change in fan noise or vibration?	☐ Yes	☐ No	
Any lack of differential pressure in the manometer?	☐ Yes	☐ No	
Has the fan been turned off for any period of time?	☐ Yes	☐ No	Reason ______________________
Have there been any changes to the basement?	☐ Yes	☐ No	If so, what? ______________________

Measurements

System manometer reading ________ ″$H_2$0

Is the system manometer steady? ☐ Yes ☐ No

Initial system manometer reading ________ ″$H_2$0

Date of initial reading ________

Complete the following:

- ☐ Visual inspection of all visible components of the vapor intrusion mitigation system, inside and outside, including fans, piping, piping discharge points, seals, membranes and collection points, to ensure there are no signs of degradation or blockage. A crawl space membrane, or vapor barrier, for example, may warrant repair or replacement if its integrity is compromised.

- ☐ Compare on-site system to as-built drawing for the vapor intrusion mitigation system to verify the system configuration has not been modified.

- ☐ Visual inspection of the building to evaluate whether any significant changes were made (such as remodeled basement, new furnace, heating/cooling system altered such that it affects air distribution or pressure, extensive changes in building weatherization) that would affect the design of the vapor intrusion mitigation system or the general environment in which it is operated.

- ☐ Visual inspection of the area of concern (including basement floor and wall seals, floors generally, sumps, floor drains and utility penetrations, groundwater or slab surface water management systems added or altered) to ensure there are no significant changes in conditions that would warrant modification of the system design. Look for any sizable openings to soil in floor surface, potentially caused by settling, Integrity of lower level floors is critical to preventing vapor migration into structures.

- ☐ Compare current vacuum readings for ASSDS to prior.
  - ☐ Ensure manometers are still in place and filled. Ensure manometer reads at least 1 inch of water

- ☐ Evaluate pressure readings for both active and passive depressurization systems as well as positive pressurization systems (e.g., periodic verification of measurable pressure differences across the slab).

- ☐ Confirm that the extraction fan is operating. Feel the piping to ensure air is flowing through.
  - Inspection of the fan(s) is important throughout the operating period but may be particularly important near the end of its expected lifespan. Noisy fans typically indicate problems with ball bearings and warrant replacement on that basis.
  - ASSDS system fans generally can function well for prolonged periods without maintenance; however, EPA recommends fans be replaced periodically throughout the operating life of the system (e.g., every 4 to 10 years) to avoid breakdowns and associated problems.

- ☐ Monitor vent risers for flow rates and pressures generated by the fan to confirm the system is working and moisture is draining correctly.

- ☐ Complete routine maintenance, calibration and testing of functioning components of the venting system consistent with the manufacturers' specifications.

- ☐ Inspect external electrical components to identify undesirable conditions, such as excessive noise, vibration, moisture, or corrosion, and to verify that the fan cut-off switch is operable.

- ☐ Confirm adequate operation of the warning device or indicator (alarm), and presence of system labels.

- ☐ Confirm that building owner/occupants are knowledgeable about how to maintain system operation, whether they have made any alterations or repairs to the system and that they have been operating the system, if applicable.

- ☐ Discuss any questions or concerns about system operation with the building owner/occupants.

- ☐ Confirm that a copy of the O&M manual is present in the building and has been updated as necessary.

- ☐ Determine whether there has been any change in ownership/occupant. If such a change has occurred, EPA recommends the site manager brief the new owner/occupant on the building mitigation systems.

Comments (any repairs made while visiting, etc):