Active Mitigation Fact Sheet

ITRC has developed a series of fact sheets that summarizes the latest science, engineering, and technologies regarding vapor intrusion (VI) mitigation. This fact sheet describes the most common active vapor mitigation technologies and summarizes the considerations that go into design, installation, post-installation verification, and operation, maintenance, and monitoring (OM&M). More detailed information on the considerations related to each step of the mitigation implementation process can be found in ITRC's ***Design Considerations Fact Sheet***, ***Post-installation Verification Fact Sheet***, and ***Operation, Maintenance, and Monitoring/Exit Strategy Fact Sheet***

1 Introduction

Active mitigation of the VI pathway involves interception, dilution, or diversion of soil gas entry into a building using mechanical means that are powered by electricity. The performance of active mitigation systems is quantifiable by measurement of vacuum, area of influence, flow rates, mass flux, etc. This fact sheet presents information on the design, installation, and OM&M of active mitigation technologies for both new construction and existing buildings that range from small (i.e., residential) to large (i.e., commercial/industrial) structures. Active mitigation for new construction can be significantly different than for existing buildings due to components of new buildings and control of construction of the system during construction of the building. Details and differences between active mitigation for new construction and existing buildings is listed in this fact sheet and in the ***Design Considerations***, ***Post-installation Verification***, and ***Operation, Maintenance, & Monitoring/Exit Strategy*** Fact Sheets where appropriate.

As presented in the ***Conceptual Site Models (CSM) for VI Mitigation Fact Sheet*****,** the mitigation technologies presented in this fact sheet assume the primary means for soil gas entry is via advection, rather than diffusion. Except for situations where very high sub-slab vapor source concentrations (e.g., millions of micrograms per cubic meter [$\mu g/m^3$]) are present, diffusion through the slab is not considered a significant transport pathway. Vapor mitigation systems that are "active" are designed to achieve either depressurization of the sub-slab soil or granular fill relative to indoor air or some degree of air flow and dilution in the sub-slab space. Active mitigation systems designed for depressurization will also achieve some degree of ventilation and vice versa. These two types of technologies (depressurization and ventilation) are not separate and distinct, but they are monitored using different performance metrics and criteria.

2 Active Mitigation Types

This fact sheet includes a brief description of four of the most common types of active mitigation, each of which is also described in a supporting technology information sheet as follows:

- sub-slab depressurization (SSD; see also the ITRC ***SSD Technology Information Sheet***)
- sub-slab ventilation (SSV; see also the ITRC ***SSV Technology Information Sheet***)
- sub-membrane depressurization (SMD; see also the ITRC ***SMD Technology Information Sheet***)
- crawlspace ventilation (CSV; see also the ITRC ***CSV Technology Information Sheet***)

In addition to or in conjunction with the four active mitigation types above, the following active mitigation approaches may also be used to assist in addressing vapor intrusion risk. These methods may be used for temporary mitigation, rapid response mitigation, or in building-specific situations where the main methods (SSD, SSV, SMD or CSV) may not be effective or may not be effective on their own. Some of these technologies are described in other technology information sheets as referenced:

- indoor air filtration (see also the ITRC ***Indoor Air Treatment Technology Information Sheet*** and USEPA *Adsorption-based Treatment Systems for Removing Chemical Vapors from Indoor Air* [USEPA, 2017].)
- aerobic vapor migration barriers (AVMB; see also the ***Aerobic Vapor Migration Barriers Technology Information Sheet***)
- building pressurization/ventilation (see also the ITRC ***Heating, Ventilation, and Air Conditioning Modification***

Technology Information Sheet and **Preferential Pathway Sealing and Ad Hoc Ventilation Technology Information Sheet**)
- drain tile depressurization (DTD)
- block wall depressurization (BWD)

Existing in-depth standards for the mitigation of most building types have been developed and published by the American Association of Radon Scientists and Technologists (AARST) and the American National Standards Institute (ANSI). Published standards include:

- Soil Gas Mitigation Standards for Existing Homes: ANSI/AARST SGM-SF 2017 (AARST, 2017)
- Radon Mitigation Standards for Multifamily Buildings: ANSI/AARST RMS-MF-2018. (AARST, 2018a)
- Radon Mitigation Standards for Schools and Large Buildings: ANSI/AARST RMS-LB-2018. (AARST, 2018b)
- Soil Gas Control Systems in New Construction of Buildings: ANSI/AARST CC-1000-2018. (AARST, 2018c)

These documents can be viewed/accessed for free at https://standards.aarst.org/.

2.1 Common Active Mitigation Strategies

The following section provides a summary of the primary active mitigation technologies that are typically employed.

Sub-slab depressurization (SSD)—SSD uses an electric fan/blower to create a negative pressure beneath the building envelope, relative to inside the building envelope, to prevent vapors from migrating from the subsurface into the building through advection. When a negative pressure is present within the building envelope relative to surrounding soil, advective gas flow from the soil into the indoor air can occur. Soil gas entry pathways can be cracks through the slab or wall(s), improperly sealed utilities, etc. Depressurizing the soils below the slab with an SSD system will create a low pressure that reverses or alters the direction of soil gas flow, thus mitigating vapor intrusion. The types of fans/blowers used for SSD can vary depending on sub-slab material permeability, as well as the building type, construction quality, and size of the building being mitigated. SSD may be limited to the portion of the floor slab where volatile organic compound (VOC) vapor concentrations exceed generic or building-specific action levels. Depending on the vapor concentrations, emission rates, and proximity of receptors, air pollution controls may be needed.

Sub-slab ventilation (SSV)—SSV is an active engineering control employed to mitigate buildings at or near vapor intrusion sites. The goal for SSV is to reduce vapor concentrations below a structure's slab to levels that are low enough to maintain acceptable indoor air concentrations above the slab, regardless of whether there is a consistent or even measurable vacuum below the floor. Generally, this is practical where the material below the slab has a high permeability, including coarse-textured granular fill materials, drainage mats, and aerated floors, resulting in high airflow below the slab. SSV is also generally practical where the sub-slab concentrations are low to begin with and reduction to concentrations below generic or building-specific screening or building-specific action levels is easily achieved. Depending on the vapor concentrations, emission rates, and proximity of receptors, air pollution controls may be needed.

Sub-membrane depressurization (SMD)—For buildings or portions of buildings built over accessible dirt-floor crawlspaces (or dirt-floor basements), an SMD system can be used for active mitigation. SMD relies on the ability to install a durable membrane over the exposed soil in the crawlspace (or basement) to enable a negative pressure to be generated below the membrane. SMD is applicable if the basement or crawlspace will not be accessed (or will not be accessed frequently) so that the membrane is not disturbed or damaged. Prior to placing and sealing the membrane, a venting mechanism (e.g., perforated pipe, soil gas collection mat, etc.) is installed under the membrane and connected to a vertical section of solid piping, leading to a fan located outside the occupied building envelope. The types of fans/blowers used for SMD will vary depending on the size of the crawlspace/basement, how well sealed the membrane is, and the size and age of the building being mitigated.

Crawlspace ventilation (CSV)—For buildings with crawlspaces that are too shallow to enter, CSV may be warranted. This technology focuses on moving a minimal amount of air out of the crawlspace to create a modest but consistent air exchange rate for the space. As crawlspaces tend to not be sealed and are usually connected to other parts of the basement, or connected to the living space above, this venting strategy is used because it may not be possible, practical, or desirable to remove enough air from a crawlspace to create a significantly depressurized space. Ventilation may consist of opening existing vents around the crawlspace, if present, and usually includes connecting an exterior mounted fan to piping that is extended into the crawlspace. Care is needed to avoid freezing water lines in cold climate areas.

2.2 Other Active Mitigation Strategies

The following section provides a summary of other mitigation technologies that may be employed either on their own or in conjunction with the four main mitigation technologies detailed above.

Indoor Air Filtration—Indoor air filtration involves portable filtration units equipped with granular activated carbon, zeolites, or other filter media to remove vapor contamination from the indoor air. Indoor air filtration is primarily used for immediate response actions as a temporary way to reduce indoor air levels until a more permanent vapor mitigation technology can be implemented. Indoor air filtration can also be used as a supplemental degree of protection for SSD/SSV systems in the early stages if active mitigation systems are being installed to mitigate high sub-slab concentrations. See EPA's *Adsorption-based Treatment Systems for Removing Chemical Vapors from Indoor Air* (USEPA, 2017) and the ***Indoor Air Treatment Technology Information Sheet***.

Aerobic Vapor Migration Barrier (AVMB)—AVMB is a combination in-situ VI mitigation and remediation technology for sites with aerobically degradable compounds (e.g., petroleum hydrocarbons, methane and vinyl chloride). AVMB involves the slow delivery or circulation of atmospheric (ambient) air at low pressure or negative gauge pressure (i.e., sub-slab extraction combined with ambient pressure air inlets) below and around a building foundation through either sub-slab vents or horizontal wells installed below the building foundation. The delivery of ambient air creates elevated oxygen (O_2) conditions in the shallow soil around the foundation that are favorable for aerobic biodegradation. A successful AVMB will mitigate the potential for VI by aerobically biodegrading compounds susceptible to the enhanced aerobic conditions. See the ***Aerobic Vapor Migration Barrier Technology Information Sheet***.

Building Pressurization/Ventilation—Building pressurization/ventilation involves using the building's heating ventilation and air conditioning (HVAC) system to pressurize the building interior space sufficiently to prevent vapor intrusion or provide sufficient make-up air to reduce indoor air concentrations to acceptable levels. See ***EPA's Indoor Air VI Mitigation Approaches Engineering Issue*** for a summary of building pressurization/ventilation (USEPA, 2008). Pressurization is typically only feasible for commercial or industrial buildings with controlled door and window access so the positive building pressure can be maintained. Buildings with garage bay doors that open frequently or where tenants have free access to open and close doors and windows will not be able to consistently maintain building pressurization. This approach requires regular air balancing and maintenance and may have high operation and maintenance costs related to heating and air conditioning. Industrial building ventilation without controls may also increase fugitive emissions and recirculation of contaminants back into the building. See the ***Heating, Ventilation, and Air Conditioning Modification Technology Information Sheet*** and ***Preferential Pathway Sealing and Ad Hoc Ventilation Technology Information Sheet***.

Drain Tile Depressurization—Drain tile depressurization is similar to ***SSD***; however, it uses the presence of sub-slab sumps and associated drain tile systems to depressurize beneath the building slab to mitigate the potential for vapor intrusion. If the drain tile system is not adequate to reach all portions of the building needing mitigation, SSD can typically be used to supplement this method, except where the water table is very shallow. See *EPA's Indoor Air VI Mitigation Approaches Engineering Issue* for more information on drain tile depressurization (USEPA, 2008).

Block Wall Depressurization—Block wall depressurization uses an electric fan connected to the voids and the network within hollow block walls to create a depressurized zone to mitigate the potential for vapor intrusion through foundation walls. Uniform depressurization of block walls can be difficult. This approach is typically only recommended to supplement a traditional SSD system if the SSD is not addressing vapor intrusion through the foundation walls and it is believed that this pathway is significantly contributing to indoor air concentrations. See *EPA's Indoor Air VI Mitigation Approaches Engineering Issue* for a more information on block wall depressurization (USEPA, 2008).

3 Considerations for Active Mitigation

Many considerations and decisions are necessary to select, design, install, operate, and eventually decommission an effective active mitigation system. The approach outlined below provides a summary of information to consider during each step in the active mitigation process. More details regarding each consideration can be found in the overall Process Fact Sheets, which include:

- ***Design Considerations Fact Sheet***
- ***Post-installation Verification Fact Sheet***
- ***Operation, Maintenance, & Monitoring/Exit Strategy Fact Sheet***

The Process Fact Sheets are written to include all VI mitigation technology types and go into more detail as to the considerations to be made at each point in the stepwise process and the relative impact each consideration may have for each type of mitigation technology.

3.1 Design Considerations

Prior to mitigation system design, it is common to perform a building survey and predesign diagnostic testing to understand building-specific issues that will need to be incorporated into the system design. The larger and more complicated a building, the more predesign work is likely to be performed to create an effective system design. Design considerations for new large buildings should comport with ANSI/AARST (AARST, 2018b; ARST, 2018c).

For many small buildings (for example, single-family homes), it may be common to do very little predesign work prior to design and installation of a mitigation system. This occurs because it is often mistakenly assumed that single-family homes can be actively mitigated with a single fan and single suction point. This may be true for homes with a smaller footprint and with concrete and sub-base that are in good condition, but care should be taken because this may not be applicable in all cases. Design considerations for new buildings should comport with ANSI/AARST (AARST, 2017). Below are common considerations that professionals may review or tests they may complete prior to or in conjunction with preparation of an active mitigation system design.

For systems installed during new building construction, design considerations may be different, as there is much more control over the building and its infrastructure. Design considerations for new buildings should comport with ANSI/AARST (AARST, 2018a).

Special design considerations may also be needed if looking to convert and modify a previously installed passive system to an active system. The practitioner or designer must understand the air flow and the potential for short circuiting prior to converting a passive mitigation system to an active system. Designs should account for more than just adding a fan/blower to a passive system's vent stack(s).

The ***Design Considerations Fact Sheet*** provides details of factors that could be considered for various VI mitigation approaches, including active mitigation, passive mitigation, remediation, and rapid response. Factors that could be considered for active mitigation include:

- VI CSM considerations
  - vapor source
  - geology and hydrogeology
  - building conditions
- Design investigation and diagnostic testing
  - sub-slab diagnostic tests
  - barrier or liner material tests
  - building HVAC tests
- Mitigation system design
  - design basis
  - design layout and components
  - permit requirements
  - stakeholder requirements
- System construction and implementation
  - system effectiveness and reliability
  - operation and maintenance considerations
  - exit strategy considerations

A ***System Design and Documentation Checklist*** has also been created to provide a guide through the considerations relative to both active and passive mitigation strategies.

During this stage in the mitigation process, the installation and installation oversight of the system should be considered as it relates to the design and the components of completing a design (e.g., implementability, permitting, construction quality objectives, etc.). Additional installation considerations will be summarized in the post-installation verification process step.

3.2 Post-Installation Verification Considerations

Following design and installation, the mitigation system will be turned on and verification will be needed to document that the system is operating according to the objectives set out in the design. Verification of system installation and effective operation may include multiple criteria. It is also important during this step, as well as in the future during OM&M, to validate the CSM for which the system was designed. Below is a summary of possible post-installation verification considerations that may be needed for active mitigation approaches.

Initial system commissioning data may be collected immediately upon start-up and system balancing. It is also common to collect (or recollect) commissioning data and rebalance the system if needed, up to 30–90 days after system start-up. This is due to changing conditions in the subsurface soils where soils may dry out and/or sub-slab vapor concentrations may be reduced. Often this process results in more permeable soils and an increase in the distances of the pressure field extension (PFE) for an active system (SSD, SMD and SSV). If indoor air samples are going to be collected as part of verification testing, the time frame for sampling may be different than initial system commissioning flow and vacuum data collection. Some states have recommended data collection time frames in their VI guidance to be followed as applicable.

For systems installed during new building construction, post-installation verification testing may be easier to perform prior to building occupation, especially if any retrofits are needed to enhance system performance. These verification methods (i.e., system parameter readings, PFE tests, tracer tests, checking for leaks, etc.) can be performed relatively quickly in an empty building to minimize delay in the continued construction and occupancy schedule.

The ***Post-Installation Verification Fact Sheet*** provides details of those factors that could be considered for active mitigation and includes:

- groundwater elevation
- building information and survey
- system design and specification confirmation considerations
- confirmation testing
- permitting
- communications
- OM&M planning

Please also see the ***Post-Installation Verification Checklist*** for a checklist guide to verification considerations.

3.3 OM&M Considerations

An OM&M plan provides instructions for system operation and upkeep and should be prepared for each installed mitigation strategy. Details of a typical OM&M plan can be found in Section 6.3 and Appendix J.5 of the ITRC PVI Guidance (ITRC, 2014). The goal of OM&M is to verify performance of the system as compared to performance during system commissioning and to inspect and, if needed, repair issues with the system due to system malfunction (i.e., system not operating to meet performance objectives) or due to system equipment life expectancy.

The ***Operation, Maintenance, & Monitoring Checklist*** includes a list of considerations that may be reviewed, inspected, and/or measured during an OM&M site visit. Considerations during OM&M inspections of active mitigation systems may also need to include OM&M of any passive components to VI mitigation activities completed at the property, such as maintenance of passive membranes or maintenance of crack sealants or preferential pathway sealants that were installed/completed in combination with the active mitigation approach. Passive OM&M considerations are included in the ***Operation, Maintenance, and Monitoring Checklist*** and are also discussed in the ***Operation, Maintenance, and Monitoring/Exit Strategy Fact Sheet***.

The ***Operation, Maintenance, and Monitoring/Exit Strategy Fact Sheet*** provides details of those factors that could be considered for active mitigation and includes:

- mitigation system operation
- system start-up and shutdown
- building conditions and use
- system inspections and performance metrics
- communication and reporting

3.4 Exit Strategy

A key concept throughout the process of designing, implementing, and operating an active mitigation strategy is evaluating options for assessing and implementing exit strategies. The source of VOC vapors may be remediated or may biodegrade within the life cycle of a mitigation strategy and therefore, in some cases, render the system unnecessary. There are also cases where mitigations systems are operated out of an abundance of caution, but are not actually necessary, as a result of uncertainties associated with spatial and temporal variability in sampling and analysis of data, background sources, and/or conservative regulatory guidance. The details for exit strategy considerations can be found in the ***Operation, Maintenance, and Monitoring/Exit Strategy Fact Sheet***.

In each step of the active mitigation strategy process (from design to installation to OM&M) the exit strategy (also referred to as decommissioning or system closure) should be considered and planned. A review of existing VI regulatory guidance documents (Eklund et al., 2018) included an evaluation of various state provisions for exit strategies. States such as Massachusetts (MADEP, 2016), New York (NYSDOH, 2006), New Jersey (NJDEP, 2018), and Wisconsin (WDNR, 2018) include recommendations for certain data collection efforts to support the closure decision, such as:

- verification sampling and analysis of sub-slab vapors and/or indoor air and outdoor air and comparison to protective screening levels
- temporary shutdown of system operation prior to the verification sampling, to allow vapor concentrations to rebound to potential levels that might be expected after system closure
- multiple verification monitoring events to account for temporal variability
- operation of the system between verification monitoring events, or indoor air monitoring to maintain protectiveness

These approaches can effectively demonstrate that system operation is no longer necessary. It may be appropriate to prepare a work plan that outlines the exit strategy prior to implementation of shutdown efforts.

Research into additional approaches for VI assessment and mitigation design and performance monitoring has been demonstrated and validated through Environmental Security Technology Certification Program (ESTCP) projects. These methods can also be used to assess the continued need for a mitigation system or if the system may be considered for decommissioning. For example, the goal of ESTCP (2018) was to demonstrate and validate a more rigorous and cost-effective process for design and optimization of VI mitigation systems to reduce the capital and long-term operating costs. The mass loading and mass flux assessment methodologies applied in ESTCP (2018 and 2020) can also be used to understand if the rate of mass removal from a system has resulted in decreased concentrations of VOCs to levels below the risk-based screening level for mass loading and therefore no longer pose a risk for VI (McAlary et al., 2018; McAlary et al, 2020).

The selection of an appropriate exit strategy and whether vapor sources remain that present a risk for VI will depend on site-specific conditions and should be approached as a process, rather than as an event. The transition can be planned to proceed through multiple steps. Exit strategy considerations are detailed in the exit strategy subsection of the ***Operation, Maintenance, and Monitoring/Exit Strategy Fact Sheet***. It includes descriptions of the following:

- types of monitoring and timing
- stepdown strategies
- decommission considerations
- communication

4 Summary

Active mitigation involves the use of energized controls (e.g., a fan/blower) to maintain acceptable indoor air quality by mitigating the potential for VI into a building. As described in this fact sheet there are multiple different methods for active mitigation with the most common methods being:

- sub-slab depressurization (SSD)
- sub-slab ventilation (SSV)
- sub-membrane depressurization (SMD)
- crawlspace ventilation (CSV)

Building structures vary widely in their size, function, and use. Because of this variability, implementation of active mitigation technologies will also vary widely, depending on the type of building structure and the design objectives for the VI mitigation system. This fact sheet and associated Process Fact Sheets summarize the many considerations for the design, installation, verification, and OM&M of each of the most common active mitigation technologies as they relate to some of the more common building types and uses. Depending on vapor concentrations, emission rates, and proximity of receptors, air pollution controls may need to be installed.

The details and considerations discussed are a part of the long-term stewardship of active VI mitigation systems. Systems should not only be carefully designed and installed but procedures or guidance (or in some cases, institutional controls) should be put in place to maintain the operation of these systems until such a time that the system can be considered for shutdown.

5 References and Acronyms

The references cited in this fact sheet, and the other ITRC VI mitigation fact sheets, are included in one combined list that is available on the ITRC web site. The combined acronyms list is also available on the ITRC web site.

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