Passive 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 passive mitigation technologies and considerations that go into the design, installation, post-installation system verification and documentation, and operation, maintenance, and monitoring.

1 Introduction

Passive mitigation of the VI pathway involves interception, dilution, diffusion, or diversion of soil gas entry into a structure without the use of mechanical means. These systems physically block the entry of vapors into a building and/or rely on natural mechanisms, such as chemical diffusion and thermal- or wind-induced pressure gradients to divert volatile organic compounds (VOCs) and soil gas, around the building (e.g., to riser pipes). Passive mitigation systems require a high degree of documentation during the installation process, as well as establishing and planning methods that will confirm the system's effectiveness, such as using surrogates and tracers. This document introduces the three most common categories of passive mitigation technology—passive barrier systems, passive venting systems, and building design—and explains instances where such systems can be installed (i.e., new construction, existing structures, etc.).

As presented in the ***Conceptual Site Models 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 (µg/m^3)) are present, diffusion through the slab is not typically considered a significant transport pathway.

2 Passive Mitigation Types

This fact sheet and associated documentation focuses on three general categories of passive mitigation technologies:

- common passive barriers systems
  - asphalt latex membranes (ALM)
  - thermoplastic membranes (TM)
  - composite membranes (CM)
  - epoxy floor coatings (EFC)
- common passive venting systems
  - passive sub-slab venting
  - aerated floor void space systems (VSS)
- building design approaches
  - raised foundations (RF)
  - vented garages (VG)

2.1 Common Passive Barrier System Technologies

This section provides a summary of the common passive barrier system technologies that are typically employed.

Asphalt Latex Membranes

(See also the ***Passive Barrier Technology Information Sheet***)

The primary component of an ALM passive barrier system is the spray-on asphalt latex material. These materials are water based, free of VOCs, and used in combination with other layers to create a barrier to advective flow and diffusive transport of VOCs. A typical ALM passive barrier system consists of a base layer, a spray-applied ALM, and a cap sheet. ALMs can be modified to site-specific goals by changing one or more of the components to achieve site-specific performance criteria.

The spray-on ALM adheres directly to concrete and penetrations without the need for additional system components for fastening. The ability of the ALM to adhere to most substrates makes it ideal for sealing to penetrations and to wall terminations. This results in a fast installation by reducing the time spent on detailing when compared to TM barriers.

Thermoplastic Membranes

(See also the ***Passive Barrier Technology Information Sheet***)

TMs are composed of plastic resins formed into uniform membranes and can also be referred to as geomembranes or plastic liners. TMs most commonly consist of high-density polyethylene (HDPE), but variations such as linear low-density polyethylene (LLDPE) are also available. The physical characteristics of TMs can vary between manufacturers as resin blends are specific to each manufacturer and each type of resin blend provides unique physical and chemical resistance properties.

Thickness and installation procedures differentiate TMs from common vapor barriers. “Vapor barrier” is the term most associated with thin-mil plastic liners (e.g., 6–15 mils) that are used to mitigate moisture transmission through concrete. Vapor barriers used in standard construction practices are not typically designed to mitigate chemical vapor transmission (NJDEP, 2018).

Composite Membranes

(See also the ***Passive Barrier Technology Information Sheet***)

Advancements in technology have led to the development of CMs, which incorporate a variety of materials that can reduce diffusion rates of chemical vapors from volatile organic compounds (VOCs), petroleum hydrocarbons, methane, and radon. CMs use a variety of different passive barrier materials to create a multilayered barrier system designed to improve chemical resistance, constructability, and durability. Currently available CMs for vapor intrusion control are typically 20 mils or thicker.

Epoxy Floor Coatings

(See also the ***Epoxy Floor Coatings Technology Information Sheet***)

Epoxy products can be used for a variety of industrial, commercial, and residential applications. EFCs can be applied to concrete foundations in existing buildings and new construction. EFCs are most often used to protect existing concrete surfaces or provide a decorative finish; however, EFCs can also be applied to existing concrete slabs as a passive barrier system.

When applied, the epoxy cures by a chemical reaction that changes the material from liquid to solid. During the conversion from a liquid to a solid state, EFCs become highly adhesive, which allows EFCs to bond with the concrete floor to seal porous concrete. EFCs can be strong, durable, and chemically resistant to the VOC or other vapor contaminants. As a result, EFCs can reduce the potential for advective and diffusive transport.

2.2 Common Passive Venting Systems

This section provides a summary of passive venting systems that are often employed in conjunction with one of the four common passive barrier system technologies detailed above.

Passive Sub-slab Venting System

(See also the ***Passive Sub-slab Venting Technology Information Sheet***)

The goal of a passive sub-slab venting system is to vent contaminant vapors to the exterior atmosphere and prevent accumulation beneath a structure. Combined with a passive barrier system, contaminant vapors are blocked and rerouted through a passive sub-slab venting system to prevent contaminant vapors from entering the building and accumulating within the indoor air environment.

Passive sub-slab venting systems rely on wind effects, thermal effects, and pressure differences to induce airflow that moves contaminant vapors that accumulate beneath a building through vents to the atmosphere outside of the structure. A passive sub-slab venting system is most easily installed prior to building construction. Successful passive sub-slab venting systems have been designed for existing structures; however, their effectiveness relies on the presence of a subsurface permeable layer or venting system media and adequate access to allow for the installation of a substantial venting network. Venting system media can include gravel, perforated pipes, geogrids, or combinations of these materials. The venting system should generally underlie the entire vapor barrier between foundation structures.

Aerated Floor Void Space Systems

(See also the ***Aerated Floor VSS Technology Information Sheet***)

Aerated floor VSS are concrete slabs with a continuous void space beneath the slab that can be used for passive and active sub-slab venting or depressurization in lieu of a sand or gravel venting layer commonly associated with traditional mitigation systems. Because the void space has very low resistance to air flow, vacuum levels and air exchange rates in the void space are generally higher and more uniform than in sand or gravel layers. Aerated floor VSS are most applicable to new construction, although aerated floors can also be used for complete floor replacement or placed over existing slabs if a higher finished floor elevation can be accommodated.

2.3 Building Design Approaches

(See also the ***Building Design for Passive Vapor Intrusion (VI) Mitigation Technology Information Sheet****)*

This section provides a summary of common approaches that address VI concerns passively using building design. These common building design approaches are sometimes employed in conjunction with other passive technologies and systems detailed above or with active systems.

Raised Foundations

The primary purpose of buildings designed with raised foundations, such as buildings with block and beam construction and/or crawlspaces (also referred to as podium construction), is typically to prevent water vapor from entering the building. However, a raised foundation can also be an effective means of preventing VI. If the raised foundation is designed with sufficient ventilation, this approach can offer a sustainable, effective, and low-cost method of passive VI mitigation. This approach to passive VI mitigation is most applicable in:

- geographic locations where raised building foundations are the preferred building style
- existing buildings constructed with a raised foundation
- buildings slated for construction on contaminated sites where the potential VI risk is determined to be low
- sites with petroleum hydrocarbons impacts.

Vented Garages

When garages are constructed below occupied spaces, venting of the garage is likely to reduce the potential for VI in overlying units by dilution of VOC concentrations below the units and by normal HVAC controls that prevent garage air from entering the building. In many cases, concentrations within the garage itself may be reduced below levels of concern commensurate with garage exposure conditions. Vented garages are typically constructed in city settings on properties where a vapor source is present and space is limited, making placement of a garage under the building economically feasible.

3 Considerations for Passive Mitigation Systems

Careful consideration should be given to several factors in order to select, design, install, and maintain an effective passive mitigation system. The approach outlined below provides a summary of information to consider during each step in the passive mitigation process. More details regarding these factors can be found in the overall Process Fact Sheets listed below.

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

The fact sheets listed above describe the VI mitigation technology types covered within the collective scope of the ITRC VIMT documents and provide additional detail about considerations to be made at each point in the passive mitigation process.

3.1 Design

Prior to passive mitigation system design, it is common to evaluate construction plans for buildings proposed for construction or to perform a building survey for existing buildings. Designing a passive mitigation system for a building prior to construction allows for a greater degree of selection of available passive mitigation technologies and ultimately lower installation costs when compared to retrofitting an existing building with a passive mitigation system. This is due to a greater level of control over the building construction sequence and access during installation of the mitigation system components. For retrofitting, factors such as access, accommodating work schedules of building tenants, and structural integrity of the foundation and floor slab of existing buildings are limitations that may result in increased installation time frames and a narrower selection of cost-effective passive mitigation technologies. An explanation and summary discussion of common design considerations for passive mitigation systems is provided in the ***Design Considerations Fact Sheet***. Factors considered to have a significant impact on design of passive mitigation systems are listed below.

- VI conceptual site model (CSM) considerations
    - vapor source
    - geology and hydrogeology
    - building conditions
- design investigation and diagnostic testing
    - barrier or liner material tests

- mitigation system design
    - design basis
    - design layout and components
    - stakeholder requirements
- system construction and implementation
    - system effectiveness and reliability

The ***System Design and Documentation Checklist*** provides a list of considerations when assessing factors that may affect passive mitigation system design.

3.2 Post-Installation System Verification

Once the passive mitigation system has been designed and installed, mitigation system verification during the construction process will be needed to document that the system is functioning as designed. 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 passive mitigation systems.

The type of post-installation system verification testing approaches should be based upon the type of passive mitigation technology installed. For instance, smoke and tracer gas testing are appropriate for assessment of passive barrier systems and passive sub-slab venting systems, and can be used to verify the integrity of the barrier (especially at locations where another roll of barrier is overlapping and sealed) and to assess the adequacy of sealing around the areas of liner repairs, perimeter edges, and utility penetrations. Smoke and tracer gas testing may also be appropriate for assessing the adequacy of pipe fitting connections and/or the presence of any obstructions within sub-slab venting systems. In addition to conducting smoke and tracer gas testing, coupon sampling is an important verification testing approach appropriate for spray-on liners such as ALM to confirm liner thickness meets the design specification and may be required by certain ALM manufacturers. In many situations, a passive system may be designed such that it can be made active if needed. Pilot testing of the sub-slab venting system, after pouring the concrete slab, is common to verify that an electrical fan or blower can adequately depressurize/influence the remote extents of the system. Time frames required for collection of system verification information vary depending upon state requirements. Check with your state regulatory agency regarding requirements for the type and time frames for collection and submittal of post-installation system verification data.

An explanation and summary discussion of common post-installation system verification considerations for passive mitigation systems are provided in the ***Post-installation Fact Sheet***. Factors considered to have a significant impact on post-installation system verification of passive mitigation systems are listed below.

- building information and survey
- confirmation testing
- communications

The ***Post-installation System Verification Checklist*** provides a list of considerations when assessing which data to collect to verify whether the system is effectively mitigating the VI pathway.

3.3 Operation, Maintenance, & Monitoring

An OM&M plan provides instructions for proper system operation and maintenance required for an installed mitigation system. An OM&M plan should be prepared for each mitigation system installed, regardless of the mitigation technology implemented. Details of a typical OM&M plan are provided in Section 6.3 and Appendix J.5 of the***2014 ITRC PVI Guidance*** (ITRC, 2014). The goal of OM&M is to ensure the ongoing function of the mitigation system as designed following system installation and performance verification. This goal is achieved through performing routine inspections, as well as identification and completion of system repairs due to system malfunction (i.e., system not operating to meet performance objectives) or due to system equipment life expectancy. Indoor air and/or sub-slab soil gas testing, or other means of demonstrating continued performance of the passive barrier, may be required over time.

An explanation and summary discussion of common OM&M considerations for passive mitigation systems is provided in the ***Operation, Maintenance, and Monitoring/Exit Strategies Fact Sheet***. Factors considered to have a significant impact on OM&M of passive mitigation systems are listed below.

- mitigation system operation
- building conditions and use

- system inspections and performance metrics
- communication and reporting
- exit strategy

The ***Operation, Maintenance, and Monitoring Checklist*** includes a list of questions designed to assess vapor intrusion mitigation system (VIMS) operation and the need for corrective actions identified during regularly scheduled VIMS inspections.

3.4 Exit Strategies

A key concept to consider throughout the process of effective implementation of a passive mitigation technology is assessment of viable exit strategies. In the event the vapor source no longer poses an unacceptable risk to the receptors within the building, the VIMS may no longer be necessary. Situations may also arise when VIMS are installed out of an abundance of caution, such as presumptive mitigation to expedite property redevelopment or due to uncertainties associated with spatial and temporal variability, background sources, and/or conservative regulatory guidance. Exit strategies should be considered when these types of situations arise. The details for exit strategy considerations can be found in the ***Operation, Maintenance, and Monitoring/Exit Strategy Fact Sheet***. It may be appropriate to prepare a short work plan that outlines the exit strategy prior to implementation of system decommissioning efforts.

Recent review of existing VI regulatory guidance documents (Eklund et al., 2018), includes an evaluation of various state provisions for VIMS closure. 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 indoor air and outdoor air and comparison to protective screening levels
- 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 VIMS operation is no longer necessary. In cases where conventional approaches result in inconclusive outcomes, alternative approaches may be considered. Recent research for VI assessment and mitigation design and performance monitoring have been demonstrated and validated through Environmental Security Technology Certification Program (ESTCP) projects. For example, the goal of ESTCP 2018 was to demonstrate and validate a more rigorous and cost-effective process for design and optimization of systems for mitigating VI for VOCs and radon to reduce the capital and long-term operating costs (McAlary et al., 2018).

The selection of an appropriate exit strategy and whether vapor sources remain will depend on site-specific conditions, and should be approached as a process, as opposed to an event. The transition can be planned to proceed through multiple steps. An explanation and summary discussion of common exit strategy considerations for passive mitigation systems is provided in the ***Operation, Maintenance, and Monitoring/Exit Strategies Fact Sheet***.

4 Summary

Passive mitigation involves the use of one or more technologies that inhibit sub-slab soil vapor from entering the interior of a building without the use of mechanical means. There are three general categories of passive mitigation technologies: passive barrier systems, passive venting systems, and building design.

Successful implementation of passive mitigation technologies greatly depends upon the appropriateness of the system design to account for site-specific conditions. This fact sheet summarizes the many considerations that go into the design, installation, verification, and operation of each of the most common passive mitigation technologies.

The details and considerations discussed above are part of a long-term plan for passive VIMS. Systems should not only be carefully designed and installed, but procedures or guidance should be put in place to maintain proper operation of these systems as designed until such time that the vapor source no longer poses an unacceptable risk at the site.

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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