Post Installation Fact Sheet

ITRC has developed a series of fact sheets that summarizes the latest science, engineering, and technologies regarding the mitigation of vapors associated with vapor intrusion (VI). This fact sheet describes the most common post-installation considerations for active mitigation systems, passive mitigation systems, and environmental remediation technologies that need to be considered as part of any mitigation system verification testing process.

1 INTRODUCTION

After the implementation of a mitigation strategy, post-installation verification and testing to confirm achievement of the design and operating parameters is required. It is during this time that the conceptual site model (CSM) is validated and the mitigation system is confirmed to be operating and meeting performance specifications, typically using multiple approaches or criteria.

Below are common considerations that professionals should consider or tests they may complete after implementation of a mitigation strategy for confirmation and prior to operation, maintenance, and monitoring (OM&M**)**. Emerging technologies, such as aerobic vapor mitigation barriers (AVMB), are not addressed within this fact sheet. Please see the ***Aerobic Vapor Mitigation Barrier Technology Information Sheet*** for more information.

2 PRECONSTRUCTION AND DURING CONSTRUCTION

Planning, preparation, and oversight conducted during installation are as important as post-installation system confirmation. Attention to these items will greatly improve the post-installation evaluation and provide for a more successful implementation. The formality of planning and construction quality assurance (CQA) during installation will depend on the size and complexity of the building and the mitigation system to be constructed.

Prior to construction, plan the post-installation evaluations and documentation requirements, and communicate them to the installer and CQA representative(s). Obtain necessary permits for installation and operation, and plan how to meet the permit requirements, including those for closure of the permit.

During construction, pay attention to ensuring quality construction. Certain post-installation testing should occur during construction (while the installer is still present) to allow for rapid system adjustments. Other post-installation testing will likely occur days or weeks after the system is installed and operating. For purposes of this fact sheet, we will consider all of these items to be "post-installation" considerations.

3 POST-INSTALLATION CONSIDERATIONS

This fact sheet focuses on the most common post-installation considerations. Table 3-1, below, summarizes the considerations and identifies their impact in an active (see ITRC ***Active Mitigation Fact Sheet)*** approach, a passive (see ITRC ***Passive Mitigation Fact Sheet***)] approach, remediation (see ITRC ***Remediation & Institutional Controls as Vapor Intrusion Mitigation Fact Sheet***), or rapid response technology (see ITRC ***Rapid Response and Ventilation for Vapor Intrusion Mitigation Fact Sheet***). Detailed discussion and supporting information are presented later in this section.

Table 3-1. Summary of post-installation considerations and impact on mitigation approach

Post-installation Consideration	**Active approaches**	**Passive approaches**	**Remediation**	**Rapid response**
Groundwater elevation				
Depth to groundwater/high water conditions	●	◐	●	◒
Building information and survey				
Foundation and slab condition	●	◒	●	◐
Preferential pathways and utility penetrations	●	●	●	●
Heating, ventilation and cooling (HVAC) system	◐	◒	◒	●
Windows, air intake, and building exhaust	●	●	●	●
Building codes and industry standards	◐	◐	◐	◐
Confirmation testing				
Pressure field extension (PFE) confirmation	●	—	●	◒
System vacuum, air flow, and velocity	●	◐	●	◒
Sub-slab, indoor air, outdoor ambient air sampling	●	●	●	●
Mass removal rate	●	◒	◐	◒
Smoke and tracer gas testing	●	●	●	●
Backdraft testing	◐	—	◒	—
Coupon testing	—	●	◒	—
Telemetry	◐	◒	◐	◒
Permitting				

Table 3-1. Summary of post-installation considerations and impact on mitigation approach

Post-installation Consideration	Active approaches	Passive approaches	Remediation	Rapid response
Installation permits	◐	◐	●	◒
Operational permits	◐	◒	●	◒
Communications				
Property owner, tenant, and others	●	●	●	●
Operation, maintenance, and monitoring planning				
OM&M plans	●	◐	●	●
Key High impact ● Medium impact ◐ Low impact ◒ Not applicable —				

The remainder of this document provides a discussion of the impacts for each consideration above.

3.1 Groundwater Elevation

As the system moves past installation, a key consideration moving forward is confirmation of the control of shallow groundwater conditions. Certain mitigation strategies require air flow below the subsurface; therefore, the presence or absence of shallow groundwater may play a key role in defining the success of certain technologies. In instances where groundwater is being controlled, post-installation monitoring should confirm that the measures implemented are successful.

Active Approaches	**High Impact**. Groundwater elevation can potentially impact subsurface active mitigation systems since the presence of moisture or water can lower the air flow and pressure field extension (PFE) of an area targeted for mitigation. Specifically, sub-slab depressurization (SSD), sub-slab ventilation (SSV), sub-membrane depressurization (SMD), and drain tile depressurization can be highly impacted by groundwater near a building slab or membrane. Groundwater elevation has low impact to indoor air filtration and building pressurization.
Passive Approaches	**Medium Impact**. High water near or in direct contact with the floor slab may limit the effectiveness of venting systems. For barriers to be effective, they must be both waterproof and resistant to contact with site-specific chemicals.

Remediation	**High Impact**. Soil vapor extraction (SVE) is feasible only when sufficient unsaturated thickness is present. Multiphase extraction (MPE) can be applied at sites with or without unsaturated thickness; however, high groundwater increases the complexity and the OM&M requirements of the system.
Rapid Response	**Low Impact.** Groundwater elevation does not impact most rapid response measures. If groundwater is in contact with preferential pathway sealants, then the effectiveness of those sealants may be compromised, depending on the constituents and concentrations thereof in groundwater. Ad hoc heating, ventilation, and cooling (HVAC) modification and indoor air treatment are not impacted by groundwater elevation.

See Section J.2.6 of ***Appendix J in the 2014 ITRC Petroleum Vapor Intrusion (PVI) document*** (ITRC, 2014) for a summary of considerations to be made where high water conditions may be present.

3.2 Building Information and Survey

An existing building survey can support the conclusion that mitigation measures are successful. An existing building survey is conducted prior to the design of any mitigation strategy to collect information critical to selecting a mitigation technology appropriate for the building conditions and the CSM (see ITRC ***Conceptual Site Models for Vapor Intrusion Mitigation Fact Sheet)***. The survey additionally provides a baseline for comparison to post-construction conditions. Photographic documentation, the building sketch, and detailed notes should be examined and compared to the baseline condition. A sample existing building survey form can be found in Appendix G of the ***2007 ITRC Vapor Intrusion Pathway: A Practical Guideline (VI-1)*** (ITRC, 2007a).

The following is a summary of items typically reviewed after implementation of a mitigation strategy.

Foundation and Slab Condition:

Depending on how the mitigation strategy was implemented and any modifications to the structure that were installed as part of the mitigation system installation, a survey should be conducted that confirms that modifications to the structure, if any, do not have an adverse impact on the functionality of building structural components.

Active Approaches	**High Impact**. The foundation and floor slab are key elements of most action mitigation systems, and their collective integrity have a significant effect on system performance.
Passive Approaches	**Low Impact**. Most passive mitigation systems are installed in new construction, which makes this a lesser consideration. However, this factor may impact and apply to epoxy floor coatings (EFC).
Remediation	**High Impact**. Certain features of buildings, such as deep foundations or highly fractured slabs, may affect soil vapor flow during SVE or MPE and necessitate that these features be evaluated.
Rapid Response	**Medium Impact**. The condition of the building foundation and slab may impact the effectiveness of preferential pathway sealants.

See Section J.2.4 of ***Appendix J in the 2014 ITRC PVI document*** (ITRC, 2014) for a summary of considerations related to foundation types.

Preferential Pathways and Utility Penetrations:

Preferential advective flow pathways through openings in the building slab and into the building should have been identified and considered as part of the design. Such openings include utility penetrations, sumps, cracks, joints, perimeter drains, sewer pipes and related interior connections, and the slab-foundation perimeter joint. Elevator shafts may need to be considered separately as they may not be able to be sealed (certain building codes require there to be a soak-away at the bottom of an elevator shaft and this must not be sealed). Preferential pathways should be inspected and confirmed to be addressed through appropriate measures.

Active Approaches	**High Impact**. Sealing around preferential pathways and penetrations within the floor slab is critical to the effectiveness of active mitigation systems. Ensure abandoned or inactive utilities are appropriately sealed.

Passive Approaches	**High Impact**. Sealing around penetrations within the floor slab is critical to the effectiveness of passive mitigation systems.
Remediation	**High Impact**. Sealing around penetrations within the floor slab is critical to the effectiveness of SVE and MPE as mitigation measures.
Rapid Response	**High Impact**. Sealing major preferential pathways and utility penetrations is critical to the effectiveness of any rapid response action.

See Section J.2.4 of ***Appendix J in the 2014 ITRC PVI document*** (ITRC, 2014) and Section 8 of ANSI/AARST SGM-SF-2017 (AARST, 2017) for additional information.

Heating, Ventilation and Cooling (HVAC) System:

It is important to evaluate the air exchange rate(s) and operational changes over which the HVAC system operates after the installation is complete to confirm that it is still operating in a manner consistent with pre-installation conditions. VI mitigation implementation should not impact HVAC operation, unless HVAC adjustments were intended as part of the design.

Some mitigation systems, almost exclusively in commercial buildings, function by adjusting the HVAC to pressurize the indoor space relative to sub-slab, or by increasing the air exchange rates to reduce concentration of indoor contaminants (see ITRC ***Heating, Ventilation & Air Conditioning (HVAC) Modification Technology Information Sheet***)]. It is also critical to assess if the mitigation strategy, now that it is no longer conceptual in nature, will remain effective for reasonably anticipated operating conditions and heating and cooling seasons.

Active Approaches	**Medium Impact**. If depressurization below the building is the goal, such as with SMD and SSD, then decreased pressure within the building interior can reduce the differential vacuum with the subsurface below acceptable levels. Conversely, if the pressure within the building interior is increased, the effectiveness of a depressurization system is enhanced.

Passive Approaches	**Low Impact**. This factor primarily applies to building design with minimal impact on the effectiveness of barriers and venting systems.
Remediation	**Low Impact**. Remediation technologies are typically not impacted by the HVAC operation.
Rapid Response	**High Impact**. Modifications to HVAC systems can greatly impact indoor air quality during a rapid response. HVAC operation is best modified through adjustment of supply/return air and exhaust fan flow rates.

Windows, Air Intake, and Building Exhaust:

Vent stack location standards, including prescribed distances from building entryways (doors, windows) and building vents, are detailed in existing industry guidance for radon mitigation systems, as well as in states' VI guidance. Typically, vent stack locations are not less than 2 feet above the eve of the roof (including any walls/parapets) and not less than 10 horizontal feet away from openings (windows, doors, etc.) and mechanical equipment air intakes. Increased distancing is required for larger exhaust pipes or for angled discharge, and increased distancing may be required near certain fan-powered air intakes. Additional specifications, created for all soil gas control systems, were developed by ANSI/AASRT (AARST, 2018c) and provide a useful set of initial considerations for volatile organic compound (VOC) mitigation system vent stack design. For VOC VI mitigation systems, the vent stack height and distance from openings and air intakes will depend on the concentrations of VOCs being emitted, and air velocity. For many VOCs, the indoor air screening levels are very low, which may necessitate taller vent stacks or larger separation distances to avoid introduction of VOC vapors from the mitigation system effluent to indoor air. In some cases, air dispersion modeling may be useful to help appropriately place a vent stack for a mitigation system.

The top of the vent stack discharge pipe should also be vertical, or as close to vertical as possible (not more 45 degrees from vertical) (AARST, 2018c). Generally, rain caps are not necessary. However, if rain caps are used, they should not impinge on the vertical discharge of vapors from the stack. For more information, see Section J.3.3 of ***Appendix J in the 2014 ITRC PVI document*** (ITRC, 2014) and ANSI/AARST: SGM-SF-2017 (AARST, 2017); CC-1000-2018 (AARST, 2018c); RMS-MF-2018 (AARST, 2018a); and RMS-LB-2018 (AARST, 2018b).

During the post-installation review, vent stack distances are evaluated to confirm the design specifications have been met. Note that during construction, the vent stack may be been relocated based on input from owners, tenants, architects, or other engineers (for aesthetics, convenience, or other reasons). It is important to revisit vent stack placement requirements during relocation discussions.

Active Approaches	**High Impact**. Vent stack placement is critical to ensuring effluent vapors do not enter the building.
Passive Approaches	**High Impact**. Vent stack placement is critical to ensuring effluent vapors do not enter the building.
Remediation	**High Impact**. Placement of the SVE/MPE system discharges is critical to ensuring that system exhaust does not enter buildings.
Rapid Response	**High Impact**. The location of the outside air intake and the quality of the outside air will greatly impact indoor air quality. Any form of building exhaust should be away from HVAC air intakes.

Building Codes and Industry Standards:

There are no overarching building codes for system construction that apply to every building in every state. However, states or municipalities may have requirements in their building codes regarding system construction (material types, component locations, etc.). These codes should have been reviewed and incorporated into the design.

Post-installation activities confirm that the all building codes and industry standards have been followed. While building codes may or may not have a significant impact on VIMS, applicable building codes must be followed and must be evaluated when they impact the installed system.

Active Approaches	**Medium Impact**. The degree to which building codes affect active mitigation system installation varies from location to location and should be followed.

Passive Approaches	**Medium Impact**. The degree to which building codes affect passive mitigation system design varies from location to location and should be followed.
Remediation	**Medium Impact**. Building codes may impose certain restrictions on the construction of SVE and MPE systems.
Rapid Response	**Medium Impact**. Some states may have rules or regulations on who can evaluate/modify HVAC systems to ensure they comply with building and energy code requirements.

3.3 Confirmation Testing

Confirmation testing is performed subsequent to completion of installation and start-up of the mitigation system. Confirmation testing confirms that the mitigation system is meeting the design and performance objectives. The approach to confirmation testing will be dependent on the mitigation approach and applicable regulations/guidance.

For active mitigation and remediation systems, this process is frequently referred to as commissioning, which is an important step to verify that the system is functioning consistent with the design and specifications. Commissioning additionally provides a performance baseline for comparison to measurements collected during OM&M.

During commissioning, keep in mind exit strategies, discussed in detail in the ITRC ***Operation, Maintenance & Monitoring/Exit Strategy Fact Sheet***. Data can be collected during post-installation confirmation testing to support an exit strategy. In certain instances, it is important to demonstrate data trends early in the mitigation process.

Pressure Field Extension (PFE) Confirmation:

PFE confirmation, also called radius of influence (ROI) testing or communication testing, should be completed to understand and confirm proper SSD, SVE, or MPE operation. PFE testing consists of measuring the distance that differential pressure can be measured from a point of applied vacuum (a suction point). It is used to confirm the number and placement of suction points, and that the fan/blower sizes are appropriate to meet performance objectives, especially at the remote extents of the system. Target differential pressure levels should provide a general factor of safety range to confirm depressurization is maintained under reasonably anticipated building conditions. Certain states provide a differential pressure minimum guideline, which is generally 1–6 Pa, depending upon the state. For SSD, SSV, and SMD systems, a differential pressure as low as 1 Pa has been shown to be effective as long as it is maintained over time under normal operating building conditions (Lutes et al., 2011; Moorman, 2009). More information on differential pressure measurement collection and target ranges is in the ***Design Considerations Fact Sheet***.

The PFE distance varies based on numerous factors—primarily the contrast in permeability between the floor slab and the material beneath the floor, but also including the location of building footers, floor drains, trenches, and utilities. Floor leakage may also be indicated by PFE assessments (i.e., areas of less sub-slab vacuum than expected could be near areas of air recharge across the floor slab). Use of mathematical models for flow and vacuum can be helpful for interpolation or extrapolation of known data to demonstrate PFE coverage or excessive leakage.

Where PFE is not adequate to extend to all areas of potential concern, it may be appropriate to seal floor cracks, expansion joints, conduit openings, and joints around manhole covers to prevent short circuiting and improve efficiency of an active mitigation system. Where these pathways are inaccessible (under floor coverings, behind walls, etc.), additional suction points may be required. These pathways may have already been sealed during previous building mitigation activities (by previous rapid response activities and/or passive mitigation activities) but have failed through improper application or natural deterioration; therefore, re-application of sealants should be considered.

Active Approaches	**High Impact**. This is a critical step to demonstrate that the VI pathways are being effectively interrupted for SSD systems, but may not be practical for certain active systems, such as SMDs or block wall mitigation systems.
Passive Approaches	**Not Applicable.** PFE testing is not considered for passive approaches.
Remediation	**High Impact**. PFE testing is crucial in confirming the effectiveness of SVE and MPE systems in providing VI mitigation.
Rapid Response	**Low Impact**. PFE is not typically associated with rapid response approaches. However, during building pressurization with HVAC modification, sub-slab to indoor air differential pressure may be collected to confirm adequate pressurization.

More information on PFE testing is included in ANSI/AARST SGM-SF 2017 Section 6.2 (AARST, 2017) and more information on characterizing the transmissivity below the floor and the leakance of the floor is provided by ESTCP (McAlary et al., 2018).

System Vacuum, Air Flow, and Velocity:

System vacuum and air flow readings collected after start-up are used to verify that system operation is meeting the design specifications. Flow velocity is usually measured using a critical orifice, thermal anemometer (i.e., hot-wire anemometer), vane anemometer, pitot tube, or similar device. Vacuum is usually measured with a U-tube manometer, dial gauge, or digital manometer. Vacuum and flow readings should be collected concurrently with PFE readings so that the approximate vacuum and flow rate that generated the PFE range are known. High flow at the blower with low vacuum (e.g., 100 standard cubic feet per minute [scfm] or more of flow at a vacuum of 1 inch of water column [in-H_2O] or less) indicates highly permeable materials below the floor and is conducive to the system having a significant component of SSV. Low flow with high vacuum (e.g., 10 scfm or less flow at a vacuum of 10 or more in-H_2O) indicates low-permeability material below the floor. The ratio of flow/vacuum is the specific capacity of the venting system and is a parameter that can be affordably and easily monitored over time to evaluate whether the permeability of the material below the floor is changing.

For SSV and crawl space ventilation (CSV) systems, flow velocity is a useful performance criterion as it indicates that vapors are moving within the subsurface or crawl space, allowing for dilution and reduction of contaminant concentrations. Sub-slab tracer testing and mathematical modeling to evaluate adequate sub-slab flow velocity are detailed by ESTCP (McAlary et al., 2018). Following the initial assessment, air flow rate in the vent pipes can then be monitored over time to confirm proper system operations are maintained.

Active Approaches	**High Impact**. Active system vacuum, air flow, and velocity readings confirm the system is operating according to design criteria and are useful in evaluating effectiveness of the active system. Measurements may also be used for calculating discharge criteria or permit limits.
Passive Approaches	**Medium Impact**. Passive approaches do not use mechanical means in their design; therefore, system vacuum does not apply to passive approaches. However, confirmation of flow, even if intermittent, within passive venting systems can be used to ensure proper design and installation of passive mitigation systems.
Remediation	**High Impact**. Flow characteristics are key design elements of SVE and MPE systems.

Rapid Response	**Low Impact**. Rapid response approaches do not typically include monitoring of vacuums and flows related to blowers or fans. However, air flow rates should be evaluated during HVAC modifications. Refer to Section 3.2.3 above for information on HVAC systems.

Sub-Slab, Indoor Air, Outdoor Ambient Air Sampling

Collection of soil vapor or indoor/outdoor air samples following start-up of a mitigation system is another approach to document system effectiveness. Sampling procedures should generally match those conducted during the remedial investigation (i.e., pre-installation). However, for SSD and SSV systems, soil gas samples may be collected after system start-up from a sampling port in the vent pipe or from a monitoring point within the floor.

It may be necessary to verify that indoor air concentrations are below a building-specific cleanup level or show that continued/remaining indoor air concentrations are due to background indoor air sources, and not due to VI (either via subsurface or outdoor air [due to poor vent pipe placement or inadequate treatment, if required, of extracted soil vapor]).

Active Approaches	**High Impact**. Regulatory agencies likely will require air sampling for system verification and effectiveness confirmation.
Passive Approaches	**High Impact**. State regulatory agencies likely will require paired sampling (i.e., sub-slab soil gas and indoor air sampling) for system verification purposes.
Remediation	**High Impact**. Air quality sampling is essential to confirming the effectiveness of SVE and MPE when acting as VI mitigation measures.
Rapid Response	**High Impact**. Indoor air sampling is critical to confirm the effectiveness of a rapid response. Samples should be collected throughout the building, including within each HVAC zone, if applicable. Outdoor air samples should also be collected near air intakes to assess the quality of the air supply.

Mass Removal Rate:

Although mass removal may not be the primary function of a mitigation system, it can be useful for assessing whether an SSD/SSV is capturing appropriate sub-slab chemical mass, and whether permit conditions are met. The rate of mass removal from the mitigation system can be calculated from system airflow measurements and contaminant concentrations measured in the vent system piping. The mass removed by the system can be compared to the rate of mass removal from the building if building depressurization testing (i.e., blower door testing) was performed during the VI assessments prior to system installation (Dawson, 2016). This comparison can be used to assess whether the SSD/SSV is capturing all of the mass that might have otherwise entered the building and can inform the potential need for additional suction points or larger fans to increase the rate of mass capture.

Mass removal rate data are also useful for verifying compliance with applicable air discharge permit requirements or regulatory effluent limits, and for assessing whether emission controls would be required during system start-up. The mass removal rate can also be tracked over time, as part of an exit strategy that assesses whether the concentration of contaminants diminishes to levels that no longer require mitigation, as described in the OM&M Section (see Section 3.6 below). However, the use of mass removal rates is rarely a demonstration that does not require other forms of performance verification, such as sub-slab and indoor air sampling.

Active Approaches	**High Impact**. Mass removal can be used to assess system performance and for compliance with air discharge permit requirements.
Passive Approaches	**Low Impact**. Mass loading rates are typically not considered in passive mitigation system design.
Remediation	**Medium Impact**. Proper design is required to manage mass loadings from SVE and MPE systems (e.g., treatment). In addition, mass loading records are used to propose exit strategies.
Rapid Response	**Low Impact**. Mass loading rates are typically not considered for rapid responses.

Smoke and Tracer Gas Testing:

Smoke and tracer gas testing are options to test air flow patterns. For example, if smoke is drawn rapidly below the floor through an open sub-slab port during SSD/SSV operation, this indicates the system is effective at the location tested. In cases where the material below the floor is highly permeable, this can occur where the applied vacuum is too low to measure with the most sensitive devices, such as a digital micromanometer.

Smoke tests (implemented using a smoke pen or other suitable methods) can also be used to evaluate system effectiveness. Smoke tests can be conducted at known or suspected preferential pathways across the floor or building envelope. They can additionally be used to verify that a membrane is adequately sealed to building walls, as in an SMD system.

Helium can be used in at least two ways as a sub-slab gas flow tracer. The first is an interwell test, which consists of adding a few liters of helium to a probe at some distance (e.g., 5–15 ft) from a suction point and monitoring the concentration of helium in the extracted gas at the suction point. The second is a helium flood, which consists of reversing the mitigation system flow direction and blowing air with about 1% helium into the subsurface while monitoring the arrival time of helium at various sub-slab probe locations. The data from either test can be input into a mathematical model to evaluate the effectiveness of the system. More information can be found in Section J.4.3 of ***Appendix J in the 2014 ITRC PVI document*** (ITRC, 2014) and ESTCP (McAlary et al., 2018).

Active Approaches	**High Impact**. Smoke or tracer gas testing is an effective way to evaluate the efficacy of an active mitigation system.
Passive Approaches	**High Impact**. Smoke or tracer gas testing is an effective way to evaluate the integrity of a passive mitigation system without the need to add penetrations.
Remediation	**High Impact**. Smoke or tracer testing is crucial for confirming the effectiveness of the SVE and MPE systems when used for VI mitigation.
Rapid Response	**High Impact**. Smoke testing can be a highly effective method in evaluating the efficacy of preferential pathway seals. Smoke testing can also be used to assess the airflow paths throughout a building due to HVAC operations.

Backdraft Testing:

As stated in Section J.3.9 of ***Appendix J in the 2014 ITRC PVI document*** (ITRC, 2014), a backdraft condition occurs if a building's ventilation equipment is not properly balanced against the building's combustion devices (e.g., furnaces, clothes dryers, water heaters, fire places, wood stoves, etc.), resulting in exhaust gases (e.g., carbon monoxide) collecting inside the building. Most residential mitigation activities (SSD, SMD, SSV) add little to the potential for overall building depressurization due to the blower's low flow rates and minimal pressure differentials across the slab. However, the installer should understand the building's air supply (i.e., is it "natural draft" or does it have cold air supply vents) and conduct backdraft testing, as applicable or as recommended by state guidance. The U.S. Environmental Protection Agency provides recommended procedures for backdraft testing that can be completed before and after mitigation system installation and start-up (USEPA, 1993). Backdraft conditions should be corrected before the depressurization system is placed in continued operation. Carbon monoxide detectors are recommended within buildings, including the basement.

Active Approaches	**Medium Impact**. Active mitigation systems typically do not affect backdraft; however, it is critically important to confirm the absence of backdraft after installation of an active system.
Passive Approaches	**Not Applicable**. Backdraft testing is not employed.
Remediation	**Low Impact**. Remediation technologies generally do not affect backdraft.
Rapid Response	**Not Applicable**. Backdraft testing is not employed for rapid responses.

Coupon Testing:

Confirmation of spray-applied liner thickness can be accomplished by removing a small section of the liner (a "coupon") and measuring its thickness with calipers or another measurement device. After the spray-applied liner has cured, one or more coupons are removed. The thickness of the coupons is measured and, if a coupon is too thin, additional barrier is applied in the area of the deficient coupon. The liner is repaired where the coupons were removed. This process is typically conducted in accordance with manufacturer's guidance for the number of coupons and acceptable thickness.

Active Approaches	**Not Applicable.** Active mitigation approaches do not use coupon testing.

Passive Approaches	**High Impact**. Thickness verification is important to confirm proper installation of passive mitigation systems. It is recommended to follow the product manufacturer's guidance on frequency of coupon sample collection.
Remediation	**Low Impact**. Most SVE and MPE systems do not require the use of barriers that would require coupon testing.
Rapid Response	**Not Applicable**. Coupon testing is not considered for rapid responses.

Telemetry:

If telemetry is incorporated into the system design, then communication of the telemetry system to designated users must be tested. Telemetry could be as simple as a communication if the system shuts down, or as complex as continuous broadcast of system parameters. More information about telemetry is detailed in the ***Operation, Maintenance & Monitoring Process/Exit Strategy Fact Sheet***.

Active Approaches	**Medium Impact**. Active systems may be installed with telemetry to monitor and provide data to optimize the operation of the system.
Passive Approaches	**Low Impact**. Telemetry is not typically incorporated into passive mitigation systems.
Remediation	**Medium Impact**. SVE and MPE systems may be installed with capabilities for telemetry.
Rapid Response	**Low Impact**. Telemetry is not typically incorporated into rapid responses.

3.4 Permitting

Permits typically consist of the following two types:

- Installation permits: Some states or municipalities may require a building permit or electrical permit for system installation.
- Operational permits: Discharge permits may be required by local, county, or state government prior to start-up. Some agencies may require a permit application to be submitted with available analytical data and system flow rates to determine if a discharge permit or exhaust treatment is needed. See Section J.3.2 of ***Appendix J in the 2014 ITRC PVI document*** (ITRC, 2014).

Installation Permits:

After the installation of a mitigation system, it is important to confirm that installation permit conditions have been met. These permits will need to be appropriately closed with the regulatory agencies or building departments. The following are typical CQA or post-installation tasks that are performed related to installation permits:

- review and approval of applicable submittals, including gravel specification; membrane (and membrane adhesives, mastics, etc.); aerated slab forms; pipe and fittings; system monitors and alarms; and fans
- inspection of system components, including gravel placement; piping/vent strips; membrane; aerated floor; membrane penetrations and boots; slab placement; riser and conveyance pipes; fans; system monitors; and alarms

Active Approaches	**Medium Impact**. Installation permits may be required for active mitigation systems. Confirm installation permit requirements with your state and local regulatory agencies, and with the municipal building department.
Passive Approaches	**Medium Impact**. Permits may or may not be required for the installation of passive mitigation systems. Confirm installation permit requirements with your state and local regulatory agencies and the building department of your local unit of government.
Remediation	**High Impact**. SVE and MPE systems typically require permits related to the treatment and discharge of the impacted vapor.

Rapid Response	**Low Impact**. Permits are not typically required for rapid responses. However, if HVAC systems are modified, building permits may be required.

While permits may or may not have a significant impact on mitigation systems, applicable permits must be obtained and followed.

Operational Permits:

The two main types of operational permits that need to be considered can be classified as emission permitting and control permitting.

As detailed in Section J.3.2 of ***Appendix J in the 2014 ITRC PVI document*** (ITRC, 2014), air permits and emission controls on active mitigation or remediation systems must be considered for each project based on the system design, the conceptual site model, and the applicable state, federal, or local regulations. The regulations are generally associated with the Clean Air Act or local ordinances that have been set by statute. In some states, subsurface mitigation systems may be exempt from permitting. More detail is provided in Section J.3.2 of ***Appendix J in the 2014 ITRC PVI document*** (ITRC, 2014).

Active Approaches	**Medium Impact**. Emission or control permits may be required to operate an active mitigation system. Contact your state and local regulatory agencies to ensure compliance with applicable emission permit requirements.
Passive Approaches	**Low Impact**. While typically not required for passive mitigation systems, emission permits may be required by your state or local regulatory agencies. Contact your state and local regulatory agencies to ensure compliance with applicable emission permit requirements.
Remediation	**High Impact**. Discharge permits are typically required to operate SVE and MPE systems.
Rapid Response	**Low Impact**. Operational permits are typically not considered for rapid responses.

While permits may or may not have a significant impact on mitigation systems, applicable permits must be obtained and followed.

3.5 Communications

The building owner, tenant, and other parties involved with the building are typically provided with information regarding the mitigation system. Common items may include:

- basic description of mitigation system (components, operation, etc.) installed
- photos of typical system components
- restrictions, if any, to access, perform construction on, or use portions of the property due to the mitigation system
- information relating to the mitigation system alarm/monitors, and instructions for whom to contact in the event of an alarm condition or unusual noise related to the mitigation system
- contact information if other issues or questions arise related to the mitigation system

Active Approaches	**High Impact**. Communication with the building owner or tenant regarding the operation of the active mitigation system is critical.
Passive Approaches	**High Impact**. Community engagement is a critical part of the implementation of a passive approach, especially if the approach is large scale or highly visible. Contact your state and local regulatory agencies to confirm your regulatory obligations with respect to notification requirements.
Remediation	**High Impact.** Implementation of SVE or MPE typically involves an extensive interaction with the stakeholders, including access agreements.
Rapid Response	**High Impact**. Adjustments to HVAC systems or implementation of indoor air treatment units must be clearly communicated, as the operation of these responses may fall on the owner or tenant.

The ***Public Outreach During Vapor Intrusion Mitigation Fact Sheet*** provides additional information to plan communications with property owners and building occupants.

3.6 Operation, Maintenance, and Monitoring Planning

An OM&M plan provides instructions for system operation and upkeep and should be prepared for each installed mitigation system. Consideration of the OM&M should have begun during the design phase, and modifications to the plan will occur based on the post-installation evaluation and testing. Certain states may have standardized templates or minimum content requirements when OM&M plans are prepared.

Details of a typical OM&M plan can be found in Section 6.3 and Section J.5 of in the ***2014 ITRC PVI document*** (ITRC, 2014) and are further discussed in the ***Operation, Maintenance & Monitoring Process/Exit Strategy Fact Sheet***.

Active Approaches	**High Impact**. Since active systems are generally a part of long-term stewardship plans, the OM&M plan is critical to prepare and follow to ensure continued proper operation of the system.
Passive Approaches	**Medium Impact.** OM&M of a passive approach primarily consists of an inspection to evaluate the integrity and function of the installed system. Contact your applicable state regulatory agencies to inquire about regulatory requirements for submission of OM&M documentation.
Remediation	**High Impact**. MPE and SVE systems require that OM&M be performed on a regular basis to ensure their effectiveness, operation, and compliance with permit requirements.
Rapid Response	**High Impact**. OM&M is critical to keep the rapid responses operating properly. HVAC systems must be maintained to ensure the proper supply/return airflow rates. Indoor air treatment units, specifically their filters, must be maintained and changed out periodically.

4 SUMMARY

Any mitigation strategy implementation should be carefully evaluated during and after installation to confirm that the design and permitting requirements, if any, were followed. It is important to conduct confirmation testing of mitigation measures to provide multiple verification criteria that the system is operating properly and is protective of human health and the environment.

5 REFERENCES AND ACRONYMS

The ITRC VI Mitigation Training web page includes lists of acronyms, a full glossary, and combined references for the fact sheets. The user is encouraged to visit the ITRC VI Mitigation Training web page to access each fact sheet and supplementary information and the most up-to-date source of information on this topic.