Operation, Maintenance, and Monitoring/Exit Strategy 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 process fact sheet describes the most common Operation, Maintenance, and Monitoring considerations for active mitigation systems, passive mitigation systems, rapid response, and environmental remedial technologies that need to be considered as part of any design process. In addition, a termination or exit strategy is discussed in this process fact sheet.

1 Introduction

After the mitigation strategy has been selected, designed, and commissioned, the operation, maintenance, and monitoring (OM&M) plan plays a key role in demonstrating the ongoing effectiveness of the vapor intrusion mitigation system (VIMS). This fact sheet describes the key considerations of OM&M. Complex mitigation strategies will typically require more complex OM&M procedures. The key to OM&M is to gather data to support maintaining the VIMS to operate as designed, with the goal that it remains effective in the short and long term until it is appropriate to implement an exit strategy.

Emerging technologies, such as aerobic vapor mitigation barriers (AVMB), are not addressed within this OM&M Process fact sheet. Please see the ***Aerobic Vapor Mitigation Barriers Technology Information Sheet*** for more information.

2 Operation, Maintenance, and Monitoring Plan

An OM&M plan provides instructions for VIMS operation and upkeep and should be prepared for each installed VIMS. Details of a typical OM&M plan can be found in Section 6.3 and Section J.5 of in the***2014 ITRC Petroleum Vapor Intrusion (PVI) document*** (ITRC, 2014). Information in these sections provides details for OM&M plan content that applies to the installed VIMS in general and is not specific to just PVI. The goals of OM&M are to verify performance of the VIMS during operation as compared to performance during system commissioning, and to inspect and repair any system malfunction (i.e., VIMS not operating to meet performance objectives or due to system equipment life expectancy). "In cases where testing shows the VIMS is not working and no defects in the system components have been identified, ITRC recommends re-evaluating the CSM to determine the presence or contribution of additional VOC sources." For example, volatile organic compound (VOC) transport via sewers or other preferential pathways may require further evaluation if this pathway had not been addressed previously.

The ***Operation, Monitoring, and Maintenance Checklist*** includes a list of considerations that may be reviewed, inspected, and/or measured during an OM&M site visit. A series of summary tables are included with the ***Operation, Monitoring, and Maintenance Checklist*** to record VIMS monitoring data (logs). Considerations during OM&M inspections may range from OM&M of both active and passive components to environmental remedial technologies that act as VI mitigation activities.

Table 2-1 identifies key OM&M considerations (discussed below in greater detail) and identifies their typical importance for OM&M for different approaches to address VI, including active systems (see ***Active Mitigation Fact Sheet***), passive systems (see ***Passive Mitigation Fact Sheet***), and environmental remediation technology (see ***Remediation and Institutional Controls as Vapor Intrusion Mitigation Fact Sheet***). Depending on the situation, rapid response actions may or may not have an OM&M component. A rapid response action is typically temporary in nature and may be promptly replaced by a permanent VIMS.

Table 2-1 Summary of OM&M/exit strategy considerations and impact on mitigation approach.

OM&M consideration	**Active approaches**	**Passive approaches**	**Remediation**	**Rapid response**
Mitigation system operation				

Purpose of installation of VIMS	●	●	●	●
Brief description of VIMS	◐	◐	●	◐
Monitoring frequency & maintenance schedule	◐	◐	●	◐
VIMS start-up and shutdown				
Start-up procedure	●	◒	●	◐
Shutdown procedure	◐	◒	◐	◒
Building condition and use				
Heating ventilation and air conditioning (HVAC) system	◒	◐	◒	●
Windows, air intake, and building exhaust	●	◐	●	◒
Change in use	●	●	◒	◒
Physical modifications to building	●	●	◐	◒
Inspection of building’s lowest floor	◒	◐	◒	◐
System inspection and performance metrics				
Visual inspection of system components	◐	◐	◐	◐
Identification and collection of performance measurements	●	◐	●	◐
Telemetry	◐	◒	◐	◒
Assessment of performance metrics	●	●	●	◐
Verification of compliance with permits	◒	◒	●	◒
Audible and visible alarms and labeling	◐	◒	◐	◒
System details and expected system operational life	◒	◒	◒	◐
Communication & reporting				

Building owner/tenant engagement	◐	●	●	●
Community engagement	◒	◒	●	●
Regulatory reporting	◒	●	●	◐
Exit strategy				
Exit strategy	◐	●	●	◒
Key | High impact ● | Medium impact ◐ | Low impact ◒ | Not applicable — |				

2.1 Mitigation System Operation

The considerations under the heading of Mitigation System Operations are elements of an OM&M plan and are included here to be consistent with the ***Operation, Maintenance, and Monitoring Checklist***. The OM&M plan is normally developed as part of the design phase.

Purpose of Installation of VIMS: A mitigation strategy is developed from an understanding of the conceptual site model (CSM). The strategy should be focused on interrupting the VI pathway(s) to mitigate VOC vapor migration from subsurface sources to receptors. Please see Figure 2-1 (Flow Chart) in the ***Conceptual Site Models for Vapor Intrusion Mitigation Fact Sheet***.

A mitigation strategy may include:

- Rapid response
- Active systems
- Passive systems and/or
- Environmental remedial technologies

An approach may include one of the above strategies or a combination of multiple strategies. The purpose of the VIMS should be clearly understood and summarized as part of the OM&M plan so that it is documented for future reference. Because of the potential long-term nature of VIMS operation, this summary will help stakeholders continue to understand the context of the VIMS and facilitate review of system performance over time.

Active Mitigation	**High Impact:** It is important to understand and continue to evaluate the purpose and objectives of an operating active VIMS, especially in terms of the occupation and use of the building in which it is installed. Understanding and periodically re-evaluating this purpose will facilitate the management of the VIMS and the decision points needed to progress to an exit strategy if appropriate.
Passive Mitigation	**High Impact:** The purpose and objectives of the VIMS and its role in protecting human life are essential to understanding the OM&M process, especially for passive mitigation where there are no mechanical components.
Environmental Remedial Technology	**High Impact:** Soil vapor extraction (SVE)/multiphase extraction (MPE) systems generally are implemented to remediate the site, with VI mitigation being an additional benefit. Therefore, the purpose of the system and its relationship to the VI mitigation need to be clearly established.
Rapid Response	**High Impact:** A rapid response approach is an interim VI mitigation approach (on a timescale of days to weeks) that may be appropriate prior to implementing a long-term mitigation strategy. Approaches include administrative or engineering controls. Engineering controls may warrant an OM&M component.

Description of VIMS: OM&M plans should include a brief description of the type of VIMS that has been installed (e.g., sub-slab depressurization, passive barrier, etc.), as well as a summary of key components, plans, and as-built drawings. Operational and inspection details will vary depending on the type of VIMS installed. However, the OM&M plan should provide enough detail to answer these questions:

- What should the VIMS look like when it's working?
- How can I tell if it may not be working properly?

Active Mitigation	**Medium Impact:** The description of the VIMS in the OM&M plan is a starting point for the other OM&M activities detailed in the plan and is useful to set the context of the operating system. This information should also be captured in a postconstruction completion report or as-built report that may also be referenced in the OM&M plan.
Passive Mitigation	**Medium Impact:** Understanding the components and purpose of the VIMS is part of the OM&M plan and is essential to a proper inspection.
Environmental Remedial Technology	**High Impact:** Providing the documentation of the design and completion of an SVE/MPE system is an important element in conducting the system OM&M. This documentation should also be referenced in the OM&M plan.
Rapid Response	**Medium Impact:** Certain rapid response approaches that include engineering controls, such as HVAC modification or indoor air treatment, warrant an OM&M component to verify that the response meets or continues to meet the interim VI mitigation objectives. OM&M documentation should address mitigation components that need inspection or change-out (e.g., carbon media for air purifying units [APUs]) and, as needed, how performance monitoring will be conducted.

Monitoring Frequency and Maintenance Schedule: Following successful system start-up, a routine inspection and maintenance schedule is typically followed. Inspection frequency may be recommended in state guidance. Typically, system inspections are more frequent during the first year of operation (e.g., quarterly) and then are reduced for subsequent years (e.g., semi-annual for second year of operation and then annually thereafter). It may be useful to consider the average lifetime of the system components when determining monitoring frequency (more frequent monitoring based on the age and potential failure of the components). If an alarm or telemetry system is installed, this may reduce and/or replace the number of in-person inspections necessary, depending on the type of telemetry and controls that are installed. A system monitoring schedule is usually detailed in the OM&M plan and may include provisions to update (e.g., reduce) the monitoring frequency based on data collected over time and provisions to complete unscheduled inspections if outside factors influence system operation (e.g., floods, earthquakes, building modification) (ASTM E1745). Should such an event result in detrimental impacts to the VIMS, shutdown of the VIMS to make repairs followed by restarting the VIMS and resumption of the initial monitoring program may be necessary.

Active Mitigation	**Medium Impact:** Monitoring frequencies are important to establish in the OM&M plan so that stakeholders (e.g., regulators, responsible parties, property owners) can agree on timing and access. It should be noted though that because VIMS may operate for a long time, the monitoring frequency may change and be reduced from the schedule set in the original OM&M plan. This should be documented in OM&M plan updates or addendums as appropriate. Maintenance schedules for active VIMS are primarily driven by system components that have manufacturer maintenance requirements and should be documented in the OM&M plan.
Passive Mitigation	**Medium Impact:** Monitoring frequency and maintenance schedule are parameters that are normally contained in the OM&M plan and developed during the design phase. Maintenance is less important to passive VIMS than active or environmental remediation technologies that typically involve mechanical devices that need occasional repairs.

Environmental Remedial Technology	**High Impact:** SVE/MPE systems typically include treatment and discharge of the extracted streams. They require that OM&M be performed on a regular basis both to ensure effectiveness and to satisfy the discharge permit requirements.
Rapid Response	**Medium Impact:** Monitoring frequency is dependent on the nature and time frame of the interim mitigation and specific requirements of the mitigation components (e.g., HVAC inspection, APU carbon change-out, routine inspection if floor cracks or other pathways were sealed, etc.).

2.2 VIMS Start-up and Shutdown

Routine maintenance or unscheduled maintenance, such as a malfunction or other problem with the VIMS, may require that a VIMS be temporarily shut down to make repairs and then restarted. This discussion does not involve the normal start-up during the initial commissioning of the VIMS.

Start-up Procedure: Prior to start-up of the VIMS, it is important to inspect building conditions, the baseline condition of the VIMS, applicable permits, and some of the key baseline data. Understanding these elements will help the VIMS to meet its design objectives.

Building conditions, such as electrical connections, cracks and holes in the building floor, integrity of the exhaust stack, and the presence/absence of water seepage on the lowest floor of the building, should be visually inspected and recorded. The integrity of the VIMS components (e.g., piping, valves, blowers, etc.) should be visually inspected and documented. If system malfunction was the reason for the shutdown, the identified malfunction and the replacement and/or repair should be recorded. If sub-slab depressurization (SSD) technology is proposed, some of the key baseline data such as vacuum/pressure differential; airflow rate; and sub-slab indoor air and outdoor ambient air parameters might need to be collected and recorded following system restart. An inspection log that lists key inspection items may include inspector, start-up date, items inspected, state of installed VIMS before operation, parts replaced, parts repaired, expected lifetime of VIMS, and manufacturer's specifications. Building occupants and other stakeholders should be notified of a system shutdown (discussed below), the subsequent start-up, and confirmation that applicable performance criteria are being met.

Active Mitigation	**High Impact:** Following system maintenance or malfunction, an active VIMS will need to be restarted and parameters collected to document that the VIMS is still meeting its design objectives. Depending on the complexity of the VIMS, this may range from returning power to the VIMS and documenting airflow rate and vacuum to more involved start-up procedures that involve multiple system documentation parameters. The OM&M plan should document the start-up process specific to the installed VIMS. The start-up procedure may also need to consider the timing of a system restart, depending on the potential risk to receptors (i.e., faster response and restart if potential for immediate impact).
Passive Mitigation	**Low Impact:** Discussions of system start-up and shutdown are normally associated with mechanical devices (of which passive VIMS have none).
Environmental Remedial Technology	**High Impact:** SVE/MPE systems are relatively complex, as they include both the mechanical elements and treatment of the extracted streams. Therefore, the system start-up should be used to verify the effectiveness and compliance with the discharge permits, as well as to make the necessary adjustments.
Rapid Response	**Medium Impact:** Start-up procedures are dependent on the type of interim mitigation that is implemented. For instance, if HVAC adjustments are implemented, there should be some initial period to verify that these adjustments are effective and did not have unintended side effects (see also discussion in Section 2.3).

Shutdown Procedure: The shutdown procedure described here is related to shutdown of a VIMS during otherwise continued operation of the VIMS. For permanent shutdown of a VIMS please review the Exit Strategy section below. Shutdown of a VIMS during the normal course of system operation would typically occur on a schedule due to needed maintenance or due to property owner needs for maintenance on other parts of the building. Building occupants and other stakeholders should be notified of the planned VIMS shutdown as appropriate. Prior to a scheduled system shutdown, it may be appropriate to collect and record system parameters to understand and evaluate pre-shutdown conditions to compare to measurements collected following system restart. Shutdown of a VIMS may involve turning off the power to the VIMS and lock out/tag out of the power source, if appropriate. It may also be appropriate to close off suction points or vents to the subsurface, depending on the system design and the length of time the VIMS will be off. If the VIMS shuts down on its own due to a system malfunction or power failure, it may still be appropriate to complete portions of the shutdown procedure if the VIMS will need to remain off for a period of time.

Documentation of the reason for system shutdown, the parameters collected, and the activities completed as part of the shutdown procedure should be documented in an inspection or OM&M log.

Active Mitigation	**Medium Impact:** Shutdown procedures should be followed to document that an active VIMS is shut off safely. Formal procedures may not be necessary if a VIMS is turned off for a short period of time. The nature and complexity of the VIMS as well as the original purpose of the VIMS will determine the details of shutdown procedures and the duration of a shutdown that would warrant execution of the procedures.
Passive Mitigation	**Low Impact:** Discussions of system start-up and shutdown are normally associated with mechanical devises (of which passive VIMS have none).
Environmental Remedial Technology	**Medium Impact:** Shutdown procedures should be specified in the OM&M plan and should be followed to document that an SVE/MPE system is shut off safely.
Rapid Response	**Low Impact:** Shutdown procedures and the associated level of detail are dependent on the type of interim mitigation that is implemented. For instance, an APU may be temporarily turned off for cleaning or carbon change-out; however, the APU operator manual may be sufficient documentation for this effort.

2.3 Building Condition and Use

VIMS design should be based on the building conditions and performance goals for the current or anticipated use of the building. Changes in the building conditions may compromise the effectiveness of the VIMS. A change in building use may be incompatible with the performance goals of the VIMS. Thus, the OM&M plan should include evaluation of changes in building conditions and use specific to the VIMS design**.**

HVAC System: Modifications to the building HVAC system should be evaluated to document that the modifications have not had a negative impact on VIMS effectiveness. One type of mitigation strategy used in commercial buildings functions 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, as indicated in the ***HVAC Modification Technology Information Sheet***. Such VIMS require regular air balancing and maintenance to ensure continued effectiveness throughout the building as well as over time. For VIMS where HVAC is used as the mitigation strategy, modifications to HVAC systems without consideration of its dual purpose as a VIMS may reduce the effectiveness of the VIMS. Institutional controls (ICs) may be in place to govern changes in the building's HVAC system, depending on how integral operation of the system is to VIMS effectiveness.

Active Mitigation	**Low Impact:** Operation of the HVAC system should be taken into account during active system design such that the VIMS will meet design objectives under the normal operating range of the HVAC system. Major updates or changes in the HVAC system (e.g., adding a restaurant with a large kitchen hood to a building) will need to be evaluated as they may have an effect on VIMS operation, but most minor seasonal adjustments in HVAC or buildings with little to no formal HVAC (i.e., residential homes) will not affect VIMS operation.
Passive Mitigation	**Medium Impact:** Depending on the role of the HVAC system for the passive mitigation operation, changes to the HVAC may have low to high impact on the effectiveness of the passive VIMS. See the ***Building Design for Passive Vapor Intrusion Mitigation Technology Information Sheet***.

Environmental Remedial Technology	**Low Impact:** SVE/MPE systems are typically little affected by the operation of the building HVAC system. However, for industrial/commercial facilities, an assessment of the influence of the HVAC operation may need to be conducted.
Rapid Response	**High Impact:** See above for specific considerations related to HVAC adjustments. Potential interaction between other interim mitigation approaches (e.g., APUs, ad hoc ventilation) and the HVAC system should also be considered.

Building Ventilation: Buildings should be evaluated for any modifications that change the separation distance between VIMS vent stacks and building entryways (doors, windows). Appropriate separation distances should be maintained to avoid re-entrainment of VOC vapors from the effluent to indoor air. See Section J.3.3 of ***Appendix J in the 2014 ITRC PVI document*** and ANSI/AARST: SGM-SF-2017 (AARST, 2017); RMS-MF-2018 (AARST, 2018a); RMS-LB-2018 (AARST, 2018b); CC-1000-2018 (AARST, 2018c). ICs may be in place to govern changes in the building and the necessity to maintain certain distances from existing VIMS equipment.

Active Mitigation	**High Impact:** Re-entrainment of vented soil gas is an important consideration to check if building modifications are planned or observed during a site visit. The appropriate location of an active system's vent stack compared to existing windows, air intakes, and building exhausts will be verified during system design and installation. Although it may be infrequent that a building will go through a major renovation that would add these components to the building structure, it is important that these items are inspected if building modifications are noted.
Passive Mitigation	**Medium Impact:** Re-entrainment of vented soil gas is an important consideration to check if building modifications are planned or observed during a site inspection.
Environmental Remedial Technology	**High Impact:** Location of an SVE/MPE system's vent stack should be selected away from the windows, doors, and other openings that may cause entrainment of the exhaust into buildings, in accordance with applicable regulations. The OM&M of the system should include periodic assessments of the compliance with this requirement, especially if the building has undergone modifications.
Rapid Response	**Low Impact:** Generally not applicable. However, any modification to an HVAC system should be designed such that HVAC air intakes are not located near an exhaust vent or stack.

Change in Use: A change in the building use that results in greater exposures may result in the VIMS being no longer sufficiently protective for the new use. For example, a VIMS designed to be protective for a commercial use may not provide acceptable VI mitigation for a change to a residential use or to a school or day-care center. Similarly, a change in the type of commercial use—for example, where a dry-cleaning operation has been replaced by another type of commercial use—may warrant re-evaluation of the effectiveness of the VIMS. ICs may be in place to govern such changes in use and should be consulted as a source of information on whether a change in the building use is acceptable. Whenever a change in use is observed, the VIMS design and mitigation goals along with air monitoring results should be reviewed to evaluate whether the change in use is acceptable.

Active Mitigation	**High Impact:** In addition to the details noted above an active VIMS may be designed to operate under only a portion of a building based on current use in specific areas of a building (e.g., no VIMS in parts of the building that are unoccupied or used only for storage). Building use changes will be important, as the VIMS may need to be expanded to cover new areas of the building previously not mitigated.
Passive Mitigation	**High Impact:** Any change in use at a building can be a significant factor that impacts the design objectives of the passive VIMS (e.g., changing a building use from a dry cleaner to a day care).

Environmental Remedial Technology	**Low Impact:** The SVE/MPE systems are typically operated for relatively short time frames; therefore, major changes in building use during system operation are not common. However, should they occur, system modifications may be required.
Rapid Response	**Low Impact:** Building use would generally not be expected to change within the relatively short-term time frame of interim VI mitigation. Otherwise, the response would need re-evaluation.

Physical Modifications to Building: Some modifications in the building structure may affect the VIMS, including physical modifications to the building or to the surrounding property.

- Building additions, partial demolition, or significant building renovations may affect VIMS effectiveness. Typically, any building additions should be subject to the same requirements for VI evaluation and possible mitigation as the original building.
- Significant interior renovations, including division of spaces that had been open, may also affect the VIMS. A VIMS designed based on building pressurization or air exchange rates may be especially vulnerable to reconfiguration of the interior of the building.
- A rise in the water table such that the water table encroaches on the building slab will reduce the effectiveness of some passive VIMS, as well as SSD and sub-slab ventilation (SSV) systems. Indications of water level concerns with the VIMS include moisture on the lowest floor of a building. For sites with a dewatering system, failure of the dewatering system may be the source of the problem.
- Structural or foundation problems in the building should trigger an evaluation of impacts to a passive barrier that may have been installed above or beneath the building slab.
- Changes in surrounding property conditions may affect concentration and migration of contaminants in soil gas beneath the building and the effectiveness of the VIMS. Such changes may include new construction or paved areas in close vicinity to the building, storm water management changes, and excavation or filling activities.
- Major improvements in building insulation may reduce air exchange and result in greater accumulation of indoor air contaminants than anticipated in the original VIMS design.
- Remodeling to add new carpet, cabinetry, or other furnishings inside the building may introduce indoor sources of contaminants that could affect indoor air monitoring results. This does not affect the operation of the VIMS but may confound the analysis of data collected to evaluate VIMS effectiveness. This can be a critical point for passive VIMS where indoor air sampling is a primary performance measurement. Documentation of potential background sources of VOCs related to remodeling or other changes should be recorded in a log for later evaluation of indoor air results.

Active Mitigation	**High Impact:** Modifications to the building will have a significant effect on VIMS operation, depending on the type and level of the building modification and the specific design of the VIMS installed. Generally, physical building modifications in commercial or industrial buildings where the VIMS may have been designed to affect a portion of the building will be of greater impact than physical modifications at a residential property.
Passive Mitigation	**High Impact:** Modifications to the building or inclusion of new furnishings (carpeting, furniture, window treatments) can significantly impact the effectiveness of a passive VIMS or the performance measurements (e.g., indoor air sampling).
Environmental Remedial Technology	**Medium Impact:** The SVE/MPE systems are typically operated for relatively short time frames; therefore, major building modifications during system operation are not common. However, should they occur, system modifications may be required.
Rapid Response	**Low Impact:** Physical modifications to the building would generally not be expected to occur within the relatively short-term time frame of interim VI mitigation. Otherwise, the response would need re-evaluation.

Inspection of Building's Lowest Floor: Inspection of the lowest floor of a building is often an important component of OM&M, especially where a passive barrier has been installed either above the slab (epoxy coating) or below the slab (asphaltic membrane, etc.) (see ***Passive Mitigation Fact Sheet***). Close inspection of the bottom floor of a building can provide information on the condition of the passive barrier and any preferential pathways for VI. Floors with epoxy coatings should be examined for cracks or peeling. All utility penetrations should be inspected for cracks, gaps, or seal failures. Additionally, installation of any new utilities or other floor penetrations should be noted and inspected for proper sealing.

The presence of moisture and/or effervescence on the lowest floor of a building may be an indication of a problem with a passive barrier or groundwater near the building slab. Some VIMS require airflow below the building (for both passive and active VIMS), so the presence of shallow groundwater may require a dewatering system or other measures to control groundwater table elevation. OM&M should include evaluation to confirm that the control measures being implemented are working properly.

Active Mitigation	**Low Impact:** As noted above, inspection of the lowest building level for water should be considered during site visits. These conditions will usually be understood and accounted for during the design and installation processes and are therefore of lower impact as compared to the other considerations described in this fact sheet.
Passive Mitigation	**Medium Impact:** The presence of water or new cracks in the floor/wall can negatively impact sub-slab airflow in passive mitigation.
Environmental Remedial Technology	**Low Impact:** Condition of the floor slab as well as the groundwater table elevation are typically accounted for during the selection and design of the SVE or MPE system. Therefore, their impact on the system OM&M should be low.
Rapid Response	**Medium Impact:** Inspection of a building lower floor slab is dependent on the nature and time frame of the interim mitigation. For instance, if preferential pathway sealing was conducted on the lower floor as part of the rapid response approach, then follow-up routine inspections may be needed to verify that there is no evidence of damage to the seals or repairs.

2.4 System Inspection and Performance Metrics

Inspection and performance metrics to be detailed in an OM&M plan and reviewed during site visits may include the following:

Visual Inspection of System Components: Conduct a visual inspection of accessible system piping and pipe seals, including membrane seals (if applicable), connections, etc. Identify significant cracks/gaps or changes in the system configuration.

Active Mitigation	**Medium Impact:** This consideration is a typical component of active VIMS site inspection visits. Visual inspection of system components, specifically vent piping, is particularly important in commercial and industrial buildings where building use (e.g., forklift use) may cause the components to be bumped or hit on a continual basis.
Passive Mitigation	**Medium Impact:** A visual inspection of the system components is a standard inspection step irrespective of the type of VIMS. Without mechanical devices or externally mounted vertical piping, passive VIMS tend to have fewer visual components compared to other VIMS.
Environmental Remedial Technology	**Medium Impact:** Visual inspection of the system components for typical wear and tear or damage caused by the use of the building should be part of the system OM&M.
Rapid Response	**Medium Impact:** Depending on time frame of interim mitigation, routine visual inspection is needed to verify that rapid response engineering controls continue to operate as intended.

Identification and Collection of Performance Measurements: OM&M performance measurements should be selected during the design phase based on the specific mitigation strategy used and what information is needed to determine whether the strategy is operating as intended or the VIMS is operating as designed. For passive VIMS that consist of physical barriers, there may be limited performance metrics to be collected and monitored during OM&M site visits other than visual inspections already discussed or the collection of air samples. However, passive technologies that include VIMS that provide for some sub-slab air movement (e.g., aerated floors in new construction or passive venting) may consider some of the criteria detailed below as appropriate. For environmental remedial technologies, the performance measurements will be focused on the OM&M parameters appropriate for the chosen remedial technology. For rapid response technologies, performance measurements may include air sampling (detailed below) and manufacturer recommended parameters detailed by the equipment used during the rapid response action. For active VIMS, there are multiple different performance criteria, the most common of which are detailed below. These parameters are typically collected after initial start-up and commissioning during post-installation verification to determine if a VIMS meets its design basis and to establish baseline values. See the ***Post-Installation Fact Sheet*** for a more detailed discussion of the various performance measurements.

- System vacuum and airflow — System vacuum and airflow readings collected over time can be used to verify that system operation is meeting the design specifications. Flow velocity measurements are usually taken using a critical orifice, thermal anemometer (i.e., hot wire anemometer), vane anemometer, pitot tube, or similar devices. Vacuum can be measured with a U-tube manometer, differential pressure gauge, or digital manometer.
- Differential pressure measurements/pressure field extension (PFE) — Some active VIMS (such as SSD systems, SMD systems, and to some extent SSV systems) work by creating a negative pressure differential between the indoor air and the air beneath the building slab. Differential pressure measurements are used to confirm PFE across the mitigated area. Some telemetry systems may also be used to measure and remotely monitor differential pressures. Telemetry systems, discussed below, can be used to provide confidence in operating systems that are achieving lower levels of vacuum influence relative to baseline fluctuations or seasonal drift even if these values are lower than the applicable state's generic guidelines.
- Sub-slab flow velocity — For SSV and crawlspace ventilation (CSV) systems, flow velocity is a useful performance criterion. Flow velocity indicates that vapors are moving within the subsurface or within the crawlspace and allowing for the dilution and reductions in concentrations to be protective of indoor air.
- Sub-slab, indoor air, outdoor ambient air sampling — Collection of soil vapor and/or indoor/outdoor air samples during OM&M site visits may be another line of evidence to document continued VIMS success. With passive VIMS, analytical sampling will likely be more common to assess the effectiveness of the VIMS (compared to active VIMS).
- Photoionization detector (PID) readings — For SSV, and for some SSD, SMD, and passive VIMS, it may be useful to demonstrate that the subsurface ventilation provided by the VIMS is reducing soil gas concentrations to be protective of indoor air cleanup levels. PID measurements may be collected at sampling points in the slab or from the vent system piping. Although PIDs provide readings of total VOCs and not compound-specific concentrations, measurements of total VOC concentrations over time may be a useful indicator of the consistency of system operations over time and whether/when to collect samples for more detailed analysis.
- Mass loading rate — Mass loading rates (calculated using system flow rate readings and VOC concentrations measured in the system's vent stack) can be calculated at some frequency through the life span of the VIMS even if not completed during each routine OM&M site visit.
- Smoke and tracer gas testing — Smoke and tracer gas testing is an option to be used to test airflow patterns.
- Other parameters — VIMS designed for mitigation of PVI may also be monitored for oxygen, carbon dioxide, and methane. The consideration for monitoring of methane or for other explosive gases is important if the VIMS was not designed to address the presence of explosive gases. Additional monitoring parameters may also be specified by the system component manufacturer. For active VIMS, it may also be useful to monitor energy usage to document increased power consumption (and increased energy bills) due to an operating active VIMS.

Active Mitigation	**High Impact:** The parameters detailed in this section are important to document that an active VIMS continues to meet its design objectives. Depending on the building type and the specific active mitigation strategy chosen, one or more of the performance measurements listed above should be considered for collection.
Passive Mitigation	**Medium Impact:** While the importance of collecting performance measurements is significant to the evaluation of the system performance, most of the measurement options are limited for passive VIMS.

Environmental Remedial Technology	**High Impact:** Performance metrics are key in assessing the effectiveness of the SVE/MPE system in providing effective VI mitigation and in evaluating the progress of the remediation.
Rapid Response	**Medium Impact:** The collection of performance measurements should be considered to verify that a rapid response engineering control is performing as intended; the need for and type of measurements will depend on the type of interim mitigation approach, severity of conditions (e.g., elevated contaminant concentrations), and sensitivity of the building of interest (e.g., school, day care).

Telemetry: Telemetry is the remote source transmission of data from a measuring instrument to a recording device typically via telephone lines or other wireless equipment. Telemetry may be useful for passive mitigation for those strategies that include air movement (e.g., aerated floors or passive venting), for rapid response technologies (such as air filtration units or HVAC modifications), and for environmental remedial technologies and active mitigation. Telemetric monitoring can include basic systems that send alerts related to overall operation status (i.e., “on” or “off”) to more involved systems that allow for controlling the system operation remotely. For active mitigation, telemetry can be advantageous because VIMS performance metrics are variable and subject to weather and building pressure events that may affect the data collected at the time of the OM&M visit. If telemetry is used to monitor more detailed parameters (e.g., active mitigation parameters such as differential pressure and/or system flow and vacuum), then frequency of on-site visits may be able to be reduced or they may be unnecessary unless manual system modifications or repairs are needed. This is particularly advantageous from VIMS that may be located in remote areas or where access is challenging.

There are three distinct categories of telemetry for VIMS. They are direct fault monitoring, continuous performance monitoring, and continuous monitoring with active system management. All three technologies are designed to notify managing parties of a fault in system operation. The types of telemetry and their advantages and limitations are summarized in Table 2-2.

Table 2-2. Advantages and limitations of various categories of telemetry.

Telemetry type	**Description**	**Advantages**	**Limitations**
Direct fault monitoring	Direct fault monitoring most commonly monitors the vacuum generated by the blower by using a mechanical vacuum switch or other means of closing a circuit. Once closed, the circuit actuates a callout fault notification to the managing party. The calls can be placed using the building’s landline phone system or an independent cellular network.	• Rapid fault notification • Lower hardware and installation cost • Good for sites with a limited number of blowers • Messaging can be preprogramed by circuit to indicate the type of fault • Can use the building owner’s landline phone system or prepaid wireless phone • Battery backup can notify a manager of a power failure • A visual light and/or audio alarm indicator may be integrated	• Single direction notification • Contact messaging is generally limited to a phone call • No system performance data recording, transmission, storage, or analysis • May rely on building occupants’ landline phone service or upkeep of annual cellular fees • Equipment may require technology upgrades

Continuous performance monitoring	Continuously monitors selected system metrics; can monitor open loop or closed loop circuitry and provide electronic notification when the system has failed or if selected metrics are performing outside of a predetermined range. The functions can vary from providing electronic notification of loss of vacuum as indicated by actuating a mechanical switch to sending a message or continuous monitoring and transmitting performance data, which may be retrieved from a stored data set.	• Rapid fault notification • Lower hardware and installation cost than continuous monitoring with active system management • Good for sites with a limited number of blowers • Event messaging can be email or text • Event notification can include multiple parties • Multiple alarm thresholds can be programed for a single sensor event • Can use the building owner’s Wi-Fi or independent wireless network • Site data can be time paired with local weather data • Issuance of automated monthly or as needed reports • Offsite encrypted cloud-based data storage • Battery backup can notify a manager of a power failure • A visual light and/or audio alarm indicator may be integrated	• The hardware and sensor equipment cost more than for direct fault monitoring • May rely on building occupants’ Wi-Fi service or may require a third party to provide internet service to the site to operate the equipment • May require an annual data transmission and storage contract • Cellular modems will require sufficient signal strength and bandwidth • Installation generally requires a trained technician • An annual on-site inspection will be required to verify sensor and transmission equipment performance • Equipment may require technology upgrades

Continuous monitoring with active system management	Continuously monitors multiple system metrics through closed loop circuitry; provides electronic notification when the system has failed or if selected metrics are performing outside of a predetermined range. The consultant can remotely access response-driven controls and change performance metrics such as applied vacuum, airflow, and pressure differential set points to achieve new thresholds of performance. Performance data may be accessed live or retrieved from stored data sets for analysis.	• Rapid fault notification • Good for sites with multiple blowers • Event messaging can be email or text • Event notification can include multiple parties • Multiple alarm thresholds can be programed for a single sensor event • Can be operated using owner's Wi-Fi or independent wireless network • Some on-site control panels are equipped with touch screens to display performance metrics in real time • Site data can be time paired with local weather data • Issuance of automated monthly or as needed reports • Automated response driven system performance metrics can be viewed in real time through a web portal • Performance set points such as sub-slab pressure differentials, applied vacuum, and airflow as well as gate valve positions can be preprogrammed and changed remotely through a web portal • May be possible to use energy savings calculators to track the benefits of response-driven controls • Data storage and access to historical data • Remotely operated controls limit technician foot traffic though secure or hard-to-access areas • Battery backup can notify a manager of a power failure • A visual light and/or audio alarm indicator may be integrated	• The hardware and sensor equipment cost more than direct fault monitoring and continuous performance monitoring • May rely on building occupants' Wi-Fi service or may require a third party to provide internet service to the site to operate the equipment • May require an annual data transmission and storage contract • Cellular modems will require sufficient signal strength and bandwidth • Installation will require a trained technician (may need licensing by the equipment manufacturer) • An annual on-site inspection may be required to verify sensor and transmission equipment performance Equipment may require technology upgrades

Active Mitigation	**Medium Impact:** A telemetry system is not needed or warranted in every active VIMS, but even simple telemetry in a single residential house can provide real-time access to understand if a VIMS is on or off. Depending on the telemetry used, it can provide value-added system effectiveness by allowing for remote monitoring and in some cases remote control over system operations. In buildings where the VIMS is difficult to access or for systems located a significant distance from the responsible party, telemetry has an important role in VIMS operation and performance.
Passive Mitigation	**Low Impact:** Telemetry has limited application to passive VIMS compared to active mitigation.
Environmental Remedial Technology	**Medium Impact:** A telemetry system is useful in providing real-time data on the system operation and in identifying the need to perform OM&M activities. However, the relative complexity of the SVE/MPE system, including the need for sampling, requires that in-person OM&M also be performed.
Rapid Response	**Low Impact:** Generally not applicable (except for sophisticated HVAC systems).

Assessment of Performance Metrics: As part of OM&M, performance measurements are collected during periodic inspections to assist with the assessment of VIMS performance. Is the VI mitigation strategy operating as intended and designed? The selection of the appropriate performance measurement is typically determined during design, as indicated in the ***Design Considerations Fact Sheet***. The performance measurements are determined in part based on the type of VIMS that is implemented—active mitigation, passive mitigation, or environmental remedial technology. Performance measurements have limited application to rapid response due to the nature of the short-term action (usually replaced or augmented by a more permanent VIMS). Baseline values for these performance measurements are established during system commissioning when the VIMS is initiated. See ***Post-Installation Fact Sheet***.

Evaluation of periodic results from performance measurements is needed to ascertain if the data are consistent with the baseline values over time. It is reasonable to assume that variations in the baseline values or data trends may occur. Some state agencies may establish what variation is acceptable prior to conducting a re-evaluation of the VIMS. For the New Jersey Department of Environmental Protection (NJDEP, 2018), anything above a 20% variation triggers supplemental actions to assess the effectiveness of the VIMS at meeting the original design goals.

Active Mitigation	**High Impact:** Comparison of the performance measurements to the baseline values is a key line of evidence to document that the active VIMS is effective at meeting its design objectives. As subsurface conditions may vary over time, deviations of performance measurement from baseline values may occur. Depending on the amount of deviation, additional measurements may be needed to document that the VIMS is still effective. Updates to the baseline values or the range of acceptable performance metrics may be needed and documented in a revised OM&M plan or OM&M plan addendum.
Passive Mitigation	**High Impact:** Comparison of the performance measurements to the baseline values is the primary method to assess the effectiveness of the passive VIMS to meet its design objectives.
Environmental Remedial Technology	**High Impact:** Analysis of the performance measurements is a key line of evidence to document that the SVE/MPE system is effective at meeting its design objectives. As subsurface conditions may vary over time, deviations of performance measurement from baseline values may occur. Depending on the amount of deviation, additional measurements may be needed to document that the system is still effective. Updates to the baseline values or the range of acceptable performance metrics may be needed and documented in a revised OM&M plan or OM&M plan addendum.

Rapid Response	**Medium Impact:** Performance metrics evaluation efforts in a rapid response setting depend on the type of interim mitigation approach, severity of conditions (e.g., elevated contaminant concentrations), and sensitivity of the building of interest (e.g., school, day care).

Verification of Compliance with Permits: There are two main types of operational permits for which compliance needs to be verified:

- emission permitting
- 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 VIMS must be considered for each project based on the system design, the CSM, 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 VIMS may be exempt from or do not require permits. More detail is provided in Appendix J.3.2.

Active Mitigation	**Low Impact:** Compliance with permits is typically set during or shortly after active system commissioning. Unless major modifications to the VIMS are planned, this consideration will have a lower impact on OM&M than other considerations detailed in this fact sheet.
Passive Mitigation	**Low Impact:** The likelihood of emission permits being an issue with passive VIMS is low.
Environmental Remedial Technology	**High Impact:** SVE/MPE systems typically include permits for discharge of the extracted streams after treatment. System OM&M should include frequent assessment of the compliance with the applicable discharge permits. The treatment system may need to be modified if the permit requirements are not met.
Rapid Response	**Low Impact:** Generally not applicable.

Audible/Visual Alarms and Labeling: Verify batteries are replaced in alarms (or power remains present to plugged-in alarms), U-tube manometers are visible, properly connected, and marked with operating set points, etc. Verify placards with information for contact person in the event of an alarm condition are visible, properly secured, and legible.

Active Mitigation	**Medium Impact:** These considerations are typical components of a site inspection visit for an active VIMS. Alarm verification is important to document, as this will likely be the way the responsible party is notified in the event that a VIMS stops working.
Passive Mitigation	**Low Impact:** Audible or visual alarms are not typically associated with passive VIMS. However, labels can be required, but are unlikely to represent a problem during OM&M inspections.
Environmental Remedial Technology	**Medium Impact:** These considerations are typical components of a site inspection visit for SVE/MPE systems. Alarm verification is important to document as this will likely be the way the responsible party is notified in the event that a system stops working.
Rapid Response	**Low Impact:** Generally not applicable (except for sophisticated HVAC systems). Consider labeling APU with contact information for repair and other operational issues.

System Details and Expected System Operational Life: An OM&M plan should include specifications for equipment used within the VIMS, system or equipment warranties, and system maintenance schedules, as well as installer contact information for future questions or maintenance. If the VIMS will be maintained by another entity following installation, then contact information for the person or company responsible for the VIMS should be recorded and updated in the OM&M plan as needed.

The OM&M plan should take into consideration the expected lifetime of that VIMS. If a site is undergoing other remedial activities to address the vapor source(s), the operational life necessary for the VIMS may be limited. This may exclude the need to consider the operational life of system components. In addition, the OM&M of a VIMS may also consider the exit strategy (see Exit Strategy below) for the VIMS and when system shutdown can be recommended or the VIMS turned over to other uses. In some cases, a pre-emptive VIMS may be installed out of an abundance of caution when it may not be known whether it is needed. If initial monitoring of this type of VIMS indicates that the mass removal rate is trivial even though the pressure field extension is adequate, then the operational life of the VIMS may be as short as a pilot-scale test.

Active Mitigation	**Low Impact:** It is important to consider the operational life of system components to help plan for repairs and replacements. However, system OM&M may be dictated by other considerations such as access restrictions, stakeholder engagement, or other remedial activities at the site. Thus this consideration may have a lower impact than others in this fact sheet.
Passive Mitigation	**Low Impact:** With passive VIMS, there are no mechanical devices that are the source of most discussions about system operational life.
Environmental Remedial Technology	**Low Impact:** SVE/MPE systems are typically operated for a limited time. Therefore, in most cases the major system elements do not require replacement and general system OM&M is sufficient.
Rapid Response	**Medium Impact:** The type of information to consider (e.g., equipment lifetime and need for replacement) is dependent on the type of interim mitigation and expected time frame. For instance, an APU may require carbon change-out to remain effective; however, change-out may not be needed if interim mitigation will cease before the carbon media is exhausted.

2.5 Communication and Reporting

Like discussions with property owners or tenants during the design and installation phase, OM&M of a VIMS typically requires continued contact with property owners or tenants. OM&M of a passive VIMS may require significantly less contact, but contact nonetheless. In some cases, long-term OM&M of a VIMS and required reporting may eventually transition from the responsible party to the property owner, tenants, or property manager. The OM&M plan (or plans) needs to be written for potentially multiple different audiences to allow for understanding by people with varying backgrounds, including the community as a whole.

Communication with the regulatory oversight agency during the OM&M phase is typically limited to required reporting. Reporting requirements, including frequency, will vary depending on the state and agency jurisdiction and should be detailed in the OM&M plan.

Building Owner/Tenant Engagement: Site visits for OM&M will require access to the property and likely access inside the building. Routine OM&M may include actions such as recording manometer readings; inspecting system components; or inspecting the building for new cracks, changes in use, construction, or HVAC modifications. Occasional follow-up actions may also eventually be necessary to repair, replace, or recommission a VIMS or individual system components. It may be appropriate to provide the building owner/tenant with a copy of the results from an OM&M inspection.

Contact information for the property owner and for property access should be included in the OM&M plan and be updated as appropriate (e.g., after a property transfer). Timing and frequency of visits should be discussed with the property owner prior to documentation in the OM&M plan. A copy of the OM&M plan as well as other relevant documents, such as component manuals, may be provided to the property owner even if they are not responsible for system operation. Depending on the property owner/tenant, electronic copies of the documents may be an alternative to hard copies.

Communication with the property owner on their expectation of the design, if any, early in the design process will help to avoid problems during installation and, most importantly, during the long-term OM&M. Incorporation of certain types of telemetry in the design may limit or reduce the need for frequent property visits.

If the intent is to eventually transition OM&M of a VIMS to the property owner, which may change over time, it is *critical* that adequate instruction (both visual and written) be prepared for the intended audience. For example, an active VIMS in a single-family residence may be designed, installed, commissioned, and OM&M performed by the responsible party for a given time (e.g., 2 years). A property owner is generally not accustomed to engineering diagrams or scientific nomenclature.

While complex diagrams and language in an OM&M plan may be appropriate for use by the responsible party's environmental consultant during the first years of operation, it is not appropriate for the end user—the property owner. In addition, if the property owner sells the home after a period of time (e.g., 5 years), the new property owner will need adequate instruction and documentation available to learn the purpose and requirements of the VIMS. The purpose of a VIMS is to protect the occupants of a structure from the potential for VI. Audience-specific instruction for OM&M is imperative for a successful VIMS.

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

Active Mitigation	**Medium Impact:** Long-term monitoring of active VIMS usually requires continued contact and communication with property owners and tenants. Early and frequent communication with these stakeholders is important so that proper operation of the VIMS is maintained.
Passive Mitigation	**High Impact:** Communication with a property owner or tenant is critical throughout the OM&M phase. Long-term monitoring, including inspections, takes the cooperation of the homeowner or tenant. Good communication ensures that collaboration.
Environmental Remedial Technology	**High Impact:** Implementation of the SVE/MPE, including OM&M activities, typically involves an extensive interaction with the property owners. Access agreements are required.
Rapid Response	**High Impact:** Contact and communication with property owners, tenants, and other stakeholders is critical during rapid response given the relatively fast-paced nature of the approach and potentially significant impact to building occupants.

Community Engagement: Community and other stakeholders should be engaged as early and often as possible. After installation of a VIMS, ongoing communication regarding OM&M of a specific system is typically limited to the property owner and tenants and may include reporting to the regulatory agency. See the Building Owner/Tenant Engagement section above. Otherwise, refer to the ***Public Outreach During Vapor Intrusion Mitigation Fact Sheet*** for additional information on conducting community engagement.

Active Mitigation	**Low Impact:** Typically, active VIMS do not involve tremendous community engagement unless they are installed on buildings frequented by the public or occupied by sensitive receptors such as children in schools and day care centers. In these cases, engagement with the community may be more important.
Passive Mitigation	**Low Impact:** Once a VIMS is installed in an individual building, communication is primarily directed at the individual property owner or tenant. Thus, the OM&M phase has limited community outreach.
Environmental Remedial Technology	**High Impact:** Implementation of SVE/MPE typically involves an extensive interaction with the stakeholders, including discussions about such issues as the effect of the system noise and treated stream discharge. System elements may need to be modified based on the stakeholders' feedback during operation.
Rapid Response	**High Impact:** Contact and communication with property owners, tenants, and other stakeholders is critical during rapid response given the relatively fast-paced nature of the approach and potentially significant impact to building occupants.

Regulatory Reporting: Documentation of mitigation design; installation, including commissioning; and long-term OM&M required by the environmental regulatory oversight agency will vary depending on the jurisdiction. Required reporting during OM&M of the VIMS will also vary. It is important to research the requirements specific to your state or agency prior to developing a mitigation strategy and include the required reporting in the OM&M plan.

Reporting may be more frequent (e.g., quarterly) during the first year of operation and then decrease in frequency thereafter. A telemetry system may also change/reduce the need or type of reporting since the telemetry system may inform the responsible party or the agency directly as to the status of the VIMS. The details of the type and frequency of reporting should be summarized in the OM&M plan, including plans to reduce frequency in the future. Distribution of any required reporting should also be detailed in the OM&M plan (e.g., responsible party, regulatory agency, property owner, building manager).

Some jurisdictions require specific reporting on a form or via a system designed by the regulatory agency. This should be detailed in the OM&M plan and updated as necessary (e.g., reference the most recent revision of an agency reporting form or update a reporting procedure).

The purpose of any reporting is to communicate details of the VIMS with the interested stakeholders and address their short- and long-term concerns. For example, while the primary stakeholder for construction and commissioning documentation may be the regulatory oversight agency in the short-term, reporting also serves as a reference document for persons responsible for OM&M in the long-term to assure the VIMS continues to operate as intended for long-term protectiveness. Similarly, documentation of routine inspections may be important in the short-term for the regulatory agency but also useful for the persons responsible for OM&M of a VIMS to identify changes in system effectiveness over time. In addition, a regulatory agency may perform inspections or audits of VIMS. For this and other purposes, it is important for all stakeholders to keep records of all reporting.

Active Mitigation	**Low Impact:** Reporting for documentation of active system operation may be required by a regulatory agency or may be requested by the responsible party to document consistent system operation. Reporting may range from simple documentation of OM&M logs to larger reports documenting system performance measurement data trends, air sampling results, and mass flux calculations.
Passive Mitigation	**High Impact:** As with active mitigation, reporting for documentation of passive mitigation system operation may be required by a regulatory agency or may be requested by the responsible party to document consistent system operation. Reporting may range from simple documentation of OM&M logs to larger reports.
Environmental Remedial Technology	**High Impact:** Reporting on the compliance with the discharge permits is typically required as part of the OM&M of SVE/MPE systems. Additionally, reporting on the progress of the site remediation is generally performed as part of the exit strategy toward the site closure.
Rapid Response	**Medium Impact:** The type and frequency of reporting are expected to depend on the type of interim mitigation approach, associated time frame, regulatory requirements, severity of condition, and building use (e.g., sensitive use).

3 Exit Strategy

Unlike radon, the source of VOC vapors can be remediated within the lifecycle of a VIMS in some cases, rendering the system unnecessary. Termination and implementation of an exit strategy for a vapor mitigation action occur when the objectives of cleanup activities have been met, or when VIMS that were presumptively installed are investigated and found no longer necessary.

When mitigating VI through subsurface source remediation, building mitigation, and ICs, it is important to develop termination criteria, including the rationale for their selection, early in the remedy planning (e.g., design phase) process. Termination criteria generally refer to numeric cleanup levels for each site-specific contaminant and narrative cleanup objectives that are to be attained by the response actions. The termination criteria are generally recorded in decision documents, design reports, and commissioning reports and should specify how it will be determined that the termination criteria have been attained (e.g., monitoring data and associated statistics that will be used to demonstrate attainment). Concurrence from the appropriate regulatory authority should be obtained for the termination criteria and for termination of remediation, VIMS, and ICs once those criteria are met.

Stakeholders should be provided with a clear and comprehensive set of termination criteria for the remediation, VIMS, and ICs. If site conditions (e.g., building usage, vapor flux) change during the cleanup activities, it may become necessary to modify the termination criteria and/or strategy. When reviewing VI activities, considerations for evaluating termination activities may include termination of:

- subsurface remediation activities
- engineered exposure controls (building mitigation)
- monitoring
- associated ICs

3.1 Termination of Subsurface Remediation Activities

Where feasible, the preferred response to address VI is to eliminate or substantially reduce the level of volatile chemical contamination in the source media (e.g., groundwater and subsurface soil) to levels that eliminate the need to mitigate or monitor VI. If subsurface remediation activities are being conducted at the site, termination of these activities will likely be contingent on demonstrating that the chemical-specific cleanup levels for the subsurface media have been attained.

Typically, monitoring will continue until the source(s) are remediated to cleanup levels that eliminate the need to mitigate VI at the point of exposure. As appropriate, the exit strategy may provide criteria for phased remediation, resulting in a termination evaluation as source cleanup levels are achieved in parts of the contaminated area. If the subsurface vapor source(s) is not remediated, it is generally anticipated that remediation (and monitoring and any building mitigation) will continue.

If evaluation of the site-specific data indicates an increase in subsurface vapor concentrations during the monitoring period, it may be appropriate to evaluate whether the subsurface remediation plan and the CSM are adequate and appropriately protective.

Once it is established that the subsurface VIMS may be terminated, a period of attainment monitoring is typically required. During the attainment period, the remediation system (e.g., reagent delivery equipment, SVE wells) will not be operated for a sufficient period to allow subsurface vapors to reach equilibrium and indicate post-remediation conditions. The types and frequency of data collected during attainment monitoring entail site-specific determination. In order to be able to effectively establish the equilibrium time necessary, a detailed understanding of the source of vapors is required as well as an estimated rate of vapor migration.

Most states and the U.S. Environmental Protection Agency (USEPA) recommend that criteria be described and documented, as part of exit strategy development, to determine when ending the attainment monitoring period is appropriate. To develop an exit termination strategy, site-specific fate and transport data may be used to identify an appropriate time period to allow the vapor concentrations to equilibrate. In addition, the termination of the attainment monitoring period may involve an evaluation of the contaminant attenuation in the vadose zone.

3.2 Termination of Building Mitigation

For purposes of this Process Fact Sheet, “termination of building mitigation” refers to ending the use of an engineered exposure control(s) that reduces or eliminates human exposure via the VI pathway. Typically, vapor mitigation is implemented when it is determined that:

- the potential exists for unacceptable human health risk to inhabitants or
- the VIMS was installed as part of an early action strategy

As described in ***An Introduction to Vapor Intrusion Mitigation Fact Sheets*****,** a vapor mitigation strategy can be implemented using active, passive, or environmental remediation technology (or a combination thereof).

Active Building Mitigation: Generally, building VIMS are implemented in conjunction with the investigation and remediation of a subsurface vapor source(s). Typically, building VIMS will be operated until the source(s) is remediated to attain the cleanup levels [e.g., for the subsurface vapor source(s)] that eliminate the need to mitigate VI at the point of exposure. If subsurface vapor source(s) are not remediated, it is generally anticipated that mitigation activities will continue indefinitely. As appropriate, the termination strategy may provide criteria for phased evaluation of system cessation as source cleanup levels are achieved in parts of the contaminated area.

Once the subsurface vapor source(s) is remediated to levels that meet the remedial objectives and protect human health from the VI pathway, it is recommended that the site-specific monitoring data be evaluated to determine if the termination criteria for the building VIMS have been met. These monitoring data, in part, could be based on data similar to those that were used for characterizing human health risk or for supporting the decision to undertake pre-emptive mitigation/early action during the VI investigation (e.g., sub-slab soil gas sampling and/or indoor air sampling). It is normally recommended that the party proposing to implement the exit strategy identify and document target concentration(s) that would allow for system termination, along with recommended monitoring/sampling frequencies. In addition, certain site-specific performance assessment data (e.g., standpipe vapor sampling) may also warrant consideration to make this determination.

When it is determined that the termination criteria have been met for a building VIMS as identified above, a period of attainment monitoring is conducted. During the attainment period, it is recommended that the VIMS (e.g., sub-slab suction wells or ventilation fans) be offline for a sufficient period to allow vapors beneath the structure to reach equilibrium and indicate post-remediation conditions. The types and frequency of data collected during attainment monitoring entail site-specific determination. Additionally, criteria should be established in the exit strategy to determine when ending the attainment monitoring period is appropriate. Many of these issues may be dictated by the regulatory agency.

For example, a recent review of existing VI regulatory guidance documents (Eklund et al., 2018) included an evaluation of various state provisions for termination. 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:

- 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 (e.g., 7–30 days) (MADEP, 2016; NJDEP, 2018)
- verification sampling and analysis of sub-slab vapors and/or indoor air and outdoor air and comparison to protective screening levels over a prescribed sampling interval (e.g., 4–24 months (MADEP, 2016; WDNR, 2018)
- operation of the VIMS between verification monitoring events, or indoor air monitoring to maintain protectiveness

These approaches can effectively demonstrate that a VIMS is no longer necessary. Alternative approaches may also be considered such as the mass loading and mass flux assessment methodologies (McAlary et al., 2018; Dawson, 2016).

To develop an exit termination strategy, site-specific fate and transport data may be used to identify an appropriate time period to allow the vapor concentrations to equilibrate. In addition, the termination of the attainment monitoring period may involve an evaluation of the contaminant attenuation in the vadose zone.

If the attainment criteria evaluation indicates that cleanup levels and objectives are not being met, it may be necessary to continue or resume subsurface remediation and mitigation activities. Once it is determined that the cleanup levels and objectives have been met, the active components of the VIMS may be removed from the building. On the other hand, the building owner may elect to continue to operate the mitigation system under their own discretion and for their own purposes (e.g., radon reduction and moisture control). Once the cleanup levels and objectives have been met, all OM&M and monitoring of the VIMS specified can cease.

Passive Building Mitigation: The termination of passive VIMS will typically be similar to the criteria established for the termination of active VIMS. In summary:

- Like active VIMS, passive VIMS are typically implemented in conjunction with the investigation and remediation of subsurface vapor source(s).
- Generally, once the subsurface vapor source(s) is remediated to levels that meet the cleanup objectives that will protect human health from the VI pathway, it is recommended that the site-specific monitoring data be evaluated to determine if the termination criteria have been met.

If the site-specific criteria evaluation indicates that cleanup levels and objectives are not being met, it may be appropriate to evaluate the current system's effectiveness or the possible application of an active mitigation system. Once it is determined that contaminant cleanup levels and objectives have been met, all OM&M specified can typically cease. Generally, most states and the USEPA do not have a need to seek removal of barriers or seals that comprise a passive mitigation system as part of termination activities and they are typically left in place.

Environmental Remediation Technology: In the case of remediation implemented as part of a VI mitigation approach, the consideration of terminating the system component of the remediation is based on the effective removal of the VI source (e.g., groundwater contamination, NAPL, or soil contamination). The removal of the VI source does not necessarily mean that residual soil gas contamination has been addressed. Thus, it is recommended that the site-specific monitoring data discussed for active and passive building mitigation (above) be evaluated to determine if the system termination criteria have been met.

3.3 Termination of Monitoring

For purposes of this process fact sheet, monitoring includes activities conducted to verify that the VI pathway does not pose a health concern to building inhabitants while remediation and mitigation activities are underway and in the event that the remediation and mitigation activities are terminated. "Termination of monitoring," for purposes of this process fact sheet, refers to ending any monitoring that is needed to verify that no further response action, including IC-related activity, is necessary to protect human health from indoor air exposures posed by VI. When developing termination criteria for monitoring, the decision is generally based on data collected from all the affected media.

As noted above, monitoring is generally implemented in conjunction with the remediation of subsurface vapor sources(s) and to evaluate performance of a VIMS. Typically, monitoring will continue until the source(s) is remediated to cleanup levels that eliminate the need to mitigate VI at the point of exposure (i.e., allow building VIMS to be terminated). If the subsurface vapor source is not remediated, it is generally anticipated that any associated monitoring of both the source area and VIMS will continue. As appropriate, the exit strategy may provide criteria for phased monitoring, resulting in a termination evaluation as source cleanup levels are achieved in parts of the contaminated area.

3.4 Termination of ICs

"Termination of ICs" as used in this process fact sheet refers to discontinuing any and all ICs because restrictions on land or resource use and/or notices and other informational devices are no longer necessary to help ensure protection of human health (i.e., human health risk from exposures to VI, if any, are expected to be acceptable in the absence of all IC(s)). Generally, ICs are implemented in conjunction with the investigation and remediation of the source(s). It is anticipated that ICs selected and implemented will be needed until (1) the subsurface vapor source(s) is adequately remediated, or (2) restrictions on land, resource, or building use are no longer necessary based on current and reasonably anticipated future exposure scenarios. Therefore, when developing a termination strategy for ICs that have been selected as part of a response action, the strategy is typically based on data collected from the affected media.

The exit strategy must consider and identify cleanup levels for the subsurface vapor source(s). As long as the subsurface vapor source exceeds such cleanup levels, it is generally anticipated that the associated ICs will continue. As appropriate, the termination/exit strategy may provide criteria for a phased IC termination evaluation as source cleanup levels are achieved in parts of the contaminated area.

If the site-specific criteria evaluation indicates that terminating the ICs is appropriate, the regulatory agency may conclude that site conditions no longer warrant ICs being used as part of the response action for the VI pathway. At this point, the regulatory agency could notify the appropriate entity(s), such as local or state government, tribe, affected landowner, or responsible parties, in writing that the response objectives have been met and that the IC need not be maintained.

Active Mitigation	**Medium Impact:** The exit strategy is an important component to OM&M of an active VIMS and should be considered frequently during the operation of the VIMS. As active mitigation performance data are collected they may be evaluated against criteria that may indicate that a VIMS may be ready for shutdown.
Passive Mitigation	**High Impact:** An exit strategy is typically developed as part of the design documents and is agreed to by all parties. This early consensus on the exit strategy avoids a moving target so that all sides should agree when the VIMS can be terminated.
Environmental Remedial Technology	**High Impact:** SVE/MPE systems are typically operated for a limited time; therefore, a clear exit strategy must be developed.
Rapid Response	**Low Impact:** Interim VI mitigation is intended to occur on a short-term basis prior to long-term mitigation. While there is no direct exit strategy associated with interim mitigation, consideration should be given to transitioning to long-term mitigation (e.g., reasonable implementation timeline, potential delays) so that interim mitigation does not run indefinitely.

4 References and Acronyms

The references cited in this fact sheet are included in a combined list with references cited in other fact sheets and technology information sheets prepared by the ITRC VI Mitigation Training team. This reference list, along with an acronym list and glossary, is available on the ITRC web site.

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