



Advancing
Environmental
Solutions

Vapor Intrusion Mitigation

VIM-1, 2021

Session 2

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Current time budget = 20-22 minutes (as of 2-10-2021)

Housekeeping

- ▶ Recording for On Demand Viewing



- ▶ Course Information and Materials:
<https://clu-in.org/conf/itrc/vim-1/>



- ▶ Technical difficulties? Use Q&A Pod



- ▶ Certificate of Course Completion



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Today's Presenters



Kelly Johnson, PG
North Carolina Department of
Environmental Quality
kelly.johnson@ncdenr.gov



Rick Gillespie
Regenesis
rgillespie@regenesis.com



Keith Brodock, P.E., P.P.
Integral Consulting, Inc.
kbrodock@integral-corp.com



Catherine Regan, P.E.
ERM
catherine.regan@erm.com



Matthew Williams
Michigan Department of
Environment, Great Lakes, & Energy
(EGLE)
WilliamsM13@Michigan.gov

Trainer Bios: <https://clu-in.org/conf/itrc/VIM-1/>



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Internet Based Training (IBT)

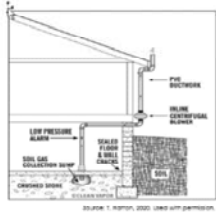
Session 2



Passive Mitigation



System Verification and
OM&M/ Exit Strategy



Active Mitigation



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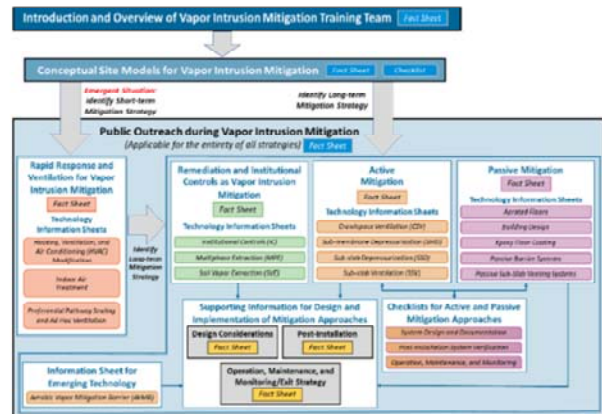
What You Should Learn

- ▶ Background on the VIM Training team
- ▶ Overview of available documentation
- ▶ How access the mitigation strategies information
- ▶ Identify the sections that will be discussed in today's session



ITRC VIM Webpage

- ▶ Interactive Directory
- ▶ Fact Sheets
- ▶ Technology Information Sheets
- ▶ Flow Chart for VIM CSM Development (Figure 2-1)
- ▶ Considerations and impacts of various VIM approaches
- ▶ Checklists
- ▶ Additional information



<https://vim-1.itrcweb.org/>



Supporting Information:

Design Considerations; Post-Installation; and Operation, Maintenance, and Monitoring/Exit Strategy

Checklists for Active and Passive Mitigation:

System Design and Documentation; Post-Installation System Verification, and Operation, Maintenance, and Monitoring

***NOTE THAT checklists for active and passive are covered in their respective modules, not as a separate module

Vapor Intrusion (VI) Reminder

- ▶ Contaminants in soil and groundwater can volatilize into soil gas.
- ▶ VI occurs when these vapors migrate upward into overlying buildings and contaminate indoor air.
- ▶ *Chlorinated Vapor Intrusion (CVI)*: addresses chlorinated compounds
- ▶ *Petroleum Vapor Intrusion (PVI)*: subset of VI that deals exclusively with petroleum hydrocarbon (PHC) contaminants



Source: ITRC Vapor Intrusion Pathway: A Practical Guideline (VI-1, 2007)



Source: ITRC Petroleum Vapor Intrusion Guidance (PVI-1, 2014)



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Start by talking about "What is Vapor Intrusion" or VI and why we are here so that there is a common understanding of what it is.

First it requires contaminants or hazardous substances to be released into soil and groundwater that can volatilize into soil gas.

Vapor Intrusion occurs when these vapors migrate upward into overlying buildings and contaminate indoor air.

It requires soil for vapors to migrate and diffuse through

If present at sufficiently high concentrations, these vapors may present a threat to the health and safety of building occupants.

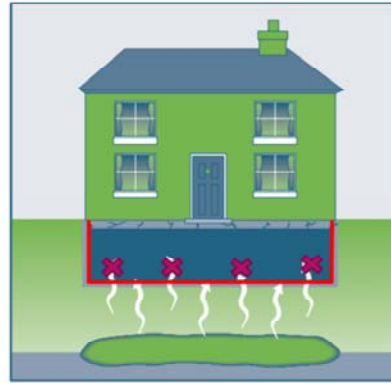
Also, quickly **mention preferential pathways**

There are generally considered 2 specific types of vapor intrusion Chlorinated Vapor Intrusion (CVI) which addresses chlorinated compounds and Petroleum Vapor Intrusion (PVI) is a subset of VI that deals exclusively with petroleum hydrocarbon (PHC) contaminants

Understanding the differences between each is critical as there may be different mitigation strategies for each type of vapor intrusion

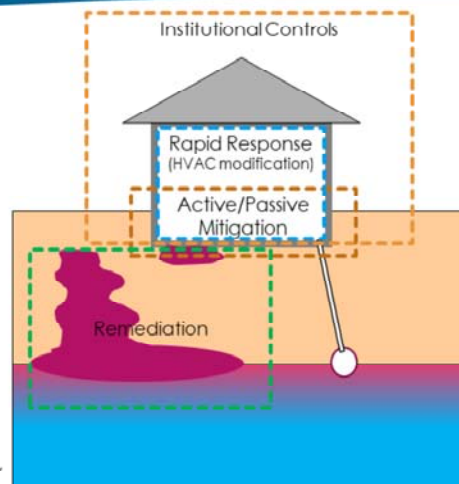
VI Mitigation (VIM)

- ▶ Implemented to reduce indoor air contaminants due to VI below applicable action or screening levels
- ▶ Accomplished by
 - ▶ Modifying the VI pathway to reduce the mass flux of contaminants entering the building
 - ▶ Reducing indoor air contaminant concentrations by removal or dilution



What is VI Mitigation (or Vapor Control)?

- ▶ VOC Vapor control can include
 - ▶ Source remediation
 - ▶ Active or passive mitigation
 - ▶ Rapid response
 - ▶ Institutional controls



Source: Geosyntec & GSI Environmental, 2020. Used with permission.

NOTE: THESE SLIDES WILL STEP THROUGH EACH

Multiple different mitigation strategies which is also called vapor control

Environmental remediation (**CLICK**) which address the contamination at the source
Building mitigation measures (**CLICK**) which typically involve active and passive mitigation
Rapid Response (**CLICK**) which is employed to quickly address known or potential vapor intrusion until longer term remedies can be implemented
Institutional controls (ICs) (**CLICK**) which are tools used to restrict different types of development or event the development itself

You will learn about the tools for each today and when appropriate each of these methods can be designed to reduce or prevent VI from occurring

Steps in the VIM Process

Pre-System Installation

1. Assessment of Site Conditions
2. Technology Selection
3. Develop and Document System Design

System Installation

4. Pre-construction Meeting
5. Installation
6. Installation Oversight

Post-System Installation

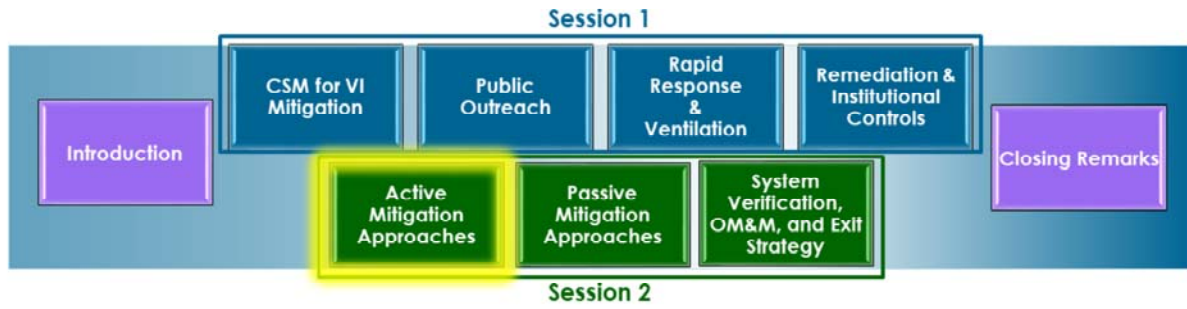
7. System Verification
 - a) Inspection
 - b) Verification Sampling
 - c) Confirming Performance QA/QC
8. Documentation
9. Operation, Maintenance, and Monitoring



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E C O S

Coming Up Next...



Q&A Session to be conducted after each module



Advancing
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Active Mitigation Approaches

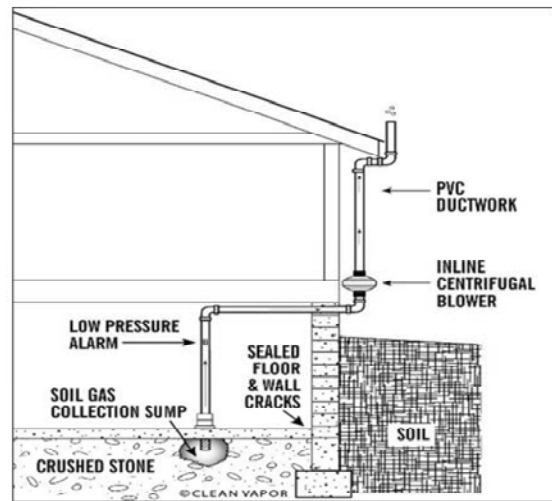


Figure 1 of the Sub-slab Depressurization (SSD) Technology Information Sheet.



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Objectives of Module

- ▶ Active mitigation definition
- ▶ Technology overview
- ▶ Design considerations



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- The goal of today's presentation is to provide an overview of active mitigation to a wide audience with varying degrees of experience with these technologies.
- Training is applicable to state and federal regulators who may be tasked with evaluating active mitigation designs, industry professionals who are considering various technology options
- The training content based on the work documents developed by the ITRC VIMT
- Objectives are
 - Set definition for what we consider active mitigation when developing docs
 - Provide an overview of various Active approaches covered by the VIMT .
 - Review key design considerations for active mitigation

What is Active Mitigation?

- ▶ Interception, dilution, diversion of soil gas
- ▶ Mechanized features (e.g., fan)
- ▶ Quantifiable by physical measurements, may include
 - ▶ Vacuum
 - ▶ Flow rate
 - ▶ Mass flux
 - ▶ Differential pressure

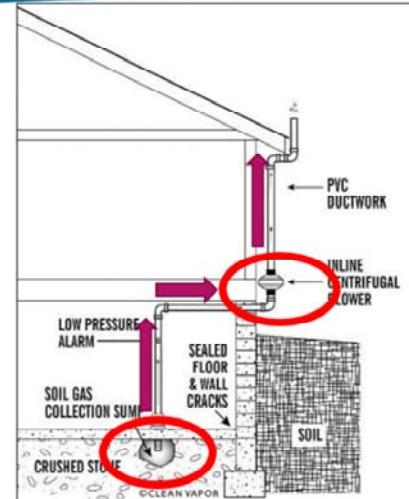


Figure 1 of the Sub-slab Depressurization (SSD) Technology Information Sheet.

- Active mitigation is the **continuous** diversion of vapors from under the building to the atmosphere outside using mechanical means like a fan or blower.
- The mechanized feature is what defines it as active.
- Active systems can be measured with, physical measurements, so it is **easy to determine effectiveness**
- Some of the measurement types are listed here on the slide for example vacuum and flow within the piping or differential pressure which measures vacuum under the slab relative to the indoor air space

Active Mitigation Fact Sheet

- ▶ Overview for work products
- ▶ Quick summaries of active mitigation approaches
- ▶ References to previous ITRC documents and ANSI/AASRT standards

Vapor Intrusion Mitigation (VIM)

Active Mitigation Fact Sheet

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

1 Introduction

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

As presented in the **Conceptual Site Models (CSM) for VI Mitigation Fact Sheet**, the mitigation technologies presented in this fact sheet assume the primary means for soil gas entry is via advection, rather than **diffusion**. Except for situations where very high sub-slab vapor source concentrations (e.g., millions of micrograms per cubic meter ($\mu\text{g}/\text{m}^3$)) are present, **diffusion** through the slab is not considered a significant transport pathway. Vapor mitigation systems that are 'active' are designed to



<https://vim-1.itrcweb.org/active-mitigation-fact-sheet/>

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- Fact sheet is laid out as a **summary guide** to the content in various other Active work products
- Note quick summaries on the technologies that were common enough that we created Tech Sheets
- but also has quick descriptions of other lesser common technologies that may be encountered
- Numerous references to previous ITRC documents (2007 and 2014)
- References to updated ANSI/AASRT standards if you are looking for details to actually design a system

Tech Sheet – Sub-Slab Depressurization (SSD)

General Design

- ▶ Negative pressure in sub-slab soil relative to building envelope
- ▶ Air flow direction: sub-slab → suction point → riser pipe → vent stack → atmosphere
- ▶ Fans outside occupiable building envelope
- ▶ Seal cracks and other penetrations (utility entrances, etc.)

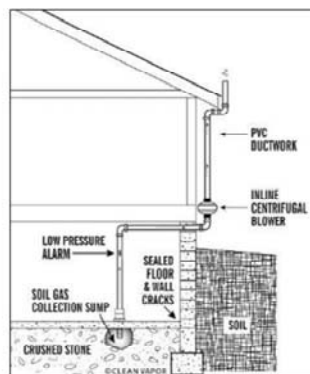


Figure 1 of SSD Technology Information Sheet

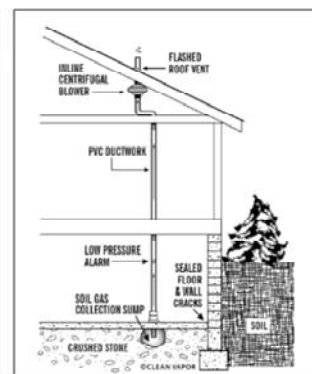


Figure 2 of SSD Technology Information Sheet



<https://vim-1.itrcweb.org/sub-slab-depressurization-ssd-tech-sheet/> 17

- Next we will go into more details of what the four most common types of active mitigation systems look like.
- VIMT created technology information sheets for each of the common active approaches
- Each goes through their general design, components, pros and cons and possible cost implications.
- Here is the first one - Sub-Slab Depressurization (PRESENTER: DO NOT SAY "S-S-D", TOO HARD TO UNDERSTAND OVER IBT)
- Draws air from beneath the slab to collection point, through riser pipe, vented to the atmosphere
- Notice fan placement both outside or, if inside it is outside the occupiable building space
- Typically thought of as a retro fit of an existing building but can be used during building construction
- Often coupled with crack sealing to increase effectiveness and efficiency
- **Most common** and **most conservative** mitigation method
- Has been **shown to be very effective**

Tech Sheet - Sub-Slab Depressurization (SSD)

Components

- ▶ Electric fan/blower
- ▶ Suction points
- ▶ Vent piping & valves
- ▶ Measurement equipment (manometers, gauges, sensors, etc.)
- ▶ Optional: condensate knockout, condensate bypass, emission controls



Source: Clean Vapor, 2020. Used with permission.



Source: ERM, 2020. Used with permission.



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- Components listed on slide
- Measurement equipment includes (u-tube manometer, vacuum gauge, pressure sensor, etc.)
- Emission controls usually not needed for vent stacks but need to check your state's regs
- Large systems may need emission controls, condensate knockout
- There **are adv and limitations** to this technology and they are in the tech sheet, talk about some in the course of this presentation but **not specifically listed in this presentation**

Tech Sheet – SSD in New Construction Scenario

- ▶ Greater system influence
 - ▶ Higher subgrade material transmissivity
 - ▶ Membrane installation
- ▶ Active fan can be added after building construction
- ▶ Side benefits
 - ▶ Radon protection
 - ▶ Decrease basement moisture



Source: Clean Vapor, 2020. Used with permission.



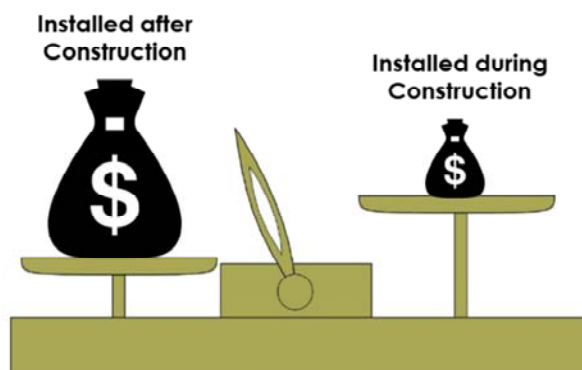
Source: ERM, 2020. Used with permission.



- SSD is most often thought of in existing buildings but I want to just mention quickly that it can also be considered in New construction
- Most control on the materials in the subgrade
- **Membranes may not need to be as robust if going straight to active** versus trying passive first.
- If not sure system is needed can be "roughed in" for later use

Tech Sheet – SSD in New Construction Scenario

► Positive cost impact



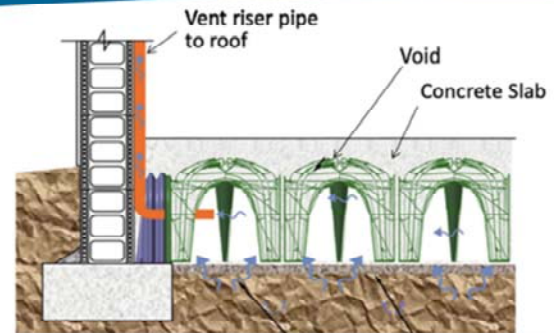
Source: Pixabay (adapted)

- Ultimately lead to a **positive cost impact**
- A roughed in system will be cheaper than a system put in later as a retrofit.
- With the increased influence of the system (as compared to a retrofit)
- It may eliminate the need for a larger fan or multiple extraction points to obtain adequate coverage.
- Able to plan the location of the vent stack (e.g. placing in utility closet rather than center of basement)
- If installed after construction will need to access building and potentially disrupt ongoing operations.

Tech Sheet – Sub-Slab Venting (SSV)

General Design

- ▶ Similar to SSD
- ▶ Air flow reduces sub-slab vapor concentrations
- ▶ High-permeability soils or void spaces
- ▶ Relatively low vapor concentrations
- ▶ Performance measurements include air velocity, system vacuum, vapor concentrations, mass flux



- Next tech sheet is sub-slab venting (PRESENTER – SAY FULL WORD, DON'T SAY "S-S-V", TOO HARD TO UNDERSTAND OVER AUDIO)
- **Variant of SSD**
- Similar to depressurization in that it draws vapor out from under the slab
- As you see in the pic through these vapors are drawn out from either a very permeable layer like a gravel or from a void space
- Drawing out vapors **reduces conc below slab** and mitigates VI
- **Due to relative ease in drawing out air, and the potential for dilution air to be introduced in some cases less vacuum may be generated, performance metrics could be slightly different** than SSD and include those listed
- Typically used when high permeability is already present (or new construction when you can create that layer)

Tech Sheet – Sub-Slab Venting (SSV)

Components

- ▶ Components same as SSD
- ▶ May incorporate aerated floor system (void spaces)
- ▶ May include inlets for sub-slab dilution air



Source: Clean Vapor, 2020. Used with permission.

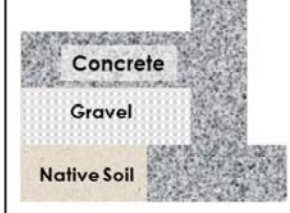
- As mentioned, almost exact same components to SSD
- Void spaces more common with SSV and more common when added to new construction (see picture) although a new floor in a retrofit or adding a floor on top of an existing floor could also allow for an aerated floor system
- Some systems may intentionally incorporate dilution inlets that allow fresh air to circulate in the surface as the fan draws out the vapors or leakage may occur naturally into the subsurface creating that same dilution.

Knowledge Check

Poll Question

Scenario A

High permeability (gravel)
under slab



Scenario B

Low permeability native soil
under slab



Source: ERM, 2020. Used with permission.



Which condition is more amenable to sub-slab venting?

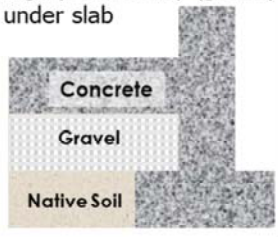
- A knowledge check based on what we just learned

Knowledge Check

Poll Question

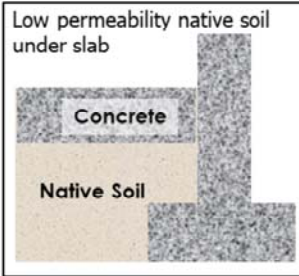
Scenario A

High permeability (gravel)
under slab



Scenario B

Low permeability native soil
under slab



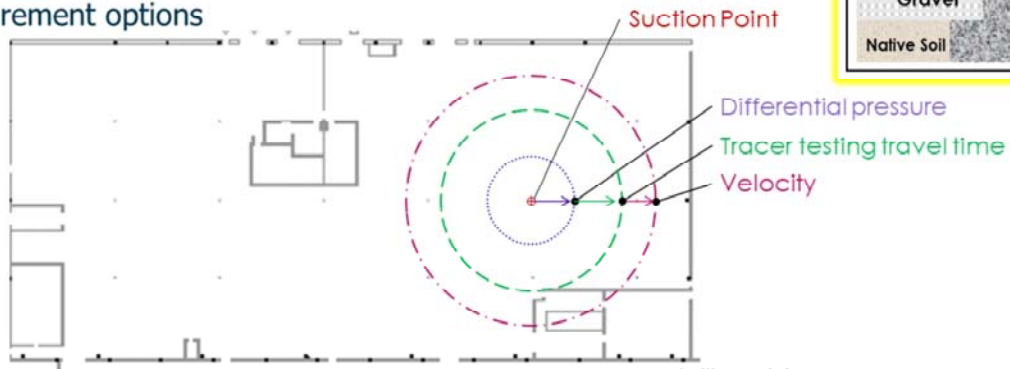
Source: ERM, 2020. Used with permission.



Which condition is more amenable to sub-slab venting?

Measurement of SSV Performance

► Measurement options



Source: ERM, 2020. Used with permission.

Differential pressure can underestimate lateral influence of SSV



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- Dig deeper into scenario A where there is high permeability material under the slab and how we would want to evaluate the performance of an SSV system.
- So if you have a suction point here and if you were to just measure the induced vacuum as differential pressure, you may see the influence of the system to here [CLICK](#)
- But if we use the metrics discussed earlier like a tracer test we could show that the SSV system actually has an influence much greater to say here [CLICK](#)
- and if we measured velocity under the slab you may see evidence of air movement to here [CLICK](#)
- [CLICK](#) This is all to say that differential pressure as a performance metric may underestimate SSV systems because of the conditions where SSV system operate.

Tech Sheet – Sub-Membrane Depressurization (SMD)

General Design

- ▶ Most often used for dirt floors, crawlspaces, and compromised floors
- ▶ Negative pressure below sealed membrane relative to interior space
- ▶ Membrane provides plenum for active mitigation
- ▶ More residential than industrial/commercial applications

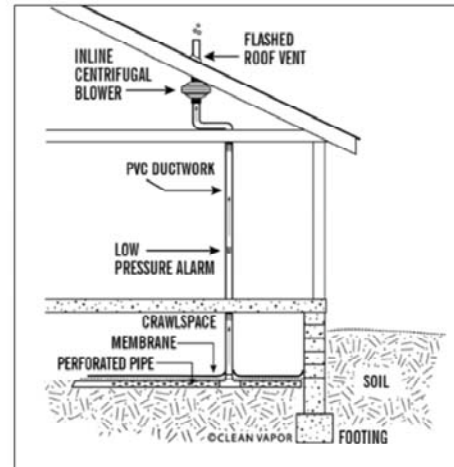


Figure 1 of the SMD Tech Sheet



<https://vim-1.itrcweb.org/sub-membrane-depressurization-smd-tech-sheet/>

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- Next Tech sheet is Sub-Membrane Depressurization
- Very similar to SSD except for locations where there is no slab, this system installed a membrane and then vapors are drawn from underneath to create the depressurization.
- **Preferred method for crawlspace mitigation, intercepts vapors before entering crawlspace**
- Draws air from beneath the sealed membrane to collection point, through riser pipe, vented to the atmosphere
- Fan put outside occupiable living area or outside
- Membrane provides sealed space for active mitigation consideration when impermeable surface is not present
- Best used with crawlspaces or earthen floor exposures
- Typically installed more in residential homes as usually this dirt floor occurs in a crawlspace but could be used in other types of buildings.

Tech Sheet – Sub-Membrane Depressurization (SMD)

Components

- ▶ Electric fan/blower
- ▶ Vent piping & valves
- ▶ Membrane sealed to walls and around pipe penetrations
- ▶ Vapor collection piping/plenum under membrane
- ▶ Measurement equipment (manometers, gauges, sensors, etc.)
- ▶ Optional: condensate bypass, emission controls



Source: Arcadis, 2020. Used with permission.

- Components mostly the same as an SSD include the fan/blower, vent piping, stack, balancing valves, measurement equipment such as manometers, vacuum gauges.
- Biggest difference is the membrane that is needed to create the plenum and the place where vapor can be drawn from.
- See the membrane in the picture with batting to seal it to the walls of the crawlspace

Tech Sheet – Crawlspace Ventilation (CSV)

General Design

- ▶ Crawlspace air replaced with fresh air
- ▶ Vapor dilution via air exchange
- ▶ Consider significant heating or cooling impacts
- ▶ Used when other technologies are not feasible

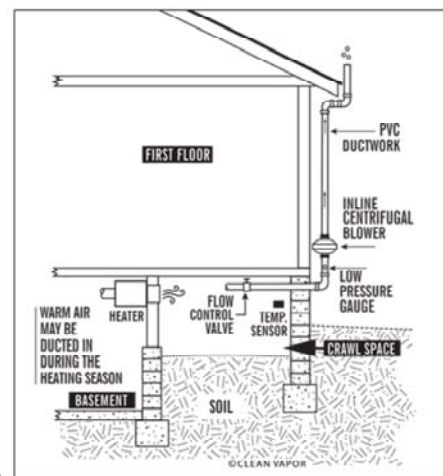


Figure 1 of the CSV Tech Sheet



<https://vim-1.itrcweb.org/crawlspace-ventilation-csv-tech-sheet/>

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- Last tech sheet is Crawlspace Ventilation
- Typically a **last option** for crawlspaces that you are not able to access to put in a membrane
- **Does not prevent vapors from entering**/traveling through the crawlspace
- Should not be used unless unable to enter crawlspace to install barrier
- Draws air out of the vent space and out to the atmosphere
- Used to dilute the vapors in the crawlspace
- However, heating or cooling may impact the vapors beneath the slab
- Frozen pipes that are in the crawlspace could be a concern if living in a cold climate
- Not as common for crawlspace mitigation as other technological options will be more effective and efficient

Tech Sheet – Crawlspace Ventilation (CSV)

Components

- ▶ Electric fan/blower
- ▶ Vent piping & valves
- ▶ Measurement equipment (manometers, gauges, sensors, etc.)
- ▶ Optional: temperature actuated heating, condensate bypass, emission controls



Source: ERM, 2020. Used with permission.

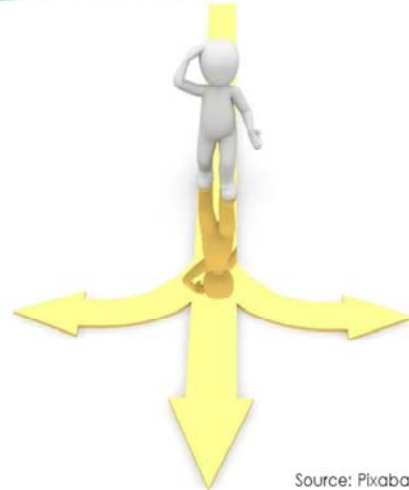
- Again Construction components similar to SSD with venting including piping to the atmosphere and a fan
- May not have enough flow to measure vacuum with a manometer but can **measure flow** and also may need sensors for temperature control.

Starting the Design Process...

Now that you have seen what's out there, let's assume you have chosen

- ▶ active mitigation
- ▶ the specific approach to implement

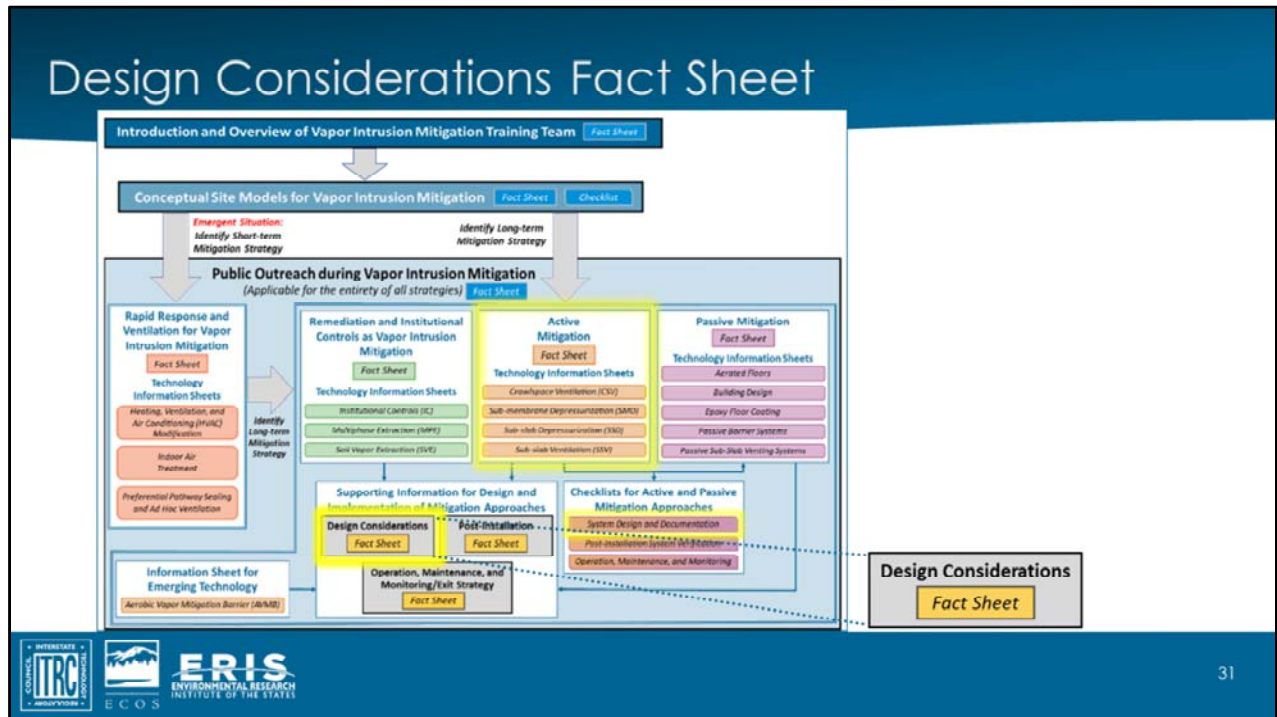
Now what???



Source: Pixabay

- Those were the end results.....
- How do we get there?
- ITRC created the process fact sheets to summarize the considerations to be thought about when planning the design of vi mitigation including active mitigation

Design Considerations Fact Sheet



- Location of design considerations fact sheets in the document map
- Started at the Active mitigation fact sheet and the associated tech sheets and not moved down to the process of designing a mitigation.
- Here we will talk about design process considerations for active mitigation.
- Couple other process steps you see here after design but those are covered in another module.

Design Considerations Fact Sheet

- ▶ Guide through design considerations
- ▶ Relative importance to active mitigation

Don't Forget:

- ▶ Take into account the CSM
- ▶ Plan for system verification
- ▶ Plan for future exit strategy



Source: Pixabay

Vapor Intrusion Mitigation (VIM)

Design Considerations Fact Sheet

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

1 Introduction

Multiple factors affecting the suitability and efficacy of a mitigation system should be considered during the design review and approval process, as discussed in this fact sheet. The selected technology should be based on a good understanding of the VI conceptual site model (CSM) (see ITRC [Conceptual Site Models for Vapor Intrusion Mitigation Fact Sheet](#)) and able to meet the remedy objectives pertaining to soil vapor conditions at the site, whether applying an active system, passive system, rapid response, and/or an environmental remediation technology.

The design process should begin with a non-selection of the VI CSM elements applicable to mitigation and the remedy objectives, leading to the design basis (i.e., an explanation of how the selected approach and technologies will meet the remedy objectives at the site). In many cases, this review indicates that additional information is needed for design of a specific type of mitigation system; therefore, the need for pre-design investigations and/or testing should be considered. Once sufficient information is available for design, the next consideration is the design itself—the area that requires mitigation along with the system components, installation details, and specifications. Other design considerations include installation and operating permitting requirements, stakeholder requirements and communications, and the need for construction quality control, demonstration of system effectiveness and reliability, and operation, maintenance, and monitoring (OM&M) plans, including an exit or closure strategy.

Table 1-1 identifies the design considerations that are discussed in more detail below and evaluates their typical importance and impact on the design of an active (see ITRC [Active Mitigation Fact Sheet](#)), passive (see ITRC [Passive Mitigation Fact Sheet](#)), or an environmental remediation technology (see [Remediation and Environmental Controls as Vapor Intrusion Mitigation Fact Sheet](#)). Note that the importance of any factor can vary depending on site and building-specific



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<https://vim-1.itrcweb.org/design-considerations-fact-sheet/>

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- Design Considerations Fact Sheet is a guide through many of the considerations to be thought about for various VI mitigation approaches .
- Documents then discusses the relative importance of different considerations as they pertain to the various types of mitigation approaches (like active, passive, rapid response....)
- The process fact sheet does not help you choose a technology, it assumes you have chosen your technology already
- Points out the major considerations for each technology for each step of the way.
- As discussed before don't forget that during the design process you are still taking into account CSM, how you will verify system operates to your objectives and how you will plan to turn it off someday.
- Important for designs to both look backwards and to look forwards
- **Fact sheet written for all types of mitigation approaches. We are going to go through some factors to take into consideration in the design that are particularly important and in some cases unique to the Active approach. Other considerations particularly important to Passive approaches will be covered later in the session.**

Design Considerations – Building Conditions New Construction

- ▶ Different components will be considered versus existing buildings
- ▶ Typically combined with passive mitigation technologies
- ▶ May be designed and installed but not activated



Source: Clean Vapor, 2020. Used with permission.

- Some of the more important design considerations for active mitigation are the building type
- Is the building for example new construction
- Whether a building is new, about to be constructed, or existing will have a major impact on an active mitigation design strategy
- Components will be considered differently for new construction than for existing buildings and will most likely be combined with passive mitigation technologies
- If passive is going to be the primary approach, active systems may be designed and installed but not “turned on” in new construction
- Activated at a later date when it is determined if they are needed.

Design Considerations – Building Conditions

Existing Buildings

Factors included in design may be:

- ▶ Foundation type (multiple foundations)
- ▶ Slab integrity
- ▶ Preferential pathways
- ▶ HVAC
- ▶ Building dimensions
- ▶ Exterior façade requirements

Source: ERM, 2020. Used with permission.



Source: Clean Vapor, 2020.
Used with permission.



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- If the building condition is that it is an existing building then design considerations may focus on the items listed for example here
- Basic foundation type or multiple foundation types and locations due to building additions over time
- Slab integrity and if sealing is needed like in the photo
- HVAC systems present and how they need to be incorporated or overcome within the Active system design.
- Working with the exterior façade requests of the building owner (picture far right).
- Soil permeability and DTW will significantly impact the design
- Also important to determine feasible pipe routing and identify discharge locations that meet separation requirement from openings into the building

Design Considerations – Sub-slab Diagnostics

- ▶ Diagnostics used to determine
 - ▶ Suction point configuration
 - ▶ Number and size of fan(s)
- ▶ Pressure field extension (PFE) testing
- ▶ Differential pressure measurements
- ▶ Other diagnostics like tracer testing may also be used



Source: ERM, 2020. Used with permission.

- Sub-slab diagnostics are an important design consideration for an existing building
- The most common sub-slab diagnostic tests conducted in existing buildings are pressure field extension (PFE) testing and measurement of differential pressures across the slab.
- Using diagnostics may be dependent on building size (smaller building or residential homes may not need them if sufficient information is available to be reasonably confident in the mitigation system design or there is an expectation to modify system design during system construction as effectiveness is tested (i.e. a design-build method).
- used to understand sub-slab conditions to select the number and locations of suction points, fan sizes, etc.

Design Documentation – Design Work Plan

- ▶ Design basis
- ▶ System components and system layout
- ▶ Permitting
- ▶ Installation instructions and specifications
- ▶ Construction quality assurance (CQA)
- ▶ Plan for verification and OM&M
- ▶ Plan for exit strategy



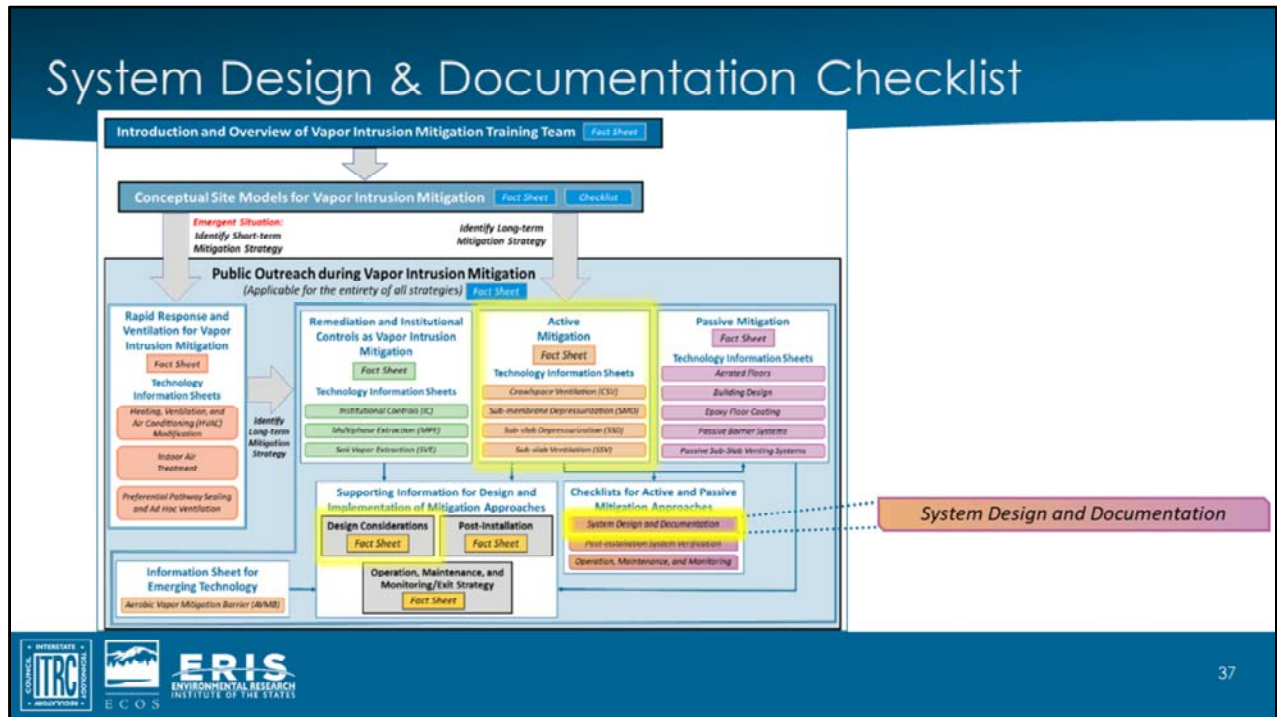
Source: Pixabay



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- Design work plan is also an important consideration for active mitigation
- design work plan is where you will gather all of your important information like your design basis and reason for mitigation
- Design basis that explains how vapor intrusion is occurring (or could occur in new buildings) and how the mitigation approach and technologies selected will control vapor intrusion sufficiently to meet the design objectives.
- Work plan will commonly include one or more layout sheets, showing where the various components of the system, design specs, piping layouts, suction point locations, vent stack location, etc.
- Mitigation system designs must consider building codes, and other permits that need to be addressed, highly variable to cities and towns) and in some states an emissions permit and/or emissions controls
- You should plan out what you plan to use as the metrics to show that your system, once installed and operating, is meeting your design objectives as well as a plan to make sure construction quality is maintained during installation with a quality assurance plan.
- You can also lay out in the design how you intend to do routine OM&M and how to eventually plan for turning off the system.
- Communication with the property owner, tenants, other stakeholder key at the design stage (so they know what you are doing and if they agree with where you are doing it

System Design & Documentation Checklist



- Along with the Design Considerations Fact Sheet is the companion check list
- here it is listed in the document map

System Design & Documentation Checklist

- ▶ Walks through each design consideration
- ▶ Prompts user for site-specific information
- ▶ Not all items may be applicable for all sites

**Active Mitigation Checklist
for
Existing Buildings and New Construction**

Details and types of active mitigation can be reviewed in the *Active Mitigation Fact Sheet*. The primary active technologies that are the focus of this design checklist are sub-slab depressurization, sub-slab venting, sub-membrane depressurization, and crawlspace venting, and these technologies are detailed in their respective technical information sheets. This section focuses on design checklist considerations for existing buildings where the design needs to accommodate an existing building slab. Some of the considerations in the checklist below may also apply to new construction if an active system such as a sub-slab depressurization (SSD) system is being installed. This is different than mitigation of new construction that consists of a passive barrier or aerated floor. For the passive mitigation systems, see the passive mitigation checklist below.

I. ACTIVE MITIGATION SYSTEM DESIGN AND DOCUMENTATION

- Have all the building slab areas been fully characterized for contaminants? Yes No NA
- Has pressure field extension (PFE) testing been completed? Yes No NA

I.1. Selection of system materials and methods

- Were total building footprint, foundation type, and under-slab compartments (created by haunches, thickened slab, or elevation changes) considered in the design process? Yes No NA



<https://vim-1.itrcweb.org/system-design-and-documentation-checklists/>

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- Checklist is not just for active mitigation, it is for passive as well
- This checklist provides information necessary to proceed through the design process
- Checklist focuses on system design and documentation items (i.e., are certain aspects and components included in the design package)
- The checklist is a template out there to aid in the design. The checklist can be used to help prompt the user to think about each of these aspects of the design. Not all items will be applicable to all situations. Depending on the complexity of the design, it may be appropriate to identify why certain items are NOT applicable to your site scenario.
- Some designs will be very different or will be very basic depending on complexity of the building (e.g., small residential home, design-build situations)
- Some buildings may not need almost any part of the design checklist if they are very simple

Summary

- ▶ Definition of active mitigation
- ▶ Common active mitigation approaches for new construction and existing buildings
- ▶ Considerations for designing an active mitigation technology
- ▶ Key elements in active mitigation system design
- ▶ Design documentation

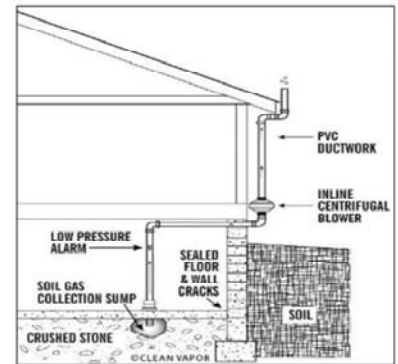


Figure 1 of the Sub-slab Depressurization (SSD) Technology Information Sheet.

- In summary....
- We have reviewed what definition the ITRC used to define an active mitigation
- What we consider to be the 4 most common types of active mitigation approaches
- Some of the most relevant design considerations for active and the tools that ITRC has developed to help you through the design process or reviewing a design work plan.
- And we have highlighted where in the document map you can find all of the active mitigation information for you to review on your own

Next Steps

- ▶ Install the system as designed
- ▶ Verify effective installation and operation
- ▶ Conduct routine OM&M
- ▶ Monitor and plan for an exit strategy



Source: Pixabay



Subsequent steps covered in other modules

- So where do we go from here
- The next logical step in the path of this system is that the design is approved and the system is installed as designed.
- The installation and operation of the system would be verified and then the system would be operated and monitoring for some period of time
- Eventually the system, based on data, may be shutdown
- All of these steps will be discussed in subsequent modules.

Question & Answer Break



Source: Pixabay

At this time we will open the questions and answers portion of our training.



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Passive Mitigation Approaches



Source: thenounproject.com.
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- Transition slide from Active group
- Introduction of speakers (both)
- General welcome

- Welcome to the passive mitigation approaches training module.

Objectives of Module

- ▶ Passive mitigation definition
- ▶ Technology overview
- ▶ Design considerations
- ▶ Installation planning
- ▶ Construction quality assurance



- During the 1st half of the presentation, I will:
 - Define passive mitigation
 - Introduce documents
 - Discuss common technologies
- During the 2nd half of the presentation, [CO-PRESENTER'S NAME] will introduce:
 - Key considerations for system design, installation, and planning
 - End with construction quality control measures

What is Passive Mitigation?

- ▶ Block or divert contaminant vapors from entering building
- ▶ Does not rely on mechanical means (e.g. blower)
- ▶ Relies on natural mechanisms



Source: Adapted from ITRC.



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- Define passive mitigation
 - No mechanical means
 - Blocks VI pathways and relies on natural mechanisms
 - Most commonly used in new construction
- Remember to review and update the CSM often
 - Evaluate whether current site conditions warrant mitigation
 - Ensure appropriate mitigation approach
- Public outreach - Any time mitigation is necessary
 - Ensures the mitigation systems installed are understood and not compromised in the future

Passive Mitigation Fact Sheet

- ▶ Summary guide to the content in other work products
- ▶ Summaries of both common and less common passive technologies
- ▶ References to previous ITRC documents and various state vapor intrusion guidance documents

Vapor Intrusion Mitigation (VIM)

HOME

Passive Mitigation Fact Sheet

ITRC has developed a series of fact sheets that summarize the latest science, engineering, and technologies regarding **vapor intrusion** (VI) mitigation. This fact sheet describes the most common passive mitigation technologies and considerations that go into the design, installation, post-installation system verification and documentation, and operation, maintenance, and monitoring.

1 Introduction

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

As presented in the **Consistent Site Models for VI Mitigation Fact Sheet**, the mitigation technologies presented in this fact sheet assume the primary means for soil gas entry is via advection rather than **diffusion**. Except for situations where very high sub-slab vapor source concentrations (e.g., millions of micrograms per cubic meter (µg/m³)) are present, **diffusion** through the slab is not typically considered a significant transport pathway.

2 Passive Mitigation Types

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



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<https://vim-1.itrcweb.org/passive-mitigation-fact-sheet/>

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- The information we're covering today is based on the Passive Mitigation Fact Sheet
 - Walks reader through the mitigation process from start to finish
 - Direct reader to additional resources
 - Includes links to five Technology Information Sheets

Tech Sheet – Common Passive Barrier Systems



Asphalt Latex Membranes (ALM)

Source: EPRO Services, Inc, 2020. Used with permission.



Thermoplastic Membranes (TM)

Source: Steve Weiterman, 2020. Used with permission.



Composite Membranes (CM)

Source: Vadose Remediation Technologies, 2020. Used with permission.

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- Introduce passive barrier systems:
 - Asphalt Latex Membranes
 - Thermoplastic Membranes
 - Composite Membranes
- Subtle differences - Materials and installation methods
- All seal foundation and block preferential pathways
- Site conditions may dictate which barrier you use

Tech Sheet – Passive Barrier Systems Asphalt Latex Membranes (ALMs)

General Design

- ▶ Barrier to prevent VI in new buildings
- ▶ Typically comprised of
 - ▶ Base layer
 - ▶ Continuous spray-applied asphalt
 - ▶ Cap sheet
- ▶ Effective for a wide range of contaminants

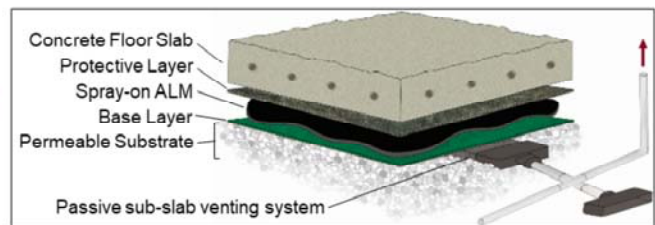


Figure 1 of Passive Barriers Technology Information Sheet.



- Asphalt Latex Membranes
 - Base layer, asphalt latex core, and a cap sheet
 - Base and cap materials vary
 - Usually consists of a thin plastic membrane backed with geotextile fabric
 - Base provides surface for spray-applied asphalt latex
 - Cap provides protection to barrier system

Tech Sheet – Passive Barrier Systems

Asphalt Latex Membranes (ALMs)

Installation

- ▶ ALM application to Thermoplastic Membrane
- ▶ Manufacturers provide specific installation instructions



Source: EPRO Services, Inc, 2020. Used with permission.



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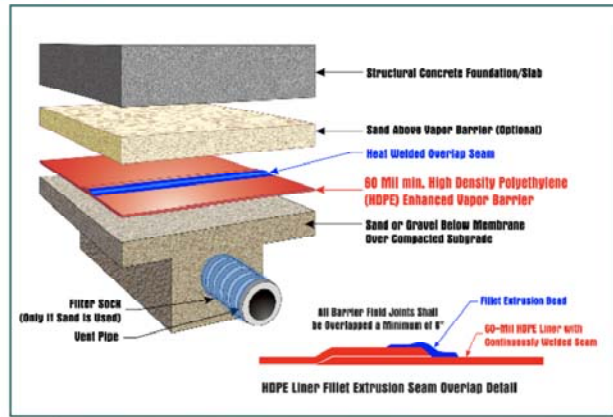
- Core is spray applied and cures in place
 - Provides a seamless layer of protection
- Cap sheet creates bond between barrier and slab
 - No mechanical fasteners or caulking at penetrations
- Mil thickness specified by the manufacturer

Tech Sheet – Passive Barrier Systems

Thermoplastic Membranes (TMs)

General Design

- ▶ Single layer sheet systems with heat-welded seams
- ▶ TMs are different (thicker) than "moisture vapor barriers"
- ▶ Effective for a wide range of contaminants



Source: Geokinetics, Inc., 2021. Used with permission.

JANUARY 2021
GeoKinetics

Typical HDPE Vapor Barrier System



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- Thermoplastic Membranes
 - Typically are single layer systems comprised of HDPE
 - May consists of other materials such as LLDPE
 - Thicker and more rigid
 - Thickness affects installation procedures

Tech Sheet – Passive Barrier Systems

Thermoplastic Membranes (TMs)

Installation

- ▶ Heat-welded seams
- ▶ Terminations require mechanical fastening
- ▶ Pre-fabricated boots to seal penetrations
- ▶ Manufacturers provide specific installation instructions



Source: Steve Weiterman, 2020. Used with permission.



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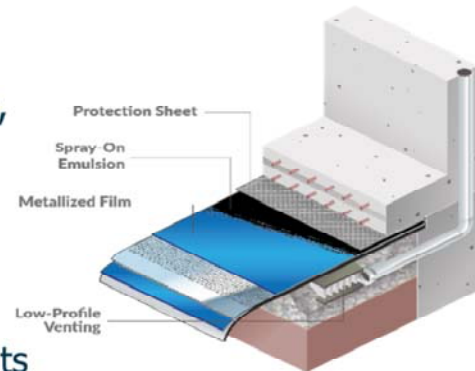
- During installation
 - Sheet overlapped and heat welded
 - Prefabricated boots to seal penetrations
 - Mechanical fasteners secure terminations
 - Often used in conjunction with a vapor collection system
- More puncture resistant
- Offer high level of chemical resistance
- Materials costs are low, but installation process is more difficult
- Typically used for new construction

Tech Sheet – Passive Barrier Systems

Composite Membranes (CMs)

General Design

- ▶ Typically comprised of multiple materials, such as
 - ▶ EVOH
 - ▶ Metallized films
 - ▶ Spray-on emulsion/ALM
- ▶ Effective for a wide range of contaminants



Source: Land Science, 2020. Used with permission.



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- Composite Membranes
 - Multi-layered system
 - Materials can improve chemical resistance, constructability, and durability
 - Sum of the whole is greater than the sum of the parts
- Gray area between CMs and other barriers
 - Example: CMs and ALMs both use multiple materials that can reduce diffusion rates

Tech Sheet – Passive Barrier Systems Composite Membranes (CMs)

Installation

- ▶ Seams and penetrations sealed by various methods
- ▶ Manufacturers provide specific installation instructions



Source: Vadose Remediation Technologies, 2020. Used with permission.



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- Installation methods vary depending upon materials used
- Depending upon materials used, may offer greater protection using thinner mil systems
- Some use tape-based seams that may delaminate
- Smooth materials may not adhere to slab
- Some states require minimum mil thickness and/or regulatory approval for new technologies

Tech Sheet – Other Passive Systems



Aerated Floors

Source: Vapor Mitigation Sciences, LLC, 2020. Used with permission.



Passive Sub-Slab Venting (SSV) Systems



Epoxy Floor Coatings (EFCs)

Figure 1 of Epoxy Floor Coatings Technology Information Sheet.



Building Design

Figure 2 of Building Design Technology Information Sheet.



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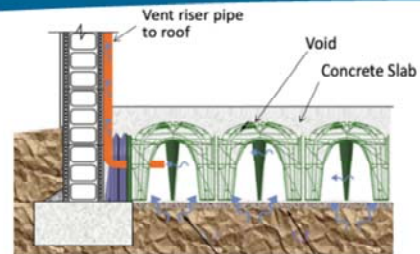
Figures 1 and 5 of Sub-slab Venting Technology Information Sheet.

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- Other approaches are effective against a variety of contaminants
 - Aerated Floors
 - Passive sub-slab venting
 - Epoxy floor coverings
 - Building Designs
 - Raised foundations or vented crawl spaces

Tech Sheet – Aerated Floors

- ▶ Create continuous void space under slab
- ▶ Low resistance to air flow, air exchange rates are high
- ▶ Most applicable to new construction
- ▶ Proprietary forms designed for all building types
- ▶ Designed for SSV or SSD in either passive or active mode



Source: Pontarolo Engineering, Inc.



Source: Vapor Mitigation Sciences, LLC, 2020. Used with permission.



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- Aerated Floor Void Space Systems
 - Uses forms to create a void space beneath slab
 - Very low resistance to air flow
 - Allows high vacuum levels and air exchange rates
 - Forms connect to vent risers that discharge vapors above the roof
 - Can rely on passive venting, but often use active depressurization

Tech Sheet – Passive Sub-Slab Venting (SSV) Systems

- ▶ Fundamentally different from SSD
- ▶ Relies on pressure differences to induce flow
- ▶ Most applicable to new construction
- ▶ Often used in conjunction with passive barriers to improve performance
- ▶ No power source required

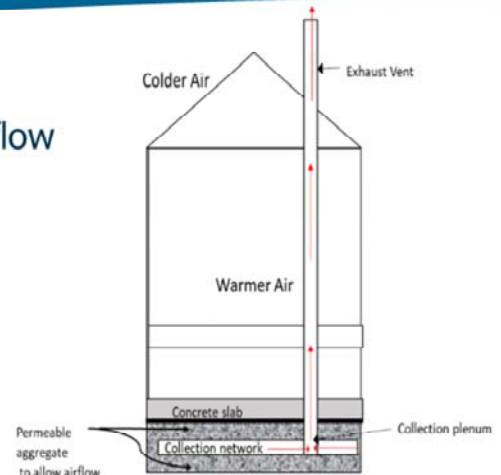
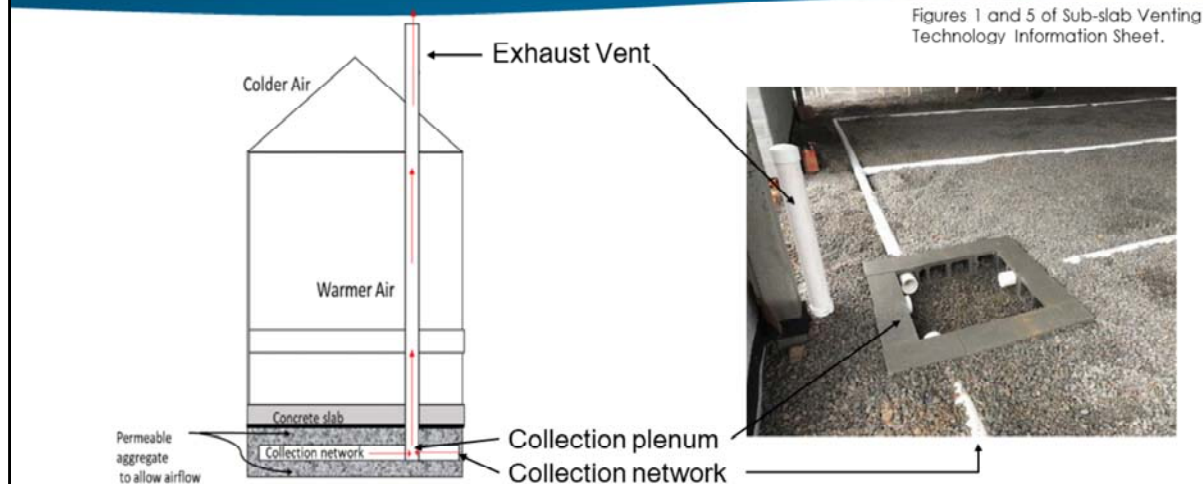


Figure 1 of Sub-slab Venting Technology Information Sheet.

- Passive Sub-Slab Venting Systems
 - Horizontal vent piping installed in a permeable layer
 - Perforated pipe or permeable geotextile matting connected to vent risers
 - Vapors beath building travel through piping and are discharged above the roof
 - Relies on pressure differences to induce air flow
 - Almost always used in combination with a passive barrier

Tech Sheet – Passive Sub-Slab Venting (SSV) Systems



- Discuss photo of passive sub-slab venting system
 - Click 1 – Horizontal vent piping (aka collection network)
 - Click 2 – Void space (aka collection plenum) where horizontal vent piping connects to vent risers
 - Click 3 – Vent riser (aka exhaust vent). The exhaust vent is capped.
- Under the right conditions can capture vapors over a large area
- Simple design avoids need for long term OM&M
- Compared to an active venting system
 - May require more vent risers
 - Has reduced performance
- Almost always used in combination with a passive barrier

Tech Sheet – Epoxy Floor Coatings (EFCs)

- ▶ Applicable to all building types
- ▶ Most applicable to existing building floors/walls as a passive VI barrier
- ▶ Involves concrete surface preparation prior to application
- ▶ Can protect concrete
- ▶ Requires specialty applicators



Figure 1 of Epoxy Floor Coatings Technology Information Sheet.



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- Epoxy Floor Coatings
 - Can be applied to an existing floor slab
 - Floor slab condition and surface preparation affect overall quality of the EFC
 - Concrete must be clean and dry, and the surface must be scarified
- Provides a strong, durable, chemically resistance barrier
- Easy to clean, maintain, and repair
- Easy to customize (color/finish)
- Require special preparation to control moisture content and scarify the concrete to prevent delamination

Tech Sheet – Building Design for Passive VIM Vented Garages

- ▶ Mainly city setting where space is limited
- ▶ Naturally vented (passive) or mechanically vented (active)
- ▶ Design and OM&M often included in building code
- ▶ Adequate ventilation rate needed to mitigate VI

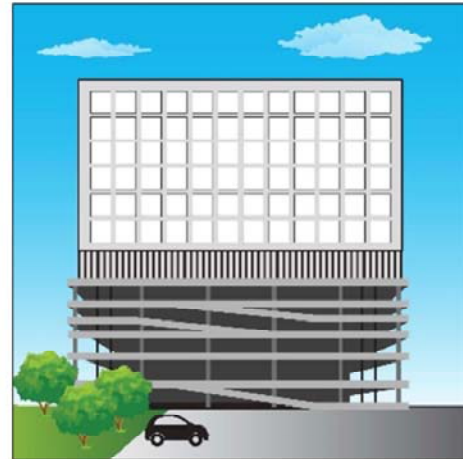


Figure 1 of Building Design Technology Information Sheet.



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- Building Design
 - Building design can be used to prevent VI from occurring or mitigate the VI pathway
 - Parking garage example
 - Designed to prevent the build up of vehicle exhaust by increasing air flow
 - In some locations air exchange rates are specified by building code
 - Documenting the air exchange rates are being maintained may address the VI risk

Tech Sheet – Building Design for Passive VIM

Raised Foundations or Crawlspace

- ▶ Temperate climates
- ▶ High water tables/flooding
- ▶ Naturally induced air exchange
- ▶ Adequate ventilation rate needed to mitigate VI

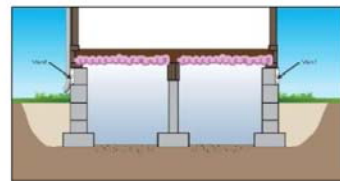


Figure 2 (top) and 3 (bottom) of Building Design Technology Information Sheet.

- Raised Foundations
 - Other forms of building design, such as raised foundations and vented crawlspaces can address VI concerns for smaller buildings
 - Raised foundations usually found in warm climates and areas prone to flooding
 - Block and beam construction raises a building, separates the building from the vapor source, and cuts off the VI pathway

Knowledge Check

Poll Question

Which mitigation technology is commonly used in combination with a passive barrier system?

- A. Aerated Floors
- B. Epoxy Floor Coatings
- C. Passive Sub-Slab Venting Systems
- D. None of these



Source: Pixabay

Knowledge Check

Poll Question

Which mitigation technology is commonly used in combination with a passive barrier system?

- A. Aerated Floors
- B. Epoxy Floor Coatings
- C. **Passive sub-slab venting systems**
- D. None of these



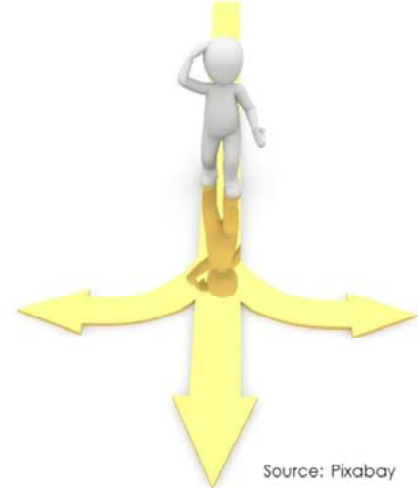
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Starting the Design Process...

Now that you have seen what's out there, let's assume you have chosen

- ▶ Passive mitigation
- ▶ The specific approach to implement

Now what???



Source: Pixabay



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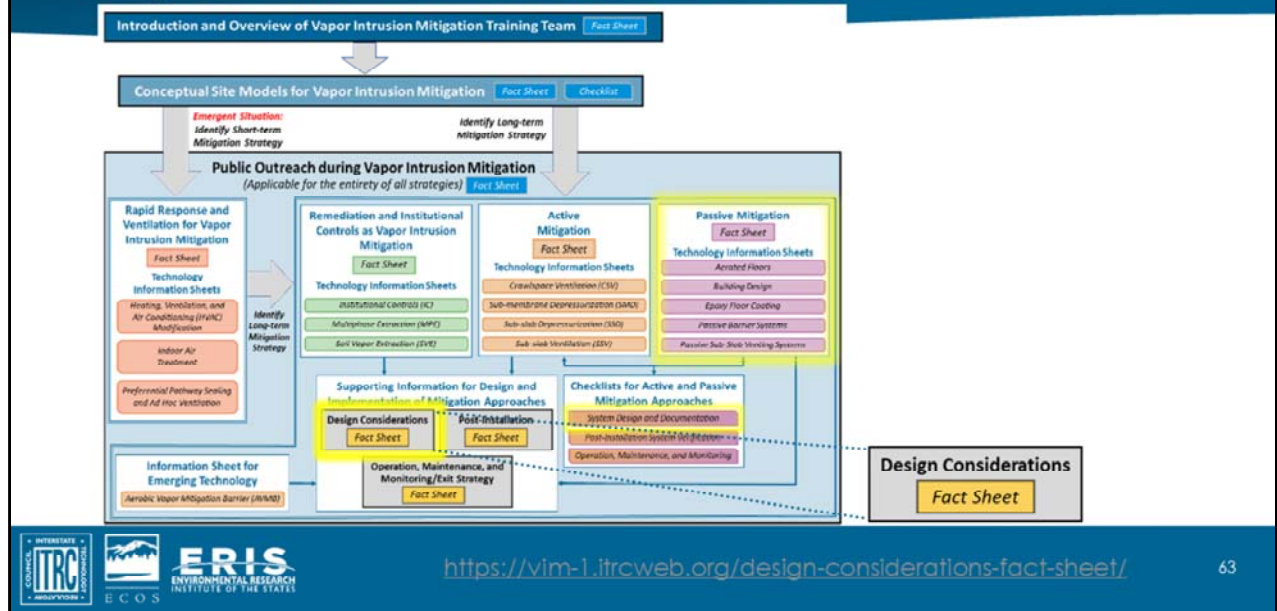
Segue:

- During the second half of this training module, [PRESENTER NAME] will discuss mitigation system design and installation.
- So let's turn things over to [PRESENTER NAME].

----- TRANSITION TO NEXT PRESENTER -----

- Hi, I am [PRESENTER NAME].
- During the second half of this training module.... (I will introduce key considerations for mitigation system design and installation planning and include a discussion of construction quality assurance measures.)
- Now that we've covered the common passive mitigation approaches, let's discuss the mitigation system design process.

Design Considerations Fact Sheet



ITRC created the process fact sheets to summarize the considerations that may need to be incorporated into implementation of a project from design to install to verification to OM&M and finally exit.

The process fact sheets assume you have chosen your technology already (if you haven't, go back to the CSM section) and point out the major considerations for each technology for each step of the way.

Here we will talk about design process considerations for passive mitigation.

The post installation and OM&M will be covered in another module.

Design Considerations Fact Sheet

- ▶ Guide through design considerations
- ▶ Relative importance to passive mitigation

Review the CSM:

- ▶ What are your COCs?
- ▶ How strong is the vapor source?
- ▶ Where is the vapor source located relative to the building?



Source: Pixabay

Vapor Intrusion Mitigation (VIM)

Design Considerations Fact Sheet

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

1 Introduction

Multiple factors affecting the suitability and efficacy of a mitigation system should be considered during the design, review, and approval process, as discussed in this fact sheet. The selected technology should be based on a good understanding of the VI conceptual site model (VI-CSM) (see ITRC [Conceptual Site Models for Vapor Intrusion Mitigation Fact Sheet](#)) and able to meet the remedy objectives pertaining to soil vapor conditions at the site, whether applying an active system, passive system, rapid response, and/or an environmental remediation technology.

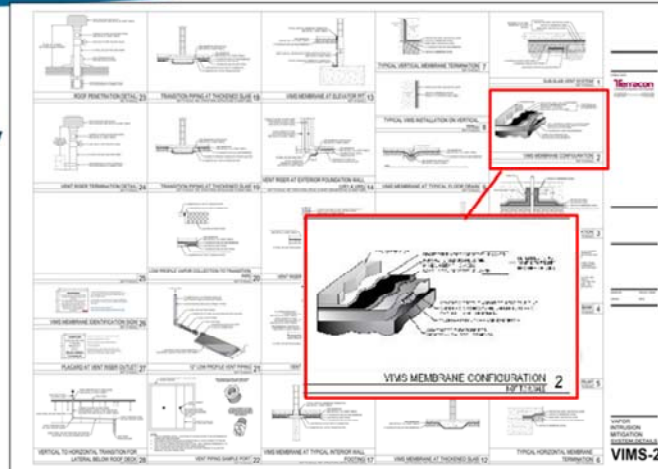
The design process should begin with a non-selection of the VI-CSM elements applicable to mitigation and the remedy objectives, leading to the design basis (i.e., an explanation of how the selected approach and technologies will meet the remedy objectives at the site). In many cases, this review indicates that additional information is needed for design of a specific type of mitigation system; therefore, the need for pre-design investigations and/or testing should be considered. Once sufficient information is available for design, the next consideration is the design itself—the area that requires mitigation along with the system components, installation details, and specifications. Other design considerations include installation and operating permitting requirements, stakeholder requirements and communications, and the need for construction quality control, demonstration of system effectiveness and reliability, and operation, maintenance, and monitoring (OM&M) plans, including an exit or closure strategy.

Table 1-1 identifies the design considerations that are discussed in more detail below and evaluates their typical importance and impact on the design of an active (see ITRC [Active Mitigation Fact Sheet](#)), passive (see ITRC [Passive Mitigation Fact Sheet](#)), system, or an environmental remediation technology (see [Remediation and Remedial Controls on Vapor Intrusion Mitigation Fact Sheet](#)). Note that the importance of any factor can vary depending on site and building-specific

- Establish a basis for design
 - The mitigation system design should include a design basis document that explains how vapor intrusion is occurring (or could occur in new buildings) based on the VI CSM (see ITRC CSM Technology Sheet) and how the mitigation approach and technologies selected will control vapor intrusion sufficiently to meet the mitigation objectives.

Design Considerations Drawings

- ▶ Materials used
- ▶ Layout of system components, including vent, stack, and monitoring points
- ▶ Installation instructions and specifications
- ▶ Performance testing



Source: Terracon Consultants, Inc, 2020. Used with permission.



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- Establish a basis for design:
 - The mitigation system design should include a design basis document that explains how vapor intrusion is occurring (or could occur in new buildings) based on the VI CSM (see ITRC CSM Technology Sheet) and how the mitigation approach and technologies selected will control vapor intrusion sufficiently to meet the mitigation objectives.
- Design Documentation:
 - Mitigation system designs will commonly include one or more layout sheets, that identify and locate system components in relation to the building. Detail drawings should also include how system components will be configured in specific areas; and the components dimensions, materials, and other specifications.
 - For designs with ventilation systems, documentation of vent layout and stack placement is critical to ensuring effluent vapors do not enter adjacent buildings.

Installation Instructions.

Performance Testing

- For example,

- Diffusion Coefficients
 - More nuanced testing methods have been developed to more accurately calculate diffusion coefficients for passive barriers.
 - Diffusion coefficients can be a good indicator of a product's ability to be protective against chemicals of concern and, if available, should be included within the mitigation system design documentation

System Installation Planning

Pre-Construction Meeting

- ▶ Include all persons involved with the installation
- ▶ Include ancillary trades who might impact the performance of the VIMs



□ Pre-Construction and Installation Oversight

- After the vapor mitigation system design has been developed and documented, the engineer of record (or equivalent) should confirm that a preconstruction meeting is planned with all persons involved with the installation of the mitigation system as well as any sub-contractors whose work may affect the performance of the mitigation system during and following the installation process.
- During this meeting, all parties should review the vapor mitigation system installation drawing set to confirm the details shown in the drawings match the project conditions.
 - This allows all contractors to review and confirm aspects of the mitigation system design such as:
 - Substrate specifications
 - Vent layout
 - Locations of vent risers and utility penetrations
 - And allows the general contractor to clarify the construction and installation sequence with all trades
- Frequency and duration of the installation oversight should be specified in the vapor mitigation system plan.
 - Providing oversight prior to, as well as during installation, will increase the likelihood that the system has been installed in accordance with the

system design.

≡

Design Considerations System Verification

- ▶ Incorporate quality assurance & quality control (QA/QC) into design
- ▶ QA/QC sources:
 - ▶ Manufacturer's specifications
 - ▶ Applicable regulations
 - ▶ Site-specific considerations
- ▶ System Verification
 - ▶ Smoke testing/Tracer gas testing
 - ▶ Coupon sampling
 - ▶ Oversight documentation



Source: EPRO Services, Inc, 2020. Used with permission.



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First and foremost, QA/QC procedures should be selected during the design phase of a mitigation system to ensure these procedures will be incorporated during the construction process.

Quality Control:

- Quality control and assurance procedures should be selected during the design phase of a mitigation system to ensure these procedures will be incorporated during the construction process.
- The manufacturer's requirements, regulatory requirements, and site-specific needs should be considered when selecting which system integrity testing methods to utilize.

Common approaches include:

- Smoke or tracer gas testing
- Coupon Sampling

Passive barriers are constructed in the field and applied prior to placing a concrete slab.

Each barrier system should have installation specifications along with quality control procedures to test the integrity of seams, seals around penetrations, system termination points, and overall field membrane integrity.

Design Considerations New Construction vs. Existing Buildings



Source: EPRO Services, Inc, 2020. Used with permission.

◀ High level of control
in New Construction

Must work around
conditions within
Existing Buildings ▶



Source: Contractors Waterproofing, 2021. Used with permission.



Considerations for new vs. existing structures. (Insert chart showing which passive technologies are generally used for each)

- New buildings – Mitigation system design is incorporated during building construction process.
- Existing buildings – Mitigation system design must work around existing building conditions.

Some situations may require rapid mitigation of the vapor intrusion pathway.

Please see **ITRC Rapid Response and Ventilation Fact Sheet** when these situations arise.

Design Considerations - New Construction

- ▶ Building-specific customization of mitigation system
- ▶ Coordination with multiple construction trades required
- ▶ VIMS design drawings aid in successful installation
- ▶ Able to combine mitigation approaches



Source: Kelly Johnson, 2020. Used with permission.

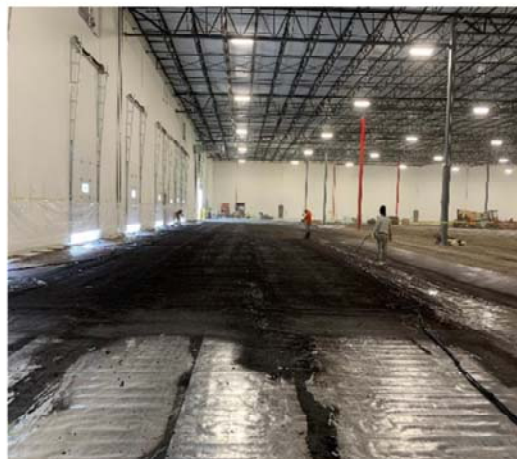
Clean slate provide for proper planning and evaluation of mitigation approaches. Regardless of what type of system is utilized, planning and construction oversight is a very important step in the process and required to assure the systems are installed per design.

The planning and resulting design, should be used to help coordinate with the project team and subsequent trades. This design should become part of the building plans to aid in managing the system in the future.

A key advantage in new construction is the ability to combine multiple mitigation approaches to create redundancy. I.e. venting and barrier. Barrier and building control, etc.

Design Considerations - Existing Buildings

- ▶ Conditions may limit the passive technologies which can be used
- ▶ Foundation can impact system effectiveness
- ▶ Building modification may be necessary to accommodate mitigation system
- ▶ Planning and construction oversight required



Source: Land Science, 2020. Used with permission.



Existing buildings do not provide the flexibility that comes with new construction. This may limit the use of passive mitigation technologies.

The key consideration in incorporating a mitigation system is having an understanding of existing foundation, unless as built drawings exist, it may take time to understand how the building foundation might impact any form of mitigation. Active group provides more details considerations for how to address these conditions.

Buildings may need to be modified, and the implementation of these systems also requires a high level of planning and construction oversight.

Regardless of passive or active, a design should be used to document how these systems are installed.

Knowledge Check

Poll Question

What is the most important element of good design?

- A. Figuring it out as you go
- B. Skipping the CSM
- C. Letting the project team know you want passive mitigation
- D. Proper site evaluation and planning



Image source: Pixabay



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Knowledge Check

What is the most important element of good design?

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- B. Skipping the CSM
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Poll Question



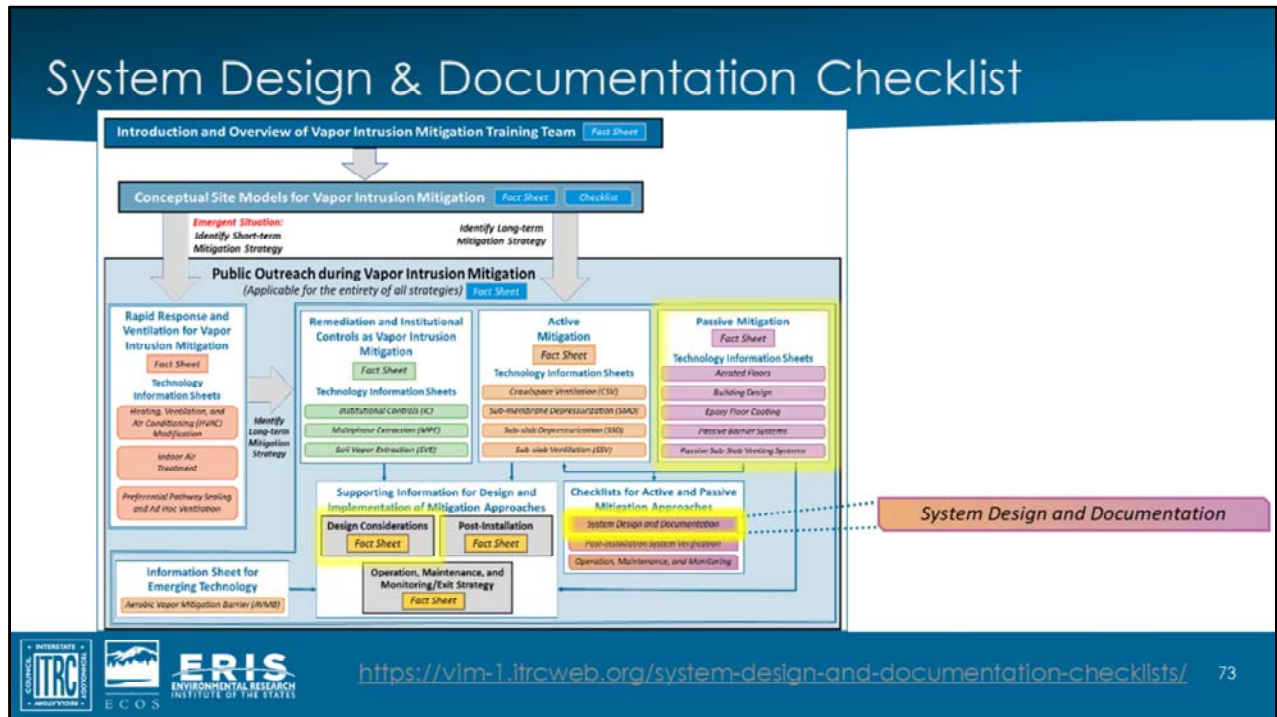
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Clean slate provide for proper planning and evaluation of mitigation approaches. Regardless of what type of system is utilized, planning and construction oversight is a very important step in the process and required to assure the systems are installed per design.

The planning and resulting design, should be used to help coordinate with the project team and subsequent trades. This design should become part of the building plans to aid in managing the system in the future.

A key advantage in new construction is the ability to combine multiple mitigation approaches to create redundancy. i.e. venting and barrier. Barrier and building control, etc.

System Design & Documentation Checklist



System Design and Documentation, more information can be found here. It is designed to prompt users to think about each aspect. Not everything will be applicable to all situations, but it is a great place to start for reviewing the many aspects of passive VI mitigation. The complexity of the site may dictate how applicable the check list is for your site.

Depending on site conditions, it may be appropriate to provide information why certain items are NOT APPLICABLE rather than simply noting they are NOT APPLICABLE

Notes:

- The System Design and Documentation Checklist provides information to proceed though the pre-system installation process.
- The checklist is meant to prompt the user to think about each of these aspects of the system design.
- Not all items will be applicable to all situations.
- Sites with complex CSMs or system designs may utilize the checklist to a greater degree than less complex sites.
- Depending on site conditions, it may be appropriate to provide information why certain items are NOT APPLICABLE rather than simply noting they are NOT APPLICABLE.

Summary

- ▶ Define passive mitigation
- ▶ Major categories of technologies
- ▶ Key elements of system design
- ▶ Importance of Quality Assurance, oversight, and documentation



Source: thenounproject.com.
Used with permission.

So what did we learn during this module?

We covered:

- Why a system would be considered a passive mitigation system (vs an active mitigation system)
- The three major categories of passive mitigation systems
- Considerations for selecting appropriate passive mitigation technologies for new construction vs. existing buildings
- Major components to incorporate into passive mitigation system design, and finally
- The importance of construction quality assurance, installation oversight, and appropriate documentation

Next Steps

- ▶ Passive mitigation system verification
- ▶ Conduct routine OM&M
- ▶ Assess need for continued operation of passive mitigation system
- ▶ Consideration for these steps are covered within another module.



Source: Pixabay.

Subsequent steps covered in other modules



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The next step in the process include:

- Verification that the passive mitigation system is functioning as designed
- Conducting routine Operation, Maintenance, & Monitoring, and
- Assessing the need for continued operation of the passive mitigation system

Consideration for each of these steps are covered within subsequent modules.

Question & Answer Break



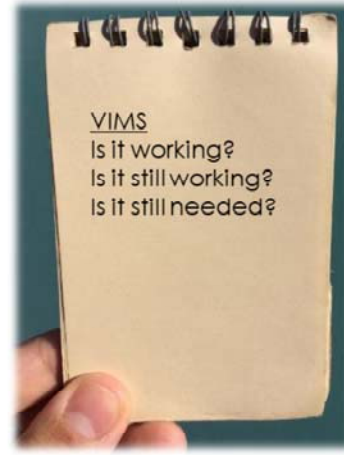
Source: Pixabay

At this time we will open the questions and answers portion of our training.



Advancing
Environmental
Solutions

System Verification, Operation, Maintenance, and Monitoring, and Exit Strategy



Source: Pixabay (adapted)



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E C O S

Objectives of Module

- ▶ How to use the ITRC documents in your work
- ▶ Importance of early communication
- ▶ How to verify VIMS success
- ▶ How to address underperformance
- ▶ Planning for discontinuing a mitigation system



- How to verify VIMS success
- Proper system performance and how to address underperformance
- Significance of early communication and planning for discontinuing a mitigation system
- How to use the ITRC documents in your work

Communicate with your Stakeholders

Concurrence with stakeholders is critical during design:

- ▶ Keep stakeholders informed
- ▶ Confirm acceptable confirmation testing
- ▶ Select appropriate performance metrics
- ▶ Define acceptable scenarios for shutdown



Source: Pixabay

Don't Wait Until
the Last Moment

- You will see this theme repeated during the presentation: communication is key
- Keeping stakeholders informed includes regulators, consultants, property owners/tenants, responsible party
- We will touch on the role of community outreach in a subsequent slide
- We select appropriate performance metrics to establish baseline readings for subsequent OM&M inspections
- We want to communicate/confirm “acceptable scenarios for shutdown”, such as: GW below VI screening levels; soil source removed;

Post-Installation Fact Sheet

- ▶ Key considerations for VIMS verification
- ▶ Multiple technologies
- ▶ During-construction considerations

Vapor Intrusion Mitigation (VIM)

HOME

Post Installation Fact Sheet

ITRC has developed a series of fact sheets that summarize 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.

- Provides key considerations and testing for post-installation VIMS verification
- Covers active, passive, remediation, and rapid response technologies
- Describes elements that should be considered during construction

Verification – Is the VIMS Working?

- ▶ Use building condition survey
- ▶ Confirm VIMS was installed as designed:
 - ▶ Verify installed components
 - ▶ Verify proper operation
- ▶ Adjust as needed



Source: Integral Consulting Inc., 2020.
Used with permission.



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Is the VIMS working?

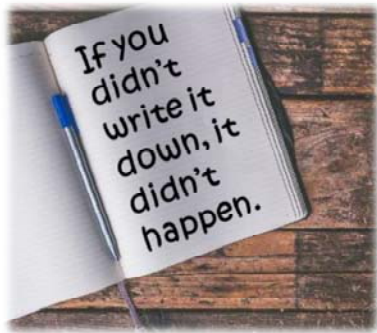
Building Survey / VIMS inspection

- Before beginning or concurrent to confirmation testing, conduct building survey and to inspect your system.
- It's important to evaluate building conditions (both pre-construction and post-construction) to understand how the building conditions may affect your mitigation system. The baseline survey conducted during the design (or pre-design) phase can be compared to the post-installation survey to identify changes that may affect the VIMS.
- For example, poor building foundations, unsealed utility penetrations, or incorrect piping can decrease the effectiveness of the VIMS.

Commissioning

- We tell that a system is working properly by commissioning, which is a series of tests (i.e. multiple forms of verification) to confirm that the system is operating properly and that we are meeting mitigation objectives (e.g., meeting vacuum level criteria for active systems and, ultimately, protecting indoor air quality).
- While not covered in detail in this module, it is important to confirm that the system is operating within the confines of issued permits, building codes, and industry standards. A VIMS can change during construction (from design), and it is important to verify that that the VIMS, once constructed, meets permit requirements and building codes. This should be evaluated as part of the building survey.
- Important to note that different VIMS may have different verification testing and parameters
- Perform a series of testing to verify systems works as designed and meet the agreed minimum requirements
- Adjust VIMS system as needed during construction or during commissioning
- Some system verification details are covered in the passive/active training modules
- More information in the Post-Installation Checklist

Documentation



Source: Pixabay

Critical foundation for future condition evaluation

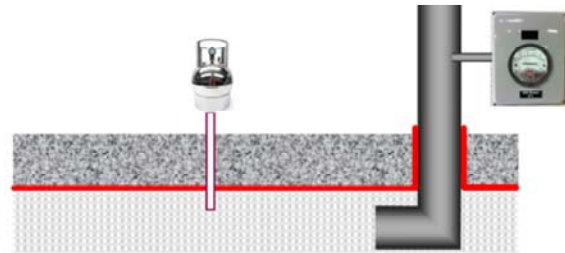
- ▶ As-built drawings
- ▶ Verification performance data

As-built drawings are important to prepare as the constructed system is often different than the design. As-built drawings may also be required for permits.

Verification performance data must be recorded and typically must be submitted to regulatory agencies. Further, it provides a baseline for comparison during the OM&M phase.

Example System Performance Metrics

- ▶ Vacuum field or pressure differential across slab
- ▶ Smoke/tracer gas testing
- ▶ IA/SG Sample results
- ▶ Long-term institutional controls
- ▶ System vacuum and airflow
- ▶ Other system/regulatory-specific metrics



Source: Geosyntec, 2020. Used with permission.

For IBT:

- Here are some example system performance metrics (not all performance metrics will be used at all sites or for all technologies; some of these look familiar because they were covered earlier in this module for active and passive):
 - If rapid response... IA/SG Sample results
 - If remediation... pressure differential across slab
- This is not a definitive list
- See the specific tech sheets for performance metrics specific to your system

For Individual Module:

- Here are some example system performance metrics (not all performance metrics will be used at all sites or for all technologies):
 - If SSD.... Vacuum field or pressure differential across slab; System vacuum and airflow
 - If passive barrier... Smoke/tracer gas testing
 - If rapid response... IA/SG Sample results
 - Active and passive VIMS can both require long-term institutional controls
- This is not a definitive list
- See the specific tech sheets for performance metrics specific to your system

Post-Installation VIMS Verification Checklist

- ▶ Field-ready checklist
 - ▶ Active
 - ▶ Passive
- ▶ Template for state-specific or site-specific needs



Vapor Intrusion Mitigation Training (VIMT)

VAPOR INTRUSION MITIGATION SYSTEM POST-INSTALLATION VERIFICATION CHECKLIST

The purpose of this checklist is to provide the user with a selection of tools to verify that the appropriate system components for the vapor intrusion mitigation system (VIMS) were installed and the system is operating as designed. This information applies to the four most common active mitigation systems (SSD, SSV, SMD, and CSV) and passive systems that are described in the associated Fact Sheets and Technology Information Sheets. The user of this checklist should review the VIMS design or as-built documentation prior to completing this checklist.

This document was prepared in consideration of multiple types of VIMS. Not all the information presented below is necessary to document system operation for all types of systems on all types of buildings. The user should be able to identify which criteria below best represent effective operation for their specific mitigation system and which criteria will validate the conceptual site model for the VIMS that was implemented. Timing on when to collect post-installation verification data may vary and more than one event may be reasonable. See the *Post-Installation Verification Fact Sheet* for additional information on timing a post-installation verification site visit.

Instructions for Use: Major system components are grouped below for this checklist, and one or more of these groups may not apply to a particular VIMS design. Those groups can be marked as Not Applicable by selecting the 'X' box to the right of the group.

Design elements within these groups that **will** apply should be selected appropriately using the dropdown boxes included for this checklist as:

Yes—the design element was considered and documented

No—this item was not considered and may be relevant to the overall system performance, applicable guidance, and/or best practices

NA—not applicable to the system design or operation



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<https://vim-1.itrcweb.org/post-installation-system-verification-checklist/>

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We can't stress documentation enough.

Knowledge Check

When is it most important to develop verification procedures and an exit strategy?

- ▶ During VI investigation
- ▶ During mitigation design and planning
- ▶ At the time of mitigation implementation
- ▶ After construction
- ▶ Never



Source: Pixabay

Knowledge Check

When is it most important to develop verification procedures and an exit strategy?

- ▶ During VI investigation
- During mitigation design and planning
- ▶ At the time of mitigation implementation
- ▶ After construction
- ▶ Never



Poll Question



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OM&M/Exit Strategy Fact Sheet

- ▶ Strategy for ongoing, acceptable performance
- ▶ Framework for exit strategy
- ▶ Early stakeholder engagement

Vapor Intrusion Mitigation (VIM)

HOME

Operation, Maintenance, and Monitoring Process/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 2.5 of in the [2014 ITRC Petroleum Vapor Intrusion \(PVI\) Assessment \(ITRC-2014-1\)](#). 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 commissioning compared to performance during system commissioning, and to inspect and report 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 CDM



<https://vim-1.itrcweb.org/operation-maintenance-and-monitoring-process-exit-strategy-fact-sheet/>

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OM&M/Exit Strategy Fact Sheet

- Provides a strategy to confirm ongoing, acceptable VIMS performance as designed
- Presents a framework for exit strategy development
- Advocates for early stakeholder engagement of VIMS termination criteria and actions
- There may be additional state-specific and system-specific requirements

OM&M – Is the VIMS Still Working?

- ▶ Determine if VIMS continues to meet performance metrics
- ▶ Analyze the cause of malfunction and implement corrective action
- ▶ Inform stakeholders if VIMS is not meeting performance metrics
- ▶ Assess results for potential to terminate VIMS



Figure 5 of the Sub-slab Depressurization Technology Information Sheet

Is the VIMS continuing to meet performance metrics?

Use the OM&M checklist to assist with periodic system inspection and to measure operational parameters

Evaluate performance and potential for implementing exit strategy

What if the VIMS is not meeting performance metrics?

Analyze data for cause of VIMS malfunction

Inform stakeholders

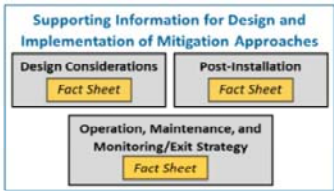
Repair/replace malfunctioning equipment, if applicable

Manage changes in site or building conditions, as applicable

Consider upgrading system or installing additional VIMS

Assess the OM&M results to see if you have a potential for terminating the VIMS

Process Fact Sheet Rating System



Ratings provided by mitigation "type"

Category
Principal consideration
Subject matter

	Active approaches	Passive approaches	Remediation	Rapid response
Design consideration				
<i>VT CSM considerations</i>				
<i>Vapor source and concentration</i>				
Vapor source and concentration	●	●	●	●
<i>Geology and hydrogeology</i>				
Subgrade soil type	●	●	●	●
Depth to groundwater/high water conditions	●	●	●	●

Key | High impact ● | Medium impact ● | Low impact ● | Not applicable —



<1st click: Harvey ball key>

Process Fact Sheet Narrative

Supporting Information for Design and Implementation of Mitigation Approaches

Design Considerations [Fact Sheet](#)

Post-Installation [Fact Sheet](#)

Operation, Maintenance, and Monitoring/Exit Strategy [Fact Sheet](#)

Design consideration	Active approaches	Passive approaches	Remediation	Rapid response
<i>V/C/S/M considerations</i>				
<i>Vapor source and concentration</i>				
Vapor source and concentration	●	●	●	●
<i>Geology and hydrogeology</i>				
Subgrade soil type	●	●	●	●
Depth to groundwater/high water conditions	●	●	●	●

Key | High impact ● | Medium impact ● | Low impact ● | Not applicable —

Subgrade Soil Type: In most cases, the properties of soils immediately adjacent to the building (e.g., below the slab or next to foundation walls and footings) have the greatest impact on active mitigation technologies that require the movement of air and/or the propagation of vacuum below the slab. Soil type plays a major consideration for active mitigation strategies and makes some remediation technologies difficult to implement. For a more detailed description of methods to test and mathematically model the sub-slab permeability and transmissivity see (McAlary et al., 2018 *). See Section 1.2.5 of [Appendix C in the 2014 ITRC PVI document \(ITRC, 2014 *\)](#) for more information on the consideration of soil type in active mitigation.

Active Mitigation	High Impact: Permeability of the sub-slab fill material and underlying soil controls the pressure field extension (PFE) and air flow rates and, therefore, the degree to which sub-slab depressurization (SSD) and sub-slab ventilation (SSV) contribute to indoor air quality protection. This affects the spacing of suction points and fan size required to induce and maintain the negative pressure field beneath the structure.
Passive Mitigation	Low Impact: Passive mitigation systems typically incorporate a permeable layer beneath barriers and around vent piping in new construction. It may not be feasible to incorporate a permeable layer beneath an existing building. Therefore, passive venting systems function best in soils that are highly permeable when retrofitting an existing building.
Environmental Remediation Technology	High Impact: Remediation technologies require the characterization of soils beyond the subsurface to evaluate the effectiveness of the proposed technology. MPE and SVE are generally not applicable to low permeability soils.
Rapid Response	Low Impact: Rapid responses typically include ventilation changes, indoor air treatment, or other efforts that are focused inside the building, therefore sub-slab conditions are not relevant.



<1st click: Subgrade soil type detail appears>

Checklists

Conceptual Site Models for Vapor Intrusion Mitigation

Fact Sheet

Checklist

Checklists for Active and Passive Mitigation Approaches

System Design and Documentation

Post-Installation System Verification

Operation, Maintenance, and Monitoring

Category

Primary prompt

Prompt to record supporting information

Conditional (secondary) prompt

Clickable Check Boxes

3. BUILDING CONDITIONS AND USE

3.1. Is the building's heating system or heating, ventilating, and air conditioning (HVAC) system operating? Yes No NA

If yes, provide a summary below and explain in Section 5 if the HVAC system operation could impact the effectiveness of the mitigation system.

Hours/day of HVAC operation 12

Climate controlled? Yes No NA

3.1.1. Is the building's heating system or HVAC system on during this OM&M event? Yes No NA

3.1.2. Is the building's heating system or HVAC system equipped with outside dampers? Yes No NA

If yes, how many? _____ % opened _____

Editable Fields

<clicks walk through checklist steps>

OM&M Checklist

- ▶ Field-ready checklist for continuing verification
 - ▶ Active
 - ▶ Passive
 - ▶ Remediation
- ▶ Template for state-specific or site-specific needs



Vapor Intrusion Mitigation Training (VIMT)

VAPOR INTRUSION MITIGATION SYSTEM OPERATION, MONITORING, AND MAINTENANCE CHECKLIST

Scope of Checklist: The purpose of this checklist is to guide the user during the inspection of a vapor intrusion mitigation system (VIMS) to (1) verify that the VIMS is operating as designed and (2) determine if certain operation, maintenance, and monitoring (OM&M) activities are necessary for continued operation and effectiveness of the system. This checklist is intended to provide factors to consider when documenting that the VIMS is operating and is effectively mitigating the vapor intrusion pathway during the lifecycle of its operation. Not all the information presented below is necessary to document system operation for all types of systems on all types of buildings, and some items may not be needed during every monitoring event. The user should be able to identify which criteria below best represent effective operation and responsible maintenance of their specific VIMS and if the conceptual site model (under which the system was designed) is still valid.

Prior to completing the inspection, it is recommended that the user review previously prepared OM&M plans. As-built drawings and performance (baseline) criteria are needed when conducting inspections of a VIMS. Monitoring scope, schedule, and methods may follow applicable agency requirements, which may be amended on a case-by-case basis through regulatory negotiation and approval. Where applicable, the monitoring and inspections must also comply with standards of practice and applicable codes (electrical code, building code).

In some situations, OM&M plans may not exist or be available or were not provided to a new operator or new building owner. Thus, the original as-built drawings and possibly the original performance criteria may not be known. In these cases, the checklist below can still be used to assist in developing the appropriate ongoing OM&M parameters for that particular site, although additional effort may be appropriate depending on the complexity of the building and site conditions.



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- Field-ready checklist for active, passive, and remediation system continuing operation verification
- Users can modify the checklist to meet state-specific or site-specific needs

System Shutdown – Is the VIMS Still Needed?

- ▶ Plan for the exit early in the VIMS process
- ▶ Continually evaluate VIMS for meeting exit conditions
- ▶ Specify the VIMS shut-down process



Source: Pixabay

Exit Strategy

- Plan for this upfront: Refer to the Active & Passive Mitigation Modules for a discussion of the Design Process Fact Sheet and its role in Planning
- All stakeholders should agree on post-installation, monitoring, and termination procedures as part of the original design process.

Continually evaluate VIMS for meeting exit conditions

- Evaluate shutdown parameters during OM&M events
- Assess if shutdown criteria is met after significant site condition changes (e.g., remediation)

Specify the VIMS shut-down process

- How will the system be decommissioned?
- May be specified in a regulatory document
- We understand that, for some sites, these systems will never be shut down

Knowledge Check

Which is the most important post-installation verification measure?

- ▶ Vacuum field or pressure differential across slab
- ▶ Smoke/tracer gas testing
- ▶ IA/SG sample results
- ▶ Long-term institution controls
- ▶ System vacuum and airflow
- ▶ It depends



Source: Pixabay

Poll Question



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Knowledge Check

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Poll Question



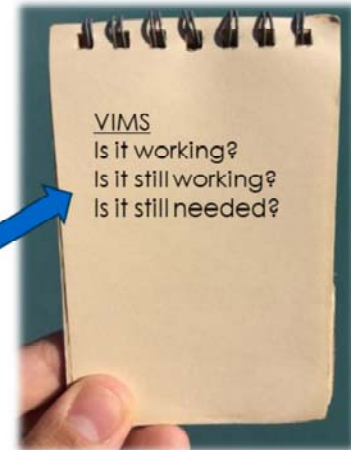
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It depends... on the system and regulatory requirements

Summary

- ▶ Early planning for verification, OM&M, and exit strategy is critical
- ▶ ITRC provides comprehensive planning and delivery tools (fact sheets and field checklists) covering multiple technologies
- ▶ Keep in mind the three essential questions



Source: Pixabay (adapted)



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In this training module, we discussed the key concepts from the Post-Installation and OM&M Process/Exit Strategy Fact Sheets and Checklists:

- We stressed planning / Exit Strategy development up front and continuing through post-installation and OM&M
 - Begin with the end in mind
- Commissioning
 - We discussed confirming that the VIMS is operating as intended and meeting mitigation objectives using multiple forms of validation (testing)
- Monitoring
 - We discussed continually evaluating if the VIMS is operating as intended and determining when the exit strategy can be implemented
- Exit Strategy
 - As part of monitoring, ask yourself if you've reached the point of turning off or discontinuing monitoring of the VIMS
 - If needed, reevaluate the exit strategy with stakeholders.

Consider the three simple questions

Is it working (after installation)?

Is it still working during OM&M?

Is it still needed? (Exit strategy)

Thank you for attending!

Questions

- ▶ Email further questions on today's session to:
training@itrcweb.org
- ▶ Feedback Form & Certificate of Completion:
<https://clu-in.org/conf/itrc/VIM-1/feedback.cfm>
- ▶ Vapor Intrusion Mitigation Training:
<https://clu-in.org/conf/itrc/vim-1>



Source: Pixabay



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We would like to hear back from you today so please be sure to fill out the online feedback form that's linked on this last slide. You can also access the feedback form by clicking Feedback in the related links section and then clicking browse to. Filling out the feedback form and certifying that you participated will allow you to receive a certificate of completion.

If you need further clarification on the answers or would like to ask more questions, feel free to email us at training@itrcweb.org and we will follow up with our trainers to get your questions answered. Or you are welcome to follow up with our trainers directly.

Special thanks to our participants today. We appreciate you taking the time out of your busy schedules to join us today. Thank you to our expert trainers for being here today and for their contribution to the ITRC document.

As a reminder, ITRC archives all its training classes, so if you find that you have additional time or looking for additional training opportunities, please visit Clu-In and the archived trainings to see if there are other courses that might interest you.