INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

# Vapor Mitigation Systems

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**Notice**
The Technology Evaluation Group (TEG) completed this evaluation of vapor mitigation systems based on professional expertise and review of items listed in the "References" section of this document. The criteria for performing the evaluation are generally described in the IDEM OLQ technical memorandum, *Submittal Guidance for Evaluation of Remediation Technologies*.

This evaluation does not approve these technologies nor does it verify their effectiveness in conditions not identified here. Mention of trade names or commercial products does not constitute endorsement or recommendation by the IDEM for use.

**Background and Technology Description**
Several technologies can reduce indoor air concentrations and/or control completed vapor intrusion (VI) pathways. The appropriate technology depends on the vapor source pathway, building construction, nature of the source, and indoor air contaminant concentrations. In Indiana, confirmatory sampling is the primary method for assessing a mitigation system's effectiveness; however, the following information is useful in determining if a mitigation technique is likely to be effective for a given situation. The chosen technology should be appropriate and amenable to performance parameters associated with long-term monitoring until the VI pathway is no longer complete.

This document describes five mitigation techniques, active depressurization or venting systems, passive venting systems, indoor air cleaners, building pressurization/HVAC modifications and sealants/barriers. For each mitigation technique, this document provides references and briefly discusses design criteria which could be expected to be in a work plan and suggests performance monitoring criteria for each type that would fit into IDEM's Vapor Remedy Selection and Implementation Draft Interim Guidance (VRSI) document; the VRSI guidance is being incorporated into IDEM's Closure Guide which will go through IDEM's non-rule policy development process.

This document provides a general overview of the technologies. For more specific discussions please see the AARST/ANSI soil gas mitigation series and the ITRC Vapor Mitigation series (draft, release date late 2020) included in the reference section. Appendix A includes a description of items which might be included in a mitigation system's long-term operations, monitoring and maintenance plan. Appendix B is an example monitoring form. Appendix C describes alternate investigation/mitigation techniques for preferential pathways which would not be mitigated via the technologies in the main body of this document.

**Active Mitigation Description**

Active mitigation refers to using mechanical (electrically powered) means to prevent soil gas entry into a building. Multiple active technologies exist including sub-slab depressurization system (SSDS), sub membrane depressurization (SMD), crawl space (CSV) venting, sub-slab venting (SSV) and others. A thorough description of each of these is provided in the ITRC Vapor Mitigation Technology sheets. Active sub-slab depressurization is the most common type of system. A brief description follows.

Active depressurization systems work by creating a pressure barrier which keeps sub-surface air from flowing through a building slab or membrane beneath the structure. Depressurization systems do not treat contamination instead, they rely on the pressure barrier to keep the source from reaching receptors. A separate Soil Vapor Extraction (SVE) system (or other remediation) should be used if source reduction is desired. Depressurization systems have a consistently successful track record of mitigating vapor intrusion into structures. Several implementations of active SSDSs are in use including Suction Point SSDS (mainly for post construction), Vented Pipe or mat SSDS (mainly for new structures), crawl space SMDS (sub membrane depressurization system) and Vented Floor Systems.

In existing structures, a sump suction point SSDS is the most commonly used system. Sump collection points are installed through the slab into the base layer beneath the slab. The sump is usually around twelve inches deep, depending on the granular material beneath the slab and a vacuum is applied by manifolding the suction points to a fan which vents to the atmosphere. If the base layer is crushed gravel or other material it is likely to be significantly more permeable than native soil and will require fewer suction pits to be effective. Buildings built directly on native soil will require more points to develop a pressure barrier across the slab. Well-designed systems should have pressure monitoring points that allow verification of vacuum across the entire slab. Pressure monitoring points can also serve as permanent monitoring points for collection of sub-slab samples; temporary monitoring points may be acceptable also.

For new construction, a permeable layer allowing gas transport beneath a slab is included in the design. Many options exist including vented pipe SSDS consisting of a series of vented or perforated horizontal pipes embedded in a permeable base layer beneath a structure. The pipes are sized based on square footage and required airflow then manifolded through a plenum box to a riser pipe through which suction is applied. Another common option is vapor mats which replace all or some of the traditional sand and gravel sub-slab base with a geo-composite vapor transmission mat directly beneath the slab. Vapor mats are geotextile mat with channels allowing airflow incorporated. The mats are rolled across the sub-surface prior to pouring the slab and have the compressive strength to keep the air channels intact as the slab is poured. Multiple new construction active SSDSs are successfully mitigating vapor intrusion in Indiana.

Another variation for new construction is Aerated or Vented Floors. Several methods are available to create easily vented voids either embedded in the slab or directly beneath the slab. This can be accomplished using concrete formed systems (example Cupolex®) where concrete is poured over vented domes creating voids in the slab. The easily vented layers allow for smaller fans to be used while still accomplishing venting across the entire slab and may even allow eliminating the fan (see passive systems below).

A more complete description of the available active mitigation technologies is available in ITRC Vapor Mitigation (draft ITRC, 2020).

**Active Mitigation Selection and Implementation**

As discussed above, active mitigation component selection will differ for existing structures compared to new structures where the mitigation is included in the design. Most existing houses need only one or two suction pits to establish a satisfactory vacuum while larger commercial structures will likely need multiple pits, particularly if footers beneath the slab impede the pressure field development. Because of this, for new construction of large commercial structures, vented pipe/mat SSDS or vented floors are generally a better choice than sumps because it is easier to obtain uniform propagation of the vacuum across the entire slab and because they are more easily optimized for greater efficiency and could possibly be converted to a passive system if desired. Existing structures with multiple foundation types (e.g. crawl space, slab on grade) will require more than one mitigation technique. Since active systems pull soil gas through the structure, the fan needs to be placed in an unoccupied (e.g. attic) location or outside of the structure so that contaminants don't leak into occupied spaces if the fan housing fails. An SSDS will not mitigate indoor air contamination from preferential pathways or ambient air.

EPA recommends a minimum vacuum of 4-10 Pascal (EPA, 2008), but field implementations indicate this is likely the high end (Broadhead et al, 2010). ANSI/AARST (2017) recommends 1 Pascal as a design recommendation but indicates vacuum should be monitored during expected worst case conditions and the minimum applied vacuum to maintain the vacuum beneath the entire slab used. Excessive vacuum may pull contamination towards the structure and would require more energy (cost) to run the fan. Slab openings which inhibit vacuum propagation should be identified with a smoke test while a vacuum is applied and then sealed to reduce the energy required to form an adequate pressure field. The ANSI/AARST standards listed in the reference section provide expertise and standards for multiple types of active mitigation systems. ITRC's (2020) vapor mitigation documents also provide suggested details which should be provided for installation of each specific type of active mitigation system.

IDEM's VRSI specifically addresses long term monitoring of active SSDS systems. As indicated by VRSI, long term indoor air sampling is requested to continue to confirm system performance. VRSI's continued indoor air monitoring schedule is congruent with ANSI/AARST SGM-SF-2017. System proposals should include an operations and maintenance schedule including items identified in Appendix A of this document.

Telemetry monitoring systems are a relatively new advancement for monitoring at vapor mitigation sites. Programmable controllers are attached to pressure gauges across the slab or other system components and remotely notify responsible personnel when a negative pressure does not exist across the slab, a system component fails to function or if the mitigation or telemetry system otherwise fails. These systems reduce reliance on building inhabitants and infrequent monitoring to ensure that systems are working properly. Telemetry systems may be considered, particularly when vapor intrusion risks are substantial.

**Passive Venting Systems**

Passive venting systems generally have the same components as active systems but they do not have fans. The goal of the system is to passively vent contaminant vapors accumulating beneath the slab by rerouting them to the atmosphere. Thermal and atmospheric effects induce upward convection of air through the riser venting system. They may induce a small vacuum to the sub-slab but airflow to dilute the concentration beneath the slab is the primary mitigation mechanism. Additional convection occurs when the indoor air is at a higher temperature than the outdoor air. As no mechanical venting component is included, a substantial permeable layer engineered for airflow and sealing floor cracks and other pathways is extremely important. A best management practice is installing passive systems in conjunction with a physical barrier or coating as described below.  Passive systems are most appropriate for new construction where a sufficiently permeable layer and venting network are included in building design. Wind driven ventilators may increase passive system airflow, but this has not been proven likely. More details are provided in ITRC's  Passive Sub-Slab Venting Technology Information Sheet (2020).

**Passive System Implementation**

Passive venting systems are generally only appropriate for lower risk VI sites as the venting is likely transient (Ash et al, 2010). Confirmatory sampling for passive systems should be considered in both summer and winter conditions as they are likely to be less efficient in warmer conditions. If appropriately designed, passive venting systems may be converted to active with the addition of a fan; this contingency is a smart best management practice to include with any passive system proposal in case confirmatory sampling shows further mitigation is necessary. Conversely, if the risk of vapor intrusion is reduced through attenuation or remediation, eliminating an active system's fan may create a passive system if the subsurface is sufficiently permeable and an adequate venting network is present. Vacuum monitoring points installed across the slab may show an intermittent vacuum, but airflow measurements or other performance metrics should be proposed to show system performance. If a system is needed to mitigate vapor intrusion, indoor air testing will be necessary to confirm system performance. While VRSI specifically addresses active systems, the indoor air monitoring requirements provide a starting point for passive systems. Since passive systems are intermittent, more stringent long-term indoor air confirmation sampling schedules may be considered.

**Indoor Air Cleaners Description**

Indoor air cleaners rely on a filter to trap contaminants. Both whole house HVAC filters and portable stand-alone units which can be placed in areas of interest have been used.

If an HVAC filter is used, the fan needs to run continuously in order to constantly circulate air through the filter; the HVAC specifications need to be such that the HVAC is able to operate with the added pressure across the filter without mechanical failure.

Stand alone filter units rely on air circulation to clean the area where they are located. Closed doors and other circulation obstructions limit their effectiveness. Indoor air cleaners are easily installed and can have an immediate impact on indoor air. They may be a good solution either when concentrations are high enough to warrant immediate action or if there are problems in determining the VI pathway and an interim solution is needed before a permanent mitigation system is designed. They may be useful for unconventional indoor air issues such as dry cleaners where chlorinated hydrocarbons have either saturated the environment or are still in use and ambient air is causing issues.

Indoor air cleaning filters are usually carbon based. Filters are available at industrial supply stores. Ozone generators are generally not recommended and EPA research indicates they are not effective at reducing VOCs. (EPA, 2009). There is currently not a formal standard measurement for the effectiveness of gaseous contaminant filters for removing VOCs; performance measures based on contaminant removal and breakthrough time are being developed (NIST, 2008; Sideswharen et al, 2011).

**Indoor Air Cleaners Technology Selection and Implementation**

Indoor Air Cleaners provide no barrier or reduction of vapor intrusion into the home. These systems rely purely on indoor air circulation and filter capacity to remove contaminants once they have entered the structure. Portable cleaners rely on open doors and airflow to all affected areas. HVAC professionals should be consulted on the effect the increased filter resistance may have on HVAC systems. The only mechanism to assure air cleaners are working is indoor air testing. Use of indoor air cleaners as a long-term solution would be complicated by cost and maintenance issues associated with frequent filter changes. The contaminant is still present in the filter and may desorb if the filter is saturated and also may complicate indoor air testing when the filter is changed; in some cases it may be easier to replace the unit and change the filter offsite. Currently, indoor air cleaners are most appropriate as an interim measure. ITRC (2020) has a more comprehensive description of the use of indoor air cleaner as an immediate response action. Regular long-term monitoring should follow confirmatory testing to ensure that filters maintain concentrations at or below acceptable levels over appropriate time frames.

**Building Pressurization/Air Exchange Rate HVAC Modifications Description**

HVAC modifications may sometimes be used to address vapor intrusion. One type of HVAC modification attempts to pressurize the structure relative to the vapor source (usually the sub-surface) so that vapors do not move into the building. In some cases, only the vapor entry points (for example the basement) are pressurized. Open doors, windows, etc. make pressurization difficult to maintain. Cracks, sumps and any openings need to be sealed. Older structures may not be airtight enough to maintain pressurization.  This method is more appropriate for characterizing vapor intrusion than mitigation; monitoring indoor air concentrations as the building is alternately pressurized and depressurized (using fans and HVAC) can provide information on vapor pathways

(MacGregor et al, 2011). Some commercial HVAC systems may be amenable to this approach with appropriate indoor air confirmatory monitoring in place.

A different modification is to run the HVAC with an increase in ambient (clean) air so that the air exchange rate within the structure is increased to the point that the vapor intrusion flux into the building no longer causes exposure levels to be exceeded. This may cause the building to be pressurized, but pressurization is not the goal; increased air exchange is the goal. Commercial facilities are more likely than residences to have HVAC systems amenable to this mitigation approach. This is not a green technology as substantial energy and associated costs are needed to condition the additional outside air and run the system continuously.

**Building Pressurization/Air Exchange Rate HVAC Modifications Technology Selection and Implementation**

Building pressurization techniques require confirmation that the building is pressurized at the point of vapor entry. Measuring the pressure differential across the slab in conjunction with HVAC operational metrics and confirmatory indoor air testing allows use of the HVAC metrics as long term monitoring confirmation (similar to using vacuum measurements for SSDS) to show that the system is working between indoor air sampling events.

When implementing air exchange HVAC modifications, keep in mind that the calculated air exchange rate is a theoretical calculation which assumes complete mixing of the air in the structure; in actuality, incomplete mixing will cause the air exchange rate to vary throughout the structure. Care needs to be taken that the necessary exchange rate is being achieved where receptors are present, for example office areas, break rooms etc. The 'true' air exchange rate can only be measured with a tracer gas as described in MacGregor, 2011. However, if confirmatory indoor air sampling is conducted at a known HVAC air influent rate as measured by an anemometer or pressure gauge installed on the HVAC system, the air flow or pressure could be monitored between indoor air sampling events to see if the airflow rate is continuously maintained as a long term performance metric. Frequent indoor air monitoring is necessary to confirm the continued effectiveness of these systems. ITRC (draft 2020) provides a more complete description of building HVAC modifications for vapor intrusion mitigation.

**Vapor Barriers and Sealants Description**

Vapor barriers usually are VOC resistant geo-membranes installed below the slab in new construction. VI mitigation barriers should not be confused with common construction moisture barriers which are not VOC resistant. Some spray or paint-on technologies have also been used in existing structures. See ITRC 2020 for a more complete description of the available technologies. Vapor barriers and sealants are a great way to seal a structure for a more efficient depressurization or venting system. Vapor barriers and sealants are most appropriately installed in conjunction with a permeable venting/depressurization layer. Barriers are not a suitable stand-alone remedy for most sites.

**Vapor Barriers and Sealants Implementation**

While vapor barriers and sealants provide a physical barrier similar to the vacuum barrier provided by an SSDS, there is not a continual metric to confirm the barriers continued presence or effectiveness as there is with an SSDS pressure gauge. Smoke tests and other measures during installation are needed to confirm their likely effectiveness. ITRC 2020 provides a robust description of installation requirements. A physical barrier's effectiveness as a mitigation measure requires ensuring that the barrier remains intact through construction, as the building settles post construction and if subsequent remodeling occurs. Frequent inspections and long-term indoor air monitoring are needed to confirm the barriers continued effectiveness.

### Risk Communication

Effective risk communication plays a vital role in successful vapor mitigation outcomes. Most people are unfamiliar with vapor intrusion and helping people understand their risks and how mitigation will affect them is everyone's responsibility from the regulator to the installer. Being proactive in communication will help build the cooperation and trust needed to gain access to drive projects towards completion and ensure public health and the environment remain protected.  ITRC 2020 has a vapor mitigation risk communication fact sheet covering many of the issues and things to be aware of that anyone involved in vapor mitigation should consider.

## CONCLUSIONS

Vapor intrusion mitigation is a rapidly evolving field with new tools constantly being introduced. Active depressurization systems are the most proven long-term mitigation system for sub-surface vapor intrusion. Passive systems are an energy efficient option which may be appropriate in some cases. Indoor air cleaners can immediately reduce indoor air impacts and may be useful as an immediate response for preferential pathway mitigation. HVAC modifications are possible long-term solutions but monitoring similar to depressurization systems must be included to verify that they continually work. Sealants and barriers are excellent supplemental technologies but their use as a stand along remedy is not advisable since they require frequent inspection and long-term indoor air monitoring.

### Further Information

If you have any additional information regarding vapor intrusion mitigation technology or any questions about the evaluation, please contact the Office of Land Quality, Science Services Branch at (317) 232-3215.  This technical guidance document will be updated periodically or when new information is acquired.

References;

**ANSI/AARST SGM-SF-2017**; 2017;– **Soil Gas Mitigation Standards for Existing Homes; available at standards.aarst.org.**

**ANSI/AARST RMS-MF-2018 Radon Mitigation Standards for Multifamily Buildings available at standards.aarst.org**

ANSI/AARST RMS-LB-2018 Radon Mitigation Standards for Schools and Large Buildings available at **standards.aarst.org**

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https://www.in.gov/idem/cleanups/files/remediation_tech_guidance_vapor_remedy_selection.pdf

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https://iavi.rti.org/attachments/WorkshopsAndConferences/12_McAlary_IAVI_3-10-11.pdf

NAVFAC Naval Facilities Engineering Command; Vapor Intrusion Mitigation in Construction of New Buildings Fact Sheet; available online at: https://clu-in.org/download/contaminantfocus/vi/vi_mit_new_bldg_fs.pdf

NIST (National Institute of Standards and Technology), 2008; Standards Development for Gas Phase Air Cleaning Equipment in Buildings; NISTIR7525; available online at:
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## Appendix A
## Long Term Operations, Maintenance and Monitoring Plan Components

Routine indoor air monitoring and system operation and maintenance inspections are necessary until the system is no longer needed. VI remediation work plans should include a site-specific Operation Maintenance and Monitoring (OM&M) plan. Keep a copy of the OM&M plan at a location specified in the plan. OM&M plans should include:

**Background**:
The background section should give a brief site history including a summary of vapor intrusion sampling data, why the mitigation system was the chosen remedy and, if available, confirmatory mitigation system sampling results. This section should clearly note if the system was installed due to confirmed vapor intrusion or if it is pre-emptive mitigation. The party responsible for maintaining the system should be identified.

**Indoor Air Monitoring Plan:**
Specify the frequency of indoor air monitoring. Describe sampling procedures and locations. Include, if possible, the proposed years for indoor air monitoring.

**System Design/Installation:**
Include a description of the system components, a system diagram, if possible, and the location where any system manuals will be kept. Include either within the report or as an addendum, system installation summary and any problems encountered.

**System Monitoring:**
IDEM's Vapor Remedy Selection and Implementation Draft Interim Guidance Document (VRSI) allows indoor air sampling on a less frequent basis as long as system performance is verified on an annual basis (Table 3, IDEM's VRSI). As described in VRSI, the OM&M plan specifies which performance metric will be used as verification. For depressurization systems, the metric is likely pressure measurement across the slab. For HVAC modifications, a gauge will likely need to be installed on the system to provide a similar metric as described above.

Section 3.2 of IDEM's VRSI recommends yearly visual inspection of the mitigation system, documentation of the gauge measurement and a determination of whether alterations or augmentations are needed. The OM&M plan specifies the personnel who will perform inspections and what qualifications or training they will have and may include a component checklist indicating monitoring frequency and the location of forms containing recorded monitoring data. Field data describing the system monitoring events as well as system component pressure monitoring data is recorded.

It would be helpful if the system monitoring event form also included:

**General Information:**

- Contact Information for the party responsible for issues found during the inspection
- Monitoring Date and Time
- Property Address
- Tenant's Name

- Owner’s Name and Address
- Inspector’s Name
- Inspector’s Company
- Weather conditions
- Is the HVAC operating?

**Visual Inspections**:

- Is fan intact and operational?
- Is the fan making any unusual noises or vibrations?
- Is the riser piping intact?
- Does the system still appear to be sealed?
- Do the suction points appear sealed?

**Comments:**
Record any comments about the inspection. If relevant, document conversations with the tenant or owner indicating if the tenant noticed any system changes. Note whether the fan was turned off for any period of time or if any changes were made to the structure. Note any changes in measurements at each system component and describe any actions taken.

Record monitoring data for each component in a manner that any changes in measurements are easily recognized. Record the baseline measurement associated with system confirmatory sampling. Appendix B is a sample monitoring form.

**System Maintenance:**
The OM&M plan should specify procedures and time frames for maintenance and monitoring issues associated with the system. For example, if the fan or other system component quits working, the plan should specify who is responsible for fixing it and the time frame allowed for investigation and repairs. As indicated above, the responsible party contact information should be clearly identified on the monitoring forms.

**System Termination:**
Site specific mitigation system termination procedures should be outlined in the OM&M plan in accordance with IDEM’s VRSI Section 4.0.

## Appendix B: Sample System Component Monitoring Form

| | System Manometer | Monitoring Point 1 | Monitoring Point 2 |
|---|---|---|---|
| Location | | | |
| Baseline Reading | | | |
| Monitoring Date | | | |
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Significant Changes in monitoring data should be reported to:

**Appendix C**
**Sewers**
**Preferential Pathway Identification & Mitigation**

Although sewers have long been suspected of containing chlorinated solvents, they have only recently begun to be addressed as a vapor intrusion issue. EPA, 2015 acknowledges that vapor intrusion issues can arise from within sewers but provides little guidance on investigation or mitigation. This appendix will attempt to provide guidance on investigations to determine if sewer gases are a source at a particular site and describe some mitigative techniques which may be useful. McHugh et al (2018a and b) provide substantially more detail on investigation and mitigation of sewer systems as vapor mitigation preferential pathways.

## INVESTIGATION

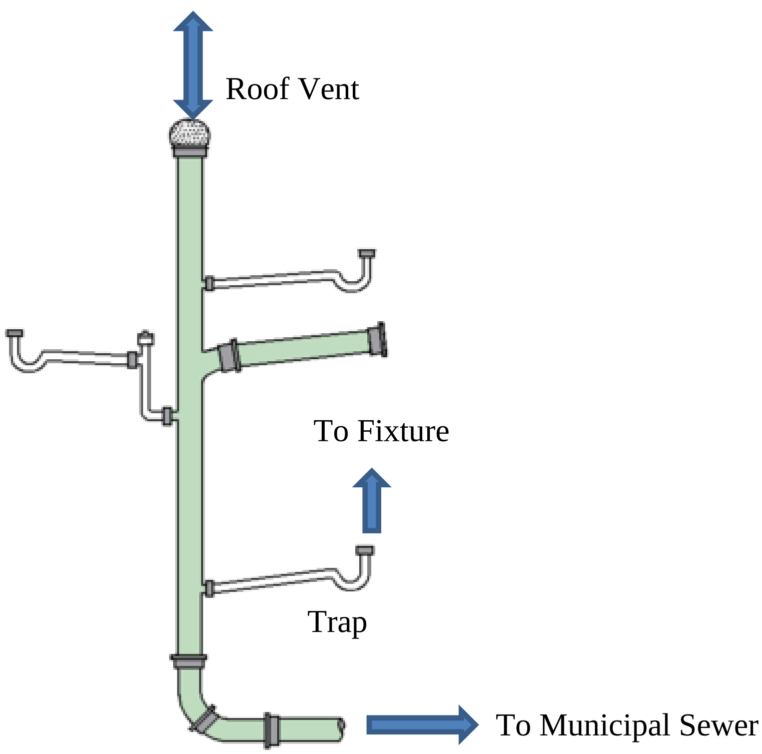


Diagram 1. Sewer waste vent system diagram. (Creative Commons license at: https://en.wikipedia.org/wiki/Drain-waste-vent_system#/media/File:SoilStack.PNG)

**A brief explanation of sewers:**
Household sewer systems rely on gravity to drain wastewater to the municipal sewer. Sewers are filled with odorous gases in addition to potential contaminants of concern that could cause odor issues in houses. Traps are u-shaped pipes which should continually remain filled with water to seal out sewer gases (Diagram 1). Individual fixtures have traps and often a 'whole house' trap is located near the entry point.

However, not all houses will have the ‘whole house’ trap and sometimes fixtures either do not have a trap or the trap is not functioning due to age of the plumbing or disrepair.

When present, traps function to keep sewer gases out of the house because the retained water acts as a pipe seal. In addition, the entire system needs to be vented to the atmosphere to provide a source of ambient pressure to keep the system flowing. A roof vent pipe extends from the entry through the roof (Diagram 1). Air will flow both ways in the vent pipe depending on what is happening in the system. When water drains through the system, air is pulled into the vent system to avoid vapor lock. When water is not flowing, gases would exhaust through the pipe; therefore, air is flowing out the pipe.

The system is designed to be watertight, but joints are not necessarily vapor tight and any contaminants of concern within the sewer may leak out at any joint or break in the vent pipe. This Appendix addresses these indoor entry points. In addition, sewer gases can potentially contaminate the sub-slab or crawl space if leaks in the system occur at those points.  Traditional crawl space or sub slab depressurization mitigation systems discussed earlier would mitigate these instances.

**Lines of evidence that sewer gas may be causing VI issues:**
Determining if sewers are causing indoor air issues is difficult because dramatic fluctuations in concentrations within the sewer would be expected as the sewers operate. A common misconception is that homeowners would smell sewer gases if vapor intrusion were an issue but the low health protective concentration of several VOC’s would cause them to be an issue at infiltration rates which will not cause sewer gas odor issues (Pennell, 2013).

**Portable VOC detectors**:
Indoor air anomalies such as higher concentrations on higher floors may be a sign of sewer vapor intrusion but indoor air sources would cause these same issues and need to be ruled out. A portable VOC monitor may assist in determining where indoor air VOC’s are the highest (ESTCP, 2013). Higher concentrations in vicinity of the sewer system (e.g. drains, sinks etc.) may indicate sewer gas vapor intrusion rather than indoor air sources. Concentrations would need to be confirmed with traditional sampling for use in risk-based data evaluations.

**Sewer Video:**
Sewer videos by reputable companies may be capable of determining locations of current and historic laterals, joints and other features.  Historic sewer and sewer lateral locations are important because they may provide migration pathways if they are in the vicinity of the source and were not sealed when abandoned. Additionally, the type and condition of the sewer are lines of evidence that they may be allowing infiltration of contaminated groundwater causing subsequent indoor air vapor intrusion issues.

**Sewer VOC Testing:**
The presence of contaminants of concern within the sewer conduit is a line of evidence that the potential for sewer vapor intrusion exists. Vapor concentrations within a sewer may be expected to be extremely high if contaminated water is present as there is

nothing to attenuate the expected vapor pressure concentrations. The vapors may either leak into the sub slab/ crawl space or into some point of the structure where breaks in the system exist. Representative reproducible sampling methods in sewer conduits are not currently well defined. Sample data will not be quantitative but instead will be a qualitative line of evidence that contaminants are present and sewer leaks may be causing VI issues. Sampling may be conducted with a canister or adsorbent sampling device. Humidity and other environmental factors can dramatically affect sorbent samplers. Suppliers should be consulted for the appropriate sampling device which will be less affected by humidity and other environmental factors. Currently, no universally accepted screening attenuation factors exist for sewer samples. McHugh, 2018a cites 0.03 as a conservative starting point.

**Controlled pressure testing methods:**
Controlled pressure testing methods are time consuming and can be expensive but could aid in a preferential pathway determination (Guo et al, 2013). Basically, a fan system is used to either blow air into the house (pressurize/ minimize sub slab intrusion) or pull air out of the house (vacuum/ maximize sub slab intrusion) while contaminant concentrations are measured. Trends opposite from what would be expected indicate alternate pathways.

**Sewer Smoke Test:**
A smoke test by a licensed plumber can identify locations where gases may be escaping sewer piping. An artificial smoke generator is attached to the roof vent (Figure 1). Smoke can be visually observed at leaks in the system (Figure 2).


Figure 1. Compressor and smoke generator with attachment going to the roof vent.

Figure 2. Visual observation of smoke at a potential sewer gas leak.

**Mitigation Options:**
Mitigation options for the inside the sewer preferential pathway will be structure specific and generally consist of limiting gas infiltration through p-traps and drain traps and limiting leaks from joints and other places where a smoke test or indoor air detector has indicated possible leaks. Rerouting or venting the sewer may be an option in extreme cases. In all cases, if contaminants are inside the sewer, sub slab samples should be considered to assess whether sewer leaks have contaminated the sub slab. Table 6-13 in McHugh 2018 provides a brief description and references for sewer mitigation techniques. A brief description of two common mitigation techniques follows.

**P-Traps:**
Properly functioning p-traps provide a water seal to stop sewer gases/contaminants from entering the house and therefore mitigate vapor intrusion from the sewers. Older traps may be made of cast iron which may corrode until no longer watertight. Plumbing renovations may use the trap access for other purposes or drains may be used so infrequently that the traps become dry allowing gas intrusion. Trap primers, low vapor pressure trap filling liquid or a homeowner maintenance routine that includes periodically dumping a little water down the drain may stop vapor intrusion due to dry traps. Several floor drains are available that allow the drain to function when necessary but provide a seal when not actively draining (http://proventsystems.com/trap-guard-floor-drain-csi-specifications/ , http://www.rectorseal.com/sureseal-plus/). Fixtures and drains that are no longer used should be removed and/or sealed to prevent vapor intrusion. A whole house trap, often part of the sewer cleanout, would seal sewer gases at the point of sewer entry and may help alleviate vapor intrusion issues from breaks or leaks in the system that individual fixture traps would not help. A licensed plumber is needed to determine if traps are present and functioning to stop sewer gas intrusion.

**Fix Improper/Broken Plumbing:**
If a smoke detector or portable VOC meter detects leaking points in the system, a licensed plumber may be able to fix the issue and mitigate the vapor intrusion from that location. Older homes with remodeled plumbing may have multiple oddities making them susceptible, for example, a HVAC drain plumbed directly into the sewer,

cleanouts converted to drains which eliminates the whole house trap, absent p-traps, breaks in the vent line etc. Fixing these issues may help alleviate vapor intrusion issues.

**Conclusions:**

Sewers may need to be investigated to effectively mitigate structures. Current methods are not reliably quantitative to measure COC's concentrations within sewers and sewer to indoor air attenuation factors do not exist. Sewers have caused documented indoor air exceedances due to release chemicals in the sewer and lines of evidence can be made that the sewer is causing indoor air exceedances. If sewer gas entry into the house happens at some point in the sewer vent system, ensuring proper plumbing including functional p-traps and drain caps may provide a relatively inexpensive but effective mitigation. Additionally, if the sewer is a source, sub-slab samples should be taken to confirm that the sewer has not caused subsequent contamination of the sub-slab.

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ITRC Vapor Mitigation coming soon- documents will be available here:
https://www.itrcweb.org/Team/Public?teamID=85

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