Vapor Intrusion Mitigation

Let Me Count the Ways

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"Help! I have a VI problem!"

Industry's increased focus on vapor intrusion has escalated to the point where we as environmental professionals receive calls weekly from clients asking, "Help! I have a vapor intrusion (VI) problem, can you tell me how much it is going to cost to fix it?" To answer that question more intelligently, we queried vapor intrusion practitioners across TRC to determine if we could provide a representative range of costs. Perhaps not surprising, the answer is – costs can vary significantly.

The mitigation of VI concerns, like many other segments of the environmental industry, is maturing rapidly. New technologies are emerging, offering multiple methods of mitigating indoor air inhalation risks and meeting the ever increasingly stringent screening levels. With these new approaches and the maturity in the industry, unit costs for installation are decreasing. However, selecting the proper mitigation for both new construction and building retrofits can be daunting to property owners and responsible parties. Technologies and installation costs range widely, depending upon the contaminant and the building construction. Mitigation of chlorinated compounds is especially difficult, given their recalcitrant nature in the environment.

Vapor Intrusion Mitigation Options

There is no "one size fits all" approach to vapor intrusion mitigation. Different classes of chemical compounds have vastly different volatilization potentials, and the difficulty accounting for these characteristics is sometimes compounded when more than one type is present. Chlorinated compounds often have very low regulatory thresholds, as discussed on the new U.S. EPA's updated *Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway From Subsurface Vapor Sources to Indoor Air* (OSWER 9200.0-154, June 2015). Mitigating these compounds requires a method that will be dependable for the long term.

Available mitigation methods and systems are both active and passive, supporting new construction and retrofits of existing buildings, including:

1) Ventilation;
2) Pressurization/ depressurization; and
3) Source control/ removal.

The table on page 3 presents a broad range of vapor intrusion mitigation methods that are well established in the industry and cover a breadth of applications. Source remediation is also a valid approach, but often not viable due to time restrictions, costs, and construction deadlines to meet market demands (i.e., new buildings) or the inability to access the source location without extensive intrusion and potential loss of rental revenue (i.e., existing buildings).

Ventilation methods can be active or passive. Passive venting involves the installation of sub-slab piping connected to risers that run through the building structure, venting to the atmosphere above the roofline. The stacks are usually constructed with wind-driven turbines. Active systems add fans to this construction to pull the vapors from beneath the slab and vent them at the stack. Active ventilation methods can also be as simple as installing additional fans to the building HVAC system and increasing the building's air exchange rate. This approach can be made more effective by sealing foundation cracks and openings.

Table 1. Vapor Intrusion Mitigation Method Matrix

Technology/Material*	Description	Costs [1] [2]		
		Engineering [3]	Install [4]	O&M
HVAC Adjustment	Actively manage existing building HVAC by creating slightly positive interior pressures. Limited application; typically low risk, petroleum only (non-chlorinated releases). Slight pressure increase can be uncomfortable to some occupants.	$5,000 - 10,000	$0 [5]	$200-1,000+/yr. [6]
Sub-Slab Depressurization (SSDS)	Retrofit existing buildings using sumps and/or sub-floor collection piping with active venting (i.e., fan) system. Similar to radon collection system used in residential construction.	$10-100,000 [7]	$1-70/sq.ft.	$250-1,000/yr. for power; $500 - 1,000/yr. for 1-2 yrs. for verification of efficacy.
Venting	Passive and active sub-slab venting in new or existing construction. Typically only used alone and/or passively on lower-risk, petroleum release locations. Does not include porous, sub-slab bedding material (i.e., gravel layer).	$5,000 - 10,000 [7]	$0.50-1.50/lft.	$100-500/yr. [8]
Spray-On Vapor Barrier	Thickness determined relative to contaminant concentrations; typically minimum of 60 mil. Often combined with underlying passive venting to create redundant system.	$10,000 - 20,000 [7]	$2-5/sq.ft.	$5,000-10,000 [9]
Field Constructed Barrier	HDPE, PVC, or other field-constructed polymeric liner system. New construction only. Material can provide greater strength and durability, but process is labor intensive.	$10,000 - 30,000 [10]	$5-10/sq.ft.	$0
Specialty & Multi-Purposes	Some materials can provide multiple protections (e.g., waterproofing and vapor intrusion) concurrently in new construction.	$30-60,000 [11]	$8-16/sq.ft. [12]	$0
Low Porosity Sealant	Low porosity, chemical resistant coatings (e.g., polyurethane and other) of interior floor surfaces; typically used on existing buildings.	$5,000 - $15,000	$3-7/sq. ft. [13]	$0 [14]

TABLE 1 FOOTNOTES

(1) - based on 10,000 sq. ft. commercial/industrial structure.

(2) - Unit costs decrease for larger buildings, but are also affected by geographic location and building construction in case of retrofits.

(3) - includes permitting & engineering; varies by State regulatory program. Does not include extents of contamination investigation.

(4) - contractor costs

(5) - assumes existing system capable of continuously providing pressure.

(6) - increased utility cost above normal operation expense. Dependent upon actual building size and zones being mitigated.

(7) - includes design, pilot testing, and/or structural engineering & architecture.

(8) - utility costs for active system with fan.

(9) - 1-2 yrs. post installation verification monitoring.

(10) - includes design and field installation oversight & QA/QC.

(11) - includes on-site installation inspection and verification. Additional engineering, such as architectural and structural, may be required to integrate into building foundation.

(12) - includes flashing and Waterstop joint compound.

(13) - cost ranges based thickness based on chemical of concern and anticipated wear, and on addition of surface grit for traction.

(14) - occasional resurfacing may be necessary, depending on surface use and wear.

Pressurization/depressurization methods involve preventing vapor intrusion through active methods that prevent impacted soil gas from entering the structure. Using the building's HVAC system, whether as-is or enhanced to increase air flow beyond normal ranges to create a pressure barrier, requires routine monitoring and maintenance. There is also an increased utility expense – much more than that for just ventilation.

Sub-slab depressurization systems are often deployed in existing structures by installing collection sumps equipped with extraction fans. These systems actually reduce the pressure beneath a building floor slab, creating a pressure barrier to the interior air space. The volatile vapor enters the piping and sumps, and is then discharged by the fan to the outside atmosphere. The fans, the same as those used on household radon systems, use very little electricity (a single fan typically costs $100-200 per year to operate).

Source control methods include one popular approach for new construction today: vapor barriers. Spray-on methods, the thicknesses of which are adjusted for the particular contaminant and concentrations, can be adapted to a variety of foundation designs and easily installed, are common. When vapor barriers are equipped with an underlying passive venting layer (which can be converted to active, if needed), a robust and redundant system is created at a relatively affordable price. Covering of interior floor spaces with a low-permeability coating material can be done from inside an existing building without the need for costly floor removal or modifications to install collection piping networks or sub-slab vapor barriers.

The Question of Cost

Once the investigation and conceptual site model are complete, it is time to select a mitigation approach that works for the site conditions and expected site use(s). Costs of implementation and subsequent costs for O&M

are of paramount concern to the building developers and owners – this is the tangible number they can relate to their construction and operation budgets. But the vapor mitigation system should also be viewed as an asset. If the mitigation system is correctly installed and properly maintained, you can alleviate any concerns about using the building throughout the mitigation system's expected lifetime.

The summary mitigation methods table includes price ranges for a variety of active and passive vapor intrusion mitigation methods and materials, subdivided by Engineering (e.g., plan development and regulatory negotiations), Installation (actual construction costs), and Operations & Maintenance (O&M; e.g., post-installation verification testing and increased utility expenses) costs.

Building size, geographic location (e.g., impacts on contractor pricing, building codes, etc.), accessibility to the building (e.g., is it occupied), and building construction (e.g., can vertical risers be easily installed) all impact pricing.

As shown on the table, unit prices can range from less than $1 per square foot (/sq.ft.) for simple ventilation approaches to as much as $70/sq.ft. for sites with significant access issues and higher construction labor costs. Installation in the Midwest and Southeast is typically less expensive than in major metropolitan locations in the Northeast and West Coast. Retrofitting existing buildings is the most difficult to price, because the cost is impacted by factors beyond the technologies related to the contaminant type. Existing building construction can also require additional engineering / architectural service needs, as well as modifications to the building construction itself, to meet vapor intrusion mitigation metrics.

Doing More For Less

Vapor intrusion mitigation can be complicated for projects where building structures extend below grade into the groundwater. Not only does the vapor phase protection standard need to be met above the water line, but the waterproofing component must prevent water intrusion and stand up to long-term exposure to the contaminants in groundwater.

New materials combining construction applications, such as vapor intrusion protection and water proofing, have been entering the market in recent years. These products are more expensive per square foot when evaluated individually, but when compared to the two individual materials/technologies they can offset, expenditures for the combined material can be a cost-effective approach that meets all technical goals while remaining on budget. In addition, the use of such dual-role materials can decrease overall time to construction, and decrease the number of foundation construction steps required.

Beyond the use of institutional controls (ICs) to prohibit construction over areas of vapor intrusion concern, backing up engineering controls with ICs is one way to secure long-term risk abatement. ICs, such as administrative and legal controls, can be employed as interim response mechanisms to prevent VI concerns until longer-term response activities have sufficiently reduced contaminant source concentrations. However, time is of the essence to keep buildings habitable so that businesses can continue operation, or to facilitate a property transfer.

ICs can also be prepared to require ongoing operation, maintenance and monitoring (OM&M) of VI mitigation systems. These OM&M ICs extend beyond the original responsible party into perpetuity, and can, in part, place responsibility on the property owner and operator regardless of property transfer. ICs can also require additional assessment and/or remediation in the event of future construction in areas of unacceptable VI risk.

Certain exposures can also be limited, such as restricting the type of land use to industrial, potentially decreasing the level of VI mitigation required to ensure site conditions do not present an unacceptable risk to human health and safety. This use of an IC may allow a property to continue to be beneficially utilized and profitable while cleanup continues.

Recommendations for a Successful Project

The details make the difference when developing vapor intrusion mitigation strategies, whether for new or existing construction. Building owners, operators and others responsible for indoor air inhalation safety are urged to follow these suggestions:

1. Retain an environmental consultant experienced in the selection and implementation of multiple forms of vapor intrusion mitigation.
2. Prepare a comprehensive conceptual site model to provide a complete understanding of site conditions.
3. Start planning early, especially for new construction – integration of vapor mitigation into a building can affect engineering and architectural design, as well impact the construction schedule.
4. Consider a redundant system – mitigation costs are typically a small percentage of the overall development investment, so a backup system may be warranted (especially for residential use). Retrofits for failed systems are much more expensive when considering the impacts to occupancy revenue and risks to the owner's reputation.
5. Make sure that the expected performance standards of the selected method are clearly defined and demonstrable through direct measurement (which can include construction QA/QC) or testing. The frequency and duration of this verification O&M should also be agreed upon in advance, and should have a definable completion date if the performance standards are met.
6. Complete all post-installation verification testing and reporting required to close out any regulatory requirements with regulators.

Companies have more flexibility than ever before to manage indoor air inhalation concerns in an effective and affordable manner, and TRC's vapor intrusion professionals are ready to provide assistance with evaluations and developing a proactive approach. Please review the following recent project examples for more information:

- Design of a Sub-Slab Depressurization System
- Vapor Intrusion Evaluation and Mitigation
- Soil Vapor/Indoor Air Investigation, Mitigation, and Monitoring
- Enhanced Reductive Dechlorination

References

EPA, 2008. Engineering Issue – Indoor Air Vapor

Intrusion Mitigation Approaches.
EPA, 2015a. OSWER Publication 9200.2-154 Technical Guide For Assessing and Mitigating The Vapor Intrusion Pathway From Subsurface Vapor Sources To Indoor Air.
EPA, 2015b. OSWER EPA-510-R-15-001 Technical Guide For Addressing Petroleum Vapor Intrusion At Leaking Underground Storage Tank Sites.

About the Authors

Graham Crockford, Michigan ECR Practice Lead and Senior Client Service Manager – Graham has 25 years of professional experience in the fields of consulting, environmental engineering, geology, and hydrogeology, including 20 years of consulting experience. He currently serves as TRC's Office Practice Lead for the Ann Arbor and Grand Rapids Michigan offices. He also serves as a Client Services Manager/Project Manager for TRC's utility and industrial clients. TRC provides Energy, Infrastructure and Environmental consulting/engineering, and construction management services.

Graham has extensive experience in RCRA, CERCLA and state-specific regulatory programs throughout the US. He has assisted clients in compliance audits, strategic due diligence, sustainable remediation, petroleum hydrocarbon and chlorinated solvent investigation and remediation, MGP investigation and remediation, soil/groundwater investigations, vapor intrusion assessment and mitigation, groundwater monitoring programs, enhanced reductive dechlorination (ERD), permeable reactive barriers (PRBs), in situ chemical oxidation (ISCO), in situ thermal desorption (ISTD), phytoremediation, and groundwater containment/treatment. Graham provides technical/strategic leadership in assessment and mitigation of the Vapor Intrusion pathway at TRC. Graham also provides litigation support (expert and fact witness) to clients.

Doug Kilmer, P.G., Client Service Manager and Senior Project Manager – Doug has over 23 years of professional experience representing stakeholders' technical, logistical and financial interests for the utility, manufacturing, petroleum distribution, real estate development and industrial sectors. He is an expert in site characterization, legacy site and remedial risk management, and Brownfield redevelopment. Doug's expertise includes regulatory interaction, peer review, work plan preparation and implementation, and contractor supervision. He is adept at defining and characterizing hydrogeologic systems and remediating a variety of environmental contamination, and has worked at impacted sites across the U.S.

Doug has completed numerous vapor intrusion evaluations, investigations and mitigation designs in support of brownfield redevelopment for residential, commercial and mixed use properties. His investigation and remediation experience has addressed VI concerns related to crude and refined petroleum, chlorinated solvent and manufactured gas plant releases. Many of these projects were conducted supporting mergers, acquisitions, and divestitures or legacy site management.

Darby Litz, E.I.T. and L.P.G., Project Environmental Scientist – Darby has over 9 years professional hydrogeology and engineering consulting experience. Darby has contributed to the successful implementation and completion of multiple investigation and remediation projects related to the delineation and cleanup of impacted soil, sediment, groundwater, surface water and indoor air. Her projects have included the evaluation and design of numerous groundwater, soil and indoor air remediation activities. Darby is also adept at performing statistical analyses of solid waste facility groundwater monitoring data.

Darby is also experienced in the evaluation of *in situ* remediation treatments for multiple contaminant types. She was key in developing the Corrective Measures Implementation (CMI) plan using soil mixing, ISCO, dechlorination amendment injections and thermal desorption to address chlorinated volatile organic compound concerns at an automotive parts manufacturer regulated under RCRA. Darby has also developed, implemented and managed the use of monitored natural attenuation for various contaminants of concern. Among her many roles, Darby is the Quality Coordinator for Michigan Operations and also serves on TRC's Standard Operating Procedures Quality Work Group.

Stacy Metz, P.E., Project Environmental Engineer – Stacy has 8 years of professional environmental engineering experience. Since joining TRC in 2007, Stacy has worked on numerous environmental projects, including characterization and remediation of contaminated commercial, industrial and landfill properties. Her responsibilities have included: environmental site assessments; development of project plans and specifications; project coordination; implementation of field investigation, monitoring, and remediation activities; risk assessment; report writing; and project permitting. Stacy has significant experience with the design, installation and evaluation of vapor mitigation systems, including residential sub-slab depressurization/ventilation systems and soil vapor extraction systems. She has also evaluated and developed site-specific risk-based screening levels for vapor intrusion. Stacy is TRC's Michigan expert on vapor intrusion issues, providing critical review of the USEPA VI guidance, assisting in the preparation of a paper regarding short-term exposure to TCE in indoor air, and providing technical support for the development of internal SOPs for VI investigation.