CONCEPTUAL SITE MODELS FOR VAPOR INTRUSION MITIGATION FACT SHEET

Introduction

This fact sheet describes the importance of understanding the vapor intrusion (VI) pathway and how it can be modified by various mitigation technologies to reduce indoor air concentrations and provides information needed to evaluate VI mitigation alternatives by enhancing the VI conceptual site model (CSM).

The value of a CSM when evaluating the potential for VI is well established in Chapter 4 of this guidance document and other resources (ITRC 2003; USEPA 2012). The VI CSM provides a general overview of the VI pathway, including the locations and types of vapor sources, subsurface vapor transport mechanisms, foundation and other building conditions affecting the rate of vapor entry, and receptors that could be impacted by VI. The VI CSM helps the practitioner evaluate the potential for a complete VI pathway, identify data gaps, and communicate findings and conclusions to other stakeholders.

Nevertheless, a VI CSM adequate for evaluating the potential for VI might not provide enough information to select an appropriate mitigation approach. For example, more detailed information related to slab and sub-slab conditions might be required to evaluate the efficacy of sub-slab depressurization or sub-slab ventilation. Similarly, more detailed information related to building conditions might be required to evaluate the efficacy of mitigation that relies on increasing building air exchange rates and/or interior pressure levels. In some cases, more information may be required about the nature of preferential pathways to evaluate mitigation options. Because CSMs are evolving documents, this additional information should be used to enhance the VI CSM to better evaluate and select an appropriate vapor control strategy for the site.

This fact sheet introduces two tools to help enhance the VI CSM for mitigation decision-making purposes. The first is a checklist to help identify information that might be needed to enhance the VI CSM for evaluation of mitigation alternatives. The second is a conceptual flowchart illustrating various VI pathways to help identify strategies that could be employed to control these pathways that are consistent with the VI CSM.

Information Needed to Evaluate Mitigation Alternatives

As discussed above, the information needed to evaluate the potential for VI might not be sufficient to evaluate mitigation alternatives. This fact sheet is supported by a Vapor Intrusion Mitigation Conceptual Site Model Checklist of information that may be beneficial to enhance the VI CSM for the purposes of evaluating mitigation alternatives.

Checklist to Enhance the Vapor Intrusion Conceptual Site Model for Evaluation of Mitigation Strategies

This checklist assumes that VI site characterization has been completed and the user has reviewed the existing CSM, confirmed key components, and determined that VI mitigation is necessary. A CSM checklist for VI site characterization is available from the Association of Vapor Intrusion Professionals (AVIP 2024). The purpose of the Vapor Intrusion Mitigation Conceptual Site Model Checklist is to further develop and emphasize the key considerations of the VI CSM as they relate to mitigation and to identify and characterize site and building conditions as necessary for evaluation of VI mitigation alternatives.

This checklist is a tool to guide mitigation planning and facilitate communication among interested parties. The checklist can be used in various ways. For example, it can be used as a framework for enhancing the VI CSM to include mitigation considerations. It can also be completed by the preparer of the mitigation plan, or used by the reviewer of this plan, to document information contained in mitigation plans and reports. The checklist is organized with mitigation goals at the beginning to help the user focus on site features that are relevant to development of a mitigation plan to meet those objectives. For example, a detailed building-specific evaluation may not be needed if the mitigation goals and subsurface conditions indicate that the VI mitigation effort should be focused on the source area for the chemicals of concern (COC) or pathway outside of the building envelope.

How Mitigation Technologies Modify the vapor Intrusion Pathway

The objective of vapor control is to reduce indoor air concentrations of VI-related COCs, below applicable action or screening levels. This requires modification of the VI pathway to reduce the mass flux of COCs entering the building and/or to reduce indoor air COC concentrations by removal or dilution.

As indicated on **Figure 1**, measures that can be used to control VI can be applied at different points along the VI pathway to accomplish these goals. Understanding how a mitigation technology is modifying the VI pathway helps us understand (1) whether the technology is compatible with the site conditions and stakeholder objectives (e.g., cost, timeliness, sustainability, etc.), and (2) what information is needed to evaluate the performance of the system over the short and long terms.

Figure 1 presents a flowchart that may be used as a tool to guide the user in selecting appropriate exposure scenarios based on information identified in the checklist. The flowchart may also be used in the evaluation of mitigation/remediation alternatives. Note that the flowchart starts at the bottom of the page, and then moves up, mirroring the upward migration of VI. Users should start at the bottom and work upward.

The approach recommended for completing this flowchart is as follows:

- Characterize the chemical types, site sources, and relevant exposure pathways using the data and information summarized from the checklist and associated supporting site information to customize the flowchart for the site.
  - Check the small checkboxes for every relevant identified source, transport mechanism, and exposure pathway.
- Identify and characterize the relevant indoor air receptor(s) and indoor air criteria.
  - Consider land use restrictions and surrounding land use when making this selection, if there are no receptors present, or likely to be present, or if institutional controls prevent exposure from occurring and are likely to stay in place.
- Identify potential mitigation/remediation measures (shown as valve symbols) that will break the lines linking sources, transport mechanisms, and pathways leading to the indoor air receptors. If there are no connected lines and no data gaps limiting the reliability of the VI CSM, there is no exposure and no mitigation measures are required.
  - Select mitigation/remediation measures (shown as valve symbols) that will break the lines linking sources, transport mechanisms, and pathways leading to the indoor air receptor(s).
  - Adjust the mix of mitigation/remediation measures until no potential exposure routes remain.
  - Graphically illustrate the most likely mitigation/remediation measure(s) selected for the site by marking the appropriate valve symbols on the flowchart and recording and detailing the selected action on the right-hand side of the flowchart.

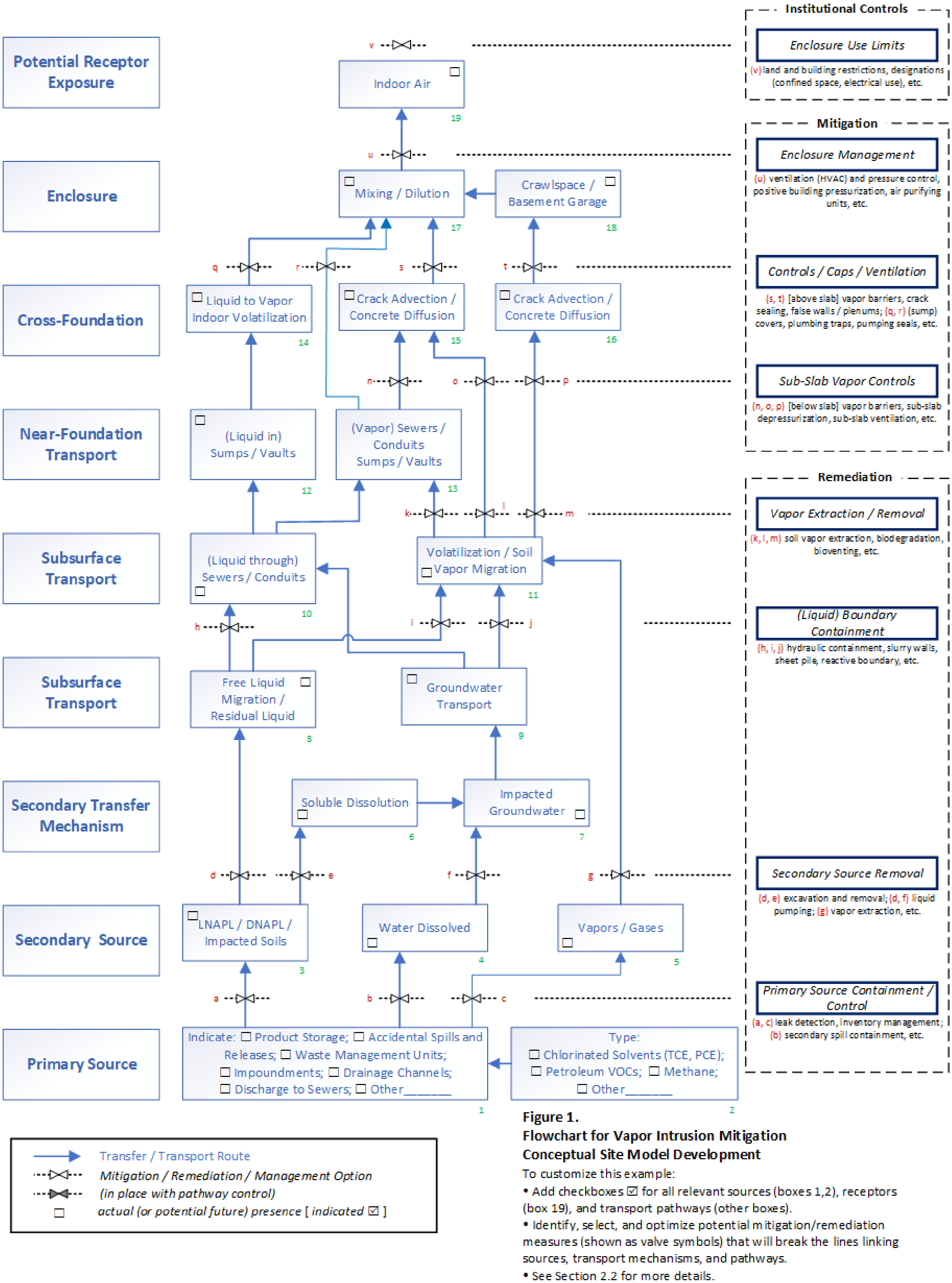

Figure 1. Flowchart for Vapor Intrusion Mitigation Conceptual Site Model Development.

More specific descriptions for the steps in **Figure 1** are provided below. **Figure 1** is a guide, may not be applicable in all situations, and may be modified as appropriate. Other CSM forms, depending on the artistic capability of the preparer, may be used to convey the same information. This can include graphic cartoons, plan views, sections, and/or tables. Although we recognize **Figure 1** is far more detailed than some CSM diagrams employed for VI, simpler diagrams may not convey some of the possible complicating (but infrequent) conditions encountered in suspected VI events. As with any CSM diagram, completeness and confidence will vary and hopefully will improve as more site-specific information is collected and interpreted.

Compartments

Primary Source: Indicate the original release (1) and type (2). Additional information may include volumes, date(s), and nature of release; phase; and possible emergency response actions. Indicate composition of the source. Include whether constituents may be of direct concern, advective carriers (methane, water), or both. Source-generated constituents (biogenic gases, intermediate reaction or degradation products) may be included as applicable.

Secondary Source: Nature of the near-release concentrated release (3, 4, 5) in the environment, including delineated areas and/or volumes. Constituent composition may vary between the phase types.

Secondary Transfer Mechanisms: This is primarily to indicate demarcation and phase transfer between a delineated residual nonaqueous-phase liquid (NAPL) (6) and the nearby higher concentration zone of a water-soluble groundwater plume (7).

Subsurface Transport: [lower row]. Includes possible initial transient migration of NAPLs (8) as dense NAPL or light NAPL, which should be delineated and monitored as part of the VI CSM. NAPL migration is transient and will eventually expand to a quasi-steady residual (near-immobile) zone. Water-soluble groundwater transport (9) may include constituent advection, diffusion, dispersion, degradation, and transformation.

Subsurface Transport: [upper row]. Liquid migration through identified subsurface conduits (10), as either water or NAPL (so indicate). Volatile gases or vapors in unsaturated (vadose) soils (11) from either NAPL or groundwater. Transformation, (aerobic) degradation, and attenuation may be included as appropriate.

Near-Foundation Transport: May include subsurface vapor migration through conduits (13) or liquid migration through conduits (12) to the immediate subsurface vicinity of a building enclosure.

Cross-Foundation: Migration of vapors through a foundation interface to a building enclosure, either through soils (16) or through a near-foundation conduit (15). Liquids (NAPL or water) may also migrate directly through a building envelope (14), either through a conduit or directly in contact with the building foundation.

Enclosure: May include indoor space intended for continuous human occupancy (17). Can also include intermediate space such as crawl spaces or basement garages (18) not designed for continuous human occupancy. Specific buildings (or impacts to multiple buildings) may certainly be more complex than indicated in the simple flowchart; add supporting information and more detail as appropriate.

Potential Receptor Exposure: Indoor air enclosures (19) with possible human cohorts of varied designations (residential, commercial, industrial, confined space), including applicable defined gas and vapor criteria levels (acute or chronic toxicity, flammability, etc.) for constituents of concern.

Transport Pathways and Controls

Transport pathways in the CSM may be connected through a series of compartments from the primary source to indoor air, including a number of valves along the route showing remediation, mitigation, or control measures that may be employed to break the exposure pathway. In some situations (such as just after initial notification by a resident of odors, for example) only a portion of the pathway is understood. Selected control measures (indicated adjacent to the Indoor Air compartment, box 19) may still be available in this situation to control exposure even in the absence of complete site-specific information.

Remediation

The list of remediation measures is not necessarily comprehensive. Other remediation options may also be employed to control or eliminate vapor exposure pathways. Note that a portion of the contaminant, outside of the remediated or controlled zone, may remain for a varied time (nominally hours for unsaturated zone vapors, or up to many years for groundwater or NAPL in soils or sediments) and might require further mitigation measures.

Primary Source Containment/Control: Indicated control actions (a, b, c) are intended to ensure the primary release is prevented, detected, terminated, controlled, and/or removed.

Secondary Source Removal/Control: Listed remedial actions (d, e, f, g) may be intended to remove all or part of a secondary source zone or to eliminate further migration beyond a defined delineated zone.

(Liquid) Boundary Containment: Remedial actions (h, i, j) are intended to control NAPL or impacted groundwater and eliminate further migration beyond a designated containment zone.

Vapor Extraction/Removal: Soil vapor extraction, bioventing, or natural vapor degradation (k, l, m) may limit further migration of vapors and may also be employed to enhance depletion of some source zones.

Mitigation

The list of engineered mitigation measures is intended to control or eliminate actual or potential risks in enclosures or indoor air. It is not necessarily a comprehensive list.

Sub-Slab Vapor Controls: Measures implemented at and below a new or existing building foundation (n, o, p) to eliminate subsurface vapor migration into air. Active and passive controls (see **Active Vapor Intrusion Mitigation Systems Fact Sheet** and **Passive Vapor Intrusion Mitigation Systems Fact Sheet**) are not differentiated in the diagram and act on the same pathway at the same point.

Controls/Caps/Ventilation: Includes measures implemented at and above a foundation interface (s, t) to eliminate vapor migration through the foundation or measures intended to control vapor migration into a building envelope through conduits (q, r).

Enclosure Management: Includes engineered measures to control entry of contaminant vapors into an enclosure or remove them by treatment (u). (For more information, see the **Rapid Response and Ventilation for Vapor Intrusion Fact Sheet, Active Vapor Intrusion Mitigation Systems Fact Sheet**, and **Passive Vapor Intrusion Mitigation Systems Fact Sheet**).

Institutional Controls

Enclosure Use Limits: Administrative controls (v) up to and including evacuation or condemnation for use to eliminate human exposure.

REFERENCES

AVIP. 2024. "Best Practices for Developing a Vapor Intrusion Conceptual Site Model." Association of Vapor Intrusion Professionals, Version 1.2, April. **https://www.vaporintrusion.org/best-practices**.

ITRC. 2003. *Technical and Regulatory Guidance for the Triad Approach: A New Paradigm for Environmental Project Management*. Interstate Technology & Regulatory Council. **https://itrcweb.org/wp-content/uploads/2024/09/SCM-1.pdf**.

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