# Risk Evaluation: Vapor

## 10.1 Introduction

Vapor intrusion (VI) occurs when contamination volatilizes and migrates from ground water, soil or non-aqueous phase liquids through the soil or some preferential pathway and into nearby buildings. VI can be a significant source of exposure in indoor air (IA).[58] This section provides guidelines for an integrated approach to assessing VI risks using ground water, exterior soil gas (SGe), subslab soil gas (SGss), crawl space air (CSA), and/or IA sampling information gathered through the conceptual site model (CSM) development process discussed in Section 5.

Risk evaluation for the VI pathway involves considerable uncertainty due to the many variables that affect vapor migration and intrusion, and the difficulty in getting a sufficient number of samples to characterize current and potential future exposure. Conflicting sample results and multiple possible interpretations of the CSM frequently complicate VI risk evaluation. Multiple lines of evidence (LOEs), samples taken under assumed worst case conditions, and conservative risk estimations are necessary to account for the uncertainty inherent in the VI pathway.

## 10.2 Applicability

Evaluation of potential risk to vapor receptors is appropriate whenever volatile contaminants are present and the preliminary screening process in Section 5.4 indicates a need for further evaluation. Rather than evaluate every volatile chemical present at a site, it may be more efficient to individually evaluate the "risk drivers" associated with a release (e.g., benzene from a gasoline release). However, many chlorinated solvents have toxic degradation products; in such cases it is appropriate to evaluate the parent and degradation products as a group.

## 10.3 Land Use Categories

The Indiana Department of Environmental Management (IDEM) uses three land use categories when evaluating VI:

Residential properties include homes, apartments, day care centers and schools. Assess residential properties relative to the residential screening levels presented in Table A-6.

Commercial/industrial properties include office complexes, retail businesses, etc. This category also includes industrial facilities where the chemicals found in the subsurface are not used in site processes. Assess these properties relative to the commercial/industrial screening levels presented in Appendix A, Table A-6. For purposes of this document, an Occupational Safety and Health Administration (OSHA) regulated facility is one where workers may simultaneously undergo exposure to the same chemical(s) through VI *and* through routine operations at the facility. If the VI chemicals under evaluation are used as part of the site process, the facility is subject to OSHA permissible exposure levels (PELs) rather than IDEM VI screening levels.

[58] The risk from contaminants volatilized into indoor air directly from contaminated tap water is evaluated as a component of the ground water direct contact pathway. See Section 9.1.

## 10.4 Screening Levels

Table A-6 lists indoor air screening levels (IASLs) and VI ground water screening levels (GWSLs) for many volatile chemicals. IDEM will evaluate site-specific screening levels calculated for CSA, SGss, and SGe using guidance in U.S. EPA (2011), other suitable guidance, or by dividing the IASL by an appropriate media specific attenuation factor listed in Table 10-A.

**Table 10-A: Attenuation Factors by Medium**

| Medium | Attenuation Factor |
|---|---|
| Ground water | 0.001 for residential/commercial/industrial<br>0.0001 for some commercial/industrial (see below) |
| CSA | 1 |
| SGss | 0.1 for residential/commercial/industrial<br>0.01 for some commercial/industrial (below) |
| Shallow* SGe | 0.1 for residential/commercial/industrial<br>0.01 for some commercial/industrial (below) |
| Deep** SGe | 0.01 for residential/commercial/industrial<br>0.001 for some commercial/industrial (below) |

*Shallow = five feet or less below the building foundation
**Deep = more than five feet below the building foundation

It may be appropriate to adjust the attenuation factors downward by a factor of ten for certain commercial/industrial buildings as shown in the table above. Justification of such adjustments should consider the following criteria:

- *Building size*. Commercial/industrial buildings typically have a significantly larger footprint than homes. The interior of the building should be open to air flow rather than subdivided into smaller offices or businesses.
- *Foundation thickness and structural integrity*. Commercial/industrial buildings are often slab-on-grade construction with thicker, more intact concrete slabs than residences.
- *Ceiling height*. Ceilings are usually considerably higher in commercial/industrial buildings, increasing the air volume compared to residences.
- *Air exchange rate*. Higher ventilation rates in commercial/industrial buildings should result in lower IA concentrations, if the rate of VI from the subsurface is constant.

As of this writing there is no widely accepted process for deriving soil screening levels. However, if a contaminant source exists in the vadose zone beneath or in close proximity to a building, SGss data are necessary for evaluation of the VI pathway into the building. In such cases, IDEM recommends evaluation of ground water data in conjunction with soil gas data, particularly if a contaminant plume extends beyond the vadose zone source. Soil contamination directly beneath or near a building, as well as the existence of preferential pathways, can indicate a higher potential for VI to occur through soil contamination. Where soil contamination exists, IDEM recommends working with the agency through the assigned project manager to develop a site-specific VI investigation plan.

### 10.4.1 Chronic IASLs and Subchronic Indoor Air Action Levels (IAALs)

IASLs use toxicity criteria associated with long term, or chronic, exposure (a 30-year exposure duration for residential buildings, and a 25-year exposure duration for commercial/industrial

buildings). IASLs are appropriate for preliminary screening, deciding whether further investigation is necessary, and for closure evaluation. Carcinogenic effects drive chronic exposure risk for most commonly encountered VI chemicals. IDEM has established a screening level target cancer risk of $10^{-5}$ as protective of human health. Considering the inherent uncertainties associated with having minimal indoor air quantitative data, IDEM considers the target risk of $10^{-5}$ as a reasonable point of demarcation for evaluation of chronic carcinogenic exposure and employs a $10^{-5}$ target cancer risk in derivation of IASLs (See Section A.5 for additional detail). While IASLs generally identify indoor air concentrations that must be addressed prior to site closure, the target risk of $10^{-5}$ is not a completely inflexible line. IDEM may consider a risk estimate around $10^{-5}$ acceptable if justified by LOEs related to site-specific conditions.

The National Contingency Plan risk range of $10^{-4}$ to $10^{-6}$ is generally not applied to indoor air inhalation exposures. IDEM will use the $10^{-5}$ target risk on a per-chemical basis to protect from exceeding $10^{-4}$ cumulative risk over the long term, recognizing that most indoor air measurements represent a narrow “snapshot in time” because of problems with getting repeat access and uncertainty over seasonal and building variations. If indoor air sampling can be conducted at a frequency that addresses these uncertainties, IDEM will consider accepting chronic remediation objectives where the cumulative target risk does not exceed $10^{-4}$ and a hazard index of 1.

IAALs assume short term, or subchronic exposure. Subchronic exposures typically represent up to ten percent of a human lifetime, and conventional risk assessment guidance typically identifies this period as a range of two to seven years. Subchronic criteria are generally appropriate for use in determining whether an interim measure, such as a VI mitigation system, is warranted due to the likelihood that receptors in a building may have already had a two to seven year exposure prior to the VI investigation. However, benchmark toxicity criteria are generally not available for subchronic inhalation exposures, so IDEM will assess subchronic exposure by incorporating a tenfold adjustment to the IASLs. At the higher concentrations associated with this tenfold increase, it is important to evaluate each chemical for both the carcinogenic and noncarcinogenic endpoints to determine the risk driver. This means that if the carcinogenic risk from inhalation of VI-related chemicals exceeds $10^{-4}$ or a hazard index of 10, prompt action is generally warranted. IAALs can be derived by simply multiplying the IASLs in Table A-6 by a factor of ten.

### 10.5 Vapor: Closure

Interpretation of VI sampling results can be a complex process, especially when evaluating IA data. Initial evaluation of sampling data simply involves the comparison of results to the applicable screening level. This comparison provides some indication of whether a VI problem may exist. However, a single sample result above or below a screening level is not enough evidence to establish or rule out a completed VI pathway.

When evaluating sampling results for the purpose of assessing the VI pathway, it is important to first determine that the samples were taken according to proper sampling procedures, in the proper locations, and under conditions conducive to vapor transport (Section 5). These factors provide additional confidence when interpreting sampling results. The sections below provide general guidelines for interpreting VI sample results under current conditions, and assume that subsurface remediation is underway to alleviate any future VI issues. If the chosen remedy for a site involves leaving contamination in place, the VI pathway may require periodic re-evaluation for changes in contaminant concentrations, subsurface conditions, and building conditions.

### 10.5.1 SGe Sample Results

SGe sampling is only appropriate as a stand alone screening tool if either:

1. The site has been characterized as “low risk” using the LOEs in Section 5.4.2, or
2. The site is an undeveloped property with no existing buildings.

If the owner of the potentially affected building does not grant permission or access for SGss sampling, SGe sampling should be paired with IA sampling. When SGe sample results are below the applicable screening levels at all sampling locations for a minimum of two sampling events, the VI pathway can be considered incomplete under current conditions and no further investigation is needed for the building or property in question.

If any SGe sampling result exceeds the applicable screening levels, further investigation of the building is warranted. When possible, paired SGss and IA sampling should be conducted. If the owner of the potentially affected building does not grant permission for SGss sampling, SGe sampling should be paired with IA sampling.

For undeveloped properties with no existing buildings, an exceedance of the SGe screening levels establishes the potential for a completed VI pathway in future buildings. In this scenario, the VI remedy should involve remediation or restrictions applied via an institutional control.

### 10.5.2 SGss and CSA Sample Results

Whenever SGss and CSA samples are not paired with IA samples, the evaluation should include a preferential pathway evaluation (Section 5.5.1), If preferential pathway sampling results are below applicable SGss screening levels and SGss or CSA sample results are below applicable screening levels for a minimum of two sampling events, the VI pathway can be considered incomplete under current conditions and no further investigation is needed for the building in question.

If the preferential pathway samples indicate the presence of site contaminants above SGss screening levels, or if any SGss or CSA sampling result exceeds the applicable screening levels, the building warrants further investigation. That investigation should include paired SGss/CSA and IA sampling.

### 10.5.3 IA Sample Results

Interpreting IA sample results requires consideration of spatial and temporal variability and possible contributions of ambient air or indoor air background (IAb) sources. Spatial and temporal variability are influenced by many factors, including: subsurface conditions, building construction and airflow dynamics, and meteorological conditions. Because of these site-specific factors, IA can change on a daily basis. It is not realistic to screen out the vapor pathway with any confidence based upon a single “snapshot in time”. Therefore, IDEM recommends multiple rounds of paired IA and SGss sampling.

IA sample results are evaluated under two separate exposure scenarios: sub-chronic exposure and chronic exposure:

*Sub-chronic Exposure*

Prompt action is necessary to reduce exposure if IA exceeds IAALs. Prompt action does not necessarily mean evacuating the building, but it does mean addressing the exposure within a period of months rather than years. It can include source removal, source remediation,

installation of a venting system, SGss depressurization system, or any other means that will reduce exposure to an acceptable level. If IA levels are between IASLs and IAALs, then a chronic VI problem may exist. Further investigation or additional sampling will be necessary to assess potential risk. IAALs can be derived by multiplying the IASLs in Table A-6 by a factor of ten.

*Chronic Exposure*

A chronic exposure problem may exist if IA exceeds IASLs. This can occur from vapor intruding at low levels over long periods of time. It may be necessary to further characterize the exposure through additional sampling events or by using long-term sampling techniques.

Concentrations near IASLs may also be the result of common IAb sources. Section 5 discusses IAb considerations, as well as LOEs to establish whether contaminants detected in IA are the result of VI or IAb.

When IA is below IASLs at all sampling locations for a minimum of two sampling events, IDEM will consider the VI pathway incomplete under current conditions. If source remediation is underway, no further investigation of the building is necessary. However, if a remedy leaves contamination in place or SGss sample results show the potential for VI to occur if building conditions change, then the VI pathway may require periodic re-evaluation.

If the VI pathway is complete, and IA exceeds IASLs, then action is necessary to reduce exposure. Possible actions include: source removal, source remediation, installation of a venting system, SGss depressurization system, or any other means of reducing exposure to an acceptable level. The action required to address the VI pathway can be determined on a site-specific basis through the evaluation of the following LOEs:

- SGss and IA contaminant concentrations
- Source contaminant concentrations
- Estimated time of exposure prior to discovery
- Source remedy selection
- Estimated time until contaminant concentrations decrease to acceptable levels.