TECHNICAL GUIDANCE DOCUMENT
INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

Attenuation Factors

Office of Land Quality

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What Are Attenuation Factors?

Attenuation factors (AFs) are *estimates* of the decimal fraction of vapor phase chemicals that pass through a barrier and enter the indoor space of a structure. Attenuation factor estimates are very useful when predicting whether vapors outside of a structure are likely to move into the structure and result in indoor air concentrations that may pose an unacceptable risk.

US EPA derives these estimates by comparing observed chemical concentrations in the indoor air of structures to observed vapor concentrations in media outside those same structures. In a particular instance, an attenuation factor is defined as:

$$Attenuation\ Factor = \frac{Observed\ Vapor\ Concentration\ Inside\ the\ Structure}{Observed\ Vapor\ Concentration\ Outside\ the\ Structure}$$

For example, given an observed indoor air concentration of 10 ug/m^3, and an observed subslab concentration of 250 ug/m^3, the attenuation factor across the slab would be (10ug/m^3)/(250ug/m^3), or 0.04. Because observed attenuation factors vary considerably between structures, over time, for different types of barriers, and under different environmental conditions, US EPA compiled thousands of data points collected at hundreds of structures under a wide variety of conditions and across several types of barriers. US EPA then applied a statistical procedure to data collected across different barrier types to produce generic attenuation factor *estimates* for specific barriers that are likely to be protective for their intended use in 95% of cases.

How Are Attenuation Factors Used?

Attenuation factors are used to predict whether or not vapors are likely to intrude into structures. To see how this works, re-arrange the previous equation to yield by analogy:

$$Attenuation\ Factor \times Observed\ Outside\ Concentration = Estimated\ Indoor\ Air\ Concentration$$

For example, if the observed subslab concentration is 100 ug/m3, and the attenuation factor estimate across a slab is 0.1, then the estimated indoor air concentration is

100 ug/m3 x 0.1 = 10 ug/m3.

It is then possible to compare this estimated indoor air concentration against health-based screening levels to decide whether indoor air sampling is necessary or a vapor intrusion remedy is warranted.

Appropriate Attenuation Factors for Various Scenarios

IDEM recommends the following generic attenuation factors when evaluating vapor intrusion potential:

Scenario	Attenuation Factor
Soil gas from backfill along an underground utility, such as a sanitary sewer	0.1[1]
Soil gas collected from shallower than five feet below ground surface adjacent to a structure or potential structure[2]	0.1[1]
Soil gas collected from deeper than five feet below ground surface adjacent to a structure or potential structure[2]	0.03[1]
Subslab soil gas	0.03[1]
Crawl space air	1
Vapors within conduits	Site-specific[3]

Notes:

[1] Section 10.4 of IDEM's Remediation Closure Guide (2012) describes various lines of evidence related to building characteristics that support the use of a large-building attenuation factor; in such cases, a ten-fold reduction in the listed attenuation factor is appropriate.

[2] US EPA recommends collecting soil gas samples from a depth slightly shallower than the subsurface source of vapor, whether the source medium is groundwater or soil.

[3] Although US EPA's 2015 VI guidance recommends collecting, under unspecified circumstances, vapor samples from within conduits, it is silent on the attenuation factor(s) to use when evaluating those results. Therefore, IDEM staff will evaluate such data on a site-specific basis.

Attenuation Factors and Groundwater

The equation that IDEM uses to derive vapor intrusion groundwater screening levels (VIGWSLs) includes an attenuation factor:

$$VIGWSL = \frac{Indoor\ Air\ Screening\ Level}{Attenuation\ Factor\ \times TAHLC\ \times 1000L/m^3}$$

Where TAHLC is the temperature-adjusted Henry's Law constant (US EPA, 2001) of the chemical for which a VIGWSL is being calculated.

IDEM's standard attenuation factor for use in this equation is 0.001. However, US EPA (2015, page A-4) permits a site-specific attenuation factor of 0.0005 at sites where laterally extensive fine grain soils have been demonstrated through site-specific sampling to underlie buildings under investigation. IDEM interprets this to mean that use of the 0.0005 attenuation factor is appropriate where laterally extensive fine grain soils *overlie* the groundwater vapor source, thus serving as a barrier of sorts to vapor migration. However, IDEM expects that laterally extensive fine grain soils will often act as aquitards, and that the uppermost water bearing unit is likely to lie *above* such soil layers. Given that VIGWSLs should be applied to the uppermost water bearing unit, IDEM does not expect to see many instances where use of the 0.0005 attenuation factor is appropriate. Nevertheless, IDEM will evaluate proposals to use the 0.0005 attenuation factor on their merits.

US EPA (2015, page 111) defines fine grain soils as clay, silty clay, silty clay loam, or silt, consistent with the US Soil Conservation Service[1] soil classification system. Many sites have undergone substantial re-working of the subsurface soil and field interpretations can be subjective based on individual experience levels. For this reason, ASTM grain size analysis (ASTM, 2009) results from samples collected in representative areas of the site should accompany proposals to employ the 0.0005 attenuation factor.

As with soil attenuation factors, it is appropriate to employ a large building adjustment when calculating VIGWSLs for buildings with certain characteristics. See IDEM (2012) Section 10.4 for additional details on this option.

Soil Concentrations as Vapor Intrusion Investigation Triggers

Volatile chemicals in soils may serve as vapor sources. However, US EPA does not provide guidance on attenuation factors for the soil to indoor air pathway. For this reason, IDEM does not publish soil to indoor air screening levels, and instead recommends that responsible parties evaluate that pathway on a site-specific basis.

Sometimes responsible parties propose soil to indoor air screening levels based on a coupling of the migration to groundwater model (IDEM 2012, Equation A-9) and the VIGWSL equation (IDEM 2012, Equation A-10). Unfortunately, this approach does not take into account the soil direct to indoor air pathway, and IDEM cannot regard the screening levels derived in this manner as meaningful. For now, the decision whether or not to screen indoor air based on soil sample results must rely on past experience and professional judgment.

[1] US Soil Conservation Service is now National Resource Conservation Service (NRCS). NRCS offers an online Soil Texture Calculator.

Derivation of Site-Specific Attenuation Factors

Responsible parties sometimes propose attenuation factors specific to particular structures. IDEM recognizes that each structure and its environment are unique, and that a generic attenuation factor may not predict vapor intrusion as well as an attenuation factor specifically developed for a particular structure.

However, given the *highly* variable nature of observed vapor concentrations, IDEM will request sufficient samples to provide adequate confidence that a proposed site-specific attenuation factor is appropriate – typically enough to generate a statistically significant result. Because the number of samples necessary to generate a statistically significant result depends on the variation observed in the sample results, it is not possible to say in advance how many samples will be needed.

Further, validation of the site-specific attenuation factor will necessitate collection of indoor air samples paired with samples from the other side of whatever barrier is under evaluation. Because the paired vapor concentrations thus obtained are a far better indication of vapor intrusion potential than the site-specific attenuation factor they were intended to model, IDEM suggests that derivation of site-specific attenuation factors may not be the best use of resources. Nevertheless, IDEM will evaluate proposed structure-specific attenuation factors on their merits.

References

ASTM International. 2009. Standard D6913. Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis.

IDEM. 2012. Remediation Closure Guide.

US EPA. 2001. Fact Sheet: Correcting the Henry's Law Constant for Soil Temperature.

US EPA. 2015. OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air. OSWER Publication 9200.2-154.