



**VAPOR INTRUSION SCREENING LEVEL (VISL) CALCULATOR**

**USER'S GUIDE**

U.S. ENVIRONMENTAL PROTECTION AGENCY  
OFFICE OF SOLID WASTE AND EMERGENCY RESPONSE  
OFFICE OF SUPERFUND REMEDIATION AND TECHNOLOGY INNOVATION  
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**DISCLAIMER**

This document describes the calculation of recommended, but not mandatory, screening levels for use in evaluating the vapor intrusion pathway at Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and Resource Conservation and Recovery Act (RCRA) sites. These screening levels are calculated using the recommended approaches in existing guidance. The information provided in this document does not impose any requirements or obligations on the U.S. Environmental Protection Agency (EPA) or on the owner/operators of sites that may be contaminated with volatile and toxic compounds. Alternative approaches for evaluating the vapor intrusion pathway may be found to be more appropriate at specific sites (for example, where site circumstances do not match the underlying assumptions used in calculating the screening levels).

## VAPOR INTRUSION SCREENING LEVEL (VISL) CALCULATOR USER'S GUIDE

### Overview

The Vapor Intrusion Screening Level (VISL) Calculator is a spreadsheet tool that (1) lists chemicals considered to be volatile and known to pose a potential cancer risk or noncancer hazard through the inhalation pathway; (2) provides generally recommended screening-level concentrations for groundwater, soil gas (exterior to buildings and sub-slab) and indoor air for default target risk levels and exposure scenarios; and (3) allows calculation of site-specific screening levels based on user-defined target risk levels and exposure scenarios. The VISL Calculator can assist Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) remedial project managers (RPMs) and on-scene coordinators (OSCs), as well as Resource Conservation and Recovery Act (RCRA) project managers in determining whether the vapor intrusion (VI) pathway has the potential to pose an unacceptable level of risk to human health by: (1) identifying whether chemicals that can pose a risk through VI are present; (2) determining if those chemicals are present at explosive levels; and (3) comparing subsurface or indoor data against screening levels provided in the Calculator. The screening level concentrations in the Calculator are not intended to be used as cleanup levels, nor are they intended to supersede existing criteria of the lead regulatory authority.

The VISLs are calculated using the recommended approaches in existing guidance and are based on current understanding of the vapor intrusion pathway. Target indoor air concentrations are calculated according to the guidance provided in Risk Assessment Guidance for Superfund (RAGS) F (EPA 2009), which does not support the route-to-route extrapolations that were used in the now outdated screening tables in the EPA's November 2002 draft vapor intrusion guidance (EPA 2002). The screening levels for groundwater and soil gas (either sub-slab gas or soil gas collected exterior to buildings) are calculated from the target indoor air concentrations using empirically-based conservative "generic" attenuation factors that reflect generally reasonable worst-case conditions as described in the EPA's draft vapor intrusion guidance (EPA 2002). The default, generic VISLs are based on default exposure parameters and factors that represent Reasonable Maximum Exposure (RME) conditions for long-term/chronic exposures. Site-specific criteria that can be input to the calculator include exposure scenario (either residential or commercial), target risk for carcinogens, target hazard quotient for noncarcinogens and average in situ groundwater temperature (stabilized temperature measured during well purging prior to groundwater sampling). The VISL Calculator incorporates the latest toxicity values in the Regional Screening Levels (RSL) tables (EPA, "Regional Screening Levels") and will be updated as new versions of the RSL tables are released<sup>1</sup>.

### Applicability of the VISL Calculator

The purpose of the VISL calculator is to provide a tool to assist RPMs, OSCs, risk assessors and others involved in decision-making concerning CERCLA hazardous waste sites and to determine whether levels of contamination found at the site may warrant further investigation or site cleanup, or whether no further investigation or action may be required.

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<sup>1</sup> EPA Regional Screening Level (RSL) tables are updated semi-annually with the latest version available online at [http://www.epa.gov/reg3hwmd/risk/human/rb-concentration\\_table/index.htm](http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm). The Vapor Intrusion Screening Level (VISL) Calculator will be revised accordingly to reflect the most recent information available.

Users within and outside the CERCLA program should use the calculator results at their own discretion, and they should take care to understand the assumptions incorporated in these results and to apply the screening levels appropriately.

The screening levels presented in the calculator are chemical-specific concentrations for individual contaminants in air that may warrant further investigation or site cleanup. The screening levels generated from the calculator may be site-specific concentrations for individual chemicals in air. It should be emphasized that screening levels are not cleanup standards. It is not recommended that the VISLs be used as cleanup levels for Superfund Sites until the recommendations in EPA's Supplemental Guidance to Risk Assessment Guidance for Superfund, Volume I, Part A, Community Involvement in Superfund Risk Assessments (EPA 1999) have been addressed. Screening levels should not be used as cleanup levels for a CERCLA site until the other remedy selections identified in the relevant portions of the National Contingency Plan (NCP), 40 CFR Part 300, have been evaluated and considered.

The subsurface target concentrations in the VISL Calculator are based on the generic conceptual model for vapor intrusion described in EPA's draft vapor intrusion guidance. This conceptual model assumes a groundwater or vadose zone source of volatile vapors that diffuse upwards through unsaturated soils towards the surface and into buildings. In this model, the soil in the vadose zone is considered to be relatively homogeneous and isotropic, though horizontal layers of soil types can be accommodated. The receptors are assumed to be occupants in buildings with poured concrete foundations (for example, basement or slab on grade foundations or crawlspaces with a liner or other vapor barrier). The underlying assumption for this generic model is that site-specific subsurface characteristics will tend to reduce or attenuate vapor concentrations as vapors migrate upward from the source and that site-specific building characteristics will tend to further dilute the vapors as they mix with the air in the building. The generic attenuation factors were developed based on analysis of VI data in EPA's VI database (EPA 2002, 2008).

In general, it is recommended that the user consider whether the assumptions underlying the generic conceptual model are applicable at each site, and use professional judgment to make whatever adjustments (including not considering the model at all) are appropriate. Specific factors that may result in unattenuated or enhanced transport of vapors towards a receptor, and consequently are likely to render the VISL screening target subsurface concentrations inappropriate, include:

- Very shallow groundwater sources (for example, depths to water less than 5 ft below foundation level);
- Shallow soil contamination vapor sources (for example, sampled at levels within a few feet of the base of the foundation)
- Buildings with significant openings to the subsurface (for example, sumps, unlined crawlspaces, earthen floors) or significant preferential pathways, either naturally-occurring or anthropogenic (not including typical utility perforations present in most buildings).

### **Description and Use of VISL Calculator**

The VISL Calculator contains nine worksheets:

Navigation Guide: Provides information regarding the Calculator's contents and structure, including a data field dictionary (see "Navigation Guide" tab in the VISL Calculator) that describes each data field and any formulas used to calculate the contents of the data field.

VISL: Main worksheet where the user can enter the exposure scenario and risk information and select chemicals to calculate the screening-level values for groundwater, soil gas (sub-slab and exterior soil gas) and indoor air.

SG IA calc: Worksheet where the user can enter the exposure scenario and site soil gas (sub-slab and exterior soil gas) concentrations to calculate the indoor air concentrations and the resulting risk values for indoor air.

GW IA calc: Worksheet where the user can enter the exposure scenario and site groundwater concentrations to calculate the indoor air concentrations and the resulting risk values for indoor air.

IA risk calc: Worksheet where the user can enter the exposure scenario and site indoor air concentrations to calculate resulting risk values for indoor air.

ChemProps: Supporting worksheet that contains a compilation of physical and chemical properties of each chemical, which are used in the calculations for the VISL worksheet.

Version Notes: Worksheet to track the changes made in each version of the VISL calculator workbook.

Tox Summary: Supporting worksheet that provides a list of contaminants, toxicity values, maximum contaminant levels (MCLs) and the lesser (more protective) of the cancer and noncancer screening levels (SLs) for resident soil, industrial soil, resident air, industrial air and tap water from EPA's RSL website (EPA, "Regional Screening Levels").

Parameters Summary: Supporting worksheet that contains physical and chemical properties from EPA's RSL website (EPA, "Regional Screening Levels"). The properties in this worksheet are linked to the ChemProps worksheet.

The list of chemicals included in the VISL calculator includes all chemicals denoted as volatile in the RSL tables by the "voc" field, and for which either an inhalation unit risk (IUR) or a reference concentration (RfC) is listed in the RSL tables.

The VISL Calculator allows the user to enter the exposure scenario (residential or commercial), target risk for carcinogens, target hazard quotient for noncarcinogens and average in situ groundwater temperature, if appropriate. Default values are provided for all these entries. For site-specific exposure scenarios, the worksheet can be unprotected to change the exposure parameters.

The Calculator uses chemical property and toxicity information to determine whether a chemical, if present in soil, is sufficiently volatile and toxic to pose an inhalation risk through vapor intrusion and

whether a chemical, if present in groundwater, is sufficiently volatile and toxic to pose an inhalation risk through vapor intrusion at the selected cancer risk or hazard quotient levels.

For a soil source, a chemical is considered sufficiently volatile and toxic to pose an inhalation risk through vapor intrusion if the vapor pressure (expressed in terms of vapor concentration using the ideal gas law) of the pure component is greater than the target indoor air concentration. The soil gas attenuation factor is not considered in this comparison, although it is considered in the subsequent calculation of the target soil gas concentration.

For a groundwater source, a chemical is considered sufficiently volatile and toxic to pose an inhalation risk through vapor intrusion if the vapor concentration (calculated using the chemical's Henry's Law Constant at the groundwater temperature) corresponding to the chemical's solubility limit in water, is greater than the target indoor air concentration. The groundwater attenuation factor is not considered in this comparison, although it is considered in the subsequent calculation of the target groundwater concentration.

The soil gas attenuation factor used in the calculations is 0.1, which is the generic attenuation factor used for sub-slab gas in the 2002 draft vapor intrusion guidance. This attenuation factor is used for all soil gas data, as additional information collected after development of the 2002 draft vapor intrusion guidance (EPA 2002) suggests that external soil gas samples need to be evaluated as conservatively as sub-slab gas samples (EPA 2010).

The groundwater attenuation factor used in the calculations is 0.001, which is the generic attenuation factor used for groundwater concentrations (expressed in terms of vapor concentration in equilibrium with groundwater concentration) in the 2002 draft vapor intrusion guidance (EPA 2002). Additional information gathered since release of the 2002 draft vapor intrusion guidance (EPA 2002) suggests the 2002 generic groundwater attenuation factor remains valid (EPA 2010).

### Data Sources

The chemical property and toxicity information used in the VISL Calculator is obtained from the EPA's RSL website at [http://www.epa.gov/reg3hwmd/risk/human/rb-concentration\\_table/index.htm](http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm) (EPA, "Regional Screening Levels").

### Target Indoor Air Concentration to Satisfy Both the Prescribed Cancer Risk Level and the Target Hazard Index (Column F).

The target breathing zone indoor air concentrations in the VISL Calculator are risk-based screening levels for ambient air. The indoor air concentrations for noncarcinogens and carcinogens are calculated following an approach consistent with the EPA's RAGS F (EPA 2009). The toxicity values used as the basis for the calculations are from the EPA's RSLs, which also include the source of the toxicity data. Separate carcinogenic and noncarcinogenic target concentrations are calculated for each compound when both unit risks and reference concentrations are available. For carcinogens, target indoor air concentrations are based on an adult residential exposure scenario and assume exposure of an individual for 350 days per year over a period of 70 years. For noncarcinogens, target indoor air concentrations are based on the corresponding reference concentration.

For carcinogens, the equation for  $C_{ia,c}$ , the target indoor air concentration based on cancer toxicity (Column V), is:

$$C_{ia,c} = \frac{TCR \times AT_c \times \left(\frac{365 \text{ days}}{\text{year}}\right) \times \left(\frac{24 \text{ hours}}{\text{day}}\right)}{EF \times ED \times ET \times IUR}$$

where  $AT_c$ ,  $EF$ ,  $ED$  and  $ET$  are the default exposure parameters for residential or commercial exposure as appropriate, and:

TCR = Target cancer risk (for example,  $1.0 \times 10^{-6}$ )  
 IUR = Inhalation unit risk ( $\mu\text{g}/\text{m}^3$ )<sup>-1</sup>

For carcinogens with mutagenic mode-of-action (MMOA), the equation is slightly modified in accordance with the RSL User's Guide (EPA, "Regional Screening Levels").

$$C_{ia,c} = \frac{TCR \times AT_c \times \left(\frac{365 \text{ days}}{\text{year}}\right) \times \left(\frac{24 \text{ hours}}{\text{day}}\right)}{EF \times ED_{MMOA} \times ET \times IUR}$$

where  $ED_{MMOA}$  is calculated with the equation:

$$ED_{MMOA} = (ED_{0-2} \times AF_{0-2}) + (ED_{2-6} \times AF_{2-6}) + (ED_{6-16} \times AF_{6-16}) + (ED_{16-30} \times AF_{16-30})$$

and

$ED_{x-y}$  = Exposure duration for the age cohort from age x to y  
 $AF_{x-y}$  = Age-dependent adjustment factor, which is 10 for ages 0 to 2, 3 for ages 2 to 6 and 6 to 16 and 1 for ages 16 to 30

For trichloroethylene, which has mutagenic and non-mutagenic components of the IUR, two  $C_{ia,c}$  values are calculated using the mutagenic and non-mutagenic components of the IUR. The reciprocal of the sum of the reciprocals of those  $C_{ia,c}$  values is used to calculate the final  $C_{ia,c}$  value, in accordance with the EPA RSL guidance (EPA, "Regional Screening Levels").

For vinyl chloride, a slightly modified version of the equation for  $C_{ia,c}$  is used (EPA, "Regional Screening Levels"):

$$C_{ia,c} = \frac{TCR}{\left( IUR + \frac{EF \times ED \times ET \times IUR}{AT_c \times \left(\frac{365 \text{ days}}{\text{year}}\right) \times \left(\frac{24 \text{ hours}}{\text{day}}\right)} \right)}$$

For non-carcinogens, the equation for  $C_{ia,nc}$ , the target indoor air concentration based on non-cancer toxicity (Column W), is:

$$C_{ia,nc} = \frac{THQ \times RfC \times AT_{nc} \times \left(\frac{365 \text{ days}}{\text{year}}\right) \times \left(\frac{24 \text{ hours}}{\text{day}}\right) \times \left(\frac{1000 \mu\text{g}}{\text{mg}}\right)}{EF \times ED \times ET}$$

where  $AT_{nc}$ ,  $EF$ ,  $ED$  and  $ET$  are the default exposure parameters for residential or commercial exposure as appropriate, and:

THQ	=	Target hazard quotient (for example, 1.0)
RfC	=	Reference concentration ( $\text{mg}/\text{m}_3$ )

The more stringent (minimum) of the cancer- and noncancer-based contaminant concentrations is chosen as the target indoor air concentration ( $C_{\text{target},ia}$ ) that satisfies both the prescribed cancer risk level and the target hazard quotient.

If  $C_{\text{target},ia}$  exceeds the maximum possible pure chemical vapor concentration, the designation NVT (not sufficiently volatile and/or toxic to pose inhalation risk) is entered in the target indoor air concentration column of the table (Column F).

The vapor concentrations in the VISL Calculator are given in units of micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ). Although the VISL Calculator uses these units for all vapor concentrations, some users may have results in parts per billion by volume (ppbv). The conversion from ppbv to  $\mu\text{g}/\text{m}^3$  is:

$$C[\text{ppbv}] = \frac{C \left[\frac{\mu\text{g}}{\text{m}^3}\right] \times \left(\frac{10^9 \text{ ppbv}}{\text{atm}}\right) \times \left(\frac{10^{-3} \text{ m}^3}{\text{L}}\right) \times R \times T}{MW \times \left(\frac{10^6 \mu\text{g}}{\text{g}}\right)}$$

where:

R	=	Universal gas constant (0.082057 L-atm/mole-degrees Kelvin)
T	=	Absolute temperature (298.15 K)
MW	=	Molecular weight (grams [g]/mole)

### Target Sub-Slab and Exterior Soil Gas Concentration Corresponding to Target Indoor Air Concentration (Column H)

The target soil gas concentration corresponding to a chemical's target indoor air concentration at the selected target cancer risk or hazard quotient is calculated by dividing the indoor air concentration by the generic attenuation factor of 0.1.

$$C_{\text{soil-gas}} = \frac{C_{\text{target},ia}}{AF_{SS}}$$

where:

$C_{\text{soil-gas}}$	=	Target soil gas concentration [ $\mu\text{g}/\text{m}^3$ ]
$AF_{SS}$	=	Attenuation factor (ratio of indoor air concentration to sub-slab or soil gas concentration; default value is 0.1)

If  $C_{\text{soil-gas}}$  exceeds the maximum possible pure chemical vapor concentration at 25°C, but  $C_{\text{target,ia}}$  does not exceed the maximum possible pure chemical vapor concentration, then NVT is entered in the table under target sub-slab or soil gas concentration (Column H).

### Target Groundwater Concentration Corresponding to Target Indoor Air Concentration (Column I)

The target groundwater concentration corresponding to a chemical's target indoor air concentration is calculated by dividing the target indoor air concentration by an attenuation factor of 0.001 and then converting the vapor concentration to an equivalent groundwater concentration, assuming equilibrium between the aqueous and vapor phases at the water table. The equilibrium partitioning is assumed to obey Henry's Law so that:

$$C_{gw} = \frac{C_{\text{target,ia}}}{HLC \times AF_{gw} \times \left(\frac{1000 L}{m^3}\right)}$$

where:

$C_{gw}$	=	Target groundwater concentration (micrograms per liter [ $\mu\text{g/L}$ ])
$C_{\text{target,ia}}$	=	Target indoor air concentration ( $\mu\text{g/m}^3$ )
$AF_{gw}$	=	Attenuation factor (ratio of indoor air concentration to groundwater concentration; the default value is 0.001)
HLC	=	Dimensionless Henry's Law Constant at the specified groundwater temperature [(milligrams per liter (mg/L) – vapor)/(mg/L – H <sub>2</sub> O)]

The following equation can be used to calculate the Henry's Law Constant at a groundwater temperature of 25 degrees Celsius:

$$H'_{25} = \frac{Hc_{25} \times \left(\frac{1000 L}{m^3}\right)}{R \times (298.15 K)}$$

where:

$H'_{25}$	=	Dimensionless Henry's Law Constant at 25 degrees Celsius
$Hc_{25}$	=	Henry's Law Constant at 25 degrees Celsius (atm·m <sup>3</sup> per mole)
R	=	Universal gas constant (0.082057 L·atm/mol·degrees Kelvin)

For groundwater temperatures other than 25 degrees Celsius, the following equation is used to calculate Henry's Law Constant:

$$H'T_{gw} = Hc_{25} \times \exp \left[ \left( \frac{DH_{v,b}}{RC} \right) \times \frac{\left(1 - \frac{T_{gw}}{T_{crit}}\right)}{\left(1 - \frac{T_{boil}}{T_{crit}}\right)} \right]^n \times \left[ \left( \frac{1}{T_{gw}} \right) - \left( \frac{1}{298.15 K} \right) \right]$$

where:

$H'T_{gw}$	=	Dimensionless Henry's Law Constant at the groundwater temperature
$Hc_{25}$	=	Henry's Law Constant at 25 degrees Celsius (atm-m <sup>3</sup> per mole)
$DH_{v,b}$	=	Enthalpy of vaporization at the normal boiling point (cal/mol)
$RC$	=	Universal gas constant (1.9872 cal/mol-K)
$T_{gw}$	=	Groundwater temperature (degrees Kelvin)
$T_{crit}$	=	Critical temperature (degrees Kelvin)
$T_{boil}$	=	Normal boiling point (degrees Kelvin)
$n$	=	If $(T_{boil}/T_{crit} < 0.57)$ , $n = 0.3$ If $(T_{boil}/T_{crit} > 0.71)$ , $n = 0.41$ If $(0.57 < T_{boil}/T_{crit} \leq 0.71)$ , $n = (0.74 \times T_{boil}/T_{crit} - 0.116)$

For some chemicals, the parameters required to calculate  $H'T_{gw}$  are not available. In these cases, the Henry's Law Constant at 25 degrees Celsius is used instead. The temperature assumed for each chemical is listed as the temperature for groundwater vapor concentration (Column M).

If  $C_{target,ia}$  is determined to be NVT, NVT is entered as the target groundwater concentration (Column I). If  $C_{gw}$  exceeds the aqueous solubility of the pure chemical, but  $C_{target,ia}$  does not exceed the maximum possible pure chemical vapor concentration, then NVT is entered in the table under this column (Column I).

For informational purposes, the calculated groundwater target concentration is compared with the MCL for the compound in Column J.

## References

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