

Radon Vapor Intrusion Screening Level Calculator – 17041

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ABSTRACT

The U.S. Environmental Protection Agency has produced a web-based calculator for the assessment of cancer risk from radon in soil, soil gas, and pore water seeping into above-ground buildings. Like the chemical vapor intrusion screening level (VISL) calculator, the radon VISL (RVISL) provides screening levels in subsurface soil and water that are protective of preliminary remediation goals (PRGs) for radon in air that are based on either cancer risk or Applicable or Relevant and Appropriate Requirements (ARARs). In addition to the screening levels calculated, the RVISL can also calculate the risk from radon concentrations in soil, water, and air. The exposure routes evaluated in the RVISL are inhalation and external exposure from submersion in radon. Two source term options are provided for the user: one without radioactive decay and one with decay. Sources continually generating radon (Rn-222 and Rn-220), such as below ground uranium, would best be modeled with the "without decay" models.

Radon is the second leading cause of lung cancer. Radon is released from the normal decay of uranium, thorium, and radium in rocks and soil. It is an invisible, odorless, tasteless gas that seeps up through the ground and diffuses into the air. In areas without adequate ventilation, such as underground mines, radon can accumulate to levels that substantially increase the risk of lung cancer. Radon can enter homes through cracks in floors, walls, or foundations, and collect indoors. It can also be released from building materials, or from water obtained from wells that contain radon. Radon levels can be higher in homes that are well insulated, tightly sealed, and/or built on soil rich in the elements uranium, thorium, and radium. Basement and first floors typically have the highest radon levels because of their closeness to the ground.

The RVISL will also allow for the calculation of screening levels for thoron (Rn-220) and Rn-219. The RVISL will be useful in assessing the final cleanup goals for subsurface soils where direct contact is not assumed. These sites can be landfills, buried waste cells or naturally occurring. By calculating protective levels of radon in subsurface soils, the likelihood of exceeding CERCLA protective standards (either risk range or ARARs) can be reduced.

INTRODUCTION

The RVISL has a user interface that steps the user through some simple decisions before generating the screening levels. The user activates selection buttons to return the desired screening levels. Options are available for the land use scenario, whether to calculate risk, whether to enter site-specific exposure parameters,

change units of activity, modify the groundwater temperature, modify the sub-slab attenuation factor, and modify the groundwater attenuation factor. Figure 1 presents an image of the main user interface. Groundwater with temperatures other than 25 °C can impact the Henry's Law and thus the screening level. The lower the groundwater temperature, the higher the resulting target groundwater concentration. The sub-slab and the groundwater attenuation factors are directly proportional to the screening level results and every effort should be made to gather site-specific values. As the attenuation factors get smaller the screening levels get smaller. (U.S. EPA 2014)

Radon Vapor Intrusion Screening Level (RVISL)

You will need Adobe Reader to view some of the files on this page. See [EPA's PDF page](#) to learn more.

Radon VISL Calculator

Contents

- Radon VISL Home
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Using the Radon VISL Calculator

Select Scenario

Resident
 Commercial

Risk Option

No
 Yes

Select Screening Level Type

Defaults
 Site Specific

Select Units

pCi
 Bq

Groundwater Temperature (°C):

Attenuation Factor Sub-Slab (unitless):

For sub-slab soil gas, the recommended generic attenuation factor (α_{ss}) is 0.03.

Attenuation Factor Groundwater (unitless):

For groundwater, the recommended generic attenuation factor (α_{gw}) is 0.001.

Figure 1. Radon VISL user interface

A secondary user interface is accessed when the site-specific screening level type option is activated. The first section, called a container, on this page allows user to enter isotope and element-specific information necessary to calculate risk and model vapor transport. The parameters available for modification are: vapor pressure, solubility, Henry’s Law constant, boiling point, critical temperature, enthalpy of vaporization, inhalation slope factor and submersion slope factor. See figure 2.

Radon VISL Calculator

Using the Radon VISL Calculator

User-provided Inputs

Change or remove any of the following parameters. These will be the only inputs to the calculator and the Master Database will NOT be used.

Radionuclide	MW (g/mole)	T _{1/2} (yr)	VP (mm Hg)	Solubility (mg/L)	ARAR	HLC (atm-m ³ /mol)	H' (unites)
Rn-220	220.011284	1.76E-06	8.50E+03	2.00E+03	7.50E+03	1.19E+01	4.86E+02
Rn-222	222.01757	1.05E-02	8.50E+03	2.00E+03	5.00E+03	1.19E+01	4.86E+02
Rn-222+D	222.01757	1.05E-02	8.50E+03	2.00E+03	5.00E+03	1.19E+01	4.86E+02

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Figure 2. Isotope and element-specific parameter modification container.

The second container in the user-interface page allows for the viewing of the screening level equations and modification of the exposure parameters to calculate site-specific indoor air screening levels. Parameters available for editing are: exposure duration, exposure frequency, exposure time, inhalation rate, and target risk. Figure 3 presents the container where these parameters can be changed.

Resident Exposure to Vapor

Indoor Air Screening Level Equations and Parameters

[Resident Air PRG Inhalation with half-life decay](#)

[Resident Air PRG Inhalation without half-life decay](#)

[Resident Air PRG Submersion with half-life decay](#)

[Resident Air PRG Submersion without half-life decay](#)

[Resident Air PRG Total with half-life decay](#)

[Resident Air PRG Total without half-life decay](#)

<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 10%; text-align: center;">26</td> <td>ED_{res} (exposure duration – resident) yr</td> </tr> <tr> <td style="text-align: center;">20</td> <td>ED_{res-a} (exposure duration – resident adult) yr</td> </tr> <tr> <td style="text-align: center;">6</td> <td>ED_{res-c} (exposure duration – resident child) yr</td> </tr> <tr> <td style="text-align: center;">350</td> <td>EF_{res} (exposure frequency) day/yr</td> </tr> <tr> <td style="text-align: center;">350</td> <td>EF_{res-a} (exposure frequency – resident adult) day/yr</td> </tr> <tr> <td style="text-align: center;">350</td> <td>EF_{res-c} (exposure frequency – resident child) day/yr</td> </tr> <tr> <td style="text-align: center;">24</td> <td>ET_{res} (exposure time – resident) hr/day</td> </tr> <tr> <td style="text-align: center;">24</td> <td>ET_{res-a} (exposure time – resident adult) hr/day</td> </tr> </table>	26	ED _{res} (exposure duration – resident) yr	20	ED _{res-a} (exposure duration – resident adult) yr	6	ED _{res-c} (exposure duration – resident child) yr	350	EF _{res} (exposure frequency) day/yr	350	EF _{res-a} (exposure frequency – resident adult) day/yr	350	EF _{res-c} (exposure frequency – resident child) day/yr	24	ET _{res} (exposure time – resident) hr/day	24	ET _{res-a} (exposure time – resident adult) hr/day	<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center;">24</td> <td>ET_{res-c} (exposure time – resident child) hr/day</td> </tr> <tr> <td style="text-align: center;">1.0</td> <td>GSF_a (gamma shielding factor – air) unitless</td> </tr> <tr> <td style="text-align: center;">161000</td> <td>IFA_{res-adj} (age-adjusted inhalation factor) m³</td> </tr> <tr> <td style="text-align: center;">20</td> <td>IRA_{res-a} (inhalation rate – resident adult) m³/day</td> </tr> <tr> <td style="text-align: center;">10</td> <td>IRA_{res-c} (inhalation rate – resident child) m³/day</td> </tr> <tr> <td style="text-align: center;">26</td> <td>t_{res} (time – resident) yr</td> </tr> <tr> <td style="text-align: center;">1.0E-6</td> <td>TR (target cancer risk) unitless</td> </tr> </table>	24	ET _{res-c} (exposure time – resident child) hr/day	1.0	GSF _a (gamma shielding factor – air) unitless	161000	IFA _{res-adj} (age-adjusted inhalation factor) m ³	20	IRA _{res-a} (inhalation rate – resident adult) m ³ /day	10	IRA _{res-c} (inhalation rate – resident child) m ³ /day	26	t _{res} (time – resident) yr	1.0E-6	TR (target cancer risk) unitless
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NOTES:

1. Input fields with a "pink" background are a required entry.
2. Input fields with a "blue" background are calculated dynamically.

Figure 3. Exposure parameter modification container.

The third container presents the equations and intermediate variables for the groundwater and soil gas equation and parameters. Equations are presented correcting the Henry's Law for groundwater temperature, enthalpy adjustment for groundwater temperature, groundwater screening level, soil gas screening level, and vapor concentration at the source. Figure 4 presents these options.

Groundwater and Soil Gas Equation and Parameters

[Correcting the Henry's Law Constant for GW Temperature](#)

$$H'_{gw} = \frac{\exp \left[- \frac{\Delta H_{v,gw} \left(\frac{\text{cal}}{\text{mol}} \right)}{R_c \left(1.9872 \text{ cal/mol} \cdot ^\circ\text{K} \right)} \times \left(\frac{1}{T_{gw} \left(^\circ\text{K} \right)} - \frac{1}{T_R \left(298.15 ^\circ\text{K} \right)} \right) \right] \times H_R \left(\text{atm} \cdot \text{m}^3 / \text{mol} \right)}{R \left(8.205\text{E-}05 \text{ atm} \cdot \text{m}^3 / \text{mol} \cdot ^\circ\text{K} \right) \times T_{gw} \left(^\circ\text{K} \right)}$$

where:
 $T_{gw} \left(^\circ\text{K} \right) = ^\circ\text{C} + 273.15$

[Enthalpy Adjustment for GW Temperature](#)

$$\Delta H_{v,gw} \left(\frac{\text{cal}}{\text{mol}} \right) = \Delta H_{v,b} \left(\frac{\text{cal}}{\text{mol}} \right) \times \left[\frac{1 - T_{gw} \left(^\circ\text{K} \right) / T_C \left(^\circ\text{K} \right)}{1 - T_B \left(^\circ\text{K} \right) / T_C \left(^\circ\text{K} \right)} \right]^\eta$$

[Groundwater Screening Level Equation](#)

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

[Soil Gas Screening Level Equation](#)

$$C_{sg} \left(\frac{\text{pCi}}{\text{m}^3} \right) = \frac{C_{ia, \text{target}} \left(\frac{\text{pCi}}{\text{m}^3} \right)}{AF_{ss}}$$

[Vapor Concentration at the Source](#)

$$C_{sv} \left(\text{pCi/cm}^3 \cdot \text{v} \right) = H'_{TS} \times C_w \left(\text{pCi/cm}^3 \cdot \text{w} \right)$$

0.001	AF_{gw} (Attenuation Factor Groundwater) unitless	25	T_{gw} (Groundwater Temperature) °C
0.03	AF_{ss} (Attenuation Factor Sub-Slab) unitless		

NOTES:
 1. Input fields with a "blue" background were selected on the intro page.

Figure 4. Groundwater and soil gas equation and parameters.

PROGRAMMING STRUCTURE

The RVISL calculations are programmed in SAS®. The user interface is a combination of Perl, JavaScript, jQuery, and HTML/CSS. These programs

communicate with an Oracle® database. Parameters from the database are combined with inputs from the user to complete the screening level calculations.

INTERPRETATION OF RESULTS

Upon submission of the user-provided information, a results screen is provided. The results screen presents the results in tables as well as in PDF and Excel formats. The first output table provided is a table of input parameters. This table is largely comprised of the exposure parameters. See figure 5.

The second output table provided presents the isotope and element-specific parameters for toxicity and chemical properties as well as the screening levels in air, sub-slab soil, and groundwater. See figure 6.

Default

Resident Equation Inputs

[Output to Spreadsheet](#)

[Output to PDF](#)

Variable	Value
TR (target cancer risk) unitless	1.0E-6
ED _{res} (exposure duration – resident) yr	26
t _{res} (time – resident) yr	26
ET _{res} (exposure time – resident) hr/day	24
ET _{res-c} (exposure time – resident child) hr/day	24
ET _{res-a} (exposure time – resident adult) hr/day	24
EF _{res} (exposure frequency) day/yr	350
EF _{res-c} (exposure frequency – resident child) day/yr	350
EF _{res-a} (exposure frequency – resident adult) day/yr	350
ED _{res-c} (exposure duration – resident child) yr	6
ED _{res-a} (exposure duration – resident adult) yr	20
IRA _{res-a} (inhalation rate – resident adult) m ³ /day	20
IRA _{res-c} (inhalation rate – resident child) m ³ /day	10
IFA _{res-adj} (age-adjusted inhalation factor) m ³	161000
GSF _a (gamma shielding factor – air) unitless	1.0

Figure 5. The output table of input parameters.

Default

Resident Risk-Based Radon Vapor Intrusion Screening Levels (RVISL)

Isotope	Inhalation Slope Factor (risk/pCi)	Submersion External Exposure Slope Factor [(risk/year)/(pCi/m ³)]	Lambda 1/yr	Halflife (yr)	Target Indoor Air Concentration (with decay) C _{i,a} (pCi/m ³)	Target Indoor Air Concentration (without decay) C _{ia,n} (pCi/m ³)	ARAR (pCi/m ³)
Rn-220	0.00E+00	2.63E-12	3.93E+05	1.76E-06	1.56E+11	1.53E+04	7.50E+03
Rn-222	3.20E-11	1.62E-12	6.62E+01	1.05E-02	3.34E+02	1.94E-01	5.00E+03
Rn-222+D	3.20E-11	1.62E-12	6.62E+01	1.05E-02	3.34E+02	1.94E-01	5.00E+03

Isotope	Is Target Air Conc. < ARAR?	Target Sub-Slab and Exterior Soil Gas Concentration (with decay) (pCi/m ³)	Target Sub-Slab and Exterior Soil Gas Concentration (without decay) C _{sg,n} (pCi/m ³)	Target Groundwater Concentration (with decay) (pCi/L)	Target Groundwater Concentration (without decay) C _{gw,n} (pCi/L)
Rn-220	No	5.20E+12	5.09E+05	3.21E+08	3.14E+01
Rn-222	Yes	1.11E+04	6.47E+00	6.86E-01	3.99E-04
Rn-222+D	Yes	1.11E+04	6.47E+00	6.86E-01	3.99E-04

Isotope	Target Groundwater Concentration (without decay) C _{gw,n} (pCi/L)	Inhalation PRG (pCi/m ³)	Inhalation PRG (no decay) (pCi/m ³)	External Exposure PRG (pCi/m ³)	External Exposure PRG (no decay) (pCi/m ³)	Total PRG (pCi/m ³)	Total PRG (no decay) (pCi/m ³)
Rn-220	3.14E+01	-	-	1.56E+11	1.53E+04	1.56E+11	1.53E+04
Rn-222	3.99E-04	3.34E+02	1.94E-01	4.25E+07	2.47E+04	3.34E+02	1.94E-01
Rn-222+D	3.99E-04	3.34E+02	1.94E-01	4.25E+07	2.47E+04	3.34E+02	1.94E-01

Figure 6. Output of screening levels and element-specific chemical properties.

ADVANCED APPLICATION

In addition to calculating screening levels, the RVISL allow for the user to enter known air, sub-slab soil, or groundwater concentrations. See figure 7. These concentrations are used to derive chronic daily intakes which when combined with the appropriate attenuation factors, can provide estimates of the cancer risk to the above ground receptor. See figure 8 for an example of the risk when the user enters groundwater concentrations.

Risk Option

- No
- Yes

Media Concentration for Risk (select only one):

- Site Sub-slab or Exterior Soil Gas Concentration (Csg)
- Site Groundwater Concentration (Cgw)
- Site Indoor Air Concentration (Cia)

Figure 7. Risk options.

VI Risk

Resident Radon Vapor Intrusion Risk

Isotope	Inhalation Slope Factor (risk/pCi)	Submersion External Exposure Slope Factor (risk/yr per pCi/m ³)	Inhalation Risk	Submersion Risk	Total Risk	Inhalation Risk (no decay)	Submersion Risk (no decay)	Total Risk (no decay)
Rn-220	.00E+00	2.63E-12	-	1.56E-14	1.56E-14	-	1.59E-07	1.59E-07
Rn-222	3.20E-11	1.62E-12	7.28E-06	5.71E-11	7.28E-06	1.25E-02	9.82E-08	1.25E-02
Rn-222+D	3.20E-11	1.62E-12	7.28E-06	5.71E-11	7.28E-06	1.25E-02	9.82E-08	1.25E-02
<i>*Total Risk/HI</i>			-	-	<i>1.46E-05</i>	-	-	<i>2.48E-02</i>

Figure 8. Cancer risk estimate output based on groundwater concentrations.

CONCLUSION AND FUTURE DEVELOPMENT

The RVISL website replaces a draft spreadsheet calculator developed by the EPA. The RVISL is now linked to the central database of toxicity and chemical-specific parameters that used in several other EPA risk assessment calculators. Currently the RVISL presents risk and ARAR-based screening levels and risk results. Future plans are to allow the user to use dose-based screening levels. Additional plans are to provide more gaseous isotopes including Rn-119.

REFERENCES

U.S. EPA 2014. Vapor Intrusion Screening Level (VISL) Calculator User's Guide. May 2014.