Utah Division of Waste Management and Radiation Control (DWMRC)

Position Paper on the use of the Johnson and Ettinger Model

June 2022

The United States Environmental Protection Agency (EPA) and State risk assessors and toxicologists participate in a quarterly Risk Assessor meeting. The topics of the April 2022 meeting were the numerical/calculational problems with Version 6.0 of the EPA Johnson and Ettinger (J&E) Model Spreadsheet Tool (September 2017) and the applicability of the J&E modeling in risk assessments.

This Position Paper outlines the concerns discussed with the J&E Model Spreadsheet Tool and provides guidance on applicability and use of the Tool at sites in Utah.

Issues and Concerns

Dr. Rich Kapuscinski, EPA Superfund Program, opened the meeting with an overview of the 2017 J&E Model Spreadsheet Tool and noted the following limitations with the 2017 J&E Model Spreadsheet Tool:

- The 2017 model was subject to limited vetting.
- An uncertainty analysis is not included in Version 6.0.
- The model should not be used alone without lines of evidence (LOE), as it could overestimate vapor intrusion (VI), as the model overlooks vapor escape to the atmosphere around buildings.
- The model may also underestimate long-term VI if VI via conduits is occurring.
- The sub-slab attenuation factor in the model differs from that applied in the Vapor Intrusion Screening Levels (VISLs).
- The current on-line version has a programming error in the calculation of lifetime cancer risks for mutagenicity. This is especially concerning for contaminants such as trichloroethylene (TCE).
- Soil moisture and other soil parameters have not been peer-reviewed.
- The tool is a heuristic model, and as such may be practical but not necessarily rigorous.

A question was posed by a member to Dr. Kapuscinski as to whether it is appropriate to use the revised or updated EPA J&E Model spreadsheet of 2017 if revisions are not made? Dr. Kapuscinski responded as follows.

"*As a general matter, appropriateness of use of any mathematical model depends upon the question one is trying to answer, the quality of the input values, and the fitness of the model for the physical situation being modeled. Personally, I do not recommend use of the current EPA modeling tool for soil vapor intrusion, particularly not for purposes of demonstrating that a response action isn't warranted.*"

Another concern that was discussed is related to the ratio of soil gas flow rates, $Q_{soil}/Q_{Building}$, which is currently fixed at 0.003. This ratio describes the rate at which subslab soil gas (Q_{soil}) mixes with indoor air ($Q_{Building}$) and translates to a form of "dilution." The default value of 0.003 is based on average air exchange and volume for a residential building (EPA, 2011) and a central value of Q_{soil} (EPA, 2012). Currently, the model holds this ratio fixed regardless of scenario. Changing from a Residential setting to a Commercial/Industrial scenario automatically increases the ceiling height, air exchange rate, and slab thickness. The ratio is taken from a lookup table and cannot be re-calculated to incorporate the changes in building parameters.

According to Dr. Kapuscinski, EPA's website content manager, "*We are and will be expeditiously addressing these problems, and we intend to have a published or revised and updated tool that is suitable for the commercial/industrial scenario.*"

According to the documentation for Version 6.0 of the model (EPA, 2017), *"Care must be taken to ensure reasonably conservative and self-consistent model parameters are used as input to the model."* Considering the limited site data typically available in preliminary site assessments, the J&E Model can be expected to predict only whether or not a risk-based exposure level is likely to be exceeded at the site. Precise prediction of concentration levels is not possible with this screening level model. In the EPA model, *"both the building ventilation rate and the difference in dynamic pressure between the interior of the structure and the soil surface are constant values."*

Furthermore, in looking at the EPA VI Guidance Document of June 2015, Section 6.6, General Principles and Recommendations for Mathematical Modeling, it states that:

- When suitably constructed, documented, and verified, mathematical models can provide an acceptable line of evidence supporting risk management decisions pertaining to VI.
- In certain situations (e.g., for future construction on vacant properties), it is particularly useful to employ mathematical modeling to predict reasonable maximum indoor air concentrations, because indoor air testing is not possible.
- Generally, mathematical models transform empirical values of input parameters into predictions of chemical concentrations in environmental media. The model input parameters are equally as important to the results as the mathematical components of the model (i.e., governing equations and solution algorithms). As a consequence, the results critically depend on the choices for the inputs.
- Historically, to assure confidence in predictions of mathematical models, they have been compared to measured, site-specific values. When measured and predicted values do not reasonably match, model input parameters are adjusted through calibration.
- Calibrating the mathematical model to the measured indoor air concentration and, possibly, the sub-slab soil gas concentration that is representative of VI (i.e., background vapor sources have been identified and removed prior to sampling and data evaluation that indicates that the concentration is reasonably attributable to VI).
- Model results (i.e., predicted sub-slab soil gas concentrations, indoor air concentrations) that match measured values increase confidence in the model. Reliability of the results

need to be confirmed, especially when limited site-specific data are available and the model is not calibrated to observed indoor air concentrations.

The above suggest that whenever a mathematical model is used to make predictions pertaining to VI (including the J&E), EPA recommends that the site planning and data team perform individual field measurements to confirm the results of the modeling exercise.

This means that to use the J&E Model, which is a predictive mathematical model, one must collect sub-slab data or other site-specific data to perform model calibration. Unless site-specific parameter values are obtained for input parameters and the mathematical model is calibrated to field data, use of default input parameter values will generate model results that lie at an unknown point within an uncertainty band of the model outcomes. Because the combined effect of parameter uncertainty is large, a one- or two-order of magnitude error might be made unknowingly.

The use of extreme and non-representative assumptions or parameter values is thus the most common weakness of mathematical modeling for environmental assessments. Mathematical modeling typically yields more reliable results when used with high-quality, site-specific data inputs that is, representative of groundwater or soil gas concentrations, depth to groundwater, soil type and moisture content underneath the building, and the building conditions (e.g., air exchange rate, building mixing height). In these cases, the site-specific data inputs and the conceptual site model (CSM) provide additional lines of evidence supporting the use of mathematical modeling as a line of evidence.

It is also EPA's practical experience that the J&E Model under-predicts VI at some well characterized sites that needed some response action. Even with scientifically defensible input parameters the J&E Model has been found not to predict the range of results observed in real life situation studies or empirical data.

On that basis, EPA is limiting the use of mathematical models such as the J&E Model in site-specific attenuation factors (AFs) evaluations without model calibration, (USEPA, 2015 and 2017).

Based on the above documented limitations of the revised J&E Model and mathematical models in general, some states, California (CalEPA, 2020) and Ohio (Ohio EPA, 2016 and 2020), along with EPA Region V (Bhooma Sundar) have limited the use of the J&E Model and do not accept its use in the determination of site-specific attenuation factors and VI screening assessment of contaminated sites without prior approval.

Policy Recommendations

- The J&E Model is not acceptable for VI assessment at contaminated sites until such time that EPA addresses the $Q_{soil}/Q_{Building}$ ratio issues and publishes a corrected and revised version.
- The J&E Model is not acceptable for use in VI assessment at contaminated sites until such time that EPA addresses the programming errors in the calculation of lifetime cancer risks for mutagens.

- In the event that EPA corrects the $Q_{soil}/Q_{Building}$ ratio issue, the calculation errors in the lifetime cancer risks for mutagens and any other errors that may come to light, prior approval from the Division will be required to use the J&E model in VI assessment at contaminated sites.
- The J&E Model is not acceptable for use in VI assessment at contaminated sites unless site-specific parameter values are obtained for input parameters and the model is calibrated using field data to produce results that confirm one or more of the modeling results.
- The J&E Model is not acceptable for the derivation of site-specific AFs for use in any VI mathematical models.
- In lieu of the J&E Model, the Division recommends the use of the EPA VISL calculator for VI assessment at contaminated sites and following the EPA Final VI guidance document of 2015.

EPA VISL Calculator

EPA compiled a database of empirical attenuation factors (AFs) for chlorinated volatile organic compounds (CVOCs) and residential building through review of data from 913 building at 41 sites with indoor air concentrations paired with sub-slab soil gas, groundwater, exterior soil gas, or crawl space concentrations (EPA 2012a). After removing data that do not meet quality criteria and data likely to be influenced by background sources, the distribution of the remaining attenuation factors was analyzed graphically and statistically. The result of these analyses produced the default recommended attenuation factors (AFs) to be used in the VISL calculator.

The recommended AFs are proposed to apply to all vapor-forming chemicals for use in estimating potential upper-bound concentrations of indoor air that may arise from VI. The recommended AFs do not however, include the effects of biodegradation, (OSWER Directive VI Guidance, 2015 Appendix A).

The reliability analyses conducted suggests the recommended AFs on which the VISL is based, can reasonably be expected to provide an acceptably small probability of ‘screening out’ (false negative conclusion) sites that pose a vapor intrusion concern and high probability or correctly identifying sites or buildings that may pose a VI concern.

EPA recommends that site assessors must generally collect and weigh multiple lines of evidence (LOE), including qualitative information, to support decision-making regarding VI pathway.

References

McHugh,T. and L. Beckley. 2018. Sewers and Utility Tunnels as Preferential Pathways for Volatile Organic Compound Migration into Buildings: Risk Factors and Investigation Protocol.

Holton, C., H. Luo, P. Dahlen, K. Gorder, E. Dettenmaier and P.C. Johnson. 2013. Temporal Variability of Indoor Air Concentrations Under Natural Conditions in a House Overlying a

Dilute Chlorinated Solvent Groundwater Plume. Environmental Science & Technology 47. Pp. 13347-13554.

Joseph Koncelik. June 23, 2016. Ohio EPA Takes Hard Look at Vapor Intrusion Risk. Ohio EPA, Ohio Environmental LAW BLOG.

CalEPA 2020. Supplemental Guidance: Screening and Evaluating Vapor Intrusion. California Department of Toxic Substances Control, California Water Resources Control Board. February 2020.

USEPA Region V. 2022. EPA Soil Vapor Intrusion Model Applications Region V Approach. Bhoomer Sundar, Webinar Presentation, State Risk Assessors, April 19, 2022.

USEPA Region V. 2022. Assessing Soil Vapor Intrusion Using Mathematical Models. Richard Kapuscinski, Webinar Presentation, State Risk Assessors, April 19, 2022, USEPA/OLEM/OSRTI/Science Policy Branch.

USEPA. 2017. Documentation for EPA's Implementation of the Johnson and Ettinger Model to Evaluate Site Specific Vapor Intrusion into Buildings, Version 6.0. US Environmental Protection Agency. Office of Superfund Remediation and Technology Innovation. September 2017.

USEPA 2015. OSWER Technical Guide for Addressing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air. Office of Solid Waste and Emergency Response. Publication 9200.2-154. June 2015.

USEPA 2012. EPA's Vapor Intrusion Database: Evaluation and Characterization of Attenuation Factors for Chlorinated Volatile Organic Compounds and Residential Buildings. Office of Land and Emergency Management. Washington, D.C. EPA 530-R-10-002. March 16.

USEPA 2011. Exposure Factors Handbook. National Center for Environmental Assessment office of Research and Development. EPA/600/R-09/052F. September.