C11 Application of a Monte Carlo Analysis to the Johnson and Ettinger Soil Vapor Intrusion Model

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After attending this presentation attendees will be able to recognize the forensic distinctions between applying a Monte Carlo analysis to estimate the most likely impact of soil vapor intrusion as opposed to calculating unique solutions to the Johnson & Ettinger Vapor Intrusion model.

This presentation will impact the forensic science community by providing understanding of how models are often used to develop the justification for forensic investigations and actions. In order to apply the models correctly, the users must recognize when a Monte Carlo analysis is appropriate.

Models are used in environmental investigations to describe the site conditions using the best available data. Known values are combined with estimates of unknown values to develop a representation of the historical or current or future site conditions. Confidence in the model may be increased as the site description improves, either by acquiring more data, or by improving the sophistication of the model. However, an environmental model should be as simple as possible to utilize or else its complexity will overwhelm practitioners.

Federal guidance and many state regulations cite the Johnson and Ettinger soil vapor intrusion model to describe the interactions of environmental factors which could influence the migration of a volatile chemical in groundwater into soil vapor and thence into the indoor air of a building. The Johnson and Ettinger (J&E) model calculates an attenuation factor, α, for the ratio of the subsurface soil vapor concentration versus the indoor air concentration due to vapor intrusion. Some of the J&E model inputs include chemical reference values, scientifically derived characteristic values, measured site specific values, and estimated site information. The J&E model's complexity is suggested by publications intended to simplify its use.[1] Confidence in the representativeness of the model is generally low when it is tested against a small number of samples from a site, but for large sites the average value of the modeled α has been shown to approximately represent the average attenuation factor for large numbers of samples.[2]

The failure of the J&E model to represent site conditions for small numbers of samples may be due to short-term fluctuations in some site factors that have very large effects on the model, but may not represent the average conditions found when analyzing many samples from the same site. The measured attenuation factors for a pair of samples could be predicted with choice selections of parameters in the J&E model, but using EPA recommended parameters probably will not generate a comparable result.

A Monte Carlo analysis using parameters from EPA and API vapor intrusion guidance gives a probability distribution for α. Single determinations of α may vary by several orders of magnitude depending on the values selected for the J&E model parameters, but the central tendency of the Monte Carlo probability distribution for α has a much smaller range. As critical input factors for the model are varied, the overall impact on the central tendency of α is less than the variation predicted from unique determinations of the model.

EPA has compiled a vapor intrusion database (http://www.epa.gov/oswer/vaporintrusion/vi_data.html) which was queried for the average attenuation factor for all results for trichloroethylene detected in soil gas versus indoor air. The average attenuation factor calculated from the database (N=75) was 1.8×10^{-3} and the 50^{th} percentile was 1.2×10^{-4} (range 9.7×10^{-7} to 5.5×10^{-2}). A Monte Carlo simulation for TCE vapor intrusion using the J&E model gave an average α of 2.3×10^{-4} which also was the same value as the 50^{th} percentile of 20,000 iterations (range 1.3×10^{-5} to 8.1×10^{-4}).

The Monte Carlo analysis gives a much narrower range of attenuation factors than are found in the EPA database of field measurements. However, the range of possible values of site specific parameters is limited for the Monte Carlo analysis, which tends to limit the range of values generated by the calculations. The mean value of the Monte Carlo analysis is comparable to the mean of all values in the EPA database, which is more precise than the range of estimated attenuation factors calculated in the EPA reference guidance.

A Monte Carlo analysis of the J&E model with a defined set of site specific characteristics will predict a small range of reasonable values of α, while a deterministic approach to using the model to describe vapor intrusion at a site might not be any more accurate than a best guess. The Monte Carlo analysis can be used to predict the most likely site conditions.

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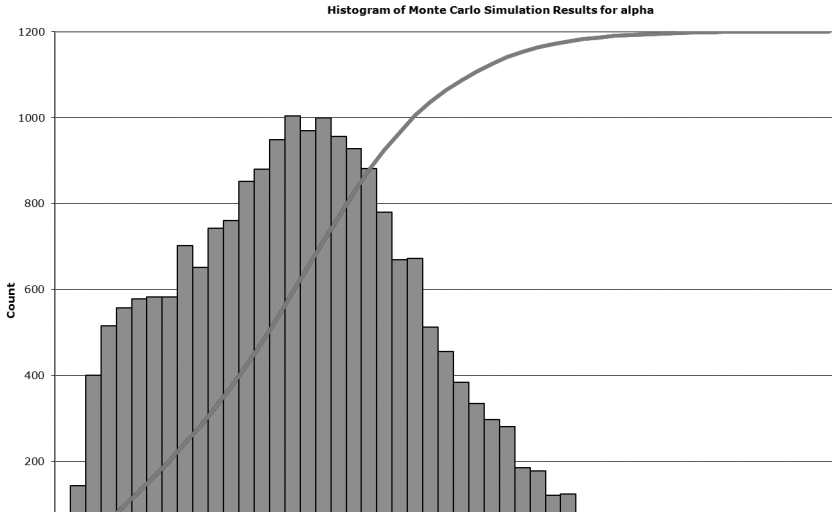

References:

1. Johnson 2002, *Identification of Critical Parameters for the Johnson and Ettinger (1991) Vapor Intrusion Model*, and, EPA 2000, User's *Guide for the Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion into Buildings*).
2. Hers et al 2003, *Evaluation of the Johnson and Ettinger Model for Prediction of Indoor Air Quality*

Monte Carlo, Johnson & Ettinger Model, Soil Vapor Intrusion

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