EVALUATION OF UNCERTAINTY IN A SITE-SPECIFIC RISK ASSESSMENT[a]

Discussion by Reza Iranpour,[4] David Miller,[5] and Ahmad Abrishamchi[6]

Not only is this an excellent paper, but the authors' overall project to model the cancer risk from soil contamination is a greatly needed advance (Thompson et al. 1992). In estimating risk by combining data about carcinogens—their chemistry, their toxicology, routes, and scenarios of exposure—with a simple geological model and systematic use of probability theory to address sources of uncertainty, the authors have set an example for other environmental researchers to follow. The discussers encourage the authors to continue development of soil risk until it can be used as an aid to decision-making by the EPA or other government agencies and private companies concerned with the environment.

The discussers invite responses to the following comments and suggestions. Because more than two and a half years have elapsed since this paper was submitted, substantial additional work already may have been done on soil risk software.

1. Not only would it be a routine programming task (perhaps already done) to add more organic chemicals to the list of carcinogens (benzene, trichloroethylene, chlordane, benzo[a]pyrene), but the fate schema of volatilization, degradation, and transport evidently can accommodate heavy metals and radioactive substances as well. Nonradioactive heavy metals do not degrade, but they can be leached; the exponential decline of radioactivity is similar for modeling purposes to bacterial degradation of organic chemicals.
2. It might be useful to perform calculations for climate parameters suitable to other areas of the United States, such as wetter and warmer climates in the south or desert conditions in the southwest. For example, a warmer climate probably would increase the rate of bacterial degradation, but increased rainfall would increase the rate of leaching and ground water transport.
3. It might be useful to investigate additional toxins that might provide other examples of a cumulative distribution with a large variance, especially if such a contaminant is a major source of risk in an exposure scenario. For example, a toxin with high mobility and high degradability might be more sensitive to variations in temperature and Darcy velocity.
4. There may be a need for a more realistic geological model to account for lateral spreading of a plume of contamination as well as spreading straight downstream from a contamination site.
5. Eventually the authors might study possible interactions between toxins, either in exposed people or in the bacterial degradation process. For example, Phenol, which acts as a disinfectant, might slow the bacterial degradation of benzene. Such interactions are difficult to discern but may be significant departures from the implicit assumption of independent risks used in this model (Fig. 2).

The discussers also have a few questions on tables and graphs in the paper.

1. There is an apparent typographical error in Table 3, in which the first parameter listed is the "fastest mile of wind (m/s)." We assume that this is the fastest typical wind in some sense, but the parameter seems unclear as stated.
2. Comparison of Table 2 with the explanation on page 240 of the selection of the probability distribution functions shows that several of the distributions of the site-related parameters were based on very little available data. Would other choices have made a significant difference in the cumulative distribution functions (CDFs) in Fig. 6?
3. Have EPA site characterization procedures changed since the late '80s to provide more of the information needed by this kind of model?
4. Based on comparison Fig. 3(a) and Fig. 3(b), it appears that exposure to BaP in the off-site residential scenario is due exclusively to the air exposure route, as would be expected because of the insolubility of BaP. However, mentioning this explicitly in the discussion of Fig. 3 would have been desirable.
5. The CPFs in Fig. 6 provided less difficulty with overlaps than plotting the PDFs would have done, but perhaps another figure, showing an example of two or three of the corresponding PDFs, would have provided a helpful comparison. For example, the four distributions for chlordane are well enough separated that the PDFs would not have overlapped significantly, and a plot of this would have provided another view of the unusual distribution for the off-site residential scenario.

Because large expenditures have been made on remediation of Superfund and other soil contamination sites, the authors' work has the potential to be economically important in modifying priorities and procedures for dealing with contaminated soil. The discussers hope that these suggestions may provide some assistance in this important research.

Closure by Paula A. Labieniec,[7] David A. Dzombak,[8] and Robert L. Siegrist[9]

The authors would like to thank the discussers for their encouragement and positive comments. Here is an itemized response to the discussers' comments and questions.

Response to comments:

1. SoilRisk, the program developed to provide estimates of carcinogenic risk as a function of contaminant concentration in soil, requires as input specific contaminant-related parameters such as aqueous solubility and Henry's Law coefficient. Users of the software need only provide required data to run SoilRisk for any organic contaminant. It is important to note that while it is true that most of the transport processes modeled in SoilRisk are also applicable to metals, the fate processes for metals, including water-solid phase partitioning, depend strongly on aqueous solution chemistry, which is not modeled in SoilRisk. Therefore, SoilRisk is not applicable to metals in its current configuration.

[a]March 1997, Vol. 123, No. 3, by Paula A. Labieniec, David A. Dzombak, and Robert L. Siegrist (Paper 9376).

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2. Just as contaminant-related input parameters can be specified for any organic contaminant, users of SoilRisk can specify the climate-related parameters to simulate any climate. However, the authors wish to repeat their caveat (Labieniec et al. 1996). Since the contaminant fate and transport modules of SoilRisk were developed to provide long-term average contaminant concentrations in environmental media for evaluation of chronic exposure and carcinogenic risk, SoilRisk utilizes annual average climatic conditions and site properties. The model may therefore be more applicable to humid regions than to arid regions, where infiltration is more event-driven. In addition, it is important to note that the biodegradation rate is user specified and is not modeled explicitly as a function of site conditions.
3. No doubt investigation of additional contaminants would provide additional insights. The authors did investigate a compound with high mobility and degradability—namely, benzene. The sensitivity analyses revealed that for the hypothetical site investigated, degradation was the primary mode by which benzene was lost from the unsaturated zone, and variations in site-related parameters such as Darcy velocity and temperature had little effect on benzene's fate and subsequently on the total risk estimate.
4. The current saturated zone model incorporated into SoilRisk is a 2-D model, which provides estimates of contaminant concentration with consideration of lateral plume spreading. However, risk estimates in SoilRisk are developed with the assumption that the exposure location (the ground water well) is on the plume centerline.
5. Synergistic effects are possible when total risk due to mixtures of chemicals is estimated. Synergistic effects are dependent on many factors, however, and are very difficult to model in a general manner.

Response to questions:

1. There is no typographical error in Table 3. The fastest mile of wind is a routinely measured meteorological variable that represents the wind speed corresponding to the whole mile of wind movement that has passed the 1 mile contact anemometer in the least amount of time (Cowherd et al. 1985).
2. This question is addressed in the sensitivity analyses. The parameters to which the total risk estimates are sensitive are identified. If different probability distribution functions (PDFs) were assigned to sensitive parameters, results presented in Fig. 6 could be affected. However, where little information was available about a particular parameter, PDF assignments were made to reflect the range of possible values at the hypothetical site based on assumed site location and characteristics. Therefore, it is unlikely that the variances of the risk CDFs for the hypothetical site presented in Fig. 6 would be any greater with additional information.
3. There have been no dramatic changes in routine site characterization procedures since this work was performed.
4. The purpose of Fig. 2 is to illustrate the relative importance of the various exposure routes for each exposure scenario.
5. The plot suggested would provide an interesting perspective, and in the course of the study the authors prepared some graphs similar to that described. Unfortunately, space limitations would not allow any additional figures in the paper.

APPENDIX. REFERENCE

Cowherd, C. J., Muleski, G. E., Englehart, P. J., and Gillette, D. A. (1985). "Rapid assessment of exposure to particulate emissions from surface contamination sites." Office of Health and Envir. Assess., Office of Res. and Dev., U.S. EPA, Washington, D.C.