John G. Haggard, Manager
Hudson River Program

General Electric Company
320 Great Oaks Office Park, Ste: 323
Albany, NY 12203
Fax: (518) 862-2731
Telephone: (518) 862-2739
Dial Comm: 8 232-2739*
E-Mail:John.Haggard@corporate.ge.com
Pager: 518-484-3177

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Owen Hoffman, Ph.D.
President and Director
SENES Oak Ridge, Inc.
120 Donner Drive
Oak Ridge, TN 37830

RE: Hudson River PCBs Superfund Site: Human Health Risk Assessment Peer Review

Dear Dr. Hoffman:

In anticipation of the upcoming peer review of EPA's Human Health Risk Assessment for the Upper Hudson River, I enclose for your consideration a short report concerning Charge Question 5. The report was prepared by Dr. Russ Keenan of Ogden Environmental and Energy Services on GE's behalf, and addresses EPA's use of Monte Carlo Analysis in the risk assessment process.

I am sending you this Report because the proper use of Monte Carlo analysis is critical to provide a more realistic assessment of risks to anglers from fish consumption and allow the risk manager and the public to understand more fully the uncertainty associated with the risk estimates. In addition, as Dr. Keenan's report explains, EPA's Responsiveness Summary fails to address many of these critical issues associated with the Agency's use of Monte Carlo Analysis or to respond in a meaningful manner to suggestions made by GE to improve the Monte Carlo Analysis approach taken in the risk assessment.

I hope that you find this report useful as you complete the peer review process. If you have any questions, please do not hesitate to contact Dr. Keenan (207-879-4222) or myself (518-862-2739).

Yours truly,

John Haggard/bg

John G. Haggard

JGH/bg

Enclosure

cc: Alison Hess, U.S. EPA
William McCabe, U.S. EPA
Douglas Tomchuk, U.S. EPA
Douglas Fischer, U.S. EPA (ORC)
Marion Olsen, U.S. EPA
Nancy Kim, NYDOH
Anders Carlson, NYDOH
Bob Montione, NYDOH

HUDSON RIVER MONTE CARLO ANALYSIS

Introduction

Charge Question 5 asks the Peer Review panel to assess whether the HHRA's

> Monte Carlo analysis makes appropriate use of the available data, uses credible assumptions, and adequately addresses variability and uncertainty associated with the fish ingestion pathway (e.g., defining the angler population, PCB exposure concentrations, ingestion rates, exposure durations, cooking losses) qualitatively or quantitatively, as appropriate, in the analysis (see HHRA, pp. 72-74).

This question is important because the proper use of Monte Carlo analysis will provide a more realistic assessment of risks to anglers from fish consumption and allow the risk manager and the public to understand more fully the uncertainty in the risk estimates.

GE believes that EPA's Monte Carlo analysis suffers from several important flaws and is inconsistent with Agency policy. Specifically,

- EPA's basis for rejecting the use of Microexposure Event Analysis is mistaken and, by not using this approach, the Agency has failed to take advantage of all available site data. The result is a gross simplification and overestimation of risk.
- EPA's description of its Monte Carlo analysis is neither transparent nor detailed enough to allow the reader to understand all the methods, uncertainties, limitations and assumptions made by the Agency.
- EPA's rationale for not conducting a Monte Carlo analysis for the mid-Hudson – because PCB levels in fish are lower than in the Upper Hudson – does not make sense. EPA's decision to not rerun the Monte Carlo analysis for the Upper Hudson with the revised fish concentration data is inconsistent with Agency guidance.
- EPA should have conducted a two-dimensional Monte Carlo analysis in order to separate variability from uncertainty and thus provide more useful information for the risk manager and the public.
- EPA can and should have considered the uncertainty and variability of non-cancer PCB toxicology in its Monte Carlo analysis.

We address each of these issues below.

EPA Should have Used Microexposure Event Analysis

EPA improperly rejected the use of Microexposure Event (MEE) analysis (EPA, 2000), claiming that MEE analysis would not be protective of human health because it would mask a high-end fish consumer by averaging high-end consumption for one meal with a low-end or average consumption for another meal. EPA stated that it is more protective to assume that a person, who, for example, consumes fish at the high-end, always consumes at a high-end rate.

EPA's rationale for rejecting microexposure modeling is flawed and unwarranted. With MEE analysis, there are many options for modeling time-dependent variations in angler behavior based on available data, without resorting to the extreme example cited by the Agency. Microexposure, a refinement of traditional Monte Carlo techniques, allows one to model varying exposures over time by aggregating a sum of independent exposure events over an individual's lifetime. In this way, it can capture temporal changes in interindividual variation (Simon, 1999). The theory and detailed methodology behind MEE analysis are documented in the literature (Harrington et al., 1995; Price et al., 1996a; Keenan et al., 1996a; Simon, 1999). In brief, an individual's total exposure to a contaminant is calculated by summing the doses received during many individual exposure events. Each event is simulated using information specific to the time and location of the exposure event. The number of events and sequence in which they occur in the person's life can be simulated based upon information on an individual's short- and long-term behavior.

Modeling long-term exposures as a summary of separate events is not new; in fact, this approach is recommended by EPA (1992a) for evaluating exposures that occur primarily during childhood, when body weights change rapidly. Microexposure analysis has been used by EPA and by independent researchers to simulate duration of residential exposure (Johnson and Capel, 1992; Sielken, 1994). It also has been used to evaluate childhood exposures to lead (Goodrum et al., 1994), exposure to contaminants in tap water (Harrington et al., 1995), and to evaluate exposure

to dioxins from the consumption of freshwater fish (Keenan et al., 1993a,b; 1995; 1996b; 1997a,b). Microexposure analysis was employed in the supplemental risk assessment for the Stringfellow Superfund site in California (Pyrite Canyon Group, 1994; Keenan et al., 1996a). Recently, MEE analysis has been described in the EPA's proposed *Risk Assessment Guidance for Superfund: Volume 3, Part A -- External Review Draft* as a viable alternative for modeling time-dependent variability in concentrations, daily activity patterns, and other behavioral exposure factors (EPA, 1999b).

By rejecting MEE, EPA fails to make full use of all available data because the Agency's risk assessment methodology is not sophisticated enough to accommodate it. For example, Boyle et al. (1990) found that 30 percent of anglers do not fish every year. Connelly et al. (1999) reported that only 25 percent of surveyed anglers fished in each of the previous six years. Finally, Connelly and Brown (1995) [as cited by EPA (1999a)] reported that one-third of all anglers move from high avidity to low avidity each year. This information should be used to model year-to-year variation, but EPA's Monte Carlo model lacks the power to make use of these data. Furthermore, studies of long-term exposure rates to contaminants in fish have demonstrated that the distribution of chronic exposure rates in a population of anglers is greatly affected by inter-year variation in consumption rates (Price et al., 1996b). EPA's failure to model inter-year variation significantly overestimated the upper percentiles of exposure and risk.

Recently, Dr. Ted Simon of U.S. EPA published a systematic comparison of the various methods of probabilistic risk analysis through application to the fish ingestion pathway at the SangamoWeston/Lake Hartwell Superfund site (Simon, 1999). In this paper, he identified a feature of microexposure event modeling that differentiates it from all of the other methods: *the ability to model decreasing concentrations of PCBs in fish tissue.* Simon (1999) found that the deterministic risk estimates and those from one-dimensional and two-dimensional Monte Carlo methods were essentially the same, whereas the microexposure event model gave risk estimates that were approximately an order of magnitude lower. He attributed this decrease to the power of the method to incorporate changes in the concentration term.

EPA's rejection of MEE analysis is also inconsistent with Agency policy. During the last few years, EPA's policies and guidelines have focused on improving risk management by presenting decision-makers with the entire range of possible risks rather than a single point estimate (EPA, 1992b,c; 1995a,b; 1997a,b; 1999b). The new policy states that numerical risk assessments should be accompanied by a full characterization of the uncertainties, limitations and assumptions in the risk assessment. The use of MEE analysis can more effectively characterize the impact of variability or uncertainty in input parameters on the estimates of dose rates in an exposed population by considering time-dependent changes. Other Monte Carlo methods cannot readily be used for this purpose, and thus, critical information for regulatory decision-making will be absent from the analysis. In summary, EPA has failed to use a valuable tool that would more accurately characterize potential risks to anglers of the Upper Hudson River.

EPA's Monte Carlo Analysis Is Not Transparent and Lacks Sufficient Explanatory Description

Good scientific practice as well as EPA's policy and guidance on Monte Carlo analysis (EPA, 1997a,b) requires that the methods, uncertainties, limitations and assumptions used in the risk assessment must be clearly identified. As noted in GE (1999), the model used in the HHRA fails to meet the above criteria. An adequate description of the data sets used to derive inputs, an adequate description of the model, and a detailed description of the inputs to the 72 model runs were not provided. For a Monte Carlo analysis to be transparent and reproducible, it is critical that sufficient information be provided to allow the reader to conduct an independent reproduction of the analysis. The level of detail provided in the HHRA (EPA, 1999a) failed to meet this level of scientific practice.

Furthermore, EPA's provision of supplemental information on the model in response to GE's request did not enhance the transparency of the HHRA. Although mathematical formulas and functions were supplied, simply providing the code does not enhance transparency absent a discussion of the detailed structure of the model, how the model inputs were selected, and what quality assurance, quality control, and debugging steps were taken to insure accuracy. A

reviewer of a Monte Carlo model should be able to perform a ground-truthing of the analysis to ascertain how a specified value is selected, stored, and used in subsequent model steps. This could not readily be done based on the information that EPA furnished in response to GE's request.

EPA Improperly Rejected Its Monte Carlo Model for the Mid-Hudson and It Did Not Rerun the Analysis With the Revised Fish Concentration Data for the Upper Hudson

Although EPA conducted a probabilistic assessment of risk for the Upper-HHRA, it failed to include such an analysis for the Mid-Hudson reasoning that "a Monte Carlo analysis of cancer risks and non-cancer hazards for the fish ingestion pathway was not warranted for the Mid-Hudson HHRA, because the concentrations of PCBs in the Mid-Hudson River are lower than in the Upper Hudson." [Mid-HHRA, page ES-2] This rationale is inconsistent with good scientific practice.

According to the EPA's guiding principles for probabilistic analysis, a Monte Carlo analysis is useful when screening-level risk estimates are above levels of concern (EPA, 1997b). In addition, a Monte Carlo analysis is useful:

> "...when it is necessary to disclose the degree of bias associated with point estimates of exposure; when it is necessary to rank exposures, exposure pathways, sites or contaminants; when the cost of regulatory or remedial action is high and the exposures are marginal; or when the consequences of simplistic exposure estimates are unacceptable." (EPA, 1997b).

All the factors favoring application of Monte Carlo techniques are present for the mid-Hudson. Simply because there are lower concentrations of PCBs in mid-Hudson fish (that still lead to excessive risks under EPA's screening level analysis) does not justify not performing a Monte Carlo analysis. Accordingly, EPA should have conducted a Monte Carlo analysis for the mid-Hudson River.

As pointed out in the *Responsiveness Summary*, EPA is now basing the HHRA on the modified future concentrations of PCBs in sediment, water, and fish presented in the January 2000 *Revised*

Baseline Modeling Report. EPA has not re-run the Monte Carlo analysis of the fish ingestion pathway to consider the changes in forecasted fish PCB concentrations. This deficiency is contrary to both logic and good scientific practice.

EPA Should Have Performed a Two-Dimensional Monte Carlo Model to Properly Separate Variability from Uncertainty

EPA (2000) asserted in the *Responsiveness Summary* that there are insufficient data to perform a two-dimensional Monte Carlo analysis of variability and uncertainty. While EPA indicated that it views uncertainty in terms of parametric uncertainty, it does not actually define the uncertainty in the parameters of the variability distributions; nor does it identify what factors or data gaps prevent it from defining the parameters and their uncertainties. GE (1999) discussed how other mechanisms besides parametric uncertainty are available to characterize uncertainty in distributions of interindividual variation. For example, empirical distributions of uncertainty and variability could be developed using two-dimensional matrices (Cullen and Frey, 1999). In addition, techniques such as meta-analysis or systems of weights could characterize uncertainty where a series of discrete distributions (such as the findings of different surveys of anglers) were used.

EPA Misapplied Agency Policy and Failed to Consider Quantitative Methods for Addressing Variability and Uncertainty of PCB Non-cancer Toxicity

In the *Responsiveness Summary*, EPA (2000) stated that, consistent with Agency policy, a quantitative evaluation of the variability and/or uncertainty associated with non-cancer toxicity values was not included in its Monte Carlo analysis. EPA's current policies, in fact, do not support this conclusion because they do not address this issue. EPA's (1997b; 1999b) *Guiding Principles for Monte Carlo Analysis* are intended to serve as a minimum set of principles that neither constrain nor prevent the use of new or innovative improvements where scientifically defensible. Furthermore, EPA's proposed *Risk Assessment Guidance for Superfund: Volume 3, Part A -- External Review Draft* does not preclude the use of distributions for toxicity in humans (EPA, 1999b). According to the proposed guidance:

> "...toxicity values will generally be characterized by point estimates because of limitations in the data and techniques for characterizing distributions for toxicity in humans. Only if adequate supporting data are available to characterize variability or uncertainty in toxicity values will the Agency consider the use of distributions for toxicity."

GE believes that adequate supporting data do exist and that a sound methodology is available for characterizing a distribution of PCB toxicity values for the probabilistic risk assessment of the Upper Hudson River. In its comments, GE discussed an innovative approach to develop a probabilistic reference dose (RfD) for PCBs. This approach was developed under a Cooperative Research and Development Agreement with U.S. EPA under the provisions of the Federal Technology Transfer Act. A number of articles describing the theory and application of this method have appeared in the peer-reviewed literature and at international toxicological symposia with EPA scientists as co-authors (Price et al., 1995; 1997a,b; 1999; Swartout et al., 1995; 1997; 1998; Carlson-Lynch et al., 1997; 1999; Harvey et al., 1997). The HHRA for the Upper Hudson River should not summarily reject consideration of a probabilistic RfD for PCBs.

In brief, a number of authors have investigated how to characterize the uncertainty in the population threshold using the IRIS framework for setting RfDs (Baird et al., 1996; Slob and Pieters, 1997; Swartout et al., 1998). The existing numerical values of the uncertainty factors can be replaced with distributions that reflect interchemical variation in appropriate ratios, resulting in an uncertainty distribution for the threshold of the compound (Swartout et al., 1998). This distribution is an estimate of the true but unknown threshold where the RfD is some point on the lower end of the distribution.

Swartout et al. (1998) developed a probabilistic approach to uncertainty factors based on the IRIS definition and use of RfDs by the EPA using a standard two-parameter lognormal distribution that is shifted on the x-axis, starting at a value other than zero (offset). The two parameters are the mean (μ) and the standard deviation (δ) in addition to the offset (τ). These are set such that the median (50^{th} percentile) is a value of $10^{0.5}$ and the 95^{th} percentile is equal to 10 (Swartout et al., 1998). As stated previously, the value of 10 represents the high-end estimate of uncertainty and the choice of $10^{0.5}$ for the median is based on the common use of the value of 3

as an alternate uncertainty factor. The mean is equal to the logarithm of the offset-adjusted median of U_R [$\mu = \log_{10}(\text{median}(U_R) - \tau)$]. The parameter values satisfying these assumptions are $\mu = 0.335$, $\delta = 0.3765$ and $\tau = 1$. In cases where an uncertainty factor of 3 represents the loose upper bound estimate of uncertainty, a simple approximation of the distribution is the square root of U_R (Swartout et al., 1998).

Swartout et al. (1998) methodology can be applied to EPA's uncertainty factors associated with the RfD for PCBs to develop an uncertainty distribution of the population threshold for PCBs. This methodology uses the equations for setting an RfD but replaces the uncertainty factors with distributions. A probabilistic technique (Monte Carlo Analysis with Latin Hypercube) is then used to determine the uncertainty in the estimate of the population threshold.

This approach allows the risk assessor to account for the uncertainty associated with the RfD in the risk characterization process by including both the exposure side and the toxicity component in a true probabilistic risk assessment.

Conclusion

As explained in this paper, GE believes that EPA's application of Monte Carlo techniques to the Hudson River is seriously deficient. EPA failed to take full advantage of this powerful analytical approach. GE believes that EPA should conduct a more refined and sophisticated analysis that will provide more accurate and useful information to the public and risk managers.

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