Using a Microexposure Event Analysis to Model Potential Exposures to PCBs through Ingestion of Fish from the Upper Hudson River

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1. Abstract

The potential risks to human health associated with the ingestion of fish containing polychlorinated biphenyls (PCBs) traditionally have been evaluated by using simple algebraic equations to calculate the dose received by a highly successful angler. A Lifetime Average Daily Dose (LADD) is estimated using default assumptions concerning the quantity of fish consumed, an angler's body weight, an angler's exposure duration, and a static measure of PCB levels in fish. Recent changes in EPA's policies and guidelines, however, have focused on improving the management of environmental risks by providing decision-makers with a distribution of possible values rather than a single point estimate of potential risk. Microexposure Event analysis is a recent development in probabilistic exposure assessment in which a LADD for a given angler is calculated as the sum of many individual doses received over the course of a lifetime from individual exposure events. Data on concentrations of PCBs in individual fish are thereby incorporated into the analysis, as are other temporal changes in the various exposure parameters. In this paper, the Microexposure Event model is applied to characterize the distribution of PCB dose rates in a hypothetical population of recreational anglers who might potentially consume fish from the upper Hudson River (New York, USA) in the absence of a fish consumption advisory. The analysis uses probabilistic techniques to account for temporal and age-related changes in exposure parameters and as a means of properly considering variation in fish concentrations, cooking practices, and fish species.

2. Introduction

In 1990 the U.S. Environmental Protection Agency (EPA) began a reassessment of their 1984 Record of Decision for the PCB-contaminated river sediments at the Hudson River Superfund Site. Subsequently, EPA[1] issued a summary report (Phase 1 Report) and project plans that described data collection and analysis activities. As part of the data analysis activities, EPA began the development of a computer model for simulating PCB fate and transport in the Upper Hudson River.

In the EPA Phase 1 Report, a preliminary human health risk assessment was prepared. The preliminary risk assessment determined that consumption of PCB-contaminated fish presented the primary source of risk from potential exposures to PCBs at the site. The default exposure assumptions and resulting estimated intakes calculated in EPA's preliminary risk assessment are shown in Table 1.

As evident by the results shown in Table 1, the period over which exposure occurs and the concentration in the fish consumed by a hypothetical angler are critical parameters. In its Phase I Report, EPA used a default guidance value of 30 years for the length of exposure[2]. Next, EPA made two projections for the concentrations in fish anticipated over this 30-year period. One estimate started with current concentrations and assumed no changes in fish PCB concentrations in the future. The second estimate was based on a trend in which PCB levels in fish were assumed to decline due to natural recovery processes at an annual rate of approximately 26 percent.

In the risk assessment, EPA used a point estimate method, selecting exposure parameter values that were a mixture of typical and "reasonable" worst-case estimates. By design, EPA had intended to calculate a "reasonable upper-bound estimate of exposure"[2] to account for the uncertainty associated with developing estimates of intensity, frequency, and duration of exposure[3]. It has been shown, however, that the point estimate approach can greatly exaggerate potential exposure[4,5,6], even when each parameter value itself appears to be "reasonable"[4,7].

In its revised guidance on exposure assessment, EPA[7] has reached the same conclusion, stating "the use of maximum or near-maximum values for each of the parameters in an exposure scenario will result in exposure estimates that are unrealistic." The current guidance favors probabilistic methods, such as Monte Carlo analysis, as a method of deriving more realistic characterizations of highly exposed individuals. These changes in EPA's policies and guidelines have focused on improving risk management by presenting decision-makers with the entire range of possible risks rather than on a single point estimate[7,8,9]. Consequently, EPA[10] has endorsed Monte Carlo methods in the Final Phase 2 Work Plan for the Hudson River Superfund site, to the extent that data are available to define distributions for the key exposure parameters.

Our objective in this paper is to improve upon the default estimates calculated by EPA in their Phase 1 Report by using Monte Carlo analysis and currently available data that are relevant to the river. Because an unusually large amount of Hudson River data has been collected which describes the interindividual variation in the key exposure parameters, we applied a specific type of Monte Carlo called Microexposure Event analysis to characterize potential exposures to PCBs through the ingestion of Hudson River fish.

3. Methods

The Microexposure Event analysis is a type of probabilistic exposure assessment that has a number of advantages over that of traditional Monte Carlo models[11,12,13]. Under this approach, the assessor separately specifies the values of the exposure parameters for each exposure event and then sums the resulting answers to yield estimated long-term dose rates. In this manner, Microexposure Event modeling provides the capability to investigate the effect of interindividual variability and time-dependent and age-dependent changes in exposure parameter values on the resulting risk estimates. This concept has been used to evaluate exposure to dioxin via fish consumption[12,13]; to VOCs in tapwater[14]; and, to evaluate exposure to lead among children[15].

The Microexposure Event technique is very useful in assessing exposures from fish consumption. In a fish consumption scenario, an angler's lifetime intake can be expressed as the sum of the individual fish that he or she consumes during each year that he or she fishes at a given location. In the case of the Hudson River, the Microexposure equation would be defined as follows:

$$\text{LADD} = \frac{1}{\text{LT}} \sum_{j=1}^{\text{Angling Duration}} \frac{1}{\text{BW}j} \sum_{i=1}^{\text{Fish Consumed}} \text{Fish Concentration}_{ij} \times \text{Fish Size}_{ij} \times (1\text{-Cooking Loss}_{ij})$$

where,

angling duration	=	the number of years that an angler fishes the Upper Hudson,
fish consumed	=	the number of fish consumed in the ith year,
fish concentration$_{ij}$	=	the concentration of PCBs in the ith fish caught in the jth year,
fish size$_{ij}$	=	the size of the edible portion of the ith fish caught in the jth year,
cooking loss$_{ij}$	=	the fraction of PCBs lost during the cooking of the ith fish caught in the jth year.

In the Hudson River exposure assessment, an angler's total consumption of fish may be estimated as a series of separate exposure events consisting of each fish eaten. The doses received from these events can be calculated independently and summed to provide estimates of chronic and lifetime exposures. In addition, the duration of an individual angler's exposure is characterized not by adoption of a distribution of durations, but is assessed using information on the angler's age at the time the exposure begins, together with age-specific rates of mobility, mortality, and angling cessation. Finally, exposure parameters such as body weight and fish consumption are also determined based on the age of the angler.

The application of the Microexposure Event analysis to the Hudson River was based on the use of several distributions for characterizing the interindividual variation in each of the key exposure parameters comprising the dose rate equation. First, the amount of fish that anglers consume is a key parameter in the estimate of exposure to PCBs from Hudson River sediments. Because of the current fish consumption restrictions, no surveys of fish consumption among Hudson River anglers can be performed. Although site-specific data on fish consumption are unavailable, Hudson River estimates can be based on data from similar bodies of water or from regional data[16]. We selected the *consumption rate distribution of sport-caught fish from freshwater rivers and streams from the Ebert et* al. study[17] for use in the Microexposure Event analysis.

Second, anglers typically seek to catch certain desirable species and to reject others. Since PCB levels in fish vary by species, it is important to capture these angler preferences in the exposure assessment. A probability distribution was developed to reflect the species consumption preferences of Hudson River anglers, based on angler preferences observed in New York's freshwater rivers[18].

Third, exposure to PCBs through ingestion of fish depends on the PCB concentrations in the fish after it is cooked or otherwise prepared as a meal. If the cooking process reduces the amount of PCBs in the prepared meal, then the intake is also reduced. Sherer and Price[19] analyzed the available literature and converted the results of each study to a percent loss of PCBs on a total mass basis, which allowed them to determine an average PCB loss for each cooking method. Cooking methods that remove fat (e.g., frying) tend to be more effective in reducing PCB tissue levels than those which do not (e.g. soup making, roasting). Information on the frequency that freshwater anglers use various cooking methods is available in the literature[17,18].

Fourth, our probabilistic analysis defined the exposure duration as the time an angler begins fishing and continuing until the angler no longer catches and consumes fish from the Hudson River. The point at which an angler stops fishing varies with the individual angler and is influenced by three factors: (1) mobility; (2) mortality; and (3) the decision to give up fishing. The duration of exposure can only be properly estimated when all of these factors are considered. Census data and surveys of age-specific angler behavior were relied upon as sources for building these distributions.

4. Results and Discussion

The results of the Microexposure Event analysis of are depicted in Figures 1 and 2 and are compared to the results of EPA's Phase 1 risk assessment. Because EPA has not yet completed its development of a computer model for simulating PCB fate and transport in the upper Hudson River, we conducted our analysis using the same rate of decline scenarios that EPA had used.

Based on the above analysis, we conclude that the EPA assessment significantly overstated potential exposures to Hudson River anglers. Although the point estimate approach using default exposure point estimates was useful for identifying fish consumption as the critical pathway warranting further investigation, our analysis indicates that potential exposures were overestimated by one-to-two orders of magnitude for the high-end fish consumer (90th percentile) and by three orders of magnitude for the typical angler. Finally, it should be remembered that the existing fish consumption advisory on the upper Hudson River almost certainly limits actual exposure through the fish ingestion pathway. Consequently, the estimates of exposure that are produced by the methodology proposed in this paper will almost certainly overestimate current exposures to Hudson River anglers.

5. REFERENCES

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Table 1. USEPA (1991) Phase I Risk Assessment Parameters and Results

Exposure Factor	Value
Fish Ingestion Rate	30g/day (nearly 100 meals/year)
PCB Levels in Fish	95% UCL of arithmetic mean concentrations in fish sampled 1986-1988 • No decline • 26% rate of decline
Species Preference	No adjustment
Cooking Loss	No adjustment
Exposure Duration	30 years
Results	
Scenario	Estimated Intakes (ng/kg-d)
No decline in PCB levels	5,100
26% rate of decline	640

Figure 1. Estimated Distribution of Potential PCB Intakes 1999 Start Date, 0% Annual Rate of Decline

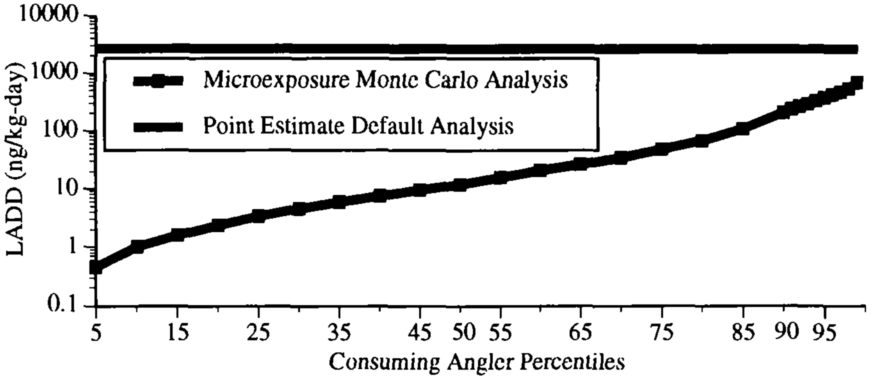

Figure 2. Estimated Distribution of Potential PCB Intakes 1999 Start Date, 26% Annual Rate of Decline