Does the use of Monte Carlo Methods in risk assessment add value? A case study of the Sangamo-Weston/Lake Hartwell site.

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Probabilistic methods in risk assessment such as Monte Carlo have been touted in many quarters as a preferred alternative to the presently used deterministic methods. Many believe these deterministic methods lead to cleanup levels that are excessively health protective and more costly to achieve. The health protectiveness or "conservative" nature of present methods in risk assessment stem from an appropriate desire by regulators in the face of often considerable uncertainty to give the benefit of the doubt to the potentially exposed public. This article presents a case study of a Superfund site at which a Monte Carlo analysis was used in the risk assessment.

As will be seen, the Monte Carlo risk assessment formed a small but important part of the set of decision criteria used at the Sangamo site. Although the Monte Carlo risk assessment did not drive the decision, its value was to provide additional information or perspective for risk managers.

The Sangamo-Weston Site, Pickens, South Carolina

The Sangamo plant manufactured capacitors that used polychlorinated biphenyls (PCBs) as their dielectric substance from 1955 to 1977. During that time, waste water containing PCBs was discharged into Town Creek. The PCBs migrated downstream where they were deposited into the sediment of Twelve Mile

Creek and Lake Hartwell. Sediment samples taken from Lake Hartwell in 1991 and 1992 showed that over 700 acres of lake bottom were contaminated with PCB-containing sediments. Fish tissue collected from Lake Hartwell by the South Carolina Department of Health and Environmental Control (SCDHEC) in 1991 and 1992 revealed concentrations of PCBs in largemouth and hybrid bass, channel catfish and bluegill.

Lake Hartwell is renowned for the quality of its fishing throughout the south. The larger migratory hybrid bass are prized as game fish. Many people living in northeast Georgia and western South Carolina depend on the lake for their living - fishing guides, bait shop operators, etc. Fishing restrictions at the lake affect them profoundly.

Fish Tissue Sampling Data and the Distribution in Game Fish

PCBs were found in 100% of the fish sampled. In largemouth and hybrid bass, the concentrations ranged from 0.5 to 19.7 mg/kg with a mean of 5.4 mg/kg. The acceptable level for the Food and Drug Administration for PCBs in fish tissue for occasional consumption (e.g. fish bought in the grocery store) is 2 mg/kg. For the Monte Carlo risk assessment, a lognormal distribution was used to model the uncertainty in fish tissue concentrations in fish from Lake Hartwell. The corresponding

deterministic Exposure Point Concentration for fish in the Twelve Mile Creek arm was 7.0 mg/kg, calculated as the 95th percent upper confidence limit on the mean.

Exposure Assessment

Exposure distributions were obtained from the Lake Hartwell and Twelve Mile Creek Recreational Angler Survey performed in 1992 by the South Carolina Wildlife and Marine Resources Department (SCWMRD). Almost 900 survey responses were available and were used to evaluate risk associated with fish consumption lake wide. Survey respondents answered questions regarding typical meal sizes and the number of individuals who might share the angler-caught fish, i.e. Ingestion Rate (IR). The number of meals and individual would eat in a month, i.e. the Exposure Frequency (EF) was also determined.

One would expect meal sizes to be correlated with age, body weight and gender; however, the information needed to effect these correlations in the Monte Carlo simulation was not included in the survey. The results of the survey for meal size may be biased upwards. The geometric mean of this survey was more than two times higher than the geometric mean of a USDA survey (120 g/meal) performed in the '70's.

Exposure Duration (ED) was assumed to be equal to enure of residence. Body weights (BW) were taken as the mean value for males and females within ten year age spans from age 25 to age 75 with an additional age group of 18-24 years.

The distribution of lifetime PCB intakes was determined by random sampling from the concentration, EF and ED distributions using Latin Hypercube sampling. Once complete, the distribution of intakes was multiplied by the upper bound cancer slope factor for PCBs to obtain a distribution of risks.

Distribution of Risks from Fish Consumption at Sangamo-Weston/Lake Hartwell

The deterministic risk from fish consumption calculated using reasonable maximum exposure (RME) assumptions to be 1×10^{-2}. From the Monte Carlo risk assessment, the 90th percentile risk was 7×10^{-3}, and the 95th percentile was 1×10^{-2}, the same as the RME risk.

Cleanup Goals for Fish in Lake Hartwell

The FDA tolerance level of 2 ppm was selected as the preliminary remediation goal. Using EPA's risk assessment methods, a cancer risk of 1×10^{-4} is associated with a fish tissue concentration of 0.036 ppm. This level was based on a receptor consuming 357 grams of fish per meal, 60 meals per year over a 30 year period. Achieving this low concentration in fish tissue was determined to be technically impracticable.

Sedimentation Study

As a part of the Remedial Investigation, a modeling study of sediment deposition was performed for the Twelve Mile Creek arm. The study showed that sediment is continually being transported from upstream locations and deposited in Lake Hartwell.

Time	Risk
Present	1×10^{-2}
1 year	4×10^{-4}
10 years	6×10^{-5}
20 years	6×10^{-6}
27 years	1×10^{-6}

Risk Reduction in time due to sediment deposition

The study also showed that the PCB-contaminated sediment would be completely covered by upstream sediment within 30 years.

Combining the sediment deposition model with a model for accumulation of PCBs in fish from sediment showed that the risks from fish consumption would continue

to decrease. The table shows the modeled reduction in risk with time assuming that clean sediment was being deposited in the lake.

Remedial Alternatives

The nine evaluation criteria for Superfund remedies are specified in the National Contingency Plan 40 CFR 300.430(e)(9). These nine criteria are:

1) Overall protection of human health and the environment
2) Compliance with Applicable or Relevant and Appropriate Requirements
3) Long-term Effectiveness and Permanence
4) Reduction of Toxicity, Mobility or Volume
5) Short-term Effectiveness
6) Implementability
7) Cost
8) State Acceptance
9) Community Acceptance

There were five proposed remedial alternatives: (1) No action; (2) Institutional Controls, including fish and sediment monitoring and public education; (3) Fishery Isolation, consisting of a semi-permanent "fish fence" at a bridge to prevent migratory hybrid and striped bass from entering the Twelve Mile Creek arm; (4) Capping with a Sediment Control Structure, consisting of placing clean sediment over the PCB contaminated sediment in the lake and constructing a weir to reduce the flow of contaminated sediment from upstream locations; and (5) Confined Disposal, a plan to rechannel the Twelve Mile Creek arm, dredging approximately 1.3 million cubic yards of sediment into a near shore landfill and stabilization of the dredge spoils with cement-based additives.

EPA chose Fishery Isolation as its preferred alternative. The community around Lake Hartwell did not accept this alternative (criterion 9). Instead, the community preferred Institutional Controls. It was felt that the "fish fence" would interfere with boating. The cost for alternatives 4 and 5 was significantly greater than any of the others with alternative 4 priced at between 30 and 50 million dollars and alternative 5 at about 600 million dollars.

The exact role of the Monte Carlo assessment was equivocal. The point estimate of risk for fish consumption in the Twelve Mile Creek arm is 1×10^{-2} as shown in the table. This

Percentile	Risk Level
RME (point Est.)	1×10^{-2}
90 (High End)	7×10^{-3}
50 (Central Tendency)	1×10^{-3}
20 (Approx. Mode)	5×10^{-4}

Risks from fish consumption at Lake Hartwell in 1992

risk level is far above the upper end of the risk range of 1×10^{-4} discussed in the NCP. However, the possible upward bias in the fish ingestion estimates indicated that the risks estimated from the distribution could be overestimates. The magnitude of overestimation of risk is unknown. Despite the fact the both the high end risk estimate from the Monte Carlo analysis and the RME point estimates were outside the acceptable risk range, the sedimentation study, cost and community acceptance were the basis for the remedial decision.

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