Calculation of Hypothetical Risks to Wildlife Receptors Associated with Polychlorinated Biphenyls (PCBs) in the Clear Creek Watershed, Bloomington, Indiana

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Abstract

An ecological risk evaluation was performed for commercial mixtures of PCBs (i.e., Aroclors 1242, 1248, 1254, and 1260) present in the Clear Creek watershed in Bloomington Indiana to evaluate the possible existence of "actionable" risks to wildlife receptors, and to determine the need for further population-level risk investigations. Tissue-residue data were collected for pelagic and bottom feeding fish and crayfish from Clear Creek to evaluate the bioaccumulation of PCBs within the food web. Concentrations of total PCBs in these organisms range from 0.26 to 26 mg/kg, and 0.12 to 3.2 mg/kg, for fish and crayfish, respectively. Single species exposure and dose-response models were used to evaluate the hypothetical toxicological risks of PCBs to higher trophic level receptors including mink and great blue heron. The results of this risk evaluation suggest that under reasonable exposure scenarios derived from the extant life history information for each species, the potential for risks from PCBs to higher trophic level receptors is *de minimis*.

Introduction

An evaluation of hypothetical ecological risks to wildlife receptors was performed for commercial mixtures of PCBs (i.e., Aroclors 1242, 1248, 1254, and 1260) present in the Clear Creek watershed in Bloomington Indiana to evaluate the possible existence of "actionable" risks to wildlife receptors, and to determine the need for further population-level risk investigations. This evaluation was limited to the lower reach of Clear Creek, where substantial ecological resources exist (Figure 1). The remainder of the Creek is surrounded by residential and commercial land use, and is impacted by a variety of physical and chemical stressors. The lower reach of Clear Creek contains suitable habitat for communities of fish and invertebrates. The riparian zone associated with this portion of the Creek is large and relatively undisturbed and may provide suitable habitat for wildlife communities.

As a result of historical and ongoing PCB transport into the Clear Creek system, exposed aquatic receptors (*e.g.*, benthic invertebrates and fish) bioaccumulate PCBs from sediment and water. Terrestrial or semi-aquatic receptors that may consume these benthic invertebrates and fish may subsequently be exposed to PCBs that are bioaccumulated through the food web, as well as through direct exposure to PCBs in sediment, surface water, and floodplain soils.

The available ecotoxicological literature indicates that certain types of organisms are more sensitive to the effects of PCBs than are others and that potential exposures to PCBs are greater for certain organisms. In particular, some researchers have reported that piscivorous birds and mammals are sensitive to the toxicological effects of PCBs, particularly at early life stages. If reproductive effects in individual organisms are substantial enough, adverse effects may propagate to populations and communities within the ecosystem. To that end, this risk evaluation has been performed to provide a hypothetical determination as to the magnitude of possible risks that may exist to representative piscivorous wildlife that exist in the Clear Creek watershed; *i.e.*, mink and great blue heron.

Experimental Methods

Single species exposure and dose-response models were used to evaluate the hypothetical toxicological risks of PCBs to higher trophic level receptors including mink and great blue heron. Exposure point concentrations for use in the models were measured in tissue-residue samples collected from Clear Creek, as described below. The mink and great blue heron models and model parameters used in this evaluation are depicted and discussed in Tables 1 and 2. Hypothetical hazard quotients (HQs) were calculated for individual receptors based on the exposure and toxicity data. Theoretically, these HQs can be used to evaluate the likelihood as to whether the potential for risks to sensitive receptors from PCBs exists. Most scientists agree that an HQ result of less than one is indicative of "no actionable risk." In general, however, an HQ greater than one requires further interpretation as to what relative potential for risk may exist, and if field investigations of potential effects may be warranted.

An attempt was made to select reasonable, yet somewhat conservative estimates for exposure and toxicity parameters in the models, so as not to underestimate the likelihood of the potential for risks. These selections were based on a review of the extant life history information for mink and great blue heron. Lowest or no observable adverse effects concentrations (LOAELs/NOAELs), as reported in the literature, were used as the toxicity reference values for each species. The toxicity values which were selected were based on a critical review of the scientific literature for the most credible research regarding the potential reproductive toxicity of PCBs to wildlife. Resulting hazard quotients were calculated for both the average (geometric mean) and upper-bound (95% upper confidence limit on the geometric mean) exposure point concentrations for each species based on the available data.

A total of 128 whole body biota tissue samples were collected from the Clear Creek watershed as part of an ecological investigation that was performed in November 1996. From these samples, PCB tissue-residue data were collected for pelagic and bottom feeding fish and crayfish from Clear Creek to evaluate the bioaccumulation of PCBs within the food web. Concentrations of total PCBs in these organisms throughout the watershed ranged from 0.26 to 26 mg/kg, and 0.12 to 3.2 mg/kg for fish and crayfish, respectively. Data for fish and crayfish from up to three locations (i.e., locations 4, 5, and 6 from Figure 1) in the lower reach of Clear Creek (which is the focus of this risk evaluation) ranged from 0.26 to 10 mg/kg, 0.17 to 0.43 mg/kg, respectively. These data were used as exposure point concentrations for mink and heron that may ingest these organisms from these areas.

Results and Discussion

A multitude of factors may act to stress an ecosystem, including both physical and chemical stressors. The most evident anthropogenic physical stressor in the upper reaches of the Clear Creek watershed is habitat alteration and destruction due to residential, commercial, and industrial development. These activities have resulted in the destruction of suitable foraging habitats and reduction in overall habitat size and quality, thus reducing the quantity and quality of the overall ecosystem. For this reason, this risk evaluation for the potential impacts of PCBs on ecological receptors, is necessarily limited to that portion of the Clear Creek system (*i.e.*, the downstream reach) where sufficient contiguous habitat exists to support substantial and diverse wildlife communities.

The results of the exposure and toxicity model calculations (*i.e.*, HQs) for mink and great blue heron at the three study locations in Clear Creek are presented in Table 2. The calculated HQs for each species under the mean and upper-bound exposure point concentrations were all less than one. The exposure assumptions used to calculate these HQ appear reasonable based on the available life history data for these species, and site-specific information on the existing habitats and biological communities associated with Clear Creek. These results suggest that the likely potential for risks to mink and great blue heron from PCBs are *de minimis*, and that no actionable risks exist to wildlife receptors from PCBs in the downstream reach of Clear Creek. Alternative risk scenarios, including more and less conservative exposure and toxicity assumptions, will be discussed as part of this presentation in addition to those depicted in Table 2.

Literature Cited

(1) U.S. Environmental Protection Agency (EPA). *Wildlife Exposure Factors Handbook*, EPA/600/R-93/187a, **1993**.

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(3) Custer, T.W., Heinz, G.H. *Environ. Pollution*, (Series A), **1980**, 21, 313-318.

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Figure 1. Lower Reach of Clear Creek Study Area and Sampling Locations

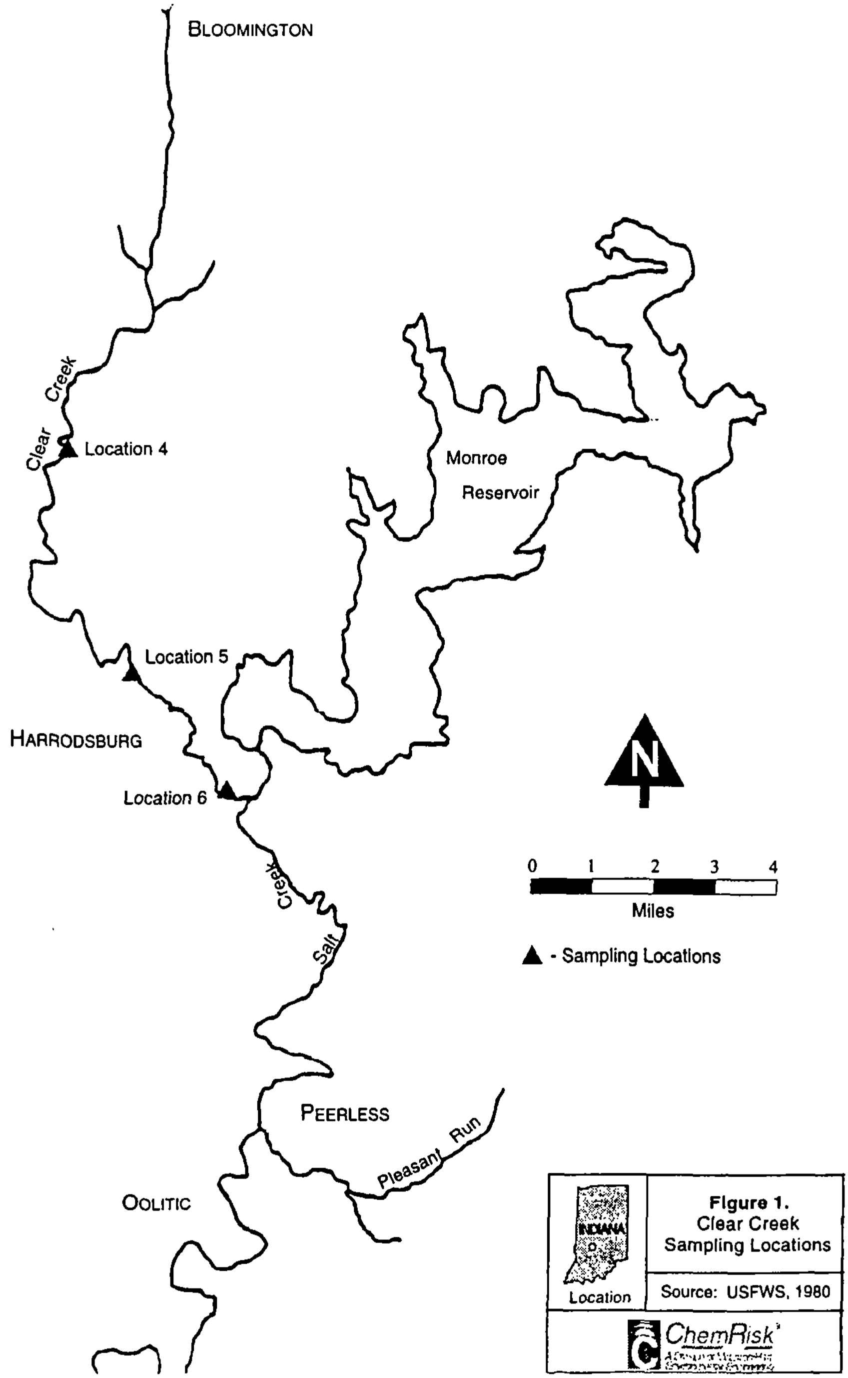

Table 1. Exposure Parameter Summary for the Ingestion of Fish and Invertebrates by Mink and Great Blue Heron

Mink Parameters	Value	Units	Assumptions
Concentration of PCBs in crayfish and fish	95% UCL/Geomean	mg/kg	1
Fraction of Diet: crayfish/fish	0.5 / 0.5	unitless	2
Fraction of Diet from Clear Creek	0.5	unitless	3
Absorption fraction	1	unitless	4
Mink Toxicity Reference Value (TRV)	1.0	mg/kgBW-day	5
Mink food ingestion rate	0.12	kg/day	6
Mink body weight	0.53	kg	7
Heron Parameters			
Concentration of PCBs in crayfish and fish	95% UCL/Geomean	mg/kg	1
Fraction of Diet: crayfish/fish	0.2 / 0.8	unitless	8
Fraction of Diet from Clear Creek	0.75	unitless	9
Fraction of Year at Clear Creek	0.6	unitless	10
Absorption fraction	1	unitless	4
Avian Toxicity Reference value (TRV)	1.22	mg/kgBW-day	11
Great blue heron food ingestion rate	0.35	kg/day	12
Great blue heron body weight	1.94	kg	13

Assumptions:

1. The concentration of PCBs in crayfish and fish are based on the 95th UCL of the geometric mean and the geometric mean of the whole body tissue analysis for total Aroclors (1248,1254, and 1260) in organisms collected from each sampling location. Data are lognormally distributed.
2. In accordance with dietary composition data published in EPA (1993), 50% of the mink's diet from the aquatic environment was assumed to consist of fish, while 50% of the diet was assumed to consist of other aquatic organisms (e.g. crayfish).
3. A 50% downward adjustment was made to reasonably account for the preference of small mammals and other animals in the diet of mink as reported in EPA (1993). Accordingly, the corresponding fraction of the mink diet along Clear Creek was assumed to be 0.5.
4. The absorbtion fraction of 1.0 is based on the assumption that the organism completely absorbs ingested PCB.
5. The selected TRV is based on a study by Wren et al. (1978), who observed no mortality or adverse chronic effects in the offspring of mink adults exposed to 1.0 mg/kg Aroclor 1254 in the diet.
6. Assumed ingestion rate is the maximum value reported in EPA (1993).
7. Assumed body weight is the minimum reported for juveniles in EPA (1993).
8. 80% of the diet is assumed to consist of fish while 20% of the diet is assumed to consist of crayfish.
9. A 25% downward adjustment was made to conservatively account for the widespread foraging behavior of great blue herons. Accordingly, the corresponding fraction of the heron diet from Clear Creek was assumed to be 0.75.
10. A 40% downward adjustment was made to account for the migratory (seasonal) behavior of great blue herons. Accordingly, the corresponding fraction of the heron diet was assumed to be 0.6.
11. The selected TRV represents a NOAEL study dose rate (Custer and Heinz, 1980), that considered the effect of PCBs on reproductive success in mallard ducks. The calculated TRV is based on a body weight scaling equation reported in a study by Opresko (1994) for converting a mallard duck NOAEL to a Great Blue Heron TRV.
12. Assumed ingestion rate is the only value reported in EPA (1993).
13. Assumed body weight is the minimum reported for juveniles in EPA (1993).

Table 2. Calculation of Hazard Quotients for the Ingestion of Fish and Invertebrates by Mink and Great Blue Heron

Mink Exposure/Toxicity Model:
DI =((Cc x Fc) + (Cf x Ff)) x IR x AF x FS x 1/BW
HQ = DI/TRV

Total PCB Exposure Point Concentration	Cc Whole Crayfish Conc. (mg/kg)	Fc Fraction Diet Crayfish (unitless)	Cf Whole Fish Conc. (mg/kg)	Ff Fraction Diet Fish (unitless)	IR Ingestion Rate (kg/d)	FS Fraction of Diet from Clear Creek (unitless)	BW Body Weight (kg)	DI Daily Intake (mg/kg-d)	TRV Toxicity Reference Value (mg/kg-d)	HQ Hazard Quotient (unitless)
Area 4										
95th UCL of the geomean	0.54	0.5	2.17	0.5	0.12	0.50	0.53	0.15	1.0	0.1
geomean	0.32	0.5	1.28	0.5	0.12	0.50	0.53	0.09	1.0	0.1
Area 5										
95th UCL of the geomean	0.54	0.5	3.76	0.5	0.12	0.50	0.53	0.24	1.0	0.2
geomean	0.32	0.5	2.12	0.5	0.12	0.50	0.53	0.13	1.0	0.1
Area 6										
95th UCL of the geomean	0.54	0.5	11.41	0.5	0.12	0.50	0.53	0.66	1.0	0.7
geomean	0.32	0.5	3.76	0.5	0.12	0.50	0.53	0.22	1.0	0.2

Great Blue Heron Exposure/Toxicity Model:
DI =((Cc x Fc) + (Cf x Ff)) x IR x AF x FS x FY x 1/BW
HQ = DI/TRV

Total PCB Exposure Point Concentration	Cc Whole Crayfish Conc. (mg/kg)	Fc Fraction Diet Crayfish (unitless)	Cf Whole Fish Conc. (mg/kg)	Ff Fraction Diet Fish (unitless)	IR Ingestion Rate (kg/d)	FS Fraction of Diet from Clear Creek (unitless)	FY Fraction of Year at Clear Creek (unitless)	BW Body Weight (kg)	DI Daily Intake (mg/kg-d)	TRV Toxicity Reference Value (mg/kg-d)	HQ Hazard Quotient (unitless)
Area 4											
95th UCL of the geomean	0.54	0.2	2.17	0.8	0.35	0.8	0.6	1.94	0.15	1.22	0.1
Geometric mean	0.32	0.2	1.28	0.8	0.35	0.8	0.6	1.94	0.09	1.22	0.1
Area 5											
95th UCL of the geomean	0.54	0.2	3.76	0.8	0.35	0.8	0.6	1.94	0.25	1.22	0.2
Geometric mean	0.32	0.2	2.12	0.8	0.35	0.8	0.6	1.94	0.14	1.22	0.1
Area 6											
95th UCL of the geomean	0.54	0.2	11.41	0.8	0.35	0.8	0.6	1.94	0.75	1.22	0.6
Geometric mean	0.32	0.2	3.76	0.8	0.35	0.8	0.6	1.94	0.25	1.22	0.2
Combined Areas (3 - 6)											
95th UCL of the geomean	0.40	0.2	3.33	0.8	0.35	0.8	0.6	1.94	0.22	1.22	0.2
Geometric mean	0.24	0.2	2.10	0.8	0.35	0.8	0.6	1.94	0.14	1.22	0.1

Notes:
(a) Crayfish were collected at Area 4, but not at 5 and 6. Therefore, exposure point estimates at Areas 5 and 6 were estimated based on the higher concentrations observed at Area 4.
(b) Summary statistics for fish concentrations were derived based on the total number of species collected for tissue analysis (e.g. creek chub, green sunfish, longear sunfish, northern hogsucker, stone roller, and white sucker) at each sampling location.