RISK ASSESSMENT OF PCBs BASED ON DIOXIN EQUIVALENCY AND TOTAL AROCLORS

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Introduction

Polychlorinated biphenyls (PCBs) are a group of chemicals consisting of 209 congeners ranging from mono to deca chloro substitution. Typical PCB analytical methods evaluated technical PCB mixtures such as Aroclors to quantify PCBs in environmental samples. Recent analytical methods have focused on identifying classes of congeners based on chlorine content (called homologues), and a set of 12 coplanar congeners that are thought to have dioxin-like effects (U.S. EPA, 1996)[1]. The World Health Organization (WHO) has developed toxicity equivalency (TEQ) factors for these coplanar congeners that relate their toxicity to that of 2,3,7,8-TCDD (Van den Berg, 1998)[2]. Current risk assessment approaches for PCBs evaluate the toxicity of both total PCBs (analyzed as total Aroclors or total homologues), and the dioxin-like coplanar congeners. In this risk assessment, we have calculated and compared the estimated risks resulting from evaluating total PCBs and the dioxin-like effects of the coplanar congeners.

A comprehensive risk assessment was conducted at the Birch Hill Dam Flood Control Project site (the Site), located in north-central Massachusetts. This Site is a flood-control dam owned and operated by the U.S. Army Corps of Engineers, New England District in Concord, Massachusetts. The Site encompasses 4,396 acres and consists of a dam (Birch Hill Dam) and dry bed reservoir on the Millers River and Otter Rivers, which are tributaries to the Connecticut River. Approximately 75% of the Birch Hill Site is forested. Open field and shrubland comprise 300 acres of the site, 200 acres of the Site are open water, and nearly 30 percent of the Site is wetland, with forested and scrub/shrub wetlands predominating. The Birch Hill Reservoir provides essential habitat for numerous species of reptiles, amphibians, birds, and mammals. The area is open for recreational activities, such as fishing and swimming.

The objective of the risk assessment was to determine whether there could be risks to human health or the environment from exposure to PCBs in sediment, floodplain soil, surface water, fish tissue, and other aquatic and floodplain organisms. The results of an extensive sediment field screening and analytical sampling program indicated that PCBs were present in surface sediment at concentrations upto 80 mg/kg total PCBs and in whole body fish tissue at concentrations up to 18 mg/kg total PCBs. PCBs were analyzed for three endpoints: Aroclors, homologues and 12 coplanar congeners that have TEQ factors.

Methods and Approach

Analytical data from various media were analyzed for trends, such as whether higher chlorinated homologues and Aroclors were present more in one medium compared to another. The analytical data for the coplanar congeners were also evaluated to see which congeners were present in the different media.

In order to conduct a risk assessment, it was necessary to develop exposure pathways through which human health and ecological receptors could be exposed to PCBs in various media. Since the site is used as a recreational area, it was assumed that recreational fishers and swimmers could be present at the site. For the human health risk assessment, the site was divided into three exposure areas: Lake Denison, Millers River and Otter River. Table 1 shows the exposure areas, receptors, media of concern and exposure routes for the human health risk assessment. The ecological risk assessment used analytical data from benthic macroinvertebrates, earthworms and amphibians, in addition to fish. Table 2 shows the receptors, media of concern and exposure routes for the ecological risk assessment.

To calculate risks, analytical results from both total PCBs and the 12 coplanar congeners were summarized. Two sets of total PCB concentrations were derived by separately summing the reported concentrations of Aroclors and homologues. A total TEQ concentration was derived by applying the WHO toxicity equivalency factors to the concentrations of each of the detected coplanar congeners. In the human health risk assessment, the cancer slope factor for PCBs was used to calculate potential cancer risks from total PCBs (2/mg/kg-day) and the cancer slope factor for 2,3,7,8-TCDD ($1.5x10^5$/mg/kg-day) was used to calculate potential cancer risks from TEQ. Adding the potential risk from TEQ to the total PCBs is necessary in order to account for risks from the effects of both total PCBs and the dioxin-like effects of PCBs, and is also consistent with U.S. EPA guidance.

Results and Discussion

Aroclor and homologue data from sediment showed that the PCBs in sediment are mainly Aroclor 1242. The fish tissue data showed that higher chlorinated homologues and Aroclors are present compared to sediment data. Mainly Aroclors 1248 and 1254 were identified in fish tissue, indicating differential bioaccumulation of higher chlorinated congeners in fish tissue.

The analysis of the 12 coplanar congeners in sediment and fish tissue showed that similar congeners were detected in both media. Table 3 shows the exposure point concentrations in sediment for total PCBs (by summing concentrations of individual Aroclors) and PCBs expressed as TEQ (by applying toxic equivalency factors to the 12 coplanar congeners). The TEQ concentration is significantly lower than the total PCB concentration. A similar result was found in fish fillet, as shown in Table 4.

Table 5 shows the carcinogenic risk results of using both total PCB and TEQ analyses for a teenager exposed to sediment and fish at the Millers River location. These results show that risks from TEQ are an order of magnitude lower than risks from total PCBs. Therefore, in the human health risk assessment, the dioxin-like effects of PCBs do not contribute significantly to the total risk from PCBs. As shown in Table 5, the total cancer risk of $1.7x10^{-4}$ is mainly due to total PCBs (estimated cancer risk of $1.6x10^{-4}$).

Figure 1 shows calculated hazard quotients for various ecological receptors based on total PCBs and TEQ. These results suggest that certain higher trophic level organisms such as the mink and piscivorous birds are more sensitive to the potential effects from TEQ and less sensitive to potential effects fromtotal PCB exposure. Lower trophic level organisms show approximately equal effects from total PCBs and TCDD-TEQ, although the total PCB hazard quotients for two avian species (mallard and tree swallow) exceeded

the TEQ hazard quotients. These results indicate that the dioxin-like effects of PCBs did not contribute significantly to the human health risk estimate, although they were significant in the ecological assessment.

Table 1. Potential Exposure Pathways for the Human Health Risk Assessment

Exposure Area	Receptor	Medium	Exposure Route
Lake Denison	Child and Adult	Surface Water Fish	Incidental ingestion, dermal contact Ingestion
Millers River	Teenager and Adult	Sediment Floodplain Soil Fish	Incidental ingestion, dermal contact Incidental ingestion, dermal contact Ingestion
Otter River	Teenager and Adult	Sediment Floodplain Soil Fish	Incidental ingestion, dermal contact Incidental ingestion, dermal contact Ingestion

Table 2. Ecological Risk Assessment Problem Formulation

Exposure Area	Receptor	Medium	Exposure Route
Entire Site	Benthic Macroinvertebrates, Amphibians and Fish	Sediment	Direct contact, direct ingestion, incidental ingestion
		Surface Water	Direct contact, direct ingestion, incidental ingestion
	Earthworms	Floodplain Soil	Direct contact, direct ingestion
	Fish and Wildlife	Food Items	Direct ingestion of food potentially contaminated through bioaccumulation
	Wildlife	Sediment	Incidental Ingestion
		Surface Water	Incidental Ingestion
		Floodplain Soil	Incidental Ingestion

Table 3. Exposure Point Concentrations of Total PCBs and TEQ in Sediment

Location	Total PCBs by Aroclor (mg/kg)	TEQ (mg/kg)
Millers River	22	1.6×10^{-5}
Otter River	65	4.1×10^{-5}

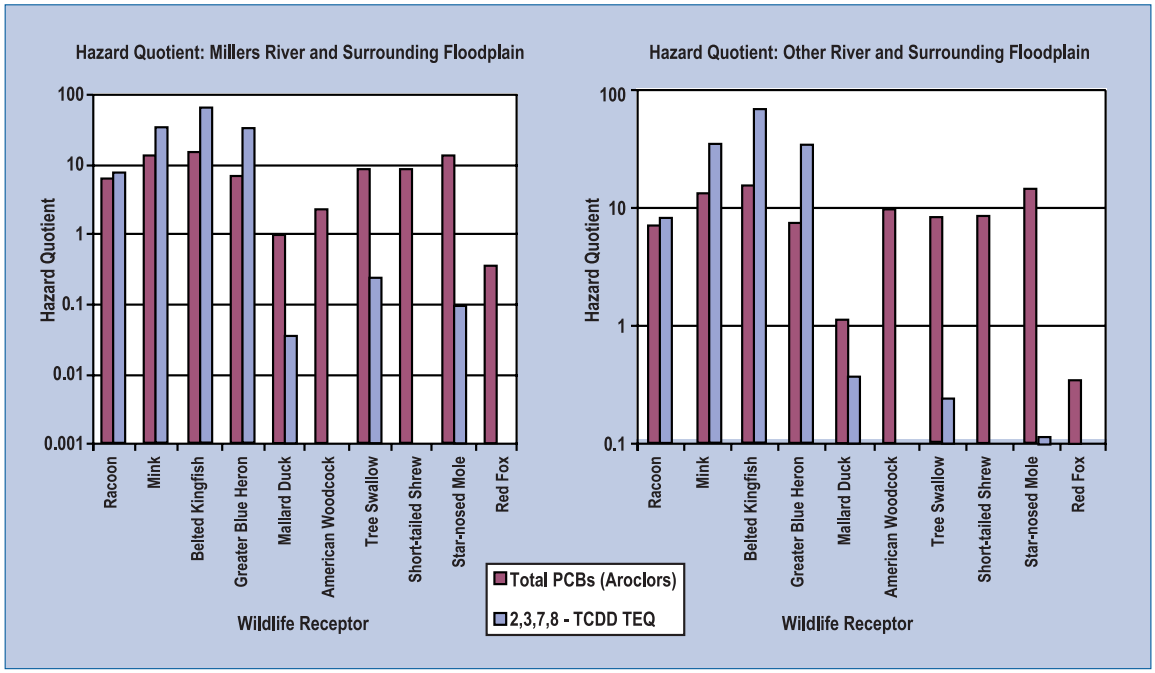
Table 4. Exposure Point Concentrations of Total PCBs and TEQ in Fish Fillet

Location	Total PCBs by Aroclor (mg/kg)	TEQ (mg/kg)
Millers River and Otter River	2.8	$5.0x10^{-6}$

Table 5. Potential Carcinogenic Risks for a Teenager at the Miller's River Exposure Area

Compound	Sediment	Fish Tissue	Total
TCDD-TEQ	$2.6x10^{-7}$	$2x10^{-5}$	$2x10^{-5}$
Total PCBs	$5.7x10^{-6}$	$1.5x10^{-4}$	$1.6x10^{-4}$
Total	$5.9x10^{-6}$	$1.7x10^{-4}$	$1.7x10^{-4}$

Figure 1. Summary of Wildlife Hazard Quotients



References

1. U.S. EPA (1996) PCBs: Cancer Dose-Response Assessment and Application to Environmental Mixtures. EPA/600/P-96/001A. External Review Draft. Washington DC 20460.
2. Van den Berg, M., Birnbaum, L., Brunstrom, A.T.C. et al. (1998) Environ Health Perspect. 106(2), 775.