DIOXIN RISK ASSESSMENT FOR THE COLUMBIA RIVER

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ABSTRACT

The Columbia River, located in the Northwestern United States, supports active commercial and recreational fisheries that may be impacted by 2,3,7,8-TCDD in effluent discharged from bleached kraft pulp and paper mills in Washington and Oregon. To determine the impact that these mills have on 2,3,7,8-TCDD residue levels in fish, the most extensive analysis of dioxin levels in fish and health risk assessment ever conducted on a major river was undertaken. A total of 680 fish, including anadromous (salmon and steelhead trout) and resident (white sturgeon, carp, and largescale sucker) species were collected at 6 sampling stations located upstream and downstream of the mills. 80% of the anadromous fish and 45% of all fish sampled had no detectable levels of 2,3,7,8-TCDD. Geometric mean concentrations in 3 subspecies of salmon ranged from 0.08 - 0.31 ppt; steelhead trout averaged 0.07 ppt. White sturgeon, largescale sucker, and carp collected in reaches impacted by mills averaged 0.55, 0.30, and 1.07 ppt, respectively, while fish collected upstream averaged 1.12, 0.24, and 1.12 ppt, respectively. These data indicate that mill effluents did not elevate fish 2,3,7,8-TCDD residues above background. Lifetime average daily doses (LADDs) for residents, recreational fishermen, Asian Americans, and Native Americans were 0.0034, 0.056, 0.013, and 0.024 pg/kg/day. The theoretical upper-bound excess lifetime cancer risks associated with the consumption of Columbia River fish were calculated using USEPA and FDA cancer potency factors (CPFs) and the CPF proposed by Keenan et al. (1990b), based on the recent histopathological re-evaluation of the Kociba et al. (1978) bioassay. For recreational fishermen, the most sensitive consumers examined in this analysis, the potential risk of cancer was below one in one hundred thousand (1×10^{-5}).

KEY WORDS

2,3,7,8-TCDD, risk assessment, Columbia River, fish, pulp and paper mill effluent, fish consumption

INTRODUCTION

As part of the U.S. Environmental Protection Agency (USEPA) National Dioxin Study, dioxins were detected in fish samples from several rivers having no previously known source of dioxin contamination (USEPA, 1987). Dioxins have since been identified in pulp, process liquors, wastewater treatment sludge, and final effluent of pulp and paper mills employing the bleached kraft process (Amendola et al., 1989a; Swanson and Rappe, 1988; Clement et al., 1989; LaFleur and Dodo, 1989). In a recent study of 104 U.S. pulp and paper mills, it was reported that final effluent contained a median concentration of 20 ppq (parts per quadrillion) of 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) (Amendola et al., 1989b). Swanson and Rappe (1988) estimated that the typical U.S. bleached kraft mill discharged approximately of 11 mg/day of 2,3,7,8-TCDD (expressed as toxic equivalents) in effluent.

The Columbia River is the largest river system in the Northwestern U. S. and supports extensive commercial and recreational fisheries. A number of Northwest Pulp and Paper Association (NWPPA) pulp and paper mills, as well as numerous municipal facilities, are believed to discharge treated wastewater effluent containing small quantities of dioxin into the Columbia River system. To determine the impact that these paper mills may have on 2,3,7,8-TCDD levels in fish, the most extensive fish dioxin study ever conducted on a major U.S. river was undertaken. The results of that study were used in conjunction with results from a region-specific fish consumption survey to evaluate 2,3,7,8-TCDD exposures to the average resident, as well as to recreational fishermen, Asian Americans, and Native Americans living in the Columbia River basin since they consume a greater than average amount of fish from the Columbia River.

METHODS

The study area encompassed the Columbia River from river mile (RM) 2 to RM 335 and from the confluence of the Snake River to RM 9 on the Snake River (Figure 1). Six sampling sites were selected to reflect longitudinal variability, to optimize the sampling of certain species, and to identify any significant trends in fish 2,3,7,8-TCDD levels relative to their location in the river. Sites 1 - 4 were located in reaches of the river that may be impacted by the effluent discharges from bleached kraft pulp and paper mills. Sites 5 and 6 were located above these mills and served as "background" sampling stations.

Fish species seleceted for 2,3,7,8-TCDD analyses were chosen based on their popularity as sport fish, preference as human food items, and/or availability for collection in the required numbers throughout the study area. Anadromous fish (salmon, and steelhead trout) were sampled at 2 of the 6 sites. Because of their migratory behavior, a "background" population could not be identified. Resident fish (white sturgeon, largescale carp, and sucker) were chosen to evaluate the relative distribution of 2,3,7,8-TCDD throughout the river. Although carp and largescale sucker are not considered to be major food species, these species were chosen as "indicators" of 2,3,7,8-TCDD accumulation in the river system. Other resident species including channel catfish, walleye, and largemouth bass were identified as indigenous to the river, but were not present in sufficient numbers at the time of sampling.

A total of 680 fish were collected from the 6 sampling stations. The concentrations of 2,3,7,8-TCDD in fish were determined in 5 replicate composite fillet tissue samples from each species collected at each sampling station according to USEPA Method 8290 modified for biological samples. For the anadromous and resident species, each composite sample contained boneless, skinless filet meat from 4 or 8 fish, respectively.

Lifetime average daily doses (LADDs) were estimated for the average resident, recreational fisherman, Asian American, and Native American living in the Columbia River Basin using equation (1). 2,3,7,8-TCDD levels measured in fish collected from the Columbia River were assumed to be representative of the levels of contamination in those species. The geometric mean concentration of 2,3,7,8-TCDD measured in the three resident, non-anadromous species (white sturgeon, largescale sucker, carp) was assumed to be representative of all resident species. Non-detectable composite samples were assigned a value equal to one-half of the analytical limit of detection.

$$LADD = Cf \times Fc \times Cl \times 1/BW \times EDa \times EDy \times 1/L \qquad (1)$$

where: LADD = Lifetime average daily dose (pg/kg-day)
Cf = Concentration of TCDD in fish (pg/g)
Fc = Fish consumption rate (g/day)
Cl = Proportion of TCDD remaining after cooking
BW = Body weight (kg)
EDa = Exposure duration (days/year)
EDy = Exposure duration (years)
L = Lifetime (days)

Species-specific consumption rates were calculated using landings data reported for commercial and Native American fisheries, including salmon, steelhead trout, and sturgeon (Beak, 1989). Landings were corrected for each species according to the estimated percentage consumed locally and were adjusted by a factor of 0.5 to account for the consumption of edible fillet tissue. For all other species, national consumption rates (Javitz, 1980) were adjusted to reflect the 23% lower freshwater fish consumption rate reported by Rupp et al. (1980) for the Pacific coast region. A summary of fish consumption rates for each consumer group is presented in Table 1.

For local residents, the average per capita consumption rate was estimated to be 1.4 g/day, based on commercially-available Columbia River anadromous and resident fish. A national fish consumption survey in the late 1970s revealed that average intake of all types of fish and shellfish for Asian Americans was higher than that of the average U.S. resident by a factor of 1.47 (Javitz, 1980). Adjusting the regional per capita species-specific rates reported by Beak (1989) to reflect the 1.47 factor and adding the rates of consumption of other freshwater fish species reported by Javitz (1980) resulted in a consumption rate estimate of 3.4 g/day for Asian Americans.

The consumption rate for recreational fishermen was based on reported landings of sport-caught fish and the population of fishermen's families in the Columbia River Basin. An average fish consumption rate of 11.6 g/day was determined for salmon, steelhead and sturgeon (Beak, 1989; ODFW, 1989). Since sportsfishermen along the Columbia River also catch and consume a number *of other freshwater finfish species, the mean national fish consumption rates estimated by* Javitz (1980) were used to calculate the amount of resident fish species caught and consumed locally. A total consumption rate of 13.4 g/day was estimated for recreational fishermen. Native Americans living in the Columbia River basin might be at a greater risk of exposure due to higher rates of consumption of locally caught fish resulting from subsistence fishing and tribal ceremonial use. The fish consumption rate for Native Americans was based on that portion (10%) of the total landings of salmon, steelhead trout, and sturgeon which were reported to be retained by the tribes (Beak, 1989). An average consumption rate was calculated to be 16.4 g/day.

Consumers were assumed to clean and cook the fish they catch from the Columbia River. Chemical losses have been observed as a result of various methods of cooking (e.g., broiling, roasting, microwaving) whole fish and fish fillets containing a variety of organic chemicals, including 2,3,7,8-TCDD (Zabik et al., 1979; Stachiw et al., 1988). A 25% reduction of the 2,3,7,8-TCDD concentration in fish fillets via cooking was used in this risk assessment. Cooking losses of between 35% and 67% (average 54.6%) were reported in a recent study using processed carp fillets containing 2,3,7,8-TCDD (Stachiw et al., 1988). Actual reductions appear to depend on the cooking method, temperature and duration of cooking, and type and size of fish fillet.

Potential human health risks associated with 2,3,7,8-TCDD exposure through the consumption of fish were estimated using a range of cancer potency factors (CPFs). The U.S. Food and Drug Administration (FDA) (1983) CPF of 17,500 $(mg/kg\text{-}day)^{-1}$ was used to represent a conservative approach to the dose-response assessment of 2,3,7,8-TCDD. Because the FDA has authority in the U.S. for the regulation of foods for human consumption, the FDA CPF is more appropriate than the USEPA value for assessing the risks associated with the consumption of fish. The USEPA (1985) CPF of 156,000 $(mg/kg\text{-}day)^{-1}$ was used to represent the maximum plausible risk estimate that would be calculated by any regulatory agency. The CPF proposed by Keenan et al. (1990a; 1990b), 9,700 $(mg/kg\text{-}day)^{-1}$, was selected as the most appropriate CPF for 2,3,7,8-TCDD. This value is based on the recent re-evaluation by an independent group of pathologists of the tumor histopathology of Kociba et al. (1978), the cancer bioassay from which the FDA and the USEPA derived their risk estimates.

RESULTS AND CONCLUSIONS

The geometric mean concentrations of 2,3,7,8-TCDD of each set of 5 replicate composite fillet tissue samples are presented in Table 2. Geometric mean concentrations of 2,3,7,8-TCDD in 3 subspecies of salmon (coho, fall Upriver chinook, and fall Tule chinook) ranged from 0.08 to 0.31 parts per trillion (ppt); steelhead trout averaged 0.07 ppt. White sturgeon, largescale sucker, and carp collected from sites 1 - 4 had fillet 2,3,7,8-TCDD levels averaging 0.55, 0.30, and 1.07 ppt, respectively. At sites 5 and 6, located upriver from all NWPPA bleached kraft pulp and paper mills, the geometric mean 2,3,7,8-TCDD concentrations in white sturgeon, largescale sucker and carp were 1.12, 0.24, and 1.12 ppt, respectively. These concentrations were higher than those measured downstream, indicating that there are additional sources of dioxin upstream from these mills which are contributing to the presence of 2,3,7,8-TCDD in the Columbia River.

The LADDs and theoretical upper-bound, excess lifetime cancer risks associated with the consumption of Columbia River fish by various consumer groups are presented in Table 3. The LADDs estimated for the average resident, Asian American, recreational fisherman, and Native American living in the Columbia River Basin are 0.0034, 0.013, 0.056, and 0.024 pg/kg-day, respectively. Although the Native American population consumes a greater quantity of Columbia River fish than recreational fishermen, species preferences resulted in a higher level of TCDD intake among recreational fishermen than Native Americans. Using a fugacity model to describe the partitioning of 2,3,7,8-TCDD from water, food, and sediments to fish, Travis and Hattemer-Frey (21) estimate that the average U.S. resident is exposed to 0.07 pg/kg-day from the consumption of fish. The potential dioxin intake via ingestion of Columbia River fish by sportsfishermen, the most sensitive population, is approximately 25% less than this national average.

Potential cancer risks associated with dioxin exposure were calculated as the product of the LADD and the CPF. The estimated carcinogenic risks associated with the ingestion of fish from the Columbia River fall well below risk levels considered *de minimis* by most U.S. state and federal regulatory agencies. For the most sensitive fish-consuming population, recreational fishermen, the potential risk of cancer is below one in one hundred thousand (1×10^{-5}) even when the most stringent CPF (USEPA, 1.56×10^{5} $(mg/kg\text{-}day)^{-1}$) is used.

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Table 1. Fish Consumption Rates (g/day) for Various Consumer Groups in the Columbia River Basin.

	Per Capita	Asian Americans	Sport Fishermen	Native Americans
Coho salmon	0.20	0.30	.80	0.15
Chinook salmon	0.76	1.10	.66	12.73
Steelhead trout	.05	0.07	1.29	2.96
Sturgeon	.04	0.06	8.87	0.53
Other resident species	.34	1.90	1.79	--
TOTAL	1.39	3.43	13.41	16.37

Table 2. Fillet TCDD Levels [a] in Columbia River Fish (ppt)

Species	Sampling Site 1	2	3	4	5b	6b
Coho salmon	0.08 ± 0.011	0.10 ± 0.025	NS	NS	NS	NS
Fall chinook salmon (Upriver)	0.08 ± 0.014	0.09 ± 0.047	NS	NS	NS	NS
Fall chinook salmon (Tule)	0.31 ± 0.027	0.18 ± 0.044	NS	NS	NS	NS
Summer steelhead trout	0.07 ± 0.023	0.07 ± 0.007	NS	NS	NS	NS
White sturgeon	0.09 ± 0.035	0.12 ± 0.007	1.09 ± 0.576	0.88 ± 0.214	1.68 ± 0.380	0.55 ± 0.545
Largescale sucker	0.32 ± 0.075	NS	0.39 ± 0.183	0.19 ± 0.092	0.22 ± 0.028	0.26 ± 0.075
Carp	0.79 ± 0.239	NS	1.06 ± 0.387	1.35 ± 0.779	1.46 ± 1.575	0.76 ± 0.103

Source: Beak (1989b).

a. Geometric mean of 5 replicate composite samples ± standard deviation. 80% of the anadromous and 45% of all species sampled had nondetectable levels of TCDD. Nondetectable samples were assigned a value equal to one half the limit of detection per EPA protocol. This results in a more conservative estimation of tissue TCDD levels because actual values could equal zero. NS = not sampled.

b. Sites located upstream from all NWPPA pulp and paper mills.

Table 3. Excess Lifetime Cancer Risk Associated with Dioxin Exposure Through Consumption of Columbia River Fish

Population (LADD) [a]	CPF [b]	Level of Risk
Average per capita (0.0034 pg/kg-day)	EPA	5.0×10^{-7}
	FDA	6.0×10^{-8}
	ChemRisk	3.3×10^{-8}
Sport fisherman (0.056 pg/kg-day)	EPA	8.7×10^{-6}
	FDA	9.0×10^{-7}
	ChemRisk	5.0×10^{-7}
Native American (0.024 pg/kg-day)	EPA	3.7×10^{-6}
	FDA	4.0×10^{-7}
	ChemRisk	2.0×10^{-7}
Asian-American (0.013 pg/kg-day)	EPA	2.0×10^{-6}
	FDA	2.0×10^{-7}
	ChemRisk	1.0×10^{-7}

a. Lifetime average daily dose from consumption of fish.

b. This analysis used the following cancer potencies $(mg/kg\text{-}day)^{-1}$: EPA 156,000, FDA 17,500, ChemRisk 9,700.

Figure 1. Location of Sampling Sites for Anadromous and Resident Fish in the Columbia River (Source: Beak, 1989).