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Hexachlorobenzene (HCB) Levels in Lake Ontario Salmonids

A. J. Niimi

Great Lakes Biolimnology Laboratory, Canada Centre for Inland Waters, 867 Lakeshore Road, Burlington, Ontario, Canada L7R 4A6

Hexachlorobenzene, C_6Cl_6, has been used as an agricultural fungicide until the early 1970's. HCB is also used as a peptizing agent for rubber products, a wood preservative, and a plasticizer for polyvinyl chloride (QUINLIVAN et al. 1975, PLIMMER & KLINGEBIEL 1976). HCB is also formed as a by-product during the manufacture of industrial chemicals, especially those products containing chlorine and chlorinated hydrocarbons, and the incineration of domestic and industrial waste (EPA 1973).

Once in the environment, HCB is persistent. Photodecomposition is extremely slow, and no decomposition products have been identified (PLIMMER & KLINGEBIEL 1976). No degradation of HCB have been reported by microbes (VERSCHUEREN 1977). Losses of surficial soil-bound HCB appears to be attributable to volatilization while losses of subsurface HCB appears to be negligible (BEALL 1976, ISENSEE et al. 1976). In the aquatic environment, HCB may be susceptible to partial degradation. Highly polar conjugates have been suggested as degradation products of HCB by invertebrates and fish (METCALF et al. 1973). Pentachlorophenol has also been identified as a product of HCB (SANBORN et al. 1977).

HCB has a solubility of 6 ng/g in water (GUNTHER et al. 1968). An octanol/water partition coefficient of 6.18 would suggest HCB has the propensity to bioaccumulate at high levels (NEELY et al. 1974). Laboratory model ecosystem studies have indicated HCB can be systematically accumulated through the food chain (LU & METCALF 1975, ISENSEE et al. 1976).

In view of the prevalence and persistence of HCB, measurements of environmental levels from a highly industrialized area such as the Great Lakes basin would provide an excellent reference on its occurrence. This study examined the levels of HCB in lake trout, rainbow trout, and coho salmon from Lake Ontario to confirm the bioaccumulative property of this compound in a natural water body, and to evaluate its potential impact as an important environmental contaminant.

MATERIALS AND METHODS

Lake trout (*Salvelinus namaycush*) were captured during the summer in the eastern basin of Lake Ontario. The 14 fish averaged

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1.02 kg in weight and ranged from 0.21-2.11 kg. Fifteen rainbow trout (Salmo gairdneri), with an average weight of 2.32 kg (0.64-3.76 kg) were taken during their spring spawning migration in the Ganaraska River, at Port Hope, Ontario. Twenty coho salmon (Oncorhynchus kisutch), whose weight averaged 3.56 kg (0.72-5.34 kg), were captured during the fall spawning migration in the Credit River, near Toronto, Ontario. All fish were wrapped in acetone-washed aluminum foil after capture and frozen. After thawing and ancillary measurements were taken, individual whole fish were ground to a homogeneous composition using a Hobart grinder. An aliquot was then frozen in a glass container for analyses.

HCB Determination

The homogenates were weighed, mixed with $MgSO_4$, and allowed to dry. Each sample was Soxhlet extracted for 6 h with hexane. After extraction, the volume of the hexane was made up to 100 mL, and a 10 mL aliquot was evaporated to near dryness. This fraction was brought up to 1 mL with hexane, placed on a Florisil column, and eluted with 50 mL hexane. HCB levels were determined using a gas liquid chromatograph with an electron capture detector. A 183 cm x 2 mm ID glass column was packed with 11% OV-17, 4% QF-1 on Gas Chrom Q. Nitrogen was used as the carrier gas at 30 mL/min. Injection port, column, and detector temperatures were 235, 210, and 300° C, respectively.

RESULTS

HCB levels in whole fish homogenates averaged 80 ng/g for lake trout, 62 ng/g for rainbow trout, and 36 ng/g for coho salmon (Table 1). The levels of HCB increased significantly with body weight for all species (Table 2). For fish of the same weight, HCB levels were highest in lake trout, followed by rainbow trout, and coho salmon (Fig. 1).

TABLE 1

Hexachlorobenzene and Fat Levels in Lake Trout, Rainbow Trout, and Coho Salmon from Lake Ontario.

Species	No.	HCB in tissue, ng/g				% Fat in tissue			
		Min.	Mean	Max.	SD	Min.	Mean	Max.	SD
Lake trout	14	40	80	120	23	8.9	16.2	22.5	4.2
Rainbow trout	15	30	62	125	24	5.3	8.9	14.7	2.3
Coho salmon	20	16	36	50	9	3.7	7.5	9.7	1.6

The average level of body fat in lake trout was higher than that observed in rainbow trout and coho salmon (Table 1). Percent body fat increased significantly with weight in lake trout although

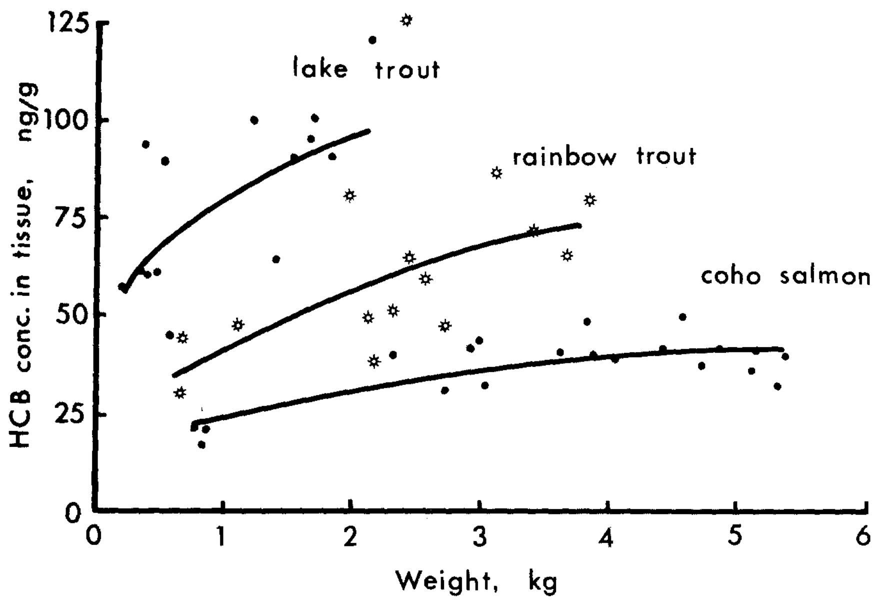

Fig. 1. Relationship between body weight and hexachlorobenzene levels in lake trout, rainbow trout, and coho salmon collected from Lake Ontario.

mean body weight and size range examined was less than the other species (Table 2). Percent body fat was not dependent on body weight for rainbow trout or coho salmon. A high preponderance of immature lake trout, female rainbow trout, and male coho salmon in the respective samples precluded any comparisons to determine differences in HCB levels and fat content that may have been attributable to sex.

TABLE 2

Regression Analyses of Lake Ontario Salmonids Expressed as $Y=aW^b$ where Y Represents HCB Levels in ng/g or % Body Fat, and W the Weight in grams. F Values with Asterisk Notes Statistical Significance at the 0.05 Level or Better.

Regression	Lake trout	Rainbow trout	Coho salmon
Weight vs HCB level in tissue	$Y=14.971W^{0.244}$ F=6.70*	$Y=2.509W^{0.411}$ F=7.61*	$Y=2.133W^{0.349}$ F=26.30*
Weight vs % fat in tissue	$Y=2.186W^{0.295}$ F=25.96*	$Y=2.618W^{0.156}$ F=1.63	$Y=5.938W^{0.026}$ F=0.09

DISCUSSION

The HCB levels reported for the three species of salmonids in this study are comparable to the average levels of 24 ng/g HCB in alewives (Alosa pseudoharengus) and smelt (Osmerus mordax), and 97 ng/g in coho salmon muscle collected from Lake Ontario (NORSTROM et al. 1978). Overall, HCB levels in fish from Lake Ontario are generally higher than those reported for a number of species surveyed throughout the United States (JOHNSON et al. 1974). Actual collection sites in that study were not sufficiently identified to establish a correlation between HCB levels and the quality of the waters that were sampled. A relationship between HCB levels in soil, water, and biota have been demonstrated for an industrialized region along the lower Mississippi River where HCB levels in the mosquito fish (Gambusia affinis) ranged from 72-380 ng/g (LASKA et al. 1976). Observations on the other Great Lakes indicate trace levels of HCB in fish tested from Lake Huron, and 1-24 ng/g HCB in fish from Lake St. Clair (FRANK et al. 1978a, FRANK et al. 1978b).

Figure 1 indicate distinct differences in the uptake kinetics of HCB among the three species examined. These differences may be partially explained when the age of the fish tested is considered. The lake trout examined included 2-5 year old fish, the rainbow trout perhaps 3-7 year old fish, and the coho salmon 3-4 year old fish. The rainbow trout appears to have originated from a self-sustaining population while the lake trout and coho salmon were fish planted as fingerlings. Differences in feeding habits may also influence HCB levels. Coho salmon feed heavily on smelt and alewives, while rainbow trout utilize other species such as perch as well. Small lake trout may feed on benthic organisms such as sculpins. The food habits of the forage species have not been sufficiently identified and monitored to establish the basis for a trophodynamic analysis of HCB in the Lake Ontario environment.

The octanol/water partition coefficient of 6.18 would suggest nearly all of the HCB in the fish homogenate would be associated with the fat fraction. This lipophilic behaviour of HCB has been well established in birds and mammals (AVRAHAMI & STEELE 1972). Based on this premise, HCB levels of the species examined were calculated from the percentage of fat in the homogenate. Mean HCB levels in fat were estimated to be 0.5 μg/g for lake trout, 0.7 μg/g for rainbow trout, and 0.5 μg/g for coho salmon (Table 3). These levels are lower than the mean values of HCB in fat of 1.0 μg/g for alewives and smelt, and 1.2 μg/g for coho salmon muscle calculated from the data reported by NORSTROM et al. (1978). To put the significance of these levels into perspective, the United States Environmental Protection Agency has recommended an interim action guideline of 0.5 μg/g in the fat of domestic animals, and the Food and Drug Administration has adopted a guideline of 0.3 μg/g in the fat of milk and dairy products. Based on these observations, further investigations on the levels of HCB in terrestrial and aquatic samples, and an assessment of the impact of HCB in highly populated areas such as the Great Lakes basin and the Mississippi River drainage would be highly desirable.

TABLE 3

Estimated Hexachlorobenzene Levels in the Fat of Lake Ontario Salmonids.

Species	No.	HCB in fat, µg/g		
		Min.	Mean	Max.
Lake trout	14	0.2	0.5	0.7
Rainbow trout	15	0.3	0.7	1.7
Coho salmon	20	0.2	0.5	1.1

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