United States
Environmental Protection
Agency

Environmental Research
Laboratory
Gulf Breeze FL 32561

Research and Development

EPA-600/S3-84-083 Sept 1984

EPA

Project Summary

Polychlorinated Biphenyl Transport in Coastal Marine Foodwebs

Joseph M. O'Connor

This project was designed to determine the rates of uptake and elimination that might be expected when fishes consume a diet contaminated with PCBs. The experiments were carried out under laboratory conditions; field verification of PCB transport from dietary sources was investigated as a subsidiary objective.

***Gammarus tigrinus* were labeled with ^{14}C-PCB (Aroclor 1254) and force-fed to juvenile striped bass in known volumes, containing known quantities of ^{14}C-PCB. The distribution of ^{14}C-PCB in the tissues of the fish was determined at 6, 12, 24, 48, 96, and 120 hours. Experiments were also conducted in which striped bass received 1, 2 or 3 doses of ^{14}C-PCB in food, and were monitored for up to 120 hours following the final dose.**

The PCBs fed to the striped bass were assimilated rapidly and almost completely (85% of administered dose). The kinetics for PCB assimilation and elimination were first order; the assimilation rate constant (k_a) was 0.1031 hr^{-1}, and the whole body elimination rate constant (k_e) was 0.0054 hr^{-1}. The elimination rate constant for the multiple-dose study was nearly identical to that observed in single-dose studies (0.0059 hr^{-1}).

From these data, rates of PCB body burden build-up were calculated in striped bass for fixed periods of time and estimates were derived of number of doses to "steady state," half-time for body burden elimination and the time-course for shifts from steady state to steady state assuming changes in PCB levels in food.

The data were also available for calculation of elimination rate-constants for individual tissues that enabled calculation of rates and routes for elimination of the PCB burden from the whole body, via the hepatic pathway.

A pharmacokinetic model was derived and is proposed as a means for estimating PCB body burdens in fishes using PCB concentration in the food as the principal data input.

This Project Summary was developed by EPA's Environmental Research Laboratory, Gulf Breeze, FL, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Between 1976 and 1979, several studies aimed at describing the distribution and fate of contaminant inputs to the New York Bight region were conducted. The conclusion reached showed that sewage sludge and dredged material disposal comprised the major source of several contaminants in the Bight Apex. Among the major contaminants deriving from these sources were the polychlorinated biphenyls (PCBs).

Efforts to determine the potential hazards and effects of PCBs on organisms from the Bight Apex were hampered by a lack of information in two areas: (1) the chemical and physical characteristics of the environment that render PCBs available to marine biota; and (2) the extent to which PCBs may be transported within the marine environment, from sediment,

to prey species, to predators. Whereas many predictive models had been published showing that bioconcentration of PCB from water was the dominant route of uptake (e.g., Hamelink et al, 1971; Mackay, 1982), equally strong arguments could be made for diet as the major route of uptake (Norstrom et al., 1976; Thomann, 1981). Resolution of the problem was impossible from either published data or from proposed field sampling; the presence of PCB in any organism does nothing to identify its source, and the Bight Apex region was subject to PCB input from many and varied sources

A two-part research project was developed, therefore, aimed at providing critical data on PCB availability and the accumulation and retention of PCB from diet by marine fishes. Part I of the project was conducted by the USEPA Gulf Breeze Environmental Research Laboratory. Part II, reported here, was carried out by the New York University Institute of Environmental Medicine and was aimed at describing the kinetics of dietary PCB transport from food organisms to a model species, the striped bass (*Morone saxatilis*).

Laboratory studies were designed to be as realistic as possible. A mixture of PCB congeners similar to the industrial mixture, Aroclor 1254, was chosen. Aroclor 1254 contains a high proportion of tri-, tetra-, and pentachlorobiphenyl congener not unlike the dominant peaks found in fishes from environmental samples.

The PCB used in experiments was uniformly ring-labeled with ^{14}C; since PCBs are not metabolized to any significant extent by fishes, the PCB compound could be tracked from food to fish and environment, with a mass-balance maintained, and pharmacokinetic analyses could be applied to the data.

Cultures of a natural food organism, *Gammarus tigrinus*, were labeled with ^{14}C-PCB and force-fed to striped bass. In all experiments care was taken to provide a known volume of food containing a known quantity of ^{14}C-PCB. Care was also taken to control the experiments, with the use of sham-fed fish to determine what proportion of the total body burden was from food and what proportion was due to secondary uptake from the water.

In single-dose studies groups of fish were force-fed and samples were taken at 6, 12, 24, 48, 72, 96 and 120 hours after feeding. Individual tissues were dissected and analyzed for ^{14}C-PCB with the use of liquid scintillation counting techniques. In the multiple-dose studies, groups of fish were given 1, 2 or 3 feedings at 48-hour intervals and were sampled for ^{14}C-PCB analysis at intervals ranging up to 120 hours after feeding.

Single-dose studies were used to determine PCB assimilation rate constants (k_a). The data from both single-dose and multiple-dose studies were used in the calculation of elimination rate-constants for whole body and individual organ PCB burdens. Mathematical treatment of the data followed the format of Goldstein et al. (1974). From the pharmacokinetic data we were able to progress to a preliminary model for dietary PCB accumulation in fishes (O'Connor and Pizza, in press) by incorporating into the dose/uptake model several parameters of growth, metabolism and feeding wich emulate those of striped bass in the natural environment.

Results

Assimilation Rate Constant

After application of a known dose, PCBs at the site of absorption, the gut, declined rapidly, decreasing from 100% of the administered dose to <10% within 24 hours (Figure 1). At the same time, the proportion of the administered dose in the whole body (Figure 2) remained above 85%. This demonstrates that PCB loss from the gut was primarily due to cross-gut transport to the tissues. Regression of the percent dose in the gut versus time yielded the assimilation rate-constant (k_a) = 0.1031 hr^{-1} and a calculated assimilation half-time of 6.7 hours.

Elimination Rate Constant

Proportional loss of PCB from the whole body over 120 hours yielded an elimination rate constant (k_e) of 0.0054 hr^{-1}, or a half-time for PCB elimination of 120 hours. Data from the multiple dose study gave essentially the same k_e; 0.0059 hr^{-1}

Approach to Plateau

Using values for k_a and k_e as determined from single-dose studies and empirical body burden data from multiple-dose studies, we fitted a curve (Figure 3)

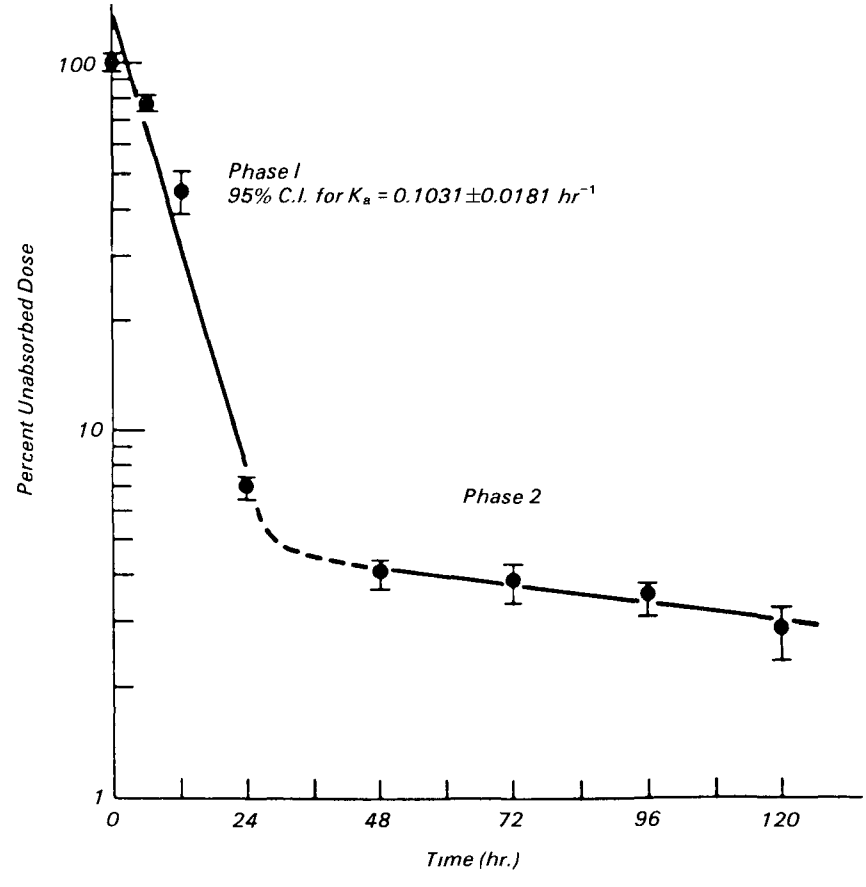

Figure 1. *Percent unabsorbed dose as a function of time. PCB removal from the alimentary tract as determined by two processes: (1) absorption of administered dose (phase 1), and (2) elimination from tract tissue (phase 2).*

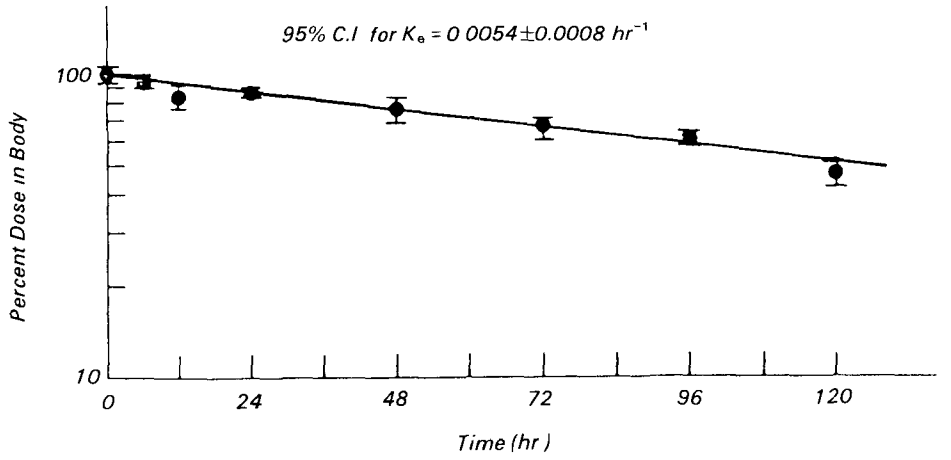

Figure 2. *Percent dose in body as a function of time PCB elimination from whole-body after a single dietary exposure.*

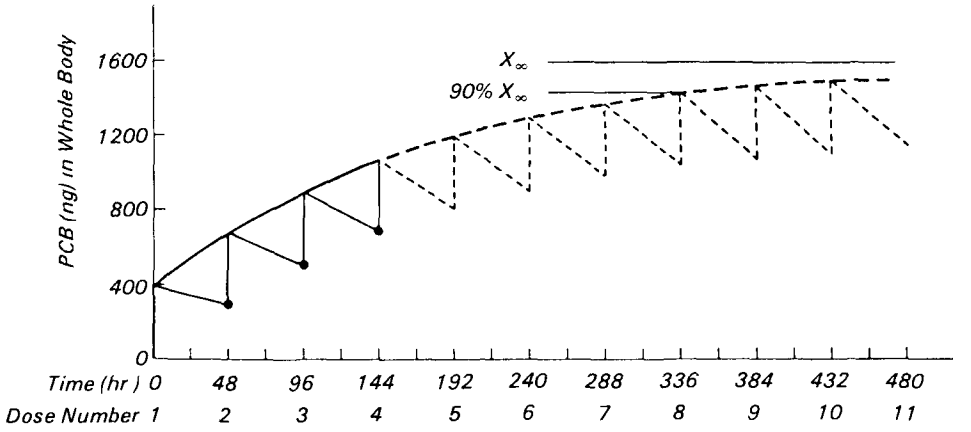

Figure 3. *Curve for the cumulative retention of PCB from multiple dosing Solid lines present the actual levels attained during the experiment. Dashed lines are the calculated extension of the data. The plateau burden ($X\infty$) is the steady state level attained from peak values after sufficient dosing (see text).*

depicting for striped bass the rate of approach to "steady-state" or "plateau" burden. According to the model, for a diet with a fixed, arbitrary, concentration of PCB, a striped bass would have accumulated 90% of the expected final body burden in about 8 doses, a rate much faster than that expected from exposure to PCBs in water.

Tissue Burdens

PCB concentrations in tissues (liver, brain, gill, heart, muscle, etc.) built up gradually over the course of several doses (Table 1). The greatest mass of PCB accumulated in the muscle ("carcass"); the greatest concentration of PCB built up in the liver/gall bladder compartment

Elimination rate-constants (k_e) for individual tissues were similar (Figure 4). The greatest turnover rate, therefore, was in the liver/gall compartment.

Interpretations

From these data, it can be concluded that, due to the rapid and nearly complete uptake of PCB from food by striped bass, dietary sources of PCBs to fish are. (1) certainly significant, and (2) possibly dominant as sources for existing body burdens.

It is also apparent from these data that PCBs assimilated by fish are not "recalcitrant"; that is, the potential exists for elimination, albeit slow ($t_{1/2}$ = 120 hours).

The pharmacokinetic interpretations of uptake and elimination can be expanded into a predictive model for PCB accumulation if appropriate constants for growth, metabolism, and dietary burdens are built in. We constructed a preliminary model (Figure 5) using a variety of constants. The model yielded predicted body burdens over a two-year period of striped bass growth, but with some unexpected characteristics Prominent among these was the failure of body burden to become asymptotic to a "steady-state" value, dictated primarily by a gradual decline in k_e with growth.

References

Goldstein, A , L Aronow, and S. M Kalman. 1974. *Principles of Drug Action: The Basis of Pharmacology* J. Wiley and Sons. New York 854 pp

Hamelink, J. L., R. C Waybrant, and R. S Ball. 1971. A proposa;: Exchange equilibria control the degree hydrocarbons are biologically magnified in lentic environments. Trans. Am. Fish. Soc. 100.207-221.

Mackay, D 1982 Correlation of bioconcentration factors Environ. Sci Technol. 16.274-278.

Norstrom, R., A. McKinnon, and A. DeFrietas. 1976 A bioenergetics-based model for pollutant accumulation by fish. Simulation of PCB and methylmercury residue levels in Ottawa River yellow perch (*Perca flavescens*) J. Fish Res. Bd. Canada 33·248-267

O'Connor, J. M and J. C. Pizza in press. Pharmacokinetic model for PCB accumulation in marine fish. In· Wastes in the Ocean, Vol. 9 Academic Press, N.Y. 1984.

Thomann, R V. 1981. Equilibrium model of fate of microcontaminants in diverse aquatic food chains. Can. J Fish. Aquatic Sci 38:280-296

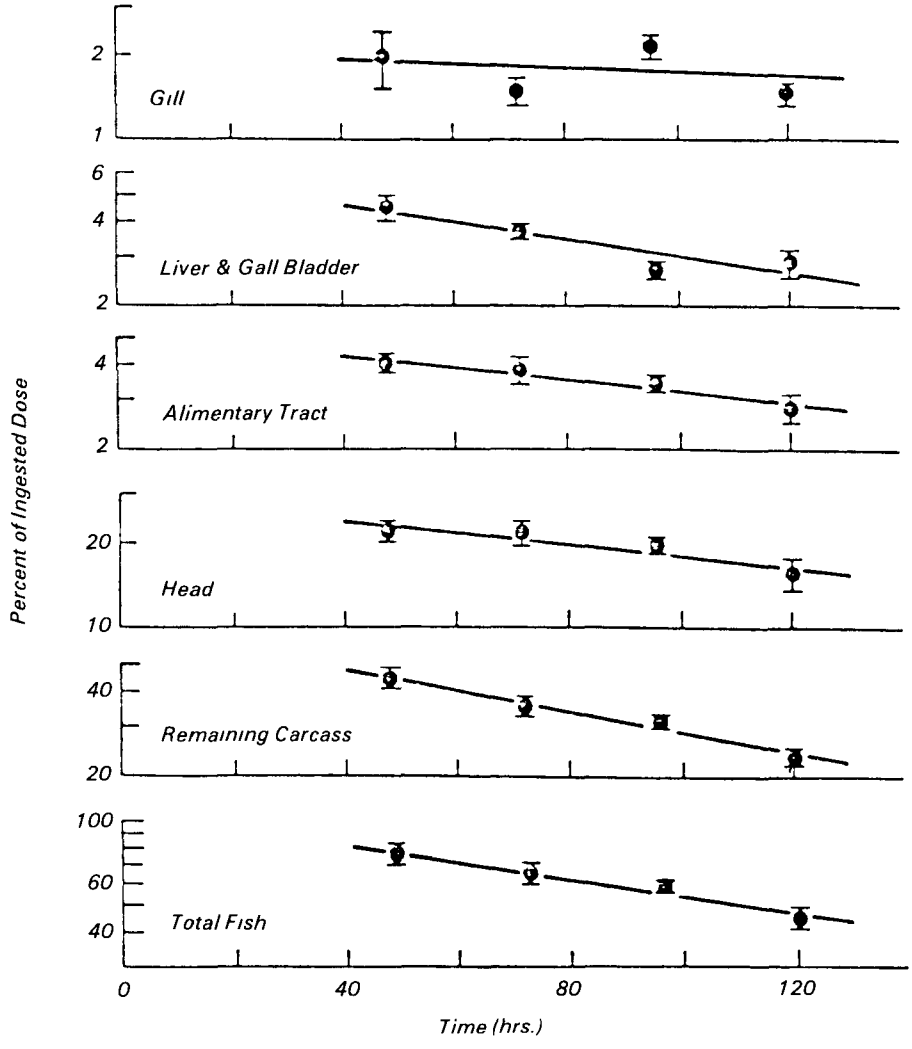

Figure 4. *Elimination of PCB from the tissues of striped bass from 48 to 120 hours after feeding. Elimination rate constants for all tissues except the gill were statistically similar.*

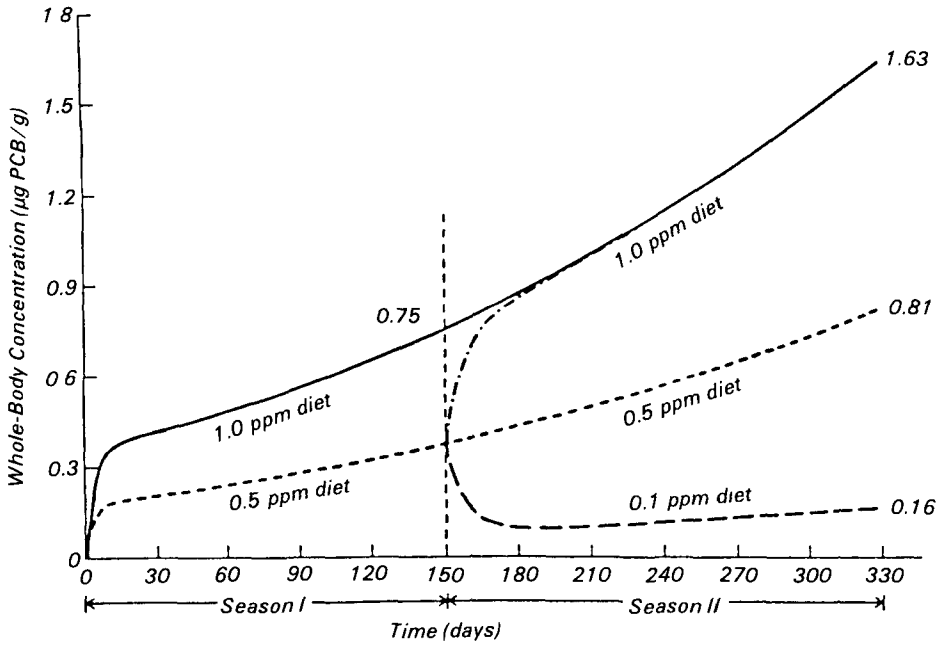

Figure 5. *Outcome of the pharmacokinetic model describing dietary PCB accumulation in striped bass. See text for details.*

Table 1. *Distribution of ^{14}C-PCB Among Tissue and Organ Compartments Measured 49 Hr After Administration of 1, 2, or 3 Doses of PCB. Each Dose was ~387 ng ^{14}C-PCB. All the Data are presented as $\bar{x} \pm s_{\bar{x}}$.*

Doses Given		Gill	Liver + Gallbladder	Alimentary Tract	Spleen + Heart	Head	Carcass	Epaxial Muscle	Whole Fish
	Percent of retained burden	2 47 (±0 38)	5 94 (±0 66)	5.35 (±0 41)	0.57 (±0.08)	28.54 (±1 00)	57 14 (±1 38)	—	100
One (n=5)	μg PCB/g (dry)	0.33 (±0.06)	1.51 (±0.17)	0.54 (±0.06)	0 34 (±0.06)	0.41 (±0.04)	0.32 (±0.03)	0 26 (±0.04)	0.37 (±0.04)
	Percent of cumulative dose	1.92 (±0.42)	4.45 (±0.43)	4.00 (±0.25)	0.42 (±0.04)	21 70 (±1.82)	46 14 (±5 40)	—	76.24 (±6.26)
	Percent of retained burden	2.44 (±0.18)	6.12 (±0.88)	5 64 (±0 15)	0.58 (±0.11)	30 11 (±1 12)	55 1 (±1 90)	— —	100
Two (n=3)	μg PCB/g (dry)	0.53 (±0.10)	2.98 (±0 23)	1.10 (±0.11)	0 95 (±0.13)	0 69 (±0 15)	0 54 (±0 09)	0.58 (±0.08)	0.63 (±0.11)
	Percent of cumulative dose	1.61 (±0.26)	3.89 (±0.33)	3.66 (±0.34)	0 36 (±0 04)	19.48 (±1 40)	36.21 (±4.92)	— —	65 23 (±6.90)
	Percent of retained burden	2.10 (±0.22)	6.15 (±0.34)	6.48 (±1.11)	0.56 (±0.04)	27.61 (±0.41)	57 09 (±1 82)	— —	100
Three (n=5)	μg PCB/g (dry)	0.74 (±0.07)	4.47 (±0.58)	1 73 (±0.16)	0 79 (±0.04)	1 01 (±0.08)	0 87 (±0.07)	0 85 (±0.07)	0 98 (±0.08)
	Percent of cumulative dose	1 25 (±0.18)	3 63 (±0.13)	3.83 (±0.71)	0.34 (±0 04)	16.25 (±0 82)	33 60 (±2 08)	— —	58 91 (±3 28)

☆U S. GOVERNMENT PRINTING OFFICE· 1984/759-102/10660

J. M. O'Connor is with New York University Medical Center, Institute of Environmental Medicine, Laboratory for Environmental Studies, Tuxedo Park, NY 10987.

***Al Bourquin** is the EPA Project Officer (see below).*

The complete report, entitled "Polychlorinated Biphenyl Transport in Coastal Marine Foodwebs," (Order No. PB 84-232 610; Cost: $13.00, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

Environmental Research Laboratory
U.S. Environmental Protection Agency
Gulf Breeze, FL 32561

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

Official Business
Penalty for Private Use $300