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Uptake, Retention, and Elimination of PCB (Aroclor 1254) by Larval Striped Bass (*Morone saxatilis*)

R. J. Califano, J. M. O'Connor, and L. S. Peters

New York University Medical Center, Institute of Environmental Medicine, A. J. Lanza Laboratories, Tuxedo, New York 10987

PCB in the Hudson River estuary has resulted in the closure of the striped bass and eel fisheries, and substantial contamination of most of the fauna and flora of the system (HETLING et al. 1978, NADEAU & DAVIS 1976). Studies of the distribution of PCB in ichthyoplankton (O'CONNOR & HERNANDEZ, unpublished data) have shown that the eggs and larvae of many species are contaminated with PCB at levels similar to that found in adult fish. It is unknown, however, whether the PCB in larval fishes is the result of transfer to the egg from ovaries of contaminated females or accumulated in eggs and larvae from the environment.

We present here the results of experiments carried out to determine rates of uptake and clearance of Aroclor 1254 in larvae of the striped bass, Morone saxatilis (Pisces; Percichthyidae). Striped bass were chosen for the study since, until 1976, they were a major commercial fish in the Hudson River, and striped bass from Hudson River stock represent a small but significant portion of the sport and commercial striped bass fishery in the Middle Atlantic Bight (MCFADDEN 1978, KOO 1970, RANEY 1952).

MATERIALS AND METHODS

Eight week old striped bass larvae (average length = 17 mm standard length, average weight = 0.1 g) were obtained from the Consolidated Edison Fish Hatchery at Verplanck, New York. The striped bass, obtained from the spawn of a single female, were maintained in Hudson River water. A thermostat/filter element aerated and filtered the water and maintained the temperature at 21 ± 1°C. About 30% of the holding water was replaced daily. Fish were fed frozen brine shrimp daily.

Experiments were carried out in Hudson River water. Water temperature during the experiments increased from 20.5 to 25.5°C and salinity increased from 2 to 4 g L^{-1}. Dissolved oxygen and pH averaged 8.3 and 7.3 mg L^{-1}, respectively.

The fish were exposed to PCB in 950 mL glass battery jars. The exposure water was maintained at ambient river

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temperature by immersing the jars in a water table receiving a continuous supply of Hudson River water.

Toxicity Testing. Range-finding tests using stable Aroclor 1254 (Monsanto Company) dissolved in acetone were performed to determine sublethal concentrations for subsequent uptake experiments (COMMITTEE ON METHODS FOR TOXICITY TESTS WITH AQUATIC ORGANISMS 1975). These tests gave 48 h LC_{50}'s between 500 and 1000 µg L^{-1} for 8-week-old striped bass. The acetone carrier, present in a 1:1000 acetone:water ratio, did not contribute to mortality (CALIFANO 1979).

Radiotracer Methodology. ^{14}C-Aroclor 1254 dissolved in acetone was purchased from New England Nuclear Corporation and diluted with anhydrous acetone to yield a stock solution of 0.1 µCi ^{14}C-Aroclor 1254 per mL. The scintillation cocktail used was a toluene-based PPO and POPOP mixture containing Triton-X-100 (4 g L^{-1} PPO, 0.3 g L^{-1} POPOP dissolved in 2:1 toluene:Triton-X-100). Fifteen mL of cocktail was added to each sample vial, the cocktail serving as the sole extracting medium for dried, pulverized fish samples. Sample counts were corrected for background and quench using channel ratios. PCB concentration in the fish was calculated from counts and the specific activity of the labeled compound (0.096 mCi mg^{-1} PCB).

Uptake and Elimination Techniques. Whole body uptake of ^{14}C-Aroclor 1254 from different experimental systems was determined by exposing fish to PCB in Hudson River water (HRW), or in Hudson River water which had been passed through a 0.45 µm millipore filter (FHRW). Uptake from HRW was determined for 11 exposure times: 0.25, 0.5, 1, 2, 3, 6, 12, 24, 34, 48 and 120 h. Exposures in FHRW were for 24 and 48 h.

Ten striped bass were exposed per battery jar in 800 mL of either HRW or FHRW. One mL of the ^{14}C-Aroclor 1254 stock solution was added to each jar and the water was stirred with a glass rod. This resulted in a calculated PCB concentration of 1.36 µg L^{-1}, well below the lethal toxicity level determined in the range-finding tests. At this concentration the maximum amount of PCB available to the fish in each tank was about 1000 ng. This concentration is also representative of PCB levels found in whole water samples from the Hudson River estuary (HETLING et al. 1978, NADEAU & DAVIS 1976). The striped bass, fed prior to the experiments, were not fed for the duration of the exposures except for the 120 h exposure in HRW. These fish were fed brine shrimp once daily in an attempt to maintain them for the 5-day exposure. All experiments were run in duplicate.

At the end of each exposure, striped bass were collected on a net-lined funnel and washed into a finger bowl

containing heated water. This served to kill and rinse the fish. Four fish from the HRW and FHRW exposures were placed in each of two scintillation vials for whole body counting. Some fish deaths occurred during the longer exposures: these fish were counted but not used in analysis of uptake. Exposed fish were oven-dried overnight at 60°, weighed on a Mettler balance, and pulverized in a mortar and pestle before addition to scintillation vials. Two fish from the HRW (except at 120 h) and FHRW exposures were preserved in 10% buffered formalin for future histological examination.

Similar procedures were used in the elimination studies. Six striped bass in each of 8 jars were exposed for 24 h in 800 mL HRW containing 1.36 μg L^{-1} ^{14}C-Aroclor 1254. At the end of 24 h, one fish from each jar was collected and reserved for 24 h uptake determination. The remaining fish from each jar were transferred into clean battery jars containing 800 mL of particle-free water in order to measure release of ^{14}C-PCB. The jars were held in the running water table for either 24 (4 jars) or 48 h (4 jars). At the termination of the experiment, two striped bass were dried, weighed, pulverized, and placed in each of two scintillation vials for counting. One was preserved in 10% buffered formalin for histological examination.

The t-test for comparison of two means (SOKAL & ROHLF 1969) was used to test the similarity of results from duplicate experiments and to compare uptake and elimination of PCB from the different experiments. Data from duplicate experiments not significantly different at the 95% confidence level were combined.

RESULTS AND DISCUSSION

Larval striped bass removed PCB from Hudson River water rapidly and nearly completely. The final whole-body concentration resulting from 48 h exposure to a single dose of ^{14}C-Aroclor 1254 was 5.9 μg g^{-1} dry weight (HRW) and 5.0 μg g^{-1} dry weight (FHRW) (Tables 1 and 2). Final concentrations in fish exposed to PCB in HRW and FHRW were not significantly different ($p > 0.05$). The transfer of PCB from water to fish was at a maximum at 48 h in HRW, at which time the fish had accumulated about 60% of the PCB available in the system (600 ng).

Rates of PCB uptake in Hudson River water were extremely rapid. More than 80% of the final concentration of PCB was attained during the first 12 h of exposure in HRW. Uptake was apparently slower in FHRW, at least for the first 24 h (Table 2).

PCB uptake between 24 and 48 h was slow and became nearly asymptotic between 34 and 48 h, suggesting that an

equilibrium or steady state condition had developed. The studies carrying PCB exposures to 120 h support this contention, showing no further PCB uptake between 48 and 120 h. Calculated values for PCB body burdens at 96 and 120 h, based on a logarithmic uptake model ($y = 1.68 + 2.53 \log x$; $r^2 = 0.96$), predicted little uptake beyond that which had occurred after 48 h. The few data available for uptake at 120 h, in fact, showed a slight decrease of PCB, from 5.9 $\mu g\ g^{-1}$ to 4.7 $\mu g\ g^{-1}$.

Table 1. Aroclor 1254 Concentration in Striped Bass Larvae Following Exposure in Hudson River Water (HRW). Striped Bass Whole-Body Levels are Expressed as µg PCB per g Dry Weight

Exposure time (hours)	n	PCB concentration $\mu g\ g^{-1} \pm$ S.E.
0.25	4	0.47 ± 0.03
0.5	4	0.93 ± 0.01
1.0	4	0.41 ± 0.06
2.0	4	2.2 ± 0.1
3.0	4	3.1 ± 0.1
6.0	4	3.5 ± 0.1
12.0	4	4.5 ± 0.2
24.0	4	5.1 ± 0.9
34.0	4	5.6 ± 0.3
48.0	4	5.9 ± 0.3
120.0	2	4.7 ± 1.2

Table 2. Aroclor 1254 Concentration in Striped Bass Larvae Following Exposure in Millipore Filtered Hudson River Water (FHRW). Striped Bass Whole-Body Levels are Expressed as µg PCB per g Dry Weight

Exposure time (hours)	n	PCB concentration $\mu g\ g^{-1} \pm$ S.E.
24.0	4	4.5 ± 0.2
48.0	4	5.0 ± 0.4

Most fishes which have been tested for PCB uptake in either static or flow-through systems required a much longer time period to reach steady-state. HANSEN et al. (1971) found that juvenile spot (Leiostomus xanthurus) required 14 to 28 days to reach saturation when exposed to Aroclor 1254 (1.0 $\mu g\ L^{-1}$). Pinfish (Lagodon rhomboides) required 21 to 28 days to reach saturation in a 1 $\mu g\ L^{-1}$ solution of Aroclor 1016 (HANSEN et al. 1974). Other species, such as fathead minnows (Pimiphales promelas), and bluegills (Lepomis macrocheirus) required up to 100 days to reach saturation with various Aroclors (DEFOE et

al. 1978, STALLINGS & MAYER 1972). Applying the regression model derived from 48 h exposures to fishes two and five years of age yields predicted PCB concentrations of 12 and 13 μg g^{-1}, respectively, values which are not inconsistent with samples of striped bass collected from the Hudson River from 1974 through 1978 (HETLING et al. 1978).

PCB elimination from larval striped bass was slow. The fish released less than 1.0% of the total PCB taken up (expressed as concentration) during the first 24 h. After 48 h of release, whole body concentrations of PCB were 4.3 μg g^{-1}, or about 18% less than the concentrations accumulated during uptake. The 48 h release concentrations were significantly less than the concentrations after 24 h of uptake, and significantly less after 24 h of release (Table 3).

Table 3. Striped Bass Retention and Elimination of PCB Following 24 h Uptake of ^{14}C-Aroclor 1254 from Hudson River Water. Mean Striped Bass Whole-Body PCB Levels are Expressed as μg PCB per g Dry Weight

Condition	n	PCB concentration μg g^{-1} ± S.E.	Percent retained
24 h uptake	7	5.2 ± 0.3	100
24 h release	8	5.2 ± 0.2	100
48 h release	8	4.3 ± 0.1	82

The uptake and release data presented herein do not lend themselves to calculation of bioconcentration factors (BLANCHARD et al. 1976, BRANSON et al. 1975). They do show, however, that the larval stages of fish exposed to PCB-contaminated environments are capable of taking the compound up directly from the water, and accumulating PCB doses, on a weight-ratio basis, to an extent similar to that of adults in the population. Studies are currently underway in our laboratory to assess the relative importance of water and dietary uptake of PCB and their contribution to total body burdens of PCB in fishes.

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REFERENCES

BLANCHARD, F.A., I.T. TAKAHASHI, H.C. ALEXANDER, and E.A. BARTLETT: in: MAYER, F.L. and J.K. HAMELINK (eds.), Aquatic Toxicology and Hazard Evaluation, ASTM STP 634. Philadelphia, Pa.: American Society for Testing and Materials 1977.

BRANSON, D.R., G.E. BLAU, H.C. ALEXANDER, and W.B. NEELY: Trans. Am. Fish. Soc. 104, 785 (1975).

CALIFANO, R.J. : Accumulation and elimination of Aroclor 1254 by juvenile striped bass, Morone saxatilis (Walbaum). M.S. thesis. New York: New York University 1979.

COMMITTEE ON METHODS FOR TOXICITY TESTS WITH AQUATIC ORGANISMS: Methods for acute toxicity tests with fish, macroinvertebrates, and amphibians. EPA-660/3-75-009. Corvallis, Ore.: U.S. Environmental Protection Agency 1975.

DEFOE, D.L., G.D. VEITH, and R.W. CARLSON: J. Fish. Res. Bd. Can. 35, 997 (1978).

HANSEN, D.J., P.R. PARRISH, and J. FORESTER: Environ. Res. 7, 363 (1974).

HANSEN, D.J., P.R. PARRISH, J.I. LOWE, A.J. WILSON, JR. and P.D. WILSON: Bull. Environ. Contam. Toxicol. 6, 113 (1971).

HETLING, L., E. HORN, and J. TOFFLEMIRE: Summary of Hudson River PCB study results. Technical paper No. 51. Albany, N.Y.: N.Y. State Dept. of Environ. Conserv. 1978.

KOO, T.S.Y.: Ches. Science 11, 72 (1970).

MCFADDEN, J.T.: Influence of the proposed Cornwall pumped storage project and steam electric generating plants on the Hudson River Estuary with emphasis on striped bass and other fish populations. Report to Consolidated Edison Co. of N.Y. 1978.

NADEAU, R.J. and R.A. DAVIS: Bull. Environ. Contam. Toxicol. 16, 436 (1976).

RANEY, E.C.: Bull. Bingham. Ocean. Coll. 14, 5 (1952).

SOKAL, R.R. and F.J. ROHLF: Biometry. San Francisco: W.H. Freeman & Co. 1969.

STALLINGS, D.L. and F.L. MAYER, JR.: Environ. Hlth. Perspect. 1, 159 (1972).