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Bioaccumulation of Aroclor 1016 in Hudson River Fish[1]

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Polychlorinated biphenyls (PCBs) are chemical mixtures which have been widely used in industry and which are marketed in the United States by the Monsanto Company. It is because of their widespread use and their persistence in the environment that PCBs may now be found in high levels in fish and wildlife from many parts of the world. Aroclor 1016 is a PCB mixture which contains 41 percent chlorine and was developed to replace Aroclor 1242 in the manufacture of capacitors.

As part of a larger study of PCB contamination in the Hudson River (New York), it was necessary to show that Aroclor 1016 would accumulate in fish after relatively short exposures to contaminated river water. Laboratory experiments have shown that PCBs are rapidly bioaccumulated by fish (VEITH and KIWUS 1976, MAYER et al. 1977, NEBEKER et al. 1974). Field studies, because they include natural environmental variations, give a better indication of what is actually occurring in the environment and are important in verifying laboratory studies.

METHODS

A total of forty-seven fish were collected from Oxbow Lake, Arietta, New York, in October 1975. These fish consisted of twenty-five brown bullheads, Ictalurus nebulosus (LeSueur), thirteen yellow perch, Perca flavescens (Mitchill), three pumpkinseeds, Lepomis gibbosus (Linnaeus), and six creek chubsuckers, Erimyzon oblongus (Mitchill). They were transferred to the Hudson River and placed in large live cages (2.0 m x 1.0 m x 0.8 m) made of hemlock framing and wire mesh.

The live cages were placed at three different locations in the river. Two were placed upstream above the Village of Fort Edward, and the third was positioned below the suspected PCB source (below Fort Edward off Rodger's Island). Two control areas were used

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because other environmental problems in this section of the Hudson River could have prevented total fish survival during the two week period. This proved to be a wise decision since one of the control cages was broken into and a large number of fish removed. The downstream live car was placed on hard bottom so that contact with the sediment was minimal, and the water depth was great enough to submerge all but the top of the cage.

Fish that were not placed in the live cages were tagged, frozen, and later analyzed as controls for background levels of Aroclor 1016. After being exposed to Hudson River water for 14 days, the fish were removed from the cages, tagged, and frozen for analysis. All fish were analyzed as whole fish composite samples by species using methods described by VEITH (1975).

PCB concentrations in the Hudson River at Rodger's Island were calculated daily by using the river flow at a nearby gaging station and the total loading of PCBs from the upstream source. Although these estimates assume ideal mixing of the PCB discharge with the river water, previous water analyses compared favorably with calculated values. Absorption of PCBs by the sediments and leaching of PCBs from the sediments did not appear to affect the calculated concentrations.

RESULTS

Analysis of fish from upstream cages and fish frozen for background levels showed residues of less than 0.02 µg/g Aroclor 1016 (lowest detectable level). Fish taken from the cage at Rodger's Island, however, had Aroclor 1016 levels which varied from 1.8 µg/g in yellow perch to 3.8 µg/g in a composite of brown bullheads (TABLE 1). The chromatograms of the fish residues were identical to those of Aroclor 1016 with a slight increase in the PCBs containing five and six chlorine atoms.

The mean PCB concentration in the Hudson River during the 14 day exposure period was computed to be 0.17 µg/l. A heavy rainfall during the last three days of the study resulted in the discharge of approximately 41.7 kg of PCBs into the river in contrast to a discharge of only 9.1 kg during the first eleven days of the study. If the high values of the last three days are deleted, the resulting mean PCB concentration in the river for the study period would be 0.10 µg/l.

Using a mean fish concentration of 2.6 µg/g (range 1.8 µg/g - 3.8 µg/g) these fish in 14 days bioaccumulated Aroclor 1016 at 15,000 times the water concentration (0.17 µg/l). If we use 0.10 µg/l as the water concentration the 14 day bioaccumulation factor is 26,000.

TABLE 1

Concentrations of Aroclor 1016 in fish confined to a live-cage for 14 days near Rodger's Island in the Hudson River (Calculations based on whole fish)

Species	Number of fish in sample	Mean weight (g)	Mean length (cm)	% Lipid	PCBs as Aroclor 1016[a] µg/g	PCBs as Aroclor 1016[a] total µg/fish
Creek Chubsucker (*Erimyzon oblongus*)	2	295	27.4	7.0	2.2	649
Yellow Perch (*Perca flavescens*)	3	187	24.9	2.8	1.8	337
Pumpkinseed (*Lepomis gibbosus*)	2	125	17.8	2.3	2.5	313
Brown Bullhead (*Ictalurus nebulosus*)	5	80	18.8	2.4	3.8	304
Brown Bullhead (*Ictalurus nebulosus*)	5	76	19.1	1.9	2.8	213

[a] The fish contained less than 0.02 µg/g Aroclor 1016 before exposure to Hudson River water.

DISCUSSION

The PCB residues which were found accumulated in the four fish species were very similar (TABLE 1). This suggests that the extent to which PCBs are accumulated from water does not differ substantially among species of similar lipid content and size.

It is interesting to note that the total quantity of PCBs accumulated by the different species of fish was closely related to the fat content and weight of the fish and also to the mean weight of the fish. The creek chubsuckers were the largest fish used in the study and contained the highest percent lipid (7.0%), and they had the largest amount of PCB accumulated per fish (649 µg). Brown bullheads on the other hand had the lowest percent oil and the least amount of accumulated PCB.

Only one sampling of fish from the live cages was possible in this study after 14 days, and therefore, the ultimate bioaccumulation of Aroclor 1016 in the fish could not be determined. However, concentrations of PCBs in native fish from the Hudson River have been reported by SPAGNOLI and SKINNER (1977) and are considerably higher than the levels reached in 14 days. They reported Aroclor 1016 levels in yellow perch from the Fort Edward area which averaged 164.36 µg/g on a whole fish basis. White suckers averaged 41.74 µg/g Aroclor 1016 from the same area. Brown bullheads collected five miles below Fort Edward averaged 77.04 µg/g.

Laboratory bioaccumulation studies with Aroclor 1016 (VEITH and KIWUS, 1976) showed a bioaccumulation factor in fathead minnows of 20,000 after 16 days exposure, which compares favorably with those found after 14 days in the Hudson River. They also showed a bioaccumulation factor of 50,000 after 32 days. This comparison of laboratory and field bioaccumulation factors lends credence to forecasts based on laboratory studies in flowing water with fish.

SCHOOR (1975) proposed that laboratory bioassays using a carrier such as acetone may give erroneous results when using compounds of low solubility, and that bioassays conducted in the field under natural conditions may result in quite different results. The close similarity in the laboratory results of VEITH and KIWUS (1976) with those presented here indicate that the acetone used in the laboratory studies did not alter the bioaccumulation rate. Also, the uptake of all Aroclor 1016 components in similar proportion to the standard Aroclor 1016 formulation under both laboratory and field conditions suggests that the theoretical effects of carriers (SCHOOR 1975) do not significantly change the partitioning of PCBs into the fish tissue.

Numerous researchers have found similar bioaccumulation factors for other PCB Aroclors. MAYER et al. (1977) reported that

after seventy-seven days channel catfish had accumulated concentrations of Aroclors 1248 and 1254 that were respectively 56,370 and 61,190 times that of the water, and the PCB uptake had still not reached an equilibrium. Fathead minnows that were exposed to Aroclor 1242 for 259 days exhibited bioaccumulation factors of from 32,000 to 274,000 (NEBEKER et al. 1974). In the same study, fathead minnows exposed for 244 days accumulated concentrations of Aroclor 1254 that were 109,000 to 238,000 times that of the water. BILLS and MARKING (1977) found that after 30 days of continuous exposure to Aroclor 1254 rainbow trout had accumulated levels 34,000 to 46,000 times the water concentration.

This field study conducted in the Hudson River compared very favorably with results obtained in the laboratory and reported by other researchers. Bioaccumulation factors were in the same range as those reported for fish of similar lipid content in laboratory studies (VEITH and KIWUS 1975). It is important to note that the methods used in this study were proved to be helpful in pinpointing the source of a suspected discharge of PCBs.

As was shown in this study and others, PCBs are rapidly taken up and accumulated by fish. The various PCB Aroclors appear also to be bioaccumulated at similar rates. It is because of this rapid accumulation of PCBs that fish from contaminated waters will continue to show high contaminant levels.

REFERENCES

BILLS, T.D. and L.L. MARKING: Prog. Fish-Cult. 39, 150 (1977).

MAYER, F.L., P.M. MEHRLE, and H.O.SANDERS: Arch. Environ. Contam. and Toxicol. 5, 501 (1977).

NEBEKER, A.A., F.A. PUGLISI, and D.L. DEFOE: Trans. Am. Fish. Soc. 103, 562 (1974).

SCHOOR, W.P.: Water Res. 9, 937 (1975).

SPAGNOLI, J.J. and L.C. SKINNER: Pestic. Monit. J. 11, 69 (1977).

VEITH, G.D.: Pestic. Monit. J. 9, 21 (1975).

VEITH, G.D. and L. KIWUS: U.S. Environmental Protection Agency Report, ERL-Duluth, Minn. 5 pp. (1976).