ENVIRONMENTAL OCCURRENCE AND FATE

DSW 347170

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Chlorinated Hydrocarbon Pollutants in the Atlantic Ocean

Summary of Investigations, 1971

We are engaged, in close cooperation with the Department of Biology, in determining the concentrations of polychlorinated biphenyls (PCB) and members of the DDT family in organisms collected from the open Atlantic Ocean, North and South. This is the first study of its kind in the high seas and has furnished us with new insights into transport mechanisms and food chains.

The data strongly indicate that the atmosphere provides the major path for delivery of both DDT and PCB to the ocean. The North Atlantic plankton show almost uniformly high levels (100-900 ppm) in their fat. Thus, the quantities of these pollutants delivered to the ocean by the atmosphere obliterate any concentration gradient from continental run-off. Secondly, there is very little difference in concentrations of these pollutants between the North and South Atlantic. Considering the smaller land surface of the southern hemisphere, the low level of industrialization and the lack of North to South circulation of Atlantic surface waters, the South Atlantic pollution must be transported there by global winds from the northern hemisphere.

Our data appear to offer no support for the widely held view that concentrations of chlorinated hydrocarbons are magnified along marine food chains. Many prey-predator couples (flying fish-plankton, Arctic Cod - Atlantic Cod, etc.) reveal concentrations just the reverse of what would be expected from biomagnification. Different species which have similar diets and collected in the same nets show widely different concentrations of DDT and PCB. We believe that the levels found within an organism are a result of the partitioning of the DDT and PCB between the water and the body lipids. The lipids of each species will have a definite capacity for these chemicals regardless of its position in the food chain. Air breathing animals must depend on excretion and metabolism, which are apparently less efficient than equilibration with water, and accumulate these pollutants. This discovery would have been extremely difficult to make in coastal waters where the organisms are subjected to sporadic and high doses of pollutants from spills, floods and dumping operations. The open-ocean is remote enough so as not to be affected by daily and local inputs.

Finally, PCB formulations must be transported to the ocean by discreet aerosol masses which do not mix with similar formulations during their atmospheric history. This phenomenon is not shared by DDT which is largely transported on atmospheric particulate matter. This must be a consequence of the different modes of injection into the atmosphere: DDT by slow evaporation from soil and PCB by distilling from incinerators, dump fires and explosions (aircraft crashes).

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We are continuing to explore these phenomena and will soon study the mechanisms of uptake and transfer of chlorinated hydrocarbons in the open-sea.

These studies are being supported by the National Science Foundation under Grant GX 28334 and by the U. S. Atomic Energy Commission under Contract AT(30-1)-3563.

John L. Hesse, Michigan Water Resources Commission, Lansing, Michigan,
December 17, 1971

PCB's in Michigan Waters

The following is a brief summary of the Michigan Water Resources Commission PCB monitoring results during 1971.

Analyses of 98 water samples (30-hour composites) from 30 major tributaries to the Great Lakes indicate that PCB contamination of surface waters is widespread with 71 percent of all samples having detectable (greater than 10 ppt) concentrations. Concentrations greater than 100 ppt have been detected in seven streams, all located in the industrialized southeastern portion of the lower peninsula. The Saginaw River has consistently had the highest concentrations with as much as 2,900 ppt on one date.

Sampling of Great Lakes water intakes has shown much lower PCB concentrations than in tributary streams. Only 3 of 36 samples contained detectable concentrations with a high of 300 ppt.

Limited sampling of groundwater supplies in the southern lower peninsula has indicated that groundwater has not been significantly contaminated with PCB's. One of 4 samples contained 19 ppt while the other 3 were less than 10 ppt.

Analyses of surface water runoff from sanitary and industrial landfills in Michigan suggest that these are a minor source of environmental contamination. Five of the 9 samples collected had PCB concentrations ranging from 40 to 300 ppt while the others contained less than 10 ppt.

Discharges from municipal wastewater treatment facilities appear to be a very significant source of PCB losses to the waters of the state. Twenty-eight of 32 WWTP discharges sampled contained greater than 100 ppt PCB's. Eight had concentrations in excess of 1,000 ppt with a high of 336,000 ppt. Investigations have been initiated which should identify the major sources of input to the municipal systems with the greatest contamination.

Discharges from a cross-section of industries throughout Michigan were sampled for PCB concentrations. PCB losses from industries is apparently very widespread. Thirty of 58 industrial discharges tested had PCB concentrations greater than 100 ppt. Eleven industries had discharges containing PCB's in excess of 1,000 ppt.

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Because the Saginaw River was identified as having the highest PCB concentrations of any major tributary to the Great Lakes within Michigan, an intensive survey effort was conducted to isolate the major sources of PCB contamination in that basin. Water samples collected at key locations ranging from each of the four major tributaries of the Saginaw down to the mouth of the river indicated that the primary increase in PCB concentrations occurs in a short zone in the immediate vicinity of Bay City and Essexville. More intensive sampling in that zone revealed two major sources of PCB losses to the river. Actions were taken toward elimination of these sources of PCB contamination.

James J. Lichtenberg, Group Leader Pesticides Identification, Environmental Protection Agency, National Environmental Research Center, Cincinnati, Ohio 45268

In anticipation of a possible probe into the historical occurrence of PCB's in surface waters, stored carbon adsorption sample extracts (CCE) from three selected sites were analyzed. The samples were cleaned-up and separated on a microcolumn of Davison 950 silica gel according to the procedure of Leoni [Journal of Chromatography, 62, 63 (1971)] prior to gas chromatographic determination. The results show an estimated 1 to 2 µg/l of PCB's in one sample. The chromatogram suggested a probable mixture of Aroclors 1242, 1248, and 1254. A trace of what appeared to be Aroclor 1232 was noted in another sample. The third sample showed no Aroclor characteristics. These positive occurrences are significant in light of the fact that they occurred in samples collected in mid-1966.

Effective procedures for clean-up and separation of the Aroclors from pesticides and other interfering materials are required for adequate analysis of CCE. Of the published procedures that we have tested, the Leoni procedure has proven the most useful for this purpose.

Ronald Parejko, Department of Biology, Northern Michigan University, Marquette, Michigan 49855

At Northern Michigan University, Marquette, Michigan, I am establishing a chlorinated hydrocarbon pesticides and PCB analysis laboratory. This laboratory will have its center of interest, at least initially, focused upon the quantification of PCB's in lake trout taken from Lake Superior.

The lab is currently in the primary stage of setting-up and as yet no data has been accumulated. Funding for the installation of the laboratory has been provided by the Office of Water Resources Research, U. S. Department of the Interior.

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TOXICITY AND OTHER PHYSIOLOGICAL EFFECTS

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Toxicity of Aroclors® to Aquatic Organisms

Fish: Tests to determine the chronic toxicity of Aroclors® to fish are continuing. Aroclors® 1242, 1248, and 1254 were about equally toxic to yellow perch (30-day TL50 = 72 to 92 µg/l), while Aroclor® 1260 was less than half as toxic.

Herman O. Sanders, Fish-Pesticide Research Laboratory, Bureau of Sport Fisheries and Wildlife, Route #1, Columbia, Missouri 65201

Invertebrates

Preliminary static bioassays with individual PCB isomers were begun using scud (Gammarus pseudolimnaeus). These organisms were selected as the amounts of pure isomers available did not permit bioassays using larger organisms.

No. Cl	PCB Component	TL50 (mg/l) 24 hr	96 hr
2	2,4'-dichlorobiphenyl	0.15	0.12
2	4,4'-dichlorobiphenyl	0.16	0.10
3	2,3,4'-trichlorobiphenyl	0.10	0.07
5	2,4,5,2',5'-pentachlorobiphenyl	0.43	0.21
6	2,4,6,2',4',6'-hexachlorobiphenyl	0.20	0.15
4	mixture of 3, decachlorobiphenyls	0.30	0.11

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Chronic Toxicology of PCBs to Fish

TL50 values (5-30 days) from continuous flow exposures of Aroclors® 1242, 1248, 1254, and 1260 to three species of fish have been determined. Comparative toxicity data for DDT was also determined.

Compound	Species	TL50[1] (µg/l) for 5-30 days					
		5	10	15	20	25	30
DDT	RBT[2]	4.22	1.39	0.51	0.41	0.22	-
	BG[3]	1.18	1.43	1.63	1.27	0.59	0.35
	CCF[4]	>1.0	1.54	2.33	1.32	0.87	0.57
1242	RBT	67	48	18	10	12	-
	BG	125	125	164	125	120	84
	CCF	>100	125	219	150	132	87
1248	RBT	54	38	16	6.4	3.4	-
	BG	136	115	111	106	100	78
	CCF	>100	121	121	115	104	75
1254	RBT	142	160	64	39	27	-
	BG	>200	>200	303	260	239	177
	CCF	>200	303	286	293	181	139
1260	RBT	232	326	143	78	49	51
	BG	>400	>400	>400	>400	>400	>400
	CCF	>400	535	482	512	465	433

[1] temperature, 17°C

[2] Rainbow trout

[3] Bluegills

[4] Channel Catfish

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These data compare favorably with our previously determined TL50 values at a comparable exposure period. However, these TL50 values are somewhat higher than the previous values. Dietary protein levels were increased during the two test periods and may have decreased the PCB toxicity during this extended exposure. Toxicity appears to be inveresely related to chlorine content and at 30 days had not become independent of exposure time.

George Yip and James D. Link, U. S. Food and Drug Administration, Washington, D.C. 20204

PCB Metabolism

Aroclor 1254 residues were determined on organs of rats which had been given single daily doses of 300 mg/kg Aroclor 1254 for 5 days or 15 mg/kg for 14 days. Livers, kidneys, fat, blood, and urine were analyzed by electron-capture GC. Except for differences in amounts found, all samples had similar type chromatograms showing major losses of early eluters and more significantly, a complete loss of one major peak. Using a standard supplied by Dr. R. G. Webb, this peak has been tentatively identified as 2,3,6,3',4'-pentachlorobiphenyl by GLC and IR. Quantities of this component will be obtained for further in vivo and in vitro studies to determine its fate in biological systems.

S. Bailey, P. J. Bunyan, and J. M. J. Page, Ministry of Agriculture, Fisheries and Food, Pest Infestation Control Laboratory, Hook Rise South, Tolworth, Surbiton, Surrey

Investigations are now under way into the effects produced by individual polychlorinated biphenyl isomers following low level chronic feeding to Japanese quail. Various parameters of microsomal activity are being measured and an attempt will be made to correlate these with tissue residue levels. Excreta are being monitored for metabolic transformation products. It is hoped that an overall picture will emerge relating these measurements to the extent and pattern of chlorination.

L. S. Merkens and W. B. Kinter, Departments of Pharmacology and Physiology, Upstate Medical Center, SUNY, Syracuse, New York 13210

Two types of studies were done with DDT and Aroclor 1221 (provided by Monsanto Co.) in marine adapted killifish (Fundulus heteroclitus). Acute toxicity and changes in serum osmolality were measured. Both tests were done using a simple static system. In each experiment 10 fish, each 5 g, were maintained in 2 liters of sea water at 15 C with 0.1% ethanol. The experimental compounds were first dissolved in 2 ml of ethanol before added to the sea water. Aroclor 1221 at 75 ppm (theoretical concentration in the sea water) was less toxic than DDT by a factor of about 100. It

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demonstrated roughly equivalent lethality (24 hours) as 0.25 ppm DDT. Exposure of these same levels (75 ppm Aroclor 1221 and 0.25 ppm DDT) for 6 hours increased serum milliosmolality (determined by freezing point depression) from 365 ± 3 (SE) (6 samples each from 3-5 ethanol control fish) to 396 ± 7 (9) and 389 ± 9 (8), respectively ($p<0.05$). A more complete description of methods and data will appear in Environmental Health Perspectives.

D. R. Nimmo, D. J. Hansen, N. R. Cooley, and J. A. Couch, Environmental Protection Agency, Gulf Breeze Laboratory, Sabine Island, Gulf Breeze, Florida 32561

The Environmental Protection Agency Laboratory at Gulf Breeze, Florida, an associate laboratory of the National Environmental Research Center, Corvallis, Oregon, is continuing to study the effects of polychlorinated biphenyls on estuarine organisms. We are now completing many experiments reported in the last newsletter and beginning new studies.

Studies have been completed on the effect of Aroclor 1248 on growth of populations of the ciliate protozoan, Tetrahymena pyriformis W, employing as criteria of effect the alteration of growth rate during exponential growth and of population density at 96 hours, when control populations are maximal. The ability of this ciliate to accumulate PCB from the medium and concentrate it was investigated. Similar studies of Aroclor 1260 are nearing completion.

The relationship of salinity of test water and toxicity of Aroclor 1254 to longnose killifish, Fundulus similis, is being investigated. As fish die, they are dissected and samples of individual tissues as well as composite samples of whole fish are analyzed for Aroclor 1254. After half of the fish die, the survivors are also dissected forresidue analysis. Results are incomplete.

We have studied the effects of 0.1, 1.0, and 10.0 ppb of Aroclor 1254 on setting and growth of animals in sand-filled aquaria during a four-month exposure. Most animals have been identified and enumerated. Species diversity indices have been computed, but statistical analysis of the data is incomplete.

The ability of animals to avoid Aroclor is being tested by allowing them to move into water containing Aroclor or into Aroclor-free-water. Experiments using pink shrimp, Penaeus duorarum, and mosquito fish, Gambusia affinis, have been completed. Use of other crustaceans and fishes is being considered.

A crystalloidal material has been found in the nuclei of hepatopancreatic cells of shrimp exposed to 5 ppb Aroclor 1254 for long periods of time. Also, liver necrosis has been found in spot, Leiostomus xanthurus, similarly exposed to this PCB.

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We have found the tolerance limit of 50% of a population of estuarine grass shrimp, Palaemonetes pugio, to be between 4.0 and 12.5 ppb Aroclor 1254. In this 16-day experiment, we found correlations between concentration of this material in the water and mortality. Preliminary tests showed that Palaemonetes kadiakensis, the fresh-water grass shrimp found in this area, was much less susceptible to this PCB than P. pugio, the local estuarine grass shrimp.

Dave Hansen reported that a newly identified source of contamination of Aroclor 1254 in bioassay water to be Teel submerisble pumps, No. 1P597, that were used to supply water to a constant-head box. At times, concentrations in the water exceeded 0.2 ppb (µg/l). Residue analyses performed on various portions of the pump revealed that the grease used to lubricate the shaft was about 0.37 percent polychlorinated biphenyl.

Therefore, this pump should be used only if the grease is replaced or in experiments in which presence of this contaminant would not alter results.

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Toxicity of Polychlorinated Biphenyls (PCB's) to Fish and Other Aquatic Life

Final Report

Summary of Findings (Abstract)

Aroclor 1248 was the most toxic of the eight Aroclors tested to Daphnia magna in static tests, with 16 percent impairment of reproduction occurring at 16 µg/liter. Aroclor 1254 was most toxic under continuous-flow conditions with 16 percent reproductive impairment at 0.48 µg/liter. The Aroclors were much more toxic under continuous-flow than static conditions, with 16 percent impairment of reproduction by Aroclor 1248 occurring at 1.0 µg/liter.

Calculated 96-hour LC50 values for newly-hatched fathead minnows were 7.7 µg/l for Aroclor 1254 and 15 µg/l for 1242. Three-month-old fatheads had a 96-hour LC50 of ca. 300 µg/l for 1242. Reproduction occurred at and below 1.8 µg/l 1254 and at and below 5.4 µg/l 1242. Polychlorinated biphenyls were acutely toxic but exhibited much greater chronic toxicity at very low levels, due to their cumulative nature. Newly hatched young were the most sensitive life stage. Young fathead growth was also affected above 2.2 µg/l 1248 and none survived above 5.1 µg/l after 30 days.

Young flagfish, Jordanella floridae, did not survive above 5.1 µg/l 1248 and did not grow well above 2.2 µg/l.

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Ninety-six hour LC50 values for Aroclor 1242 and 1248 with Gammarus pseudolimnaeus were 73 and 29 µg/liter. Survival after 30 days was 53 percent at 8.7 µg/l 1242 and 52 percent at 5.1 µg/l 1248. Threshold values were unobtainable as deaths continued to occur until end of test, indicating the cumulative chronic toxicity of PCB's. Good reproduction and survival of young occurred at 2.8 µg/l 1242 and 2.2 µg/l 1248.

Abundant adult emergence of the midge Tanytarsus dissimilis did not occur above 5 µg/l 1248 or 3.5 µg/l 1254. The calculated 3-week LC50 (50% reduction based on control as 100%) for Aroclor 1254 was .65 µg/l for larvae and .45 µg/l for pupae.

Application factors of 0.10 for 1242 and 0.15 for 1248 were calculated for the PCB's and Gammarus. Application factors of 0.2 for 1254 and 0.16 for 1242 were calculated for fathead minnows using newly hatched fish to obtain the 96-hour LC50.

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