SUMMARY OF RECENT INFORMATION REGARDING EFFECTS OF PCB'S ON FRESHWATER ORGANISMS

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Abstract

Polychlorinated biphenyls (PCB's) are toxic to freshwater organisms at concentrations below 5 µg/l (ppb), and newly hatched fish and small insects and crustaceans with short life cycles are most sensitive. Aroclor 1254 at 0.45 µg/l produced a 50 percent decrease in midge reproduction; 1.3 µg/l caused a 50 percent reduction in Daphnia reproduction; and 1.8 µg/l produced 50 percent reduction in fathead minnows. The indirect toxicity of PCB's to predators through accumulation of PCB's in tissues of food organisms causes death. Fish can accumulate 200,000 times more PCB's in their flesh than can be held in the surrounding water. The concentration of Aroclor 1260 in the water resulting in a tissue residue of 0.5 µg/l is approximately 0.002 µg/l. Aroclor 1016 and 1242 have been shown to have similar toxicity to freshwater organisms.

The Environmental Protection Agency proposed water quality criterion for PCB's is as follows: "Maximum acceptable concentration of PCB's in water is 0.001 µg/l."

Polychlorinated biphenyls (PCB's) are toxic to freshwater fish and other aquatic organisms at very low levels and direct toxic effects are evident within a few hours, but much greater harm is caused by longer exposure at lower concentrations. PCB levels that kill fish, crustacea, and aquatic insects are similar to those of DDT and several other pesticides. Environmental occurrence of these materials is increasing and there is mounting evidence that they are causing widespread harm in the freshwater aquatic environment.

One of the significant accomplishments since the discovery of the toxicity of PCB's to freshwater organisms was the synthesis of known data and their publication in the "Blue Book," or *Water Quality Criteria—1972*, sponsored by the U.S. Environmental Protection Agency and prepared by the National Academy of Sciences, National Academy of Engineering Committee on Water Quality Criteria (ref. 1). It was recommended in this report that aquatic life should be protected where the maximum concentration of total PCB in unfiltered water does not exceed 0.002 µg/l at any time or place, and the residues in the general body tissues of any ic organism do not exceed 0.5 µg/g.

The Environmental Protection Agency (ref. proposed water quality criteria for PCB's as fo "Maximum acceptable concentrations of PCB's i are 0.002 µg/l, and maximum acceptable levels o dues in general body tissues of any aquatic organis 0.5 µg/l"; following the proposed criteria recomm by the National Academy "Blue Book." Howeve criteria have not been promulgated. Recently, th vironmental Protection Agency (ref. 3), using the information available, has proposed 0.001 µg/l PCB maximum permissible concentration in freshwater has proposed no tissue level criterion.

The purpose of this paper is to present a summ of recent information dealing with the toxicity of p chlorinated biphenyl compounds to freshwater crustaceans, and aquatic insects, and to present imp tant recent information on the bioconcentration PCB's in fish tissues and its effect on consumer o nisms.

Fish

A significant amount of new information deali with the toxicity of PCB's to fish has been collec during the last 3 years. Acute and longer term studi have been conducted with a variety of freshwater spo and forage fish species. Tests with fathead minnows the National Water Quality Laboratory, Duluth, Minn sota, (ref. 4) have shown that Aroclor 1242, A-124 and A-1254 are toxic below 5 µg/l. Ninety-six-hou LC_{50} values (that concentration which kills half the fi in 96 hours) for newly hatched fathead minnows we 15 µg/l for Aroclor 1242 and 7.7 µg/l for A-1254. Fif percent died at 8.7 µg/l A-1248 after 30 days. After 6 days, half were dead at 8.8 µg/l A-1242 and 4.6 µg A-1254 (table 1).

Two 9-month continuous-flow bioassay tests were conducted (ref. 4) with the fathead minnow to deter mine the effects of Aroclor 1242 and A-1254 on survival and reproduction (table 2). Concentrations of Aroclo 1242 above 10 µg/l were lethal to newly hatched fry and all minnows were dead after 96 hours in 51 µg/l A-1242; none survived to the end of the test at 15 µg/l. Fry survived when reared in the same concentrations at which their parents lived and spawned; however growth of newly hatched fish was retarded prior to their death

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Table 1. Acute toxicity of Aroclor 1242, 1248, and 1254 to fathead minnows, Gammarus and Daphnia, in continous-flow tests

	Test temp. (C)	96-hr LC_{50}[a] (µg/1)			60-day LC_{50} (µg/1)		
		1242	1248	1254	1242	1248	1254
Fathead minnow, newly hatched	24°	15	*[b]	7.7	8.8	8.7[c]	4.6
Gammarus	18°	73	29	--	8.7[c]	5.1[c]	--
Daphnia	18°	--	12.9	6.4	--	2.6[d]	1.8[d]

[a]Concentration where 50 percent died after 96 hours.

[b]No mortality after 96 hours.

[c]Thirty-day LC_{50}.

[d]Fourteen-day LC_{50}.

Table 2. Spawning and egg production of fathead minnows exposed to Aroclor 1242 and 1254

Aroclor concentration (µg/1)	Number of spawnings per female	Number of eggs per spawning	Number of eggs per female	Percent eggs hatched
Aroclor 1242				
51.0	0	0	0	0
15.0	0	0	0	0
5.4	2.5	30	151	81
2.9	3.9	63	283	38
0.9	1.3	28	35	84
0.0	4.6	90	442	53
Aroclor 1254				
15.0	0	0	0	0
4.6	0	0	0	0
1.8	1.0	63	106	79
0.5	5.2	105	556	63
0.2	3.0	64	221	55
0.0	2.4	104	253	75

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larvae of the mosquito *Culex tarsalis*, exposed to 1.5 μg/l Aroclor 1254, survived well and pupated, but many of the pupae were unable to metamorphose into the adult form. Control organisms pupated with success.

Bioconcentration

Bioconcentration, biological magnification, bioaccumulation, PCB or tissue residues, and residue dynamics, are some of the terms used to describe the intake of PCB's from food or direct water contact into the animal and accumulation in the tissues to concentrations many thousands of times those in the water or food they were exposed to. Polychlorinated biphenyls are much more soluble in fatty tissues (lipids) than water and are selectively concentrated in those tissues. Animals that feed on aquatic invertebrates or fish that have bioaccumulated significant tissue concentrations of PCB's are threatened even when the prey species are not adversely affected.

Exposure of fish to water containing PCB's demonstrates that they can bioconcentrate PCB's directly from the water, in addition to uptake in food, and in most cases direct uptake from water is more rapid and leads to much higher accumulation in the tissues. The bioconcentration factor (concentration in fish tissue/concentration in the water) for PCB's is essentially independent of the PCB concentration in the water. The bioconcentration factor (whole body) for adult male fathead minnows at 25° C is approximately 1.2×10^5 (120,000) for Aroclor 1248 and 2.7×10^5 (270,000) for Aroclor 1260. Female fathead minnows accumulated about twice as much PCB's as the male fatheads and the difference is largely

The residue of PCB's in the tissues of fathead minnows studied by DeFoe et al. (ref. 7) was directly proportional to the concentration of the toxicant in the water. The concentration of Aroclor 1248 in the water resulting in a tissue residue of 0.5 μg/g was approximately 0.004 μg/l. The concentration of Aroclor 1260 in the water resulting in a tissue residue of 0.5 μg/g was approximately 0.002 μg/l. They showed that the more highly chlorinated PCB mixtures are bioconcentrated to a greater extent in the lipids of the fish than the lower chlorinated compounds. They also showed that the PCB residues in the fish reached an apparent steady state after approximately 100 days, and when exposed fish were placed in untreated Lake Superior water they eliminated less than 18 percent of the body burden after 60 days.

Nebeker et al. (ref. 4) showed that the bioconcentration factor for Aroclor 1254 in fathead minnows ranged from 1.1×10^5 to 2.4×10^5 and that the bioconcentration factor for several PCB's in the fathead minnow ranged from about 0.3×10^5 to 2.7×10^5 with the more highly chlorinated PCB's accumulating a greater extent. Adult fathead minnows accumulated to 430 ppm A-1242 in whole body residues, with concentrations up to 270,000 times that of water, and up 1,000 ppm of 1254, with concentrations up to 230,00 times that of the water (ref. 4), *Gammarus* accumulate over 500 ppm 1248 and 400 ppm 1242, with concentrations over 100,000 times that of the water (ref. 14).

Sodergren and Svensson (ref. 19) showed that th nymph of *Ephemera danica* accumulated Clophen A to bioconcentration factors of 3×10^3. After 60 days exposure to Aroclor 1242 and A-1248, the maximum bioconcentration factor in *Gammarus pseudolimnaeus* was approximately 3×10^4 and 5×10^4, respectively (ref. 14).

Sanders and Chandler (ref. 18) showed that th uptake and biological magnification of Aroclor 1254 b some aquatic invertebrates was very rapid. When *Daphnia magna* were exposed for 4 days to water containing 1.1 μg/l of A-1254, they accumulated total body concentrations 48,000 (4.8×10^4) times greater than those in water. The mosquito larvae *Culex tarsalis* exposed to water containing 1.5 μg/l A-1254 accumulated 19 μg/g of this compound within 24 hours, which represents a 12,600-fold magnification. Scuds, *Gammarus pseudolimnaeus*, exposed continuously to 1.6 μg/l A-1254, reached an equilibrium concentration in 1 days. Total body residues were 44 μg/g, a concentration 27,500 times that in the water.

Some evidence exists that the bioconcentration factors measured in the laboratory are essentially the same as those found in the river environment. Veith and Lee (refs. 20, 21) reported that goldfish in the lower Milwaukee River accumulated Aroclor 1248 approximately 0.7×10^5 to 2×10^5 times (depending on the lipid content) the estimated PCB concentration in the river water. The maximum concentration of Aroclor 1254 in Saginaw River shad was 165 μg/g whereas typical water concentrations averaged 1.1 μg/l, with a maximum of 2.9 μg/l (ref. 22). This indicates a bioconcentration of 0.6×10^5 to 1.5×10^5.

Studies resulting from the reproductive failure of mink fed Great Lakes fish led to the conclusion that it was PCB residues in the fish that caused the adverse effects. Ringer et al. (ref. 23) demonstrated that 10 μg/g of Aroclor 1254 in coho salmon produced 71 percent mortality in mink and that a mixture of 10 μg/g PCB's and 0.5 μg/g dieldrin in coho feed produced 100 percent mortality. No kits were born alive when the diet contained 5 μg/g or greater Aroclor alone. The "no effect" concentration of PCB's in the mink diet was estimated to be less than 1.0 μg/g.

Platonow and Karstad (ref. 24) presented similar

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at higher PCB concentrations. Reproduction occurred and good egg hatching took place at and below 5.4 µg/l A-1242. Eggs produced by control fish but maintained at the higher concentrations of 15 and 51 µg/l hatched with good success but none of the fry survived.

Aroclor 1254 was more toxic to the fathead minnow than A-1242 (ref. 4), as they did not survive and reproduce above 1.8 µg/l A-1254 (table 2). All fish in the long-term study were dead after 96 hours at 15 µg/l, and growth was delayed at 4.6 µg/l. Spawning occurred at 1.8 µg/l but was significantly less than at the lower concentrations. Egg hatchability and fry survival were good at and below 1.8 µg/l. Eggs produced by the control fish and maintained at 15 µg/l hatched readily, but all young fish were dead within 96 hours.

Growth of young fathead minnows was affected above 2.2 µg/l A-1248, and none survived above 5.1 µg/l after 30 days. Young flagfish did not survive at Aroclor 1248 concentrations above 5.1 µg/l and did not grow well above 2.2 µg/l (ref. 4).

Due to low PCB solubility, 96-hour LC_{50} values do not adequately reflect PCB toxicities to fish. For Aroclor 1221-1268, 96-hour LC_{50} values ranged from 1,170 to 50,000 µg/l for cutthroat trout. The acute oral toxicity of Aroclors 1242, 1248, 1254, and 1260 was greater than 1,500 mg/kg in rainbow trout. Intermittent-flow bioassays of A-1242, 1248, and 1254 to bluegills resulted in 15-day LC_{50} values of 54, 76, and 204 µg/l, respectively. Exposures to channel catfish gave 15-day LC_{50} values of 107, 127, and 741 µg/l for the same Aroclors. All LC_{50} values decreased significantly with longer exposure, indicating the much greater PCB hazard with increased exposure time (ref. 5). Direct water exposures appear to represent a greater hazard to fish than dietary exposures, but dietary sources are important as PCB's have a high affinity for sediments and readily enter the food chain.

Schoettger et al. (ref. 6) showed that the growth of lake trout was retarded by Aroclor 1248 in the diet for 3 months. Concentrations of 1.2, 3.8, and 12 µg/g decreased weight gain by 6, 10, and 28 percent, respectively, below that of controls. The growth of the high-exposure group (12 µg/g in diet) was only about half that of the controls after 6 months.

Fathead minnows were exposed to Aroclor 1248 and A-1260 (ref. 7), in flow-through bioassays to determine the acute (30-day) and chronic (240-day life cycle) effects on the fry and adult fathead minnows. Newly hatched young were the most sensitive lifestage to the exposure of PCB's. Total mortality occurred when newly hatched fatheads were exposed for 30 days to 8.5 µg/l A-1248. All fish exposed to 9.0 µg/1 A-1260 died after a 30-day exposure. The calculated 30-day TL_{50} for newly hatched fathead minnows (<8 hours old) was 4.7 µg/l for A-1248 and 3.3 µg/l for Aroclor 1260. PCB's did not measurably affect the ability of fathead minnows to reproduce at concentrations which were acutely toxic to the larvae. With reproduction occurring at and below 3 µg/l for A-1248 and at below 2.1 µg/l for A-1260, the 20 percent reduction in the standing crop in the second generation of minnows at concentrations as low as 0.4 µg/l is due to the mortality of the fathead larvae soon after hatching.

Aroclor 1016, a compound chemically similar to A-1242, has been introduced recently to replace PCB's of the Aroclor 1200 series in many applications. Work has been completed with this compound with freshwater organisms and what is available indicates that the toxicity of Aroclor 1016 is similar to that of Aroclor 1242.

Mayer (ref. 8) presents data on the toxicity of Aroclor 1016 to nine species of freshwater fishes. Bluegills had a 4-day LC_{50} of 260 µg/l A-1016; rainbow trout, 135 µg/l; Atlantic salmon, 134 µg/l; and yellow perch, 185 µg/l A-1016.

Johnson (ref. 9) presented data comparing the effects of A-1242 and A-1016 on rainbow trout and bluegill sunfish. Rainbow trout had a 10-day LC_{50} of 39 µg/l for A-1242 and 17-day LC_{50} of 49 µg/l for A-1016. Bluegills had a 15-day LC_{50} of 54 µg/l A-1242 and a 35-day LC_{50} of 43 µg/l for A-1016. They had 96-hour LC_{50} values of 125 µg/l A-1242 and 46 µg/l A-1016.

A test comparing the toxicity of Aroclor 1242 and Aroclor 1016 using fathead minnows was completed by Veith (ref. 10). There was no difference in the survival of fry after 96 hours between A-1242 and A-1016 at 28 µg/l; both had 50 percent mortality. In 30-day tests, 100 percent mortality of fry occurred at 42 µg/l A-1242 and 95 percent mortality occurred at 42 µg/l A-1016. Approximately 50 percent had died after 30 days at 25.5 µg/l A-1242 and 30.5 µg/l A-1016.

The effects of Aroclor 1242 on the guppy *Poecilia reticulata* were studied by Morgan (ref. 11) in static tests. The guppy had 100 percent mortality at 20 and 2 ppm, but only 25 percent mortality at 0.2 ppm after 7 days.

In preliminary investigations, Jensen, et al. (ref. 12) reported a possible relationship between PCB residues in salmon eggs and egg mortality in Sweden. When residues in groups of eggs ranged from 0.4 to 1.9 µg/g on a whole-weight basis (7.7 to 34 µg/g on a fat basis), related mortalities ranged from 16 to 100 percent.

No adverse effects were observed on survival, growth, and reproduction of brook trout exposed for 71 weeks to 0.94 µg/1 and lower concentrations of the PCB

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Aroclor 1254. Survival and growth to 90 days of alevin-juveniles from exposed parents were also unaffected. PCB concentrations in the brook trout were directly proportional to the water exposure concentration. PCB tissue concentrations appeared to have reached a steady state by the first sampling following 14 weeks of exposure. PCB residues (wet tissue basis) in chronically exposed fish were approximately 2 μg/g in the fillet and 9 μg/g in the "whole body" (minus one fillet and the gonads) at the highest water concentration, 0.94 μg/1. The higher residue in the "whole body" compared to the corresponding fillet was due to the higher fat content of the former (ref. 13).

Thyroid stimulation in coho salmon ranged from a 52 percent increase in fish fed 0.48 μg/g Aroclor 1254 of food to a 119 percent increase in the high-treatment group (480 μg/g). The lowest detectable stimulation of thyroid activity occurred in salmon dosed with 1/1000th that caused mortality. In channel catfish, 2.4 μg/g and 24 μg/g A-1254 in food caused significant increases in thyroid activity when compared to control fish (ref 15).

Crustacea

Freshwater crustaceans are very sensitive to low concentrations of PCB's. Because of their generally short life cycles they will be eliminated from PCB-contaminated waters quite rapidly, causing not only their loss from aquatic systems but impairment of fish populations because of a decrease in fish food organisms.

To assess the danger of PCB compounds to fish food organisms, bioassays were conducted with *Daphnia magna* (ref. 14) using the eight commercially available PCB's, Aroclor 1221, 1232, 1242, 1248, 1254, 1260, 1262, and 1268 (table 3). Aroclor 1248 was the most toxic to *Daphnia magna* of the eight Aroclors tested in static tests; the 3-week LC_{50} was 25 μg/l. Aroclor 1232, 1242, and 1254 had similar toxicity values to A-1248. In continuous-flow Daphnia tests, Aroclor 1254 was the most toxic, with a 3-week LC_{50} of 1.3 μg/l. No reproduction occurred at 3.8 μg/l A-1254, and no adults survived 3.5 μg/l. The Aroclors were much more toxic in continuous-flow conditions due to continual replacement of fresh PCB. Almost one-third of the PCB added to the test water was lost to the air, with some lost to bacteria, algae, waste materials, test container surfaces, and test animal tissues. The difference between static and continuous-flow results (table 3) illustrates how critical test methodology can be for certain chemicals.

The freshwater scud *Gammarus pseudolimnaeus* was also studied by Nebeker and Puglisi (ref. 14) in continuous-flow test systems to determine the effects of A-1242 and A-1248 on survival and reproduction. Ninety-six-hour LC_{50} values were 73 μg/l for A-1242 and 29 μg/l for A-1248. Fifty percent were surviving after 60 days at 8.7 μg/l A-1242 and 5.1 μg/l A-1248. No live animals remained after 2 months at 26 μg/l A-1242 or 18 μg/l A-1248 (table 4). Good reproduction occurred at and below 2.8 μg/l A-1242 and 2.2 μg/l A-1248.

Table 3. Toxicity of eight Aroclors to *Daphnia magna* in static and continous flow bioassays

Aroclor (PCB)	3-week LC_{50}[a] (μg/1)	50 percent reproductive impairment (μg/1)
Continuous-flow test conditions		
1248	2.6	2.1
1254	1.8[c]	1.1
1254	1.3	1.3
Static test conditions		
1221	180	125
1232	72	66
1242	67	63
1248	25	24
1254	31	28
1260	36	33
1262	43	41
1268	253	206

[a]Concentration where 50 percent died.
[b]Fifty percent loss of young.
[c]Two-week LC_{50}.

Static and flow-through toxicity tests with aquatic invertebrates (ref. 5) indicate that they are generally more susceptible to acute toxic effects of PCB's than fish. *Gammarus faciatus* in flow-through tests had a 96-hour LC_{50} of 10 μg/l A-1242 and a 10-day LC_{50} of 5 μg/l A-1242. The glass shrimp *Palaemonetes kadiakensis* was very sensitive to A-1254, with a 7 day LC_{50} of 3 μg/l.

In static tests with the amphipod *Gammarus pseudolimnaeus*, Mayer et al. (ref. 15) found that of four PCB homologs tested, the trichlorobiphenyl was slightly more toxic than the di-, penta-, and hexachlorobiphenyls. The trichlorobiphenyl had a 96-hour LC_{50} of 100 μg/l, two dichlorobiphenyls tested had 96-hour LC_{50} values of 100 and 120 μg/l, the hexa- and penta-homologs had 96-hour LC_{50} values of 150 and 210 μg/l respectively.

The crayfish *Orconectes nais* was reported by Stalling and Mayer (ref. 5) to have a 7-day LC_{50} of 30 μg/l for Aroclor 1242 and a 7-day LC_{50} of 80 μg/l for A-1254.

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Table 4. Survival and reproduction of *Gammarus pseudolimnaeus* after 2 months exposure to Aroclor 1242 and 1248

Aroclor concentration (µg/l)	Survival of adults (percent)	Young per surviving adult
Aroclor 1242		
234.0	0	0
81.0	0	0
26.0	0	0
8.7	52	0
2.8	77	4
0.0	48	7
Aroclor 1248		
18.0	0	0
5.1	53	7
2.2	73	22
0.5	71	20
0.2	73	11
0.0	64	11

Daphnia pulex were quite sensitive to Aroclor 1242 (ref. 11). Young *Daphnia pulex* died at levels as low as 0.02 ppm in 4-day static tests. The toxicity of Aroclor 1242 and DDT to the ostracod *Cypidopsis vidua* appeared to be approximately the same in static tests. At 20 ppm, there were no survivors out of 20 ostracods in the Aroclor cultures, and some mortality occurred at 2 ppm.

Studies by Moorman and Biesinger (ref. 16) comparing the lethality of Aroclor 1016 and Aroclor 1242 to *Daphnia magna* have shown similar toxicity for both compounds in static tests. No young survived after 3 weeks at 125 µg/l A-1016 or A-1242. At 100 µg/l, 80 percent of the young (percent of control) survived after 3 weeks in A-1016 and 19 percent of the young survived A-1242. Good survival occurred at 50 µg/l for both compounds.

A study of the toxicity of isomers of Aroclor 1242 and 1254 to *Daphnia magna* by Biesinger (ref. 17) showed significant reproductive impairment in static tests at 50 µg/l for trichloro- and tetrachlorobiphenyls, indicating that there was little difference in the toxicity of the tri- and tetra- chlorobiphenyl compounds.

Aquatic Insects

Aquatic insects also appear to be very sensitive to longer exposures of PCB's, though response is variable when exposed to brief, or acute, concentrations. The midge *Tanytarsus dissimilis* was tested through its full life cycle (ref. 14) and found to be affected at levels below 1 µg/l. Survival and growth of the midge, when tested with Aroclor 1254, were excellent in control chambers but were reduced by 50 percent at the lowest test concentration of 0.45 µg/l (table 5). At 1.2 µg/l, the numbers of larval cases were reduced to 35 percent of the control, and the numbers of pupal cases were reduced to 18 percent of the control. No adult emergence occurred above 3.5 µg/l, and abundant adult emergence did not occur above 3 µg/l, even though larvae were present. No pupal cases were constructed at 9 µg/l and no larval cases were formed at 33 µg/l A-1254. The calculated 3-week LC_{50} for A-1254 (50-percent reduction based on control as 100 percent) was 0.65 µg/l for larvae and 0.45 µg/l for pupae. Adult midges emerged at concentrations up to 9 µg/l Aroclor 1248. Larvae were present at 18 µg/l, but adult emergence did not occur. Abundant emergence did not occur above 5.1 µg/l (ref. 12).

Mayer et al. (ref. 15) report some acute data for other aquatic insects. Dragonfly and damselfly nymphs, *Macromia sp.* and *Ischnura verticalis*, were tolerant to Aroclor 1242 and A-1254 in short-term static tests. The dragonfly had a 7-day LC_{50} of 800 µg/l for Aroclor 1242 and 1,000 µg/l for A-1254. The damselfly, tested under continuous-flow conditions, had a 4-day LC_{50} of 400 µg/l for A-1242 and 200 µg/l for A-1254.

Studies by Sanders and Chandler (ref. 18) have shown that larvae of the stonefly *Pteronarcys dorsata*, the dobonfly *Corydalus cornutus*, and the phantom midge *Chaoborus punctipennis* survived concentrations of up to 2.8 µg/l A-1254 for up to 21 days without significant mortality. However, in similar experiments,

Table 5. Effect of Aroclor 1254 on the growth and survival of the midge *Tanytarsus dissimilis*

Aroclor concentration (µg/l)	Number of mature larval cases (percent of control)	Number of pupal cases (percent of control)
33.0	0	0
9.0	0.2	0
3.5	7	7
1.2	35	18
0.4	52	55
0.0 (control)	100	100

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evidence for mink fed diets enriched with Aroclor 1254. The data show that 0.64 μg/g of PCB in the rations resulted in only 1 of 12 mink producing 3 kits, all of which died on the first day.

Research with nonhuman primates indicates that the toxicity of PCB residues to consumers are not limited to mink. Barsotti and Allen (ref. 25) and Allen et al. (ref. 26) have shown that PCB enriched diets were toxic to primates. Female primates fed 2.5 μg/g Aroclor 1254 in their diet had periorbital edema, acneform lesions on face and neck, and substantially reduced fertility after 2 months.

SUMMARY

There is ample evidence that PCB's are toxic to freshwater organisms at very low concentrations. Newly hatched fish and small insects and crustaceans with short life cycles appear to be the most sensitive life forms. In larger animals or those with longer life cycles, toxic effects are delayed and acute or short-term testing does not adequately reflect the chronic or longer term effects that PCB's have on the test animals. Concentrations of polychlorinated biphenyls commonly found in contaminated waterways today, such as Aroclor 1242 and 1254, are directly toxic to fish and aquatic invertebrates in the range of 0.1 to 10.0 μg/l. Aroclor 1016 and 1242 have been shown to have similar toxicity to freshwater organisms. The indirect toxicity of PCB's to predators through accumulation of PCB's in tissues of food organisms may cause deaths from water concentrations that do not cause direct lethality.

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