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OXYCHLORDANE, HCS-3260, AND NONACHLOR IN BIRDS: LETHAL RESIDUES AND LOSS RATES

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*Oxychlordane reached lethal levels in birds given dietary dosages of HCS-3260 (70.75% cis-chlordane and 23.51% trans-chlordane) at 6 levels from 50 to 500 ppm. Oxychlordane ranged from 9.4 to 22.1 ppm in brains of cowbirds (*Molothrus ater*), grackles (*Quiscalus quiscula*), and red-winged blackbirds (*Agelaius phoeniceus*) that died on dosage and from 1.3 to 4.8 ppm in sacrificed birds, providing a clear diagnostic separation. Among starlings (*Sturnus vulgaris*), however, oxychlordane ranged from 5.0 to 19.1 ppm in brains of birds that died, significantly lower than in the other species, and from 1.4 to 10.5 ppm in sacrificed birds, overlapping the levels in those that died. Lethal levels, therefore, begin near 5.0 ppm, as in a previous study in which oxychlordane itself was fed, but the data from starlings emphasizes the need for confirmatory necropsy findings in diagnosis of poisoning.*

Nonachlor had a very low order of toxicity, killing only 1 of 12 birds dosed at 100 ppm for 35 d; 3 others died and 1 was incapacitated during a short period of food deprivation. Lethal levels of oxychlordane were present in the brains of birds that died.

Oxychlordane accumulated in the bodies of birds on dietary dosage of HCS-3260 in proportion to dosage and time, but did not approach equilibrium at the levels (10, 50, and 100 ppm) that were fed. Loss rates of oxychlordane from HCS-3260, oxychlordane, or technical chlordane dosages (the last in a previous study) did not differ significantly from each other; respective half-lives were 57, 63, and 74 d.

Residues of cis-chlordane in birds fed HCS-3260 were consistently lower than oxychlordane during the accumulation period and declined abruptly when dosage ceased; individual variation was high.

INTRODUCTION

Chlordane, a mixture of chlorinated compounds, has been widely used for insect control for many years. Difficulty in identifying the components

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and their metabolites, however, complicated and delayed evaluation of its effects on nontarget organisms. Identification improved as new analytical techniques developed; problems were elucidated in a series of papers (Polen, 1966; Saha and Lee, 1969; Cochrane and Greenhalgh, 1976; Sovocool et al., 1977; Parlar et al., 1979).

In the early 1970s, a new chlordane, HCS-3260, which contained no heptachlor and many fewer other compounds, was produced experimentally (Malina et al., 1972) but not marketed. Both *cis*- and *trans*-chlordane (also present in technical chlordane), which were the primary components of HCS-3260, produced an animal metabolite, oxychlordane (Schwemmer et al., 1970; Polen et al., 1971), that was considerably more toxic than the parent compounds (Ivie, 1973) and more persistent in animal tissue (Dorough and Hemken, 1973; Barnett and Dorough, 1974; Stickel et al., 1979). Nonachlor, another component of chlordane, and also unusually persistent (Tashiro and Matsumara, 1978; Stickel et al., 1979), has been reported to metabolize to oxychlordane through *trans*-chlordane (Tashiro and Matsumara, 1978).

Our study of technical chlordane in species of wild birds indicated a primary role for heptachlor epoxide and a secondary role for oxychlordane in lethal poisoning (Stickel et al., 1979); oxychlordane was the most persistent compound identified, nonachlor slightly less so.

Subsequent studies, reported in this paper, clarified the role of oxychlordane in lethal poisoning of birds fed HCS-3260, identified oxychlordane in nonachlor-dosed birds, and documented the accumulation and loss of residues in birds fed HCS-3260 or oxychlordane. Results of these studies are presented together primarily because of the key role of oxychlordane in all of them.

MATERIAL AND METHODS

Experiments were conducted with wild birds of four species in order to increase the diversity of experimental material and so help improve the applicability of results to the field. Birds were captured in the meadows of the Patuxent Wildlife Research Center, and were kept in large (9 X 12 X 7 ft high) roofed, outdoor flight cages equipped with swinging perches that provided ample perching space. Food (turkey starter crumbles) and water were provided *ad libitum*. Birds were cage-conditioned for several weeks before studies were begun, and only active, normal-weight (Table 1) birds were used. Individuals were assigned to treatment groups by use of random-number tables, so that no restrictions were placed on the statistical analysis of the data.

Chemicals were dissolved in Wesson oil and the solution was mixed into the diet to produce the specified dry-weight concentrations. Oil constituted 2% of both control and treated diets.

Brains and bodies (whole body less brain, beak, feet, wings, skin, and

TABLE 1. Summary of Experiments

Experiment	Initiation date	Species, age, and sex	Dosage (ppm)	Number	Pretreatment weights (g) Mean	SD
I. Lethal residues: HCS-3260	Apr. 28, 1972	Starling, ad F (*Sturnus vulgaris*)	200, 300, 400, 500	40 (10 at each level)	82.1	4.8
	Oct. 31, 1972	Grackle, ad F (*Quiscalus quiscula*)	200	10	91.4	4.2
	Oct. 31, 1972	Cowbird, ad M (*Molothrus ater*)	200	10	46.7	2.6
	Oct. 31, 1972	Red-winged blackbird, ad M (*Agelaius phoeniceus*)	200	10	65.2	3.4
II. Lethality: nonachlor	Nov. 11, 1976	Cowbird, ad M	12.5, 25, 50, 100	24 (6 at each level)	46.0	3.4
	Nov. 11, 1976	Starling, ad F	12.5, 25, 50, 100	24 (6 at each level)	78.5	3.8
III. Kinetics: HCS-3260	Mar. 7, 1972	Red-winged blackbird, ad M	100	36	66.2	4.0
	Apr. 14, 1972	Red-winged blackbird, ad M	50	27	66.0	4.1
	Mar. 7, 1972	Red-winged blackbird, ad M	10	21	65.3	2.6
IV. Kinetics: oxychlordane	Apr. 27, 1973	Grackle, ad M	12.5	24	123.6	8.5

gastrointestinal tract) were preserved in chemically pure formalin (HCS-3260 and oxychlordane dosages) or frozen (nonachlor dosages) until analysis at WARF Institute, Inc. (now Hazleton Raltech, Inc.), Madison, Wis. Gas chromatographic and mass spectrometric confirmations were performed at the Patuxent Wildlife Research Center.

Entire brains and 20-g subsamples of homogenized bodies were dried with sodium sulfate and extracted for 8 h on a Soxhlet extractor using ethyl ether:petroleum ether. Formalin (total sample for brains and a proportionate sample for carcasses) was extracted by shaking with ethyl ether:petroleum ether; the extract was added to the solvent used to extract the tissue samples. Extracts were eluted on standardized Florisil in two fractions: 3% ethyl ether in petroleum ether followed by 40% ethyl either in petroleum ether for HCS-3260 samples; 3% ethyl ether in petroleum ether followed by 15% ethyl ether in petroleum ether for nonachlor samples; and 5% ethyl ether in 50:50 hexane:pentane followed by 17% ethyl ether in 50:50 hexane:pentane for oxychlordane samples.

Gas chromatographic analyses employed several different columns: 3% OV-1 (HCS-3260, oxychlordane, nonachlor); 11% OV-17 + QF-1

(HCS-3260); and 10% DC-200 (oxychlordane). Results were not corrected for recoveries, which were 80% or greater. Detection limit was 0.1 ppm. Only oxychlordane, heptachlor epoxide, and *cis*- and *trans*-chlordane were quantified in the HCS-3260 samples, although trace amounts of unknown compounds were present in some.

RESULTS

Experiment I. Lethal Residues: HCS-3260

A dietary dosage of HCS-3260 (70.75% *cis*-chlordane and 23.51% *trans*-chlordane) was given to four species of birds at levels of 200, 300, 400, and 500 ppm (dry weight in the diet) as shown in Table 1. Data for 11 birds that died on dosage of 50 ppm and 5 that died on dosage of 100 ppm in experiment II also are reported here.

Oxychlordane residues in brains of cowbirds, grackles, and red-winged blackbirds that died on dosage ranged from 9.4 to 25.0 ppm (Table 2), with no significant ($F = 1.15$ at 2 and 30 df) differences among the species. In contrast, residues in sacrificed birds of these species ranged

TABLE 2. Oxychlordane Residues in Brains of Birds Given Dietary Dosages of HCS-3260

Species	Dosage (ppm)	No.	Oxychlordane in brains (ppm wet weight) Range	Mean	SD
		Died on dosage			
Cowbird	200	5	19.1–22.1	20.4	1.3
Grackle	200	5	12.9–25.0	18.5	5.0
Red-winged blackbird[a]	50, 100, 200	21	9.4–22.6	17.8	3.3
Starling[a]	200, 300, 400, 500	20	5.0–19.1	12.0	3.2
		Sacrificed			
Cowbird	200	5	2.3–4.8	3.7	1.0
Starling[a]	200, 300, 400, 500	20	1.4–10.5	4.0	2.6
Red-winged blackbird	200	5	1.3–3.8	2.0	1.0
Grackle	200	5	1.3–2.1	1.6	0.3

[a]Means at different dosage levels not significantly different from each other: $F = 1.7$ at 2 and 18 df (dead red-winged blackbirds); $F = 1.7$ at 3 and 16 df (dead starlings); $F = 0.6$ at 3 and 16 df (sacrificed starlings).

from 1.3 to 4.8 ppm. Residues of oxychlordane in the brain provided clear diagnostic criteria for these species.

Oxychlordane residues in starlings that died ranged from 5.0 to 19.1 ppm, significantly ($p < 0.01$, analysis of variance and *t*-test) lower than in the other species. Residues in sacrificed starlings ranged from 1.4 to 10.5 ppm (Table 2). Although mean residues in dead and sacrificed starlings differed significantly ($p < 0.01$), residues in 5 of the 20 that were sacrificed reached or exceeded 5 ppm, and so overlapped residue amounts in those that died. For starlings, therefore, brain residues between 5 and 10 ppm are ambiguous, and diagnosis must be supported by necropsy findings; behavioral data also would be helpful.

Residues of *cis*-chlordane ranged from 1.4 to 13.8 ppm (mean 4.6 ppm, SD 2.8) in brains of birds that died and from 1.7 to 5.7 ppm (mean 3.3 ppm, SD 0.9) in sacrificed birds, the 2 groups overlapping completely. Residues of *trans*-chlordane of 0.5 ppm or lower were recovered from the brains of a few birds that died and from a few survivors, without apparent differences between groups; residues in most birds evidently were below the sensitivity level, and quantitative comparisons cannot be made. Heptachlor epoxide ranged from 0.22 to 0.89 ppm (mean 0.60 ppm, SD 0.17) in a sample of 11 dead birds (all species and dosage levels represented) taken for quantification, and from 0.04 to 0.58 ppm (mean 0.21 ppm, SD 0.18) in 10 sacrificed birds; all levels were far below the lethal range, which begins near 9 ppm (Stickel et al., 1979).

The first toxic effects of HCS-3260 dosage were shown by birds becoming less active, crouching low on their perches, fluffing out their feathers, and sometimes closing their eyes. Later they tended to walk about on the cage floor and repeatedly thrust their beaks through the mesh of the cage walls. They still were able to fly readily. In later stages, they lay on their breasts with wings spread and quivering, panting rapidly and with head pointed up in opisthotonos. Some were seen flapping wildly and doing back rolls. This was the convulsive behavior expected of a cyclodiene; tremors typical of DDT poisoning were not seen. At least two birds dropped from their perches and went into convulsive behavior simply because of disturbance in the cage, a phenomenon also seen with endrin poisoning. The entire sequence of behavior was the same among birds dosed with oxychlordane or technical chlordane in a previous study (Stickel et al., 1979). Birds killed by HCS-3260 lost 11–32% of their pretreatment weights. When dissected, most were free of visible fat, but a few had traces. Musculature was moderately, but visibly reduced. Intestines were almost always empty except for accumulations of urates in the cloaca. Survivors typically were of more nearly normal weight and had food in their intestines, showing that they still were feeding. These characteristics also were typical of birds killed by oxychlordane or technical chlordane (Stickel et al., 1979).

Observations of the times to 50% mortality suggested a relationship to

dose. At 200 ppm, half of the starlings died within 14 d; at 300 ppm, 8 d; at 400 ppm, 7 d; and at 500 ppm, 5 d. Species differed somewhat also: at 200 ppm, half of the red-winged blackbirds died within 9 d; grackles within 11 d; and cowbirds within 17 d. Mortality of red-winged blackbirds dosed at 100 or 50 ppm extended over a prolonged period: at 100 ppm, one bird died after 8 d dosage, four more after 21 d, the day dosage was terminated; at 50 ppm, five died between 36 and 39 d, three between 43 and 45 d, and one each after 51, 71, and 74 d. Because birds also were sacrificed during these dosages, the sequence of mortality does not depict susceptibility of the entire sample. HCS-3260, therefore, was somewhat less toxic than technical chlordane, where a dosage of 150 ppm killed 50% of the individuals of several bird species in 6–7 d (Stickel et al., 1979).

Experiment II. Lethality: Nonachlor

A dosage of nonachlor (technical standard rated at 100% purity, but subsequently shown by mass spectrometric analysis to contain 0.3% of *trans*-chlordane) was fed to cowbirds and starlings at levels of 12.5, 25, 50, and 100 ppm, as shown in Table 1. All birds on the three lower dosages were sacrificed at 13 d (none died). The dosage of 100 ppm was fed for 5 wk (1 starling died at 35 d), followed by a period of food deprivation (42 h, cowbirds; 50.5 h, starlings) during which 3 cowbirds died and 1 was incapacitated; all others were sacrificed. Nonachlor, therefore, was very much less toxic than HCS-3260.

The few birds that died had high levels of oxychlordane in the brains, comparable to those in birds killed by HCS-3260 in experiment I (Table 3). They also contained high levels of nonachlor. The levels of oxychlordane that accumulated in the bodies far exceeded levels that could be attributed to the *trans*-chlordane in the formulation, judging from the accumulation of oxychlordane from dosage of either HCS-3260 or pure oxychlordane (experiments III and IV). The accumulation of oxychlordane from nonachlor dosage, therefore, is in accord with the findings of Tashiro and Matsumara (1978) for rats.

Experiment III. Kinetics: HCS-3260

Accumulation of residues from dietary dosage of HCS-3260 was followed at 3 dosage levels (10, 50, and 100 ppm), and loss rates were followed after discontinuation of the 100-ppm dosage, all with adult male red-winged blackbirds (Table 1). Schedules were: (1) 10 ppm dosage for 84 d, with 4 birds sacrificed after each of 3, 7, 14, and 42 d and 5 after 84 d; no birds died; (2) 50 ppm dosage for 42 d, with 4 birds sacrificed after each of 3, 7, 14, and 42 d (7 birds that died are reported with experiment I); and (3) 100 ppm dosage for 21 d, with 4 birds sacrificed after each of 3, 7, 14, and 21 d, followed by untreated feed for 84 d, with 4 birds sacrificed after each of 7, 28, and 56 d and three after 84 d (5 birds that died on dosage are reported with experiment I).

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TABLE 3. Oxychlordane and Nonachlor in Brains and Bodies of Birds Fed Nonachlor

				Residues in brain (ppm wet weight)				Residues in bodies (ppm wet weight)			
				Oxychlordane		Nonachlor		Oxychlordane		Nonachlor	
Species	Dosage (ppm)	Time (d)	No.	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)
						Died on dosage					
Starling	100	35	1	–	15.3	–	212	–	11.0	–	260
Cowbird	100	35[a]	4	21.3-31.1	26.8 (5.0)	166-259	209 (39)	30.4-39.8	33.7 (4.2)	320-519	433 (98)
						Sacrificed					
Starling	100	35[b]	5	0.43-5.18	2.3 (2.3)	16.1-108	51.5 (40.7)	7.5-19.7	12.3 (4.9)	373-545	450 (66)
Cowbird	100	35[a]	2	1.52;1.68	1.60	25.4;31.3	28.2	14.2;13.6	13.9	453;409	431
Starling	50	13	6	<0.05-0.16	–[c]	4.45-8.90	5.9 (1.6)	0.62-1.36	0.8 (0.3)	81.4-181	130 (43)
Cowbird	50	13	6	<0.05-0.30	0.17 (0.1)	5.10-7.80	6.1 (1.2)	1.30-2.18	1.7 (0.4)	61.5-168	110 (48)
Starling	12.5	13	6	<0.05-0.06	–[d]	1.13-2.31	1.7 (0.4)	0.16-0.39	0.3 (0.1)	34.1-39.1	37.3 (2.3)
Cowbird	12.5	13	6	<0.05-0.10	–[d]	1.20-1.89	1.5 (0.3)	0.21-0.44	0.4 (0.1)	23.9-44.4	32.2 (7.1)

[a] 35 d of dosage plus 42.5 h food deprivation.
[b] 35 d of dosage plus 50.5 h food deprivation.
[c] Residues in 4 of the 6 at or below 0.05 ppm.
[d] Residues in 5 of the 6 at or below 0.05 ppm.

Oxychlordane residues accumulated in bodies in proportion to dosage and time, but did not approach equilibrium at any dosage (Fig. 1). The 100-ppm dosage for 21 d resulted in residues with a mean (geometric) of 24.4 ppm, which declined to 10.1 ppm after 84 d of untreated feed. Instantaneous loss rate (slope of the regression line calculated from the means of the natural logs) was 1.21%/d. The half-life was 57 d and the estimated time for loss of 95% of the residue was 378 d.

Residues of *cis*-chlordane in bodies of birds fed HCS-3260 were consistently lower than those of oxychlordane (Table 4). The 100 ppm dosage for 21 d resulted in residues with a mean (geometric) of 14.8 ppm. Residues dropped abruptly when dosage was discontinued, reaching 5.41 ppm in 3 d and 2.65 ppm in 7 d, a loss rate of 24.5%/d in the first week. By 28 d, residues had dropped below quantifiable limits. Although the pattern of gain and loss shown by mean changes was consistent, the variability of individual measurements was high, indicating great differences in metabolic patterns of individuals.

Residues of *trans*-chlordane did not reach 0.1 ppm even at the 100 ppm dosage. Heptachlor epoxide was detected consistently at low levels,

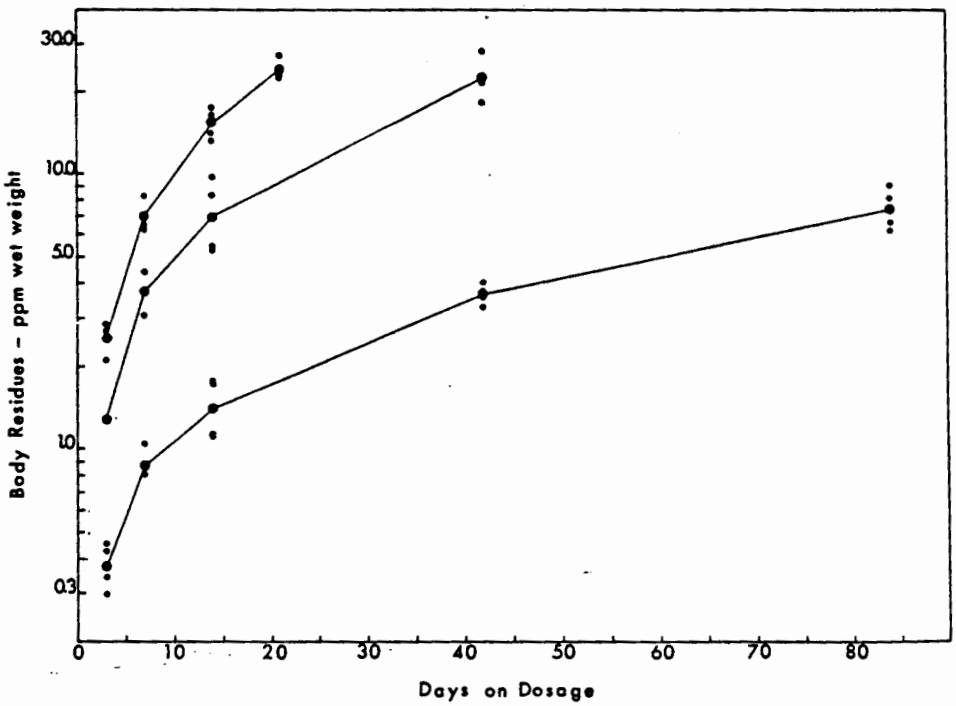

FIGURE 1. Accumulation of oxychlordane by birds on dietary dosage of HCS-3260 at 100 ppm (top), 50 ppm (middle), or 10 ppm (bottom). Larger solid circles show geometric means; smaller circles show individual values.

TABLE 4. Residues of *cis*-Chlordane in Bodies of Red-winged Blackbirds Fed Dietary Dosage of HCS-3260 and Loss of Residues When Untreated Feed Was Restored

Dosage	Time on dosage (d)	Time off dosage (d)	Body residues (ppm wet weight)	
			Mean (geometric)	Individuals
100 ppm	3	0	7.32	6.24, 6.50, 7.60, 9.33
	7	0	11.5	9.35, 10.5, 11.2, 16.0
	14	0	15.2	9.93, 11.9, 19.4, 23.0
	21	0	14.8	10.3, 12.7, 17.1, 21.2
	21	3	5.41	1.53, 7.77, 7.80, 9.24
	21	7	2.65	1.06, 2.51, 3.38, 5.47
50 ppm	3	0	2.92	1.91, 2.32, 3.88, 4.24
	7	0	5.76	2.51, 5.59, 7.64, 10.3
	14	0	6.42	4.04, 4.80, 5.38, 16.3
	42	0	9.22	4.50, 9.06, 10.6, 16.7
10 ppm	3	0	0.83	0.74, 0.80, 0.87, 0.94
	7	0	1.12	0.79, 0.88, 1.20, 1.90
	14	0	1.34	0.99, 1.18, 1.55, 1.79
	42	0	1.56	1.21, 1.52, 1.52, 2.11
	84	0	1.77	1.16, 1.38, 1.98, 2.19, 2.52

reaching no more than 1 ppm on 100 ppm dosage, and declining to 0.2 ppm by 84 d after dosage was discontinued.

Experiment IV. Kinetics: Oxychlordane

Loss of residues was followed in adult male grackles that were given untreated feed for 112 d following 6 d dosage of oxychlordane at 12.5 ppm (Table 1). [Data for 11 birds that died on dosage were reported by Stickel et al. (1979).] Four birds were sacrificed on the last day of dosage, 4 each after 3, 7, 28, and 56 d, and 5 after 112 d. Data from 1 bird in the 28-d group were not used because of a chemical analytical problem with the body sample.

By d 6 of dosage, residues of oxychlordane had reached a mean (geometric) of 6.76 ppm; residues declined to 5.39 ppm after 3 d of untreated feed, increased slightly (but not significantly) to 5.87 ppm at 7 d, and declined to 2.32 ppm after 112 d (Fig. 2). Calculated loss rate was 0.94%/d, the half-life 74 d, and the time when 95% of the residue would be gone, 488 d.

The loss rate of oxychlordane in this experiment did not differ significantly ($F = 2.4$ at 1 and 6 df) from the rate measured in experiment III in which HCS-3260 was fed, nor ($F = 0.9$ at 1 and 6 df) from the rate (1.09%/d) measured in a previous study (Stickel et al., 1979) in which technical chlordane was fed.

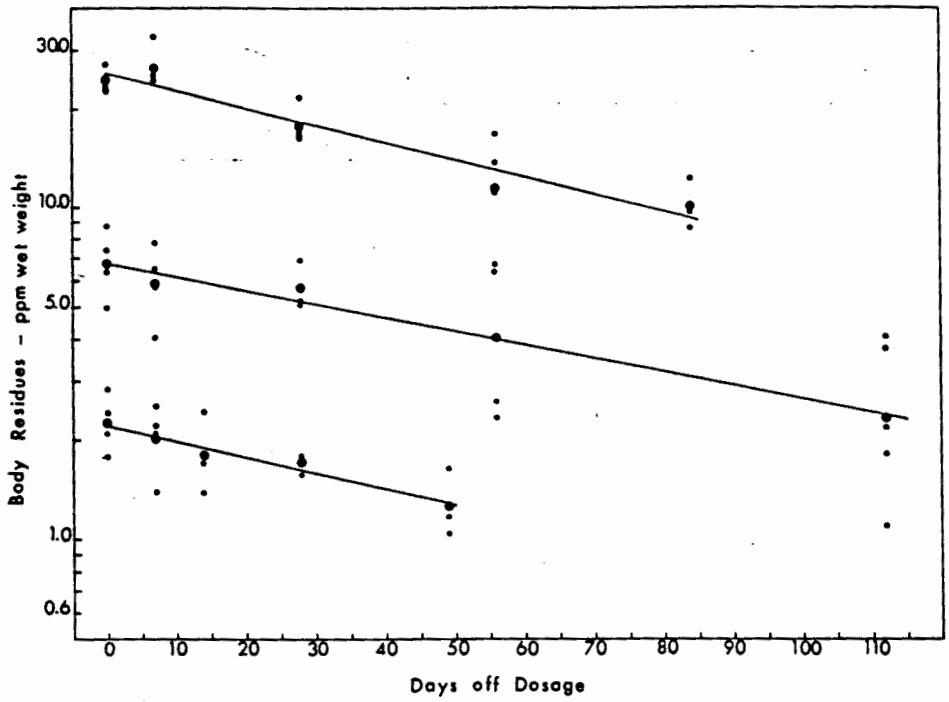

FIGURE 2. Loss of oxychlordane by birds following dietary dosages of HCS-3260 (top), oxychlordane (middle), and technical clordane (bottom). Regression equations: (1) HCS-3260 dosage, $\log_e Y = 3.240 - 0.012(\log_e X)$; (2) oxychlordane dosage, $\log_e Y = 1.91 - 0.009(\log_e X)$; and (3) technical chlordane dosage, $\log_e Y = 0.788 - 0.011(\log_e X)$. Larger solid circles show geometric means; smaller circles show individual values.

DISCUSSION

Oxychlordane was the lethal chemical to birds fed HCS-3260. Lethal residues in brains of cowbirds, red-winged blackbirds, and grackles were significantly higher than when oxychlordane itself was fed to the same species (Stickel et al., 1979) suggesting that the metabolic production of oxychlordane affected the response or that the combination of chemicals resulted in some protective or antagonistic action. Residues of oxychlordane in starlings that died on HCS-3260 dosage, however, were significantly lower than in the other species, and not clearly distinguishable from those in sacrificed birds. These anomalous results did not occur among starlings that died on oxychlordane dosage (Stickel et al., 1979), and the reasons for them are not known. They emphasize, however, the need for confirmatory necropsy findings in diagnosis of poisoning.

When technical chlordane was fed (Stickel et al., 1979), lethal action appeared to be the combined effect of heptachlor epoxide and oxychlordane. Heptachlor epoxide reached only about three-fourths the concentrations that resulted when heptachlor alone was fed, but there was

a clear break between residues in dead birds and survivors. Oxychlordane levels were about 28% of the levels in birds killed by oxychlordane dosage, and the difference between dead and survivors was somewhat less distinct.

The relatively nontoxic characteristics of *trans*-nonachlor in mammals (Banks et al., 1966) were also evident among birds. The fact that some birds died as a result of oxychlordane accumulation after extended dosage suggests that the metabolism of *trans*-nonachlor to oxychlordane may occur in birds as reported by Tashiro and Matsumara (1978) for rats. Although a small amount of *trans*-chlordane was present in the nonachlor standard that was incorporated in the dietary dosage of the birds, the amount from that source would account for only a very small fraction of the oxychlordane that accumulated.

Rates of loss of oxychlordane were not significantly different among birds fed HCS-3260 or oxychlordane in this study or those fed technical chlordane in a previous study (Stickel et al., 1979). Loss rates were 1.21%/d from HCS-3260 dosage, 1.09%/d from technical chlordane dosage, and 0.94%/d from oxychlordane dosage. Respective half-lives were 57, 63, and 74 d, and the times when 95% of the residue would be lost were estimated at 378, 418, and 488 d. The greater persistence of oxychlordane than of other residues resulting from chlordane dosage is in accord with results of studies with mammals (Street and Blau, 1972; Tashiro and Matsumara, 1977).

Accumulation of *trans*-chlordane did not reach 0.1 ppm even at a dosage of 100 ppm of HCS-3260 for 21 d or a dosage of 50 ppm for 42 d. If accumulation relative to *cis*-chlordane had occurred in proportion to their proportions in the HCS-3260 that was fed, accumulations of 5 and 3 ppm would have been expected. When HCS-3260 was fed to rats, accumulations of *cis*- and *trans*-chlordane were less discrepant, although accumulation of *trans*-chlordane in fat was less than would have been expected (Barnett and Dorough, 1974). When *cis*- and *trans*-chlordane were fed separately at the same dosage levels, *cis*-chlordane accumulated to several times the levels of *trans*-chlordane. At the same time, *trans*-chlordane dosage resulted in nearly twice the amount of oxychlordane in fat as did the *cis*-chlordane dosage. From comparable dosage, birds accumulated more *cis*-chlordane and less *trans*-chlordane than did the rats. The role of *trans*-chlordane as a primary source of oxychlordane therefore appears to be at least as great in birds as in mammals (Polen et al., 1971; Street and Blau, 1972; Barnett and Dorough, 1974).

In the practical area of exposure of birds in the field, it appears likely that had HCS-3260 been marketed, its use might occasionally have resulted in mortality of a few birds from oxychlordane poisoning. The possibility of sublethal effects is enhanced by the prolonged persistence of the chemical in the tissues. Oxychlordane, however, with a half-life of 57–74 d, still was markedly less persistent than mirex, which had a half-life of 196 d (Stickel et al., 1973), or DDE, which had a half-life of 229 d (Stickel et al., 1983).

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