Prolonged Retention of Methyl Mercury by Mallard Drakes

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During spring and fall migrations, ducks may stop for days or weeks to feed en route. Some of their stop-over areas are contaminated relatively heavily with mercury as a result of industrial effluent. The impact of these locally contaminated sites on wild waterfowl will depend therefore in part upon the accumulation of mercury during short exposure and the length of time the residues are retained.

The present study reports retention of mercury residues by mallard ducks (Anas platyrhynchos) during a period of 16 weeks following brief dietary exposure to methyl mercury.

Materials and Methods

Thirty-five mallard drakes hatched in the spring of 1970 in the captive flock at the Patuxent Wildlife Research Center constituted the experimental group. Three to 5 birds were randomly assigned to each of 8 experimental pens on December 21, 1970. The experiment began on March 2, 1971, with the sacrifice of 5 drakes for pretreatment controls. A dietary dosage of 8 ppm mercury as methyl mercury dicyandiamide was fed for 2 weeks (March 6-20). The chemical was diluted for mixing with the diet by addition of propylene glycol, which constituted 2 percent of the total diet. A group of 5 ducks was randomly selected and sacrificed immediately upon completion of dosage on March 20 and additional groups of 5 after 1, 4, 8, 12, and 16 weeks of untreated food. Pens were roofed wooden structures (2 x 3 m) with screened openings to the outdoors. Water and food (commercial duck breeder mash) were available ad libitum. Sacrificed ducks were frozen intact and stored until time for dissection and analysis. Birds were plucked, and beaks, feet, the keratinous portions of the legs, and the gastrointestinal tracts were removed and discarded. Livers and kidneys were removed for separate analysis; the remainder of the body (referred to as "carcass") was ground and homogenized, and subsamples were removed for analysis.

Total mercury was determined by cold vapor atomic absorption spectrometry, modified from the method of MONK et al. (1961). A 2-g portion was digested by refluxing with sulfuric-nitric acid mixture. A mixture of hydroxylamine,

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stannous chloride, and sulfuric acid was added to the digest to reduce the mercury (II) ions to mercury metal. The sample was aerated (3 liters/min) and passed through the absorption cell. Recoveries from spiked samples were 85-98 percent. Limits of sensitivity were 0.05 ppm (parts per million). All ppm are expressed on a wet-weight basis.

Results and Discussion

Results are summarized in Figs. 1 and 2 and Table 1. The figures show the micrograms of mercury in body and organs. This provides a truer measure of mercury retention than does the more customary expression as concentration, which is given in the table for comparison with other published data. The drakes accumulated mercury rapidly and lost it slowly. At the end of 2 weeks, concentrations were 4.46 ppm in the carcass, 16.5 ppm in the liver, and 17.6 ppm in the kidney. These levels were not greatly different from those in ducks collected at Clay Lake, Ontario; mercury averaged 6.13 ppm (range 0.9-10.4 ppm) in the breast muscle of 16 birds (VERMEER et al. 1973).

Loss of mercury from the liver and kidney followed the biphasic pattern that has been reported in some studies (SWENSSON and ULFVARSON 1968a; GARDINER 1972; GIBLIN and MASSARO 1973; IVERSON et al. 1973), but not in others (SWENSSON and ULFVARSON 1968b; BERGMAN et al. 1972; GARDINER 1972). At the end of the first week, the liver retained 64 percent and the kidney 66 percent of the amount at completion of dosage. These losses represented 6.4 and 5.8 percent per day {computed as log e (mcg at time 2/mcg at time 1) / days}. No significant additional loss occurred during the next 7 weeks. By the 12th week postdosage, however, mercury levels had passed the halfway point; the liver retained 45 percent, kidney 44.5. By the 16th week, the liver retained 23.8 percent, the kidney 19.

In contrast, mercury in the carcass showed no significant change during the first week, but declined significantly during the next 3 weeks, bringing retention to 60.4 percent. This decline was paralleled by a slight, nonsignificant, increase of mercury in both the liver and the kidney, suggesting redistribution. Loss of mercury from muscle of guinea pigs also was delayed (IVERSON et al. 1973) and evidence of a similar pattern was apparent in quail (BÄCKSTRÖM 1969). During the 2nd month, mercury in the carcass increased 13 percent, but by the 12th week postdosage, mercury was 45.6 percent of the postdosage level, a retention very similar to that of the liver and the kidney. By the 16th week, the carcass retained 17.2 percent of the postdosage amount.

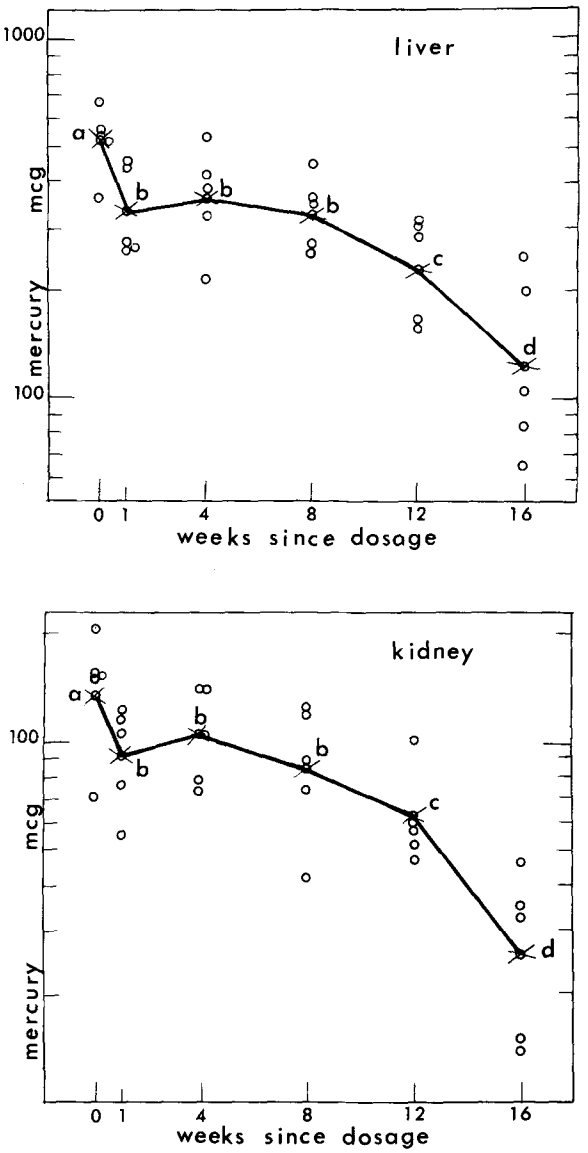
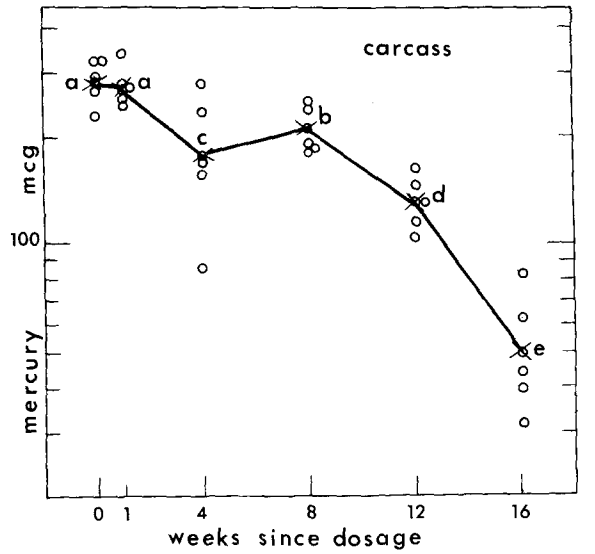


Fig. 1. Mercury content in liver and kidney upon completion of dosage and at intervals thereafter. Individual values are shown as circles, geometric means as x's. Means followed by different letters are significantly different from each other ($P<0.05$). Statistical analyses performed on log transformed data.



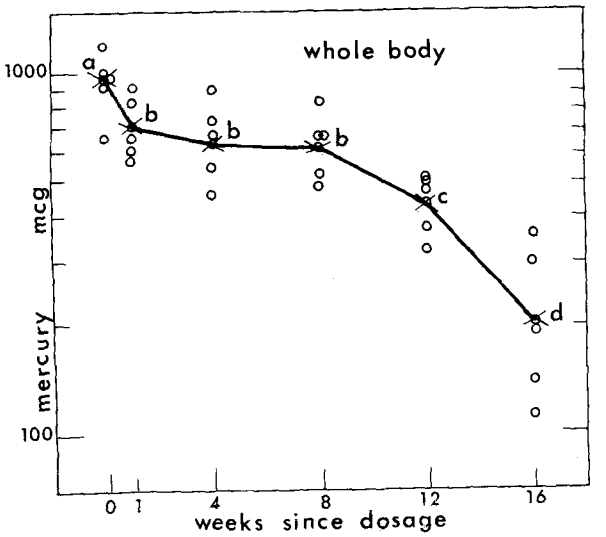


Fig. 2. Mercury content in carcass and whole body (combined totals for liver, kidney, and carcass) upon completion of dosage and at intervals thereafter. Individual values are shown as circles, geometric means as x's. Means followed by different letters are significantly different from each other ($P<0.05$). Statistical analyses performed on log transformed data.

TABLE 1

Mercury in Tissues of Mallard Drakes

Regimen	Sacrifice Date	Whole Body		Carcass		Liver		Kidney	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range
Predosage	3/2	<0.05	<0.05	<0.05	<0.05	0.06	<0.05-0.08	0.07	0.06-0.09
2 weeks' dietary dosage (8 ppm)	3/20	9.10a	7.14-11.4	4.46a	3.82-5.50	16.5a	13.3-19.9	17.6a	13.0-22.9
Postdosage:									
1 week	3/27	6.76b	5.85- 8.52	4.02a	3.12-4.93	11.4b	7.66-15.2	13.8b	11.5- 17.1
4 weeks	4/17	6.14b	4.34- 8.36	2.61c	1.24-4.84	11.3b	6.95-16.2	13.5b	11.0- 18.5
8 weeks	5/15	6.12b	4.08- 8.10	3.43b	2.77-4.08	9.50b	5.50-13.7	13.5b	6.92- 18.1
12 weeks	6/12	4.36c	3.51- 4.96	2.21c	1.83-2.91	7.04c	5.73-8.89	9.53c	8.79- 13.4
16 weeks	7/11	2.21d	1.27- 4.03	0.88d	0.66-1.46	4.21d	2.00-8.56	4.57d	2.60- 7.64

Mercury concentrations are parts per million, wet weight. Geometric means followed by different letters are significantly different from each other ($P<0.05$) n=5 at each sacrifice date. Coefficients of variation for last six sacrifice groups: whole body, 16%; carcass, 30%; liver, 16%; kidney, 12%. Statistical analyses (analysis of variance and Duncan's new multiple range test) performed on log transformed data. Whole body concentrations computed from values for carcass, liver, and kidney combined.

The drakes eliminated one-half the mercury from their bodies in about 84 days. The equivalent half-time for man has been estimated at 76 days (MIETTINEN et al. 1971), and for fish at 200 days or more (MONK et al. 1961). However, half-times for many mammals are only a few days or weeks (ÖSTLUND 1969; BERGMAN et al. 1972; IVERSON et al. 1973). Work with adult pheasants suggested a more rapid elimination of mercury than in the drakes of the present study (BORG et al. 1969). Half-times for young commercial ducks were less than 2 weeks and for young chickens and pheasants even shorter (GARDINER 1972). However, other studies with chickens (SWENSON and ULFVARSON 1968b, 1969) and quail (BÄCKSTRÖM 1969), although not carried to half-time, suggested considerably longer retention.

Although the drakes eliminated one-half the mercury from their bodies only after about 12 weeks, a relatively slow rate, it is more noteworthy that there was no measurable decline between the 1st and 8th weeks postdosage and that losses increased conspicuously thereafter. Growth of feathers very probably contributed largely to the mercury reduction during the 9th to 12th weeks. New growth of down feathers was noted on one duck as early as 4 weeks postdosage, and these feathers contained 15.4 ppm mercury dry weight. Feathers of the other 4 ducks sacrificed at the same time contained mercury in concentrations of 1.63, 1.77, 5.1, and 9.38 ppm. Tissue concentrations were lowest in the duck that contained the highest concentration in the feathers. By the 16th postdosage week, all ducks had completed molt and were in full eclipse plumage. Mercury concentrations in down feathers of these five were 20.0, 27.5, 28.4, 28.7, and 33.0 ppm. These results accord with those of TEJNING (1967), who reported very high proportions of the body burden of mercury in feathers of domestic chickens, particularly a considerable time postdosage.

It is evident that the body burden of mercury in ducks will be strongly influenced by the time of exposure in relation to seasonal molt.

Mathematically predicted half-times will have little practical value unless the changing rates can also be anticipated. For example, using total body burden of mercury in these drakes, the loss rate was 4.2 percent per day during the 1st week and the computed half-time, assuming a steady rate of loss, would be 16.5 days (computed as log 0.5/log r, where 1-r = daily loss rate, as above). Lack of significant change during the next 7 weeks precluded estimates. Losses resumed during the 8th to 12th weeks at

a rate of 1.3 percent per day for a computed half-time of 51.7 days. During the 13th to 16th weeks, the loss was 2.7 percent per day, and the computed half-time was 34.3 days.

Summary

Mallard drakes accumulated mercury rapidly from dietary dosage of methylmercury dicyandiamide and eliminated it slowly, retaining approximately one half at the end of 84 days; no measurable loss occurred between the end of the 7th and 56th days, but loss resumed concurrently with new feather growth, and continued through the 112th day, the close of the study.

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References

BÄCKSTRÖM, J.: Acta Pharmacol. et Toxicol. 27 (Supplement. 3), 103 p. (1969).

BERGMAN, T., L. EKMAN, and K. ÖSTLUND: Zbl. Vet. Med. A. 19, 753 (1972).

BORG, K., H. WANNTORP, K. ERNE, and E. HANKO: Viltrevy 6, 301 (1969).

GARDINER, E.: Can. J. Anim. Sci. 52, 419 (1972).

GIBLIN, F., and E. MASSARO: Toxicol. Appl. Pharmacol. 24, 81 (1973).

IVERSON, F., R. DOWNIE, C. PAUL, and H. TRENHOLM: Toxicol. Appl. Pharmacol. 24, 545 (1973).

MIETTINEN, J., T. RAHOLA, T. HATTULA, K. RISSANEN, and M. TILLANDER: Ann. Clin. Res. 3, 116 (1971).

MONK, H. (Ch.), J. PICKARD, N. SMART, S. YUEN, E. ATKINS, A. BEIDAS, T. BURKE, H. CROSSLEY, H. EGAN, P. LLOYD, and E. MILLER (Report by the Joint Mercury Residues Panel): Analyst 86, 608 (1961)

ÖSTLUND, K.: Acta Pharmacol. et Toxicol. 27 (Supplement. 1), 132 p. (1969).

SWENSSON, Å., and U. ULFVARSON: Acta Pharmacol. et Toxicol. 26, 273 (1968a).

SWENSSON, Å., and U. ULFVARSON: Acta Pharmacol. et Toxicol. 26, 259 (1968b).

SWENSSON, Å., and U. ULFVARSON: Poult. Sci. 48, 1567 (1969).

TEJNING, S.: Oikos (Supplement 8), 116 p. (1967).

VERMEER, K., F. ARMSTRONG, and D. HATCH: J. Wildl. Manage. 37, 58 (1973).