Bull. Environm. Contam. Toxicol. 25, 100-105 (1980)

Total and Methyl Mercury Levels in Wild Mammals from the PreCambrian Shield Area of South Central Ontario, Canada

Christopher Wren[1], Hugh MacCrimmon[1], Richard Frank[2], and Premysl Suda[2]
[1]*Department of Zoology, University of Guelph, Guelph, Ontario N1G 2W1*
[2]*Provincial Pesticide Residue Testing Laboratory, Ontario Ministry of Agriculture & Food, Guelph, Ontario N1G 2W1*

It has been established that elevated mercury levels in fish occur in areas remote from recognized point sources of mercury contamination (SUMNER et al. 1972; SMITH et al. 1975). It may be expected, therefore, that mercury levels may also be accumulated through natural processes in wild mammals inhabiting those areas. A process for demethylating organic mercury to less toxic inorganic mercury has been suggested in some marine mammals exposed to high mercury levels (FREEMAN and HORNE 1973, UTHE 1972). It is possible that a similar demethylating process exists in terrestial mammals which are exposed to elevated levels of mercury in their diet. Natural mercury levels in fish have been reported in the PreCambrian Shield of the Muskoka District (BROUZES et al. 1977). The present paper compares total and methyl mercury levels occurring in various organs of wild beaver, raccoon and otter representing herbivorous, omnivorous and carnivorous life styles, collected from the same general area where substantial mercury levels are known to occur in fish.

METHODS AND MATERIALS

Study site and field collection

Carcasses of the wild mammals were obtained from a local trapper for the purpose of this study. All animals were trapped within an undisturbed watershed located on the edge of Georgian Bay approximately 20 km south of Parry Sound in the District of Muskoka, during February and March 1979. The area consists of typical PreCambrian Shield bedrock with an abundance of lakes and marshes. The study site is remote from any direct sources of mercury contamination, yet many of the fish species have mercury levels exceeding the 0.5 ppm Canadian recommended safe level (unpub. data of the authors).

Muscle, liver and kidney tissue samples were taken from specimens of beaver (*Castor canadensis*), raccoon (*Procyn lotor*) and otter (*Lutra canadensis*) and frozen until analysis. Samples of intestine tissue were available from beaver and otter only. All tissues were analyzed for both total and methyl mercury.

0007-4861/80/0025-0100 $01.20

Analytical Procedures

For the determination of total mercury a one gram sample of tissue was accurately weighed out and digested in a mixture of sulfuric and nitric acid at 63-65°C and mercury was released as described by HATCH and OTT (1968). Mercury was detected as a cold vapour by flameless atomic absorption spectrophotometry at 253.7 nm. Methyl mercury was determined by the procedure described by UTHE et al. (1972).

RESULTS AND DISCUSSION

Varying amounts of both inorganic and organic mercury were present in all tissues from the three species tested (Tables 1 and 2).

WILLIAMS and WEISS (1973) suggest that mercury concentrations in tissue are correlated with long exposure time rather than the result of "biological magnification". In the present study, the beaver, a herbivorous animal, exhibited mercury levels an order of magnitude lower than raccoon or otter in all organs tested. Average muscle and kidney mercury concentrations were greatest in the otter, a strict carnivore. Highest mean mercury levels in livers were found in the omnivorous raccoon.

Raccoon from the District of Muskoka contain higher levels of mercury than did members of the same species from counties in southwestern Ontario, where FRANK et al. (1979) report these animals to have mean liver and muscle mercury concentrations of 950 ppb and 54 ppb, respectively. CUMBIE (1979) reports mercury concentrations in raccoon hair, liver and muscle as 7364 ppb, 3540 ppb and 360 ppb, respectively, from the southeastern United States, with a high degree of correlation between raccoon hair versus liver or muscle, with hair mercury levels being 10 to 31 times as great as mercury in muscle.

Mercury levels found in beaver are similar to tissue mercury concentrations reported by DROLET (1976) in one beaver from Quebec. DROLET (1976) also reports a mean mercury level of 1990 ppb for river otter muscle which is approximately twice the level found in similar tissue in the present study.

Total mercury concentrations were similar for all organs tested in the beaver (31 to 33 ppb). In addition, the percent as organic mercury is relatively constant in all four organs (78.6 to 87.8 percent). In contrast, raccoon and otter display significant total mercury level differences among tissues in the following order: liver > kidney > muscle > intestine. The tissue order for the proportion of methyl mercury is reversed with intestine > muscle > kidney > liver.

In the present study the lowest fraction of methyl mercury occurred in raccoon liver tissue which exhibited the greatest concentration of total mercury. All beaver tissues tested had a high ratio of organic to inorganic mercury. These animals would have little requirement for a demethylation process as vegetation, the sole food item of the beaver, contains very low amounts of mercury

TABLE I

Total Mercury Content in Various Mammal Organs

Species	N	Parameter	Weight[1] (kg)	Tissue Total Mercury (ppb)			
				Muscle	Liver	Kidney	Intestine
Beaver	4	$\bar{X}$	9.96	32	32	33	31
		SD	2.06	6	8	5	3
Raccoon	4	$\bar{X}$	5.0	278	4528	1113	-
		SD	0.86	73	3388	308	-
Otter	4	$\bar{X}$	7.33	889	2973	1046	419
		SD	1.81	217	2230	276	158

[1] Animal weight does not include weight of pelt.

TABLE 2

Methyl Mercury Concentrations and Percentage of Total Mercury as Methyl Mercury in Various Mammal Organs

Species	Methyl Mercury							
	Muscle		Liver		Kidney		Intestine	
	(ppb)	(%)	(ppb)	(%)	(ppb)	(%)	(ppb)	(%)
Beaver	27	84.4	25	78.1	29	87.8	26	83.9
Raccoon	235	84.5	484	10.7	425	38.2	-	-
Otter	640	72.0	889	29.9	648	62.0	391	93.3

TABLE 3

Comparison of Methyl Mercury in Tissues from Different Animals

Species	Average percentage of total Hg as CH_3Hg			
	Muscle	Liver	Kidney	Reference
Beaver	84.4	78.1	87.8	present study
Raccoon	84.5	10.7	38.2	"
Otter	72.0	29.9	62.0	"
Harbour porpoise	100	7.4-41.0		GASKIN et al. 1972
Harbour seal		14.3		GASKIN et al. 1973
Short-finned pilot whale	42-60	2-17	14	GASKIN et al. 1974
Long-snouted dolphin	100	2-17		"
Ringed seal	72.3	5.6		SMITH and ARMSTRONG 1975
Bearded seal		0.4		"
Mink (exp)[1]	98	46	55	JERNELOV et al. 1976
Cat (exp)	100	80	62	ALBANUS et al. 1972
Gray seal				FREEMAN and HORNE 1973
adult	47.1	2.8	7.2	
pup	37.6	7.9	6.5	
Harp seal				"
adult	28	5.6		
pup	27	13	16	
Harp seal				RONALD et al. 1977
control	82.2	6.1	13.1	
exp. low dose	110	60.3	47.5	
exp. high dose	93	28.5	91.4	

[1] exp = experimental animals treated with methyl mercury

(JONASSON and BOYLE 1971). In otter, the highest proportion of methyl mercury was found in the intestine where direct absorption from food may be occurring. The percentage of methyl mercury (93.3%) found in the intestine corresponds closely with the established percentage of methyl mercury in fish (BISHOP et al. 1975, WESTOO 1973, LOCKHART et al. 1972). Fish represent the principal food of otter. The percentages of methyl mercury in liver and kidney are much lower than in fish and would suggest that some demethylation process is occurring in both raccoon and otter.

Table 3 compares the fraction of total mercury as methyl mercury in tissues reported from a number of different mammals. With the exception of the herbivorous beaver, all wild animals show reduced proportions of methyl mercury in liver and kidney compared to muscle tissues. In seal livers, the percentage of organic mercury is generally very low ranging from 0.38% (SMITH and ARMSTRONG 1975) to 14.3% (GASKIN et al. 1972). Lowest methyl mercury fraction in the livers of harbour seals (Phoca vitulina) and harbour porpoises (Phocoena phocoena) were found in those specimens containing the highest liver total mercury levels (GASKIN et al. 1973, GASKIN et al. 1972). Liver tissue in the short-finned pilot whale also contain the highest level of any tissue tested from these animals (GASKIN et al. 1974, STONEBURNER 1978) with only 2-17 percent reported as methyl mercury (GASKIN et al. 1974).

FREEMAN and HORNE (1973) and UTHE (1972) have suggested that seals may have enzyme systems capable of converting toxic organic mercury to the less toxic inorganic form. This process may occur in the liver and kidney as these organs contain the lowest percentage of methyl mercury. In a series of feeding experiments, JERNELOV et al. (1976) report a methyl mercury degradation process in mink. It is suggested that the degrading capacity is greater than in cats but not as great as in marine mammals and that the differences may have some evolutionary explanation.

Findings from this study indicate that position in the food chain influences mercury levels in terrestial animals. The data also suggests that a demethylation process is present in the liver and kidneys of wild animals of the PreCambrian Shield naturally exposed to high levels of mercury. If some evolutionary significance is attached to the presence of a methyl mercury degrading process, one may speculate that animal species exhibiting such a capacity have been exposed to high mercury levels in their diets throughout long periods of geological time.

ACKNOWLEDGEMENTS

The authors wish to thank the Tadenac Club and Mr. Venard Robitaille for assistance in collection of the carcasses for analysis. The work was supported by a Canadian National Research Contract No. 31048.

REFERENCES

ALBANUS, L., L. FRANKENBERG, C. GRANT, V. VON HAARTMEN, A. JERNELOV, G. NORDBERG, M. RYDALV, A. SCHUTZ, S. SKERFUING: Environ. Res. 5, 425 (1972).

BISHOP, J.N. and B.P. NEARY: Ontario Ministry of the Environment, Toronto, Ontario. August 1975.

BROUZES, J.P., R.A. MACLEAN, G.H. TOMLINSON: Domtar Research Report. Senneville, Quebec. (1977).

CUMBIE, P.M.: J. Wildl. Manag. 39, 419 (1975).

DROLET, C.A.: Environment Canada, Service canadien de la faune, Manuscript, 16 p (1976).

FREEMAN, H.C. and D.A. HORNE: Bull. Environ. Contam. Toxicol. 10, 172 (1973).

FRANK, R., M HOLDRINET, P. SUDA: Bull. Environ. Contam. Toxicol. 22, 500 (1979).

GASKIN, D.E., G.J.D. SMITH, P.W. ARNOLD, M.V. LOUISY, R. FRANK, M. HOLDRINET, J.W. MCWADE: J. Fish. Res. Board Can. 31, 1235 (1974).

GASKIN, D.E., R. FRANK, M. HOLDRINET, K. ISHIDA, C.J. WALTON, M. SMITH: J. Fish. Res. Board Can. 30, 471 (1973).

GASKIN, D.E., K. ISHIDA, R. FRANK: J. Fish Res. Board Can. 29, 1644 (1972).

HATCH, W.R. and W.L. OTT: Anal. Chem 40, 2085 (1968).

JERNELOV, A., A. JOHANSSON, L. SORENSEN, A. SVENSON: Toxicology 6, 315 (1976).

JONASSON, I.R., and R.W. BOYK: Mercury in Man's Environment Symposium, Ottawa, February, 1971.

LOCKHART, W.L., J.F. UTHE, A.R. KENNEY, P.M. MEHRLE: J. Fish. Res. Board Can. 29, 1519 (1972).

RONALD, K., S.V. TESSARO, J.F. UTHE, H.C. FREEMAN, R. FRANK: Sci. Total Environ. 8, 1 (1977).

SMITH, T.G. and F.A.J. ARMSTRONG: J. Fish. Res. Board Can. 32, 795 (1975).

SMITH, E.C., F. BERKES, J.A. SPENCE: Bull. Environ. Contam. Toxicol. 13, 673 (1975).

STONEBURNER, D.L.: Sci. Total Environ. 9, 293 (1977).

SUMNER, A.K., J.G. SAHA, Y.W. LEE: Pestic. Monitor. J. 6, 122 (1972).

UTHE, J.F.: Fish. Res. Board Can. Man. Rep. No. 1167 (1972).

UTHE, J.F., J. SOLOMON, B. GRIFT: J. Assoc. Off. Anal. Chem. 55, 583 (1972).

WESTOO, G.: Science 181, 567 (1973).