Mercury Concentration in the Hair of Coyotes and Rodents in Jackson Hole, Wyoming*

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Mercury contamination of the environment has resulted in the poisoning of humans and biota in many parts of the world (WALLACE et al. 1971, NELSON 1971). The discharge of mercurials to the environment, especially methyl mercury, has diminished (WALLACE et al. 1971, LOFROTH 1970), but the amount of mercury in the environment will remain relatively high for many years (JERNELOV 1970).

Natural trace background amounts of mercury are found in most waters and soils (WALLACE et al. 1971), and animals acquire body-burdens of mercury from these sources (LOFROTH 1970). The concentration of mercury in tissues of organisms should be directly proportional to background of mercury in soils and rocks. The resultant tissue background levels of mercury have not been accurately determined in any terrestrial animal species. Determination of mercury background concentration in animal tissues would help to establish how much environmental mercury is the result of pollution and how much is natural.

The concentration of heavy metals in hair or feathers has been correlated with environmental concentrations of these metals. KOPITO et al. (1967) observed high levels of lead in the hair of children with chronic lead poisoning and found that hair concentrates lead more than any other tissue. REINHOLD et al. (1966) and STRAIN et al. (1966) tested the hair of zinc-deficient dwarfs in the Middle East and found zinc concentrations in the dwarfs' hair were lower than in hair from normal-sized controls. They claim that hair analysis is a reliable, simple method of evaluating body stores of zinc. Hair levels of Pb, As, and Cd were reported by HAMMER et al. (1971) to accurately reflect environmental exposure in humans.

Hair, feathers, and other epidermal derivatives are known to concentrate mercury and other trace metals from the vertebrate blood stream (KOPITO et al. 1967, REINHOLD et al. 1966). In laboratory experimentation, BROWN (1967) treated rats with mercury compounds and subsequently found mercury residues in their hair. NELSON (1971) reports that methylmercury was concentrated in the hair of human volunteers following oral doses. All the victims who were measured during the accidental mercury poisonings at Minimata, Niigata, and

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Alamogordo had high concentrations of mercury in their hair (NELSON 1971).

Feathers, which are chemically and embryologically similar to hair, have also been shown to concentrate mercury and lead from the environment (NELSON 1971, TEJNING 1967). TEJNING (1967) and BACKSTROM (1969) found that mercury is deposited in feathers so strongly that all body-burden mercury will eventually be contained in feathers and other keratinous structures. BERG *et al*. (1966) showed that mercury content of the feathers of Swedish birds collected during the past 100 years correlates significantly with the environmental distribution of mercury compounds. Ring-necked pheasants in Idaho that had body-burdens of mercury also had feather mercury (HUCKABEE *et al*. in press). Hair or feather analysis appears to be a reliable index to tissue stores of heavy metals, such as mercury.

High environmental levels of mercury occur in Jackson Hole, Wyoming (LOVE and REED 1968). There is no agriculture in this area except summer grazing and there is no industry utilizing any mercurial. Fallout from smoke from the burning of mercury-containing coal has been implicated as a means of regional mercury contamination (JOENSUU 1971), but the Intermountain region is not heavily industrialized. Mercury contamination in the terrestrial ecosystem from coal-burning in Jackson Hole should be minor. Two formations containing relatively high amounts of mercury, the Harebell and Pinyon conglomerates, outcrop extensively around Jackson Hole (LOVE and REED 1968). Accordingly, mercury is widely disseminated in Jackson Hole and is not a "point" source, but the highest concentrations occur near the outcrops of the mercury-bearing strata. Thus, all the animals living in Jackson Hole are exposed to relatively high background mercury; those living on or near the mercury-bearing outcrop areas receive the greatest exposure.

Methods of Analysis

A population of coyotes and some rodent species from Jackson Hole were sampled in 1970 and 1971 in order to define the relationship between a high natural background mercury concentration and terrestrial mammalian hair mercury concentration. The coyotes were live-trapped, hair samples were cut from the middorsal region for mercury analysis, and the animals were released. The rodents were snap-trapped and hair samples were pulled from the middorsal region.

Hair samples of the 10 coyotes and 51 rodents were analyzed by neutron activation at the National Reactor Testing Station in Idaho. The samples, about 0.2 mg each, were washed to remove external contaminants and then prepared for irradiation by standard techniques (HARRISON *et al*. 1969).

After being weighed the samples were encapsulated in quartz ampules. Aluminum capsules were welded around the sealed quartz ampules before insertion into the reactor. Irradiation times varied from three hours to several weeks at thermal neutron fluxes of $\sim 1.0 \times 10^{14}$ n/cm^2/sec.

The aluminum capsules were opened in the laboratory after the short-lived activity had died away, and the quartz ampules containing the hair samples were removed, washed in HNO_3, and taped to a counting card for gamma-ray spectrometry. Counts of the radioactivity of the samples were on 4096 channel pulse height analyzers (PHA) using Ge(Li) gamma-ray detectors of about 30 and 60 cc. The gamma-ray spectra accumulated by the PHA's were analyzed by computer techniques that provided printouts of the identity and quantity of the mercury (and other nuclides) present. The detection limit of mercury using the 270 keV gamma-ray peak of ^{203}Hg was $\sim$0.008 ppm without chemical separations.

Results and Discussion

Table I shows that 85% of the coyotes tested had more than 0.008 ppm mercury in their hair, and 83% of the rodents from the mineralized outcrop area had more than 0.008 ppm mercury in their hair. In contrast, only 7% of the rodents from the less-mineralized areas had more than 0.008 ppm mercury in their hair. The only species from the less-mineralized areas with hair mercury was *Zapus princeps*. No *Zapus* were caught in the outcrop area.

The only rodent caught in the outcrop area that lacked detectable mercury was a very young *Microtus montanus*. It is possible that the young *M. montanus* was not born with an adult-level hair concentration of mercury and had not yet added enough dietary mercury to exceed 0.008 ppm in its hair. It has been shown that the fetus does acquire some mercury from the maternal blood stream (WALLACE *et al*. 1971), but the placenta develops discrimination against toxic elements with time (SCHULERT *et al*. 1969). In another study dietary methylmercury (1-5 ppm) fed to rats did not produce a steady-state body-burden until after six months of exposure (BERGLUND and BERLIN 1969). The rodent measurements reported here strongly indicate a positive correlation between environmental mercury and hair mercury.

Coyote's home ranges are so large that they include both the highly mineralized outcrop areas and the less mineralized nonoutcrop areas. The occurrence and generally higher concentrations of mercury in coyote hair support the possibility of trophic level concentration of mercury. However, the coyotes may simply have been exposed to more mercury than the rodents due to their larger range.

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TABLE I.

Mercury Concentrations in the Hair of Coyotes and Sympatric Rodents from Jackson Hole, Wyoming.

Jackson Lake Marsh: (*Canis latrans*) Coyote No.	Hg (ppm)	Jackson Lake Marsh: Rodents Species	Hg (ppm)	Gros Ventre River Marsh[a] Rodent	Hg (ppm)
1	<0.008	*Clethrionomys gapperi*	<0.008	*Erethizon dorsatum*	
2	0.08	(Redbacked Vole) 13 samples		(Porcupine)	
3	<0.008			hair	0.2
4	<0.008	*Microtus pennsylvanicus*	<0.008	quills	0.02
5	0.1	(Meadow Vole) 14 samples			
6	0.7			*Eutamias* sp.	0.3
7	2.8	*Microtus montanus*		(Chipmunk)	
8	0.09	(Mountain Vole) 14 samples	<0.008		
9	0.3			*Microtus richarsoni*	0.09
10	1.7	*Zapus princeps*		(Richardson's Vole)	
11	0.4	(Western Jumping Mouse)			
12	0.09	1	0.8	*Microtus pennsylvanicus*	0.08
13	0.07	2	0.7	(Meadow Vole)	
14	1.0	3	0.3		
15	2.3	mean	0.6	*Microtus montanus*	
16	0.3			(Mountain Vole)	
17	0.9			1	<0.008
18	0.07			2	0.07
19	0.05				
mean	0.57				

[a]Located in Jackson Hole on mercury-bearing formation.

There is evidence that mercury concentrates up the trophic chain. HANKO et al. (1970) fed chickens mercury-containing grain and then fed meat from these birds to ferrets. The ferrets acquired much higher mercury concentrations than the chickens. Other Swedish studies support concentration of mercury up the trophic chain (WALLACE et al. 1971, JOHNELS and WESTERMARK 1969), and DE GOEIJ'S (1971) analyses of European organisms show higher levels of tissue mercury in predatory animals than in prey species. Work by BORG et al. (1971) and JOHNELS and WESTERMARK (1969) also indicate mercury concentrations up the food chain. FIMREITE et al. (1971) demonstrated higher mercury concentrations in piscivorous birds than in their fish prey. WALLACE et al. (1971), in a thorough literature survey, conclude that trophic level magnification of mercury in terrestrial ecosystems is a fact. If this is true, coyote tissue would contain higher concentrations of mercury than the primary consumers on which they feed. *Eutamias* and *Zapus* have generally higher concentrations of mercury in their hair than do the microtines. This difference would be expected if mercury is concentrated increasingly up the trophic chain since *Eutamias* and *Zapus* are generally more carnivorous than the microtines.

According to the food habits study of MURIE (1935), Jackson Hole coyotes feed on all the rodents sampled in this study except *Clethrionomys gapperi*. In the 64 stomachs and 714 feces examined, he found that *Microtus* sp. occurred as a food item in 20.87% of the samples, *Zapus princeps* in 3.98%, *Erethizon dorsatum* in 3.23%, and *Eutamias* sp. in 0.33%. In a similar study of the food habits of the coyote in Yellowstone National Park, MURIE (1945) examined 5,086 coyote droppings. Expressed as percentage of occurrence, *Microtus* sp. constituted 33.93%; *Erethizon dorsatum*, 0.39%; *Zapus princeps*, 0.07%; and *Eutamias* sp., 0.06%. The relative abundance of these rodents in Jackson Hole has been reported by various authors (FINDLEY 1951, NEGUS and FINDLEY 1959, CLARK 1971). It appears that these species constitute about one-third of the coyote's diet in Jackson Hole; ground squirrels and carrion make up most of the remaining two-thirds.

Mercury determinations in hair have been made of other free-ranging native species. In a trace element survey, HUCKABEE et al. (1971) analyzed 73 ungulate hair samples from Idaho and Wyoming. In 44 pronghorn antelope, mercury was found only in the hair of a herd that lived in the immediate proximity of the Idaho Chemical Processing Plant located on the National Reactor Testing Station. No mercury was found in the hair of 11 mule deer or one bighorn sheep. Two Lemhi Range, Idaho, mountain goats tested did have mercury in their hair. Mercury does occur in the Lemhi Range (ROSS 1961). Four elk hair samples out of the ten tested had more than 0.008 ppm mercury. The herd from which these samples were taken had poor winter range and were fed by the Idaho Fish and Game Department during the winter months.

Based on these 133 analyses (including HUCKABEE et al. 1971), it appears that the concentration of mercury in animal hair reflects mercury concentration in the animal's environment and hair may serve as an effective monitor of environmental mercury, with a mean of ∿0.6 ppm mercury in hair representing a realistic maximal natural concentration. Hair levels exceeding a mean of ∿0.6 ppm mercury may be evidence of an abnormally high occurrence of mercury in the environment.

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