Mercury in Mouse Hair: A Monitoring Tool for Environmental Exposure

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ABSTRACT

We determined mercury concentrations for soil and mouse hair from four Montana sites. Two of the sites associated with previous mining activity had elevated soil mercury concentrations. One site with an average total mercury concentration of 22.4 μg/g was > 200 times higher than concentrations reported for typical U.S. topsoils. Mean mercury concentrations of 4.5 μg /g and 5.1 μg /g were measured in the hair of mice living on the contaminated sites—five to six times higher than hair concentrations from mice captured at the other two sites. From the information collected during this study, monitoring of mercury levels in mouse hair could provide valuable data to assess either environmental exposure at contaminated sites or to establish environmental baseline data.

Key words: mercury, mouse hair, biomonitoring, bioindicators, mining

INTRODUCTION

The idea that small mammals could be used as monitors for environmental contamination is not new. In the 1980s Douglass (1984, 1989) and Skalski (1984) recommended that rodents be used for ecological monitoring. They pointed out that rodents are particularly useful because they are small, easy to handle, and spend their entire life cycle within a relatively small area, e.g., mines or urban sites. Mice also hold ecological importance in food chains because they are food for nearly all terrestrial and avian carnivores. Reynolds et al. (2006) recently reported that northern pocket gophers may be useful biomonitors of heavy metal (Pb, Cd, and As) contamination. Our investigation focused on the possibility of using mercury in mouse hair as an appropriate biomonitor for environmental mercury.

In biological materials mercury is often bound with sulfur in amino acids and proteins. Since it is comprised mostly of protein, hair has often been used to indicate mercury exposure in mammals including humans. Many studies have confirmed that people and mammals exposed to environments or foodstuffs contaminated with mercury accumulate mercury in their hair (Matsubara and Machida 1985, Kosatsky et al. 2000, Fortin et al. 2001; U.S. Environmental Protection Agency 1997). In human hair Kosatsky et al. (1985) found that participants who ate sportfish at least once/week had hair geometric mean mercury concentrations of 0.82 μg/g compared to 0.38 μg /g for those who ate sportfish < once/week. Fortin et al. (2001) found mercury concentrations of 30.1 μg/g in mink fur and 20.7 μg/g in river otter fur from James Bay Territory. Peterson and Madden (2006) reported using domestic pets as sentinel species by measuring heavy metals in hair.

Previous work on mercury concentrations in mouse hair was performed by Burton et al. (1977) who captured mice from four similar habitats in Utah. They found hair mercury levels in seven deer mice (*Peromyscus maniculatus*) from a rural site near Vernal, Utah, to average 0.31 μg/g, and in six mice from near Magna (the site of a copper smelter), Utah, to average 1.7 μg/g. However, mice captured from Bird and Badger Islands—two islands in the

Great Salt Lake—had much higher levels. Fourteen mice from Bird Island averaged 10.8 µg/g and eight mice from Badger Island averaged 7.8 µg/g. Burton et al. (1977) postulated that the higher concentrations in the island mice were caused from mercury found in brineflies that comprised a major part of the diet for these mice. They did not report soil concentrations.

Mercury levels in soils may vary widely depending upon the soil's origin. Warren et al. (1966) measured total mercury concentrations from 10-50 ηg/g (ppb) in soils unaffected by mineralization to concentrations as high as 10,000-20,000 ppb in immediate areas of mercury mineralization. The U. S. Geological Survey (USGS, 1970) assembled a large amount of data regarding the mercury content of various earth materials. In 2004 the USGS and the Geological Survey of Canada initiated pilot studies for the North American Soil Geochemical Landscape Project (Smith et al. 2005). They reported total mercury concentrations of 0.02-0.71 µg/g (ppm) in the soil A horizon at 260 sites across the United States with only six samples > 0.1 µg/g. Phelps and Buseck (1980) reported "background levels of mercury" in Yellowstone National Park soils that averaged 20 ppb with an anomaly threshold of 40-50 ppb.

We designed our study to determine whether deer mice living in areas with elevated soil mercury concentrations would show increased mercury in their hair compared to mice living in areas with lower soil mercury concentrations. We examined mercury levels in hair from mice captured at four sites in western Montana. Two sites, Silver and Trinity Creeks, were drainages with evidence of past gold placer mining. Another, the Comet mine site, was an engineered repository where mining waste materials had been buried, capped with a waterproof barrier and covered with topsoil. A ranch site near Cascade, Montana, had no history of mining activity. Waring and Waring fully described (2006) the Silver Creek, Trinity Creek, and Comet mine sites.

METHODS

Sampling areas of ~ 2 ha were established at each site. All soil and mice were sampled during the 2nd week of June 2003 along transects crossing the sampling areas. The soil sampling and lab procedure protocols were described by Waring and Waring (2006).

Mice were caught by placing 100 Sherman live traps in four parallel rows of 25 traps spaced at 10-m intervals. We inserted synthetic cotton for bedding and baited traps with peanut butter and oatmeal. Each animal was removed from a trap by emptying them into an unused bread bag. We removed a hair sample from the animal's back with scissors and placed it in a vial. Before release, we recorded species, sex, breeding condition, and weight of each animal. To avoid cross contamination, scissors were washed in distilled water and acid rinsed between samples. We placed sample vials on ice in a sampling cooler and returned to the laboratory.

Soil samples were obtained at 10- to 20-m intervals along transects crossing the sampling areas. Each sample was obtained at a depth of 10-20 cm using a spade to raise the soil and then obtaining the sample using a plastic spoon. We took care to sample only soil that had not contacted the shovel surface. For each soil sample location, a composite sample was obtained by combining eight sub-samples into a plastic bag. The sample was placed on ice in the cooler for transport to the laboratory where it was frozen until later analysis.

For hair analysis, samples were removed from the vials and placed onto a millipore filter in the filter apparatus. Each sample was then triple rinsed on the filter using de-ionized water to remove surface contamination and then dried on the filter in a 65 °C oven until reaching a constant weight. The filter and hair were then separated using acid-rinsed forceps. We weighed a hair sample of 10 ± 2 mg and placed it into a 20-ml straight walled vial. Two ml of 45-percent (w/v) sodium hydroxide and 1 ml of 1-percent (w/v)

L-cysteine was added and the mixture heated to near boiling with continuous gentle swirling. The solution was cooled and the volume adjusted to 10 ml with 1-percent (w/v) sodium chloride and then analyzed.

For soil analysis we removed samples from the sampling bag, mixed and placed them in beakers to air dry. Upon reaching constant air dry weight, we mixed the sample again. Samples of 0.2-gm were placed into a digestion bottle with 5.0 ml Aqua regia and heated for two minutes in a 95 °C water bath. After cooling, 50 ml of de-ionized water and 15 ml of potassium permanganate solution were added and the sample mixed and placed into a 95 °C water bath for 30 min. After cooling 6.0 ml of sodium chloride and 55 ml of de-ionized water were added before filtering and measuring the final sample volume for analysis.

The prepared hair and soil samples were analyzed for total mercury according to the U.S. Environmental Protection Agency (1991) method 245.5 and the equipment manufacturer's standard operating procedure for Cold Vapor Atomic Absorption Spectroscopy (CVAAS). For quality control we ran standard concentrations before and after each batch of 20 samples. Each batch included a blank and at least one replicated sample. The average difference between replicated samples was 8 percent for the soils and 19 percent for the hair samples.

RESULTS AND DISCUSSION

Mercury concentrations measured in hair and soils appear in Table 1. Compared to recent USGS data reported by Smith et al. (2005), the two sites impacted by mining (Silver and Trinity Creek) had highly elevated soil mercury concentrations; repository cover soils had slightly elevated concentrations; and the ranch site had similar concentrations. To compare our data to others, we used a total soil mercury content of 0.1 µg/g as a high concentration for background levels. Using 0.1 µg/g as background, we estimated ratios of site mercury concentrations to background as follows: 225:1 for Silver Creek; 12:1 for Trinity Creek; 1:1 for Comet Repository, and 0.4:1 for the Cascade ranch site. We considered a background ratio of > 10 to be contaminated.

Deer mice living in areas with contaminated soils had higher concentrations of mercury in their hair than mice from the other sites (Table1 and Fig. 1). The range of concentrations for mouse hair at the contaminated sites (1.42-15.25 µg/g)

Table 1. Mercury concentrations in soil and deer mouse hair from four Montana sites in June, 2003.

		Hg (µg /g)		
Location	Number of Samples	Mean Deviation	Standard	Range
Silver Creek				
Hair	15	4.47	2.371.42-11.17	
Soil	12	22.36	28.56	0.37-79.95
Trinity Creek				
Hair	7 5.15	4.82	1.26-15.25	
Soil	15	1.16	1.550.07-5.81	
Comet				
Hair	16	0.82	0.300.30-1.47	
Soil	10	0.10	0.090.01-0.23	
Cascade Ranch				
Hair	23	0.81	0.420.12-2.40	
Soil	10	0.02	0.005	0.018-0.03

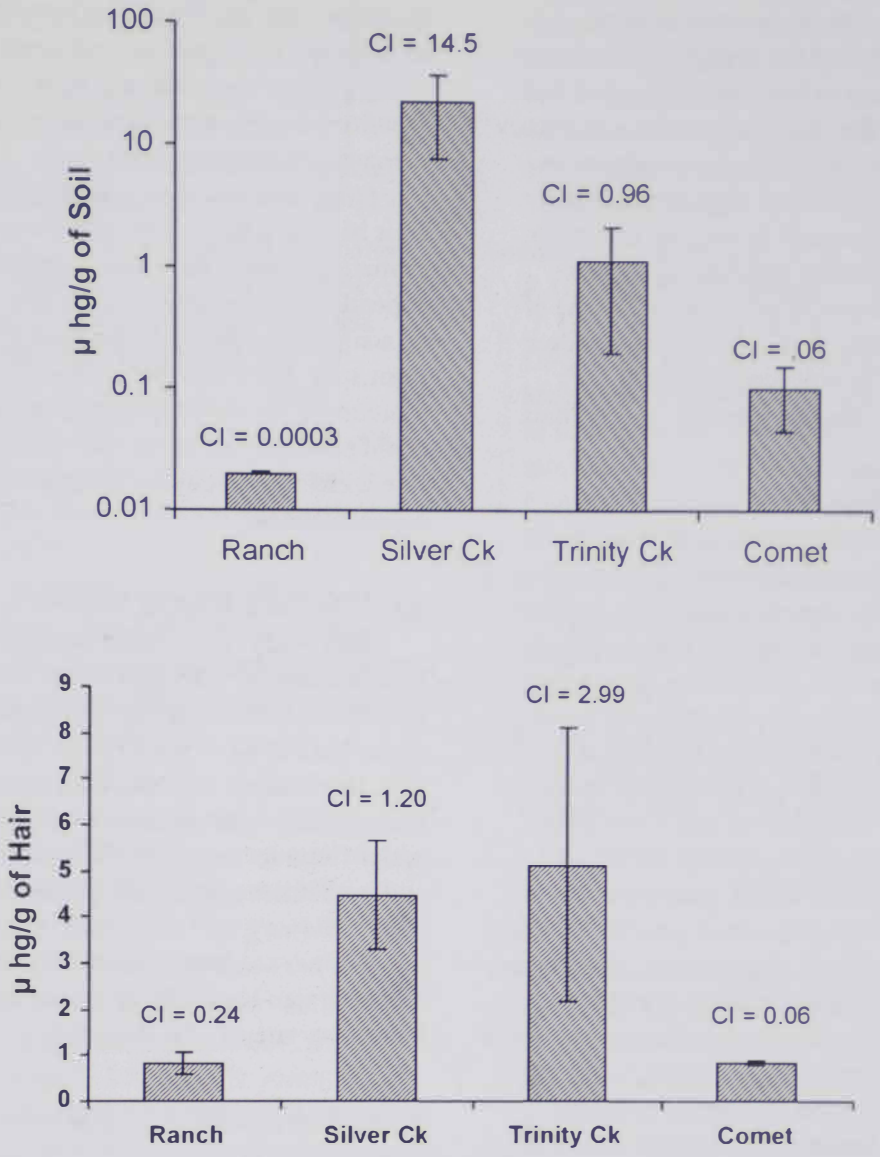

Figure 1. Average and 95-percent confidence intervals for mercury concentrations in soil and deer mouse hair from four Montana sites in June 2003.

overlapped each other as did those from the other sites (0.12-2.40 µg/g). However, only one of 39 samples from the uncontaminated sites overlapped the range of concentrations for the 23 samples from the contaminated sites. Our results show that mice from the two contaminated sites had hair mercury levels five to six times higher than mice from the uncontaminated sites, i.e., Comet Repository and the Cascade Ranch.

A comparison with deer mouse hair levels reported by Burton et al. (1977) shows that average levels at the Comet Repository and the Cascade Ranch about doubled the average levels Burton et al. (1977) reported for the rural Vernal site and one-half the levels reported from the Magna site. Average levels measured from our contaminated sites were approximately one-half those reported for the island sites but 14-16 times those found at the rural Vernal, Utah, site. Data from our study and Burton et al. (1977) show that mouse hair does indicate mouse exposure to environmental mercury.

We observed large differences in soil mercury concentrations among all sites (Fig. 1). Comparatively, we detected only slight

differences in hair concentrations between the two sites associated with mining activities that had the highest soil mercury concentrations or between the Comet and Ranch sites that had the lowest soil mercury concentrations (Fig. 1). All comparisons between sites that had high levels of soil mercury (Silver and Trinity) to sites with low levels (Comet and Ranch) showed large differences in hair concentrations of mercury. These results indicated that deer mice living on soils contaminated with mercury accumulate mercury in their hair.

CONCLUSIONS

An objective of this study was to determine if mice represent a pathway for environmental mercury transport. Our data show that mice in mercury contaminated environments did accumulate mercury in their hair and hence were an actual route for mercury transport and dissemination within an ecosystem. Because the levels of mercury in the leaves and roots of the vegetative species studied at the Silver Creek and Trinity Creek sites generally did not have elevated levels of mercury (Waring and Waring 2006), the source of the mercury in mouse hair did not likely result from consumption of vegetation. One hypothetical source of mercury in hair could result from surface deposition on hair followed by grooming. Another hypothetical source of mercury accumulation on hair could result from mice breathing/ingesting contaminated soil particles incidental to normal activity.

Although the hypothesized routes of exposure are interesting and worthy of future study, a more important aspect of our results lies in the fact that deer mice from contaminated environments accumulated more mercury in their hair than mice from uncontaminated sites. Thus, deer mice can be used as a long term bioindicator of the effectiveness of engineering treatments like repositories that are designed to isolate mercury. For example, from this study one might conclude that the Comet Repository prevented mercury in the repository tailings from contaminating mice in the ecosystem. Further, since deer mice are relatively easy to capture and are found in a broad array of habitats, they could be monitored at a relatively low cost and long term biological monitor for sites constructed to isolate mercury containing wastes.

Deer mice and levels of mercury in their hair may be used to indicate levels of mercury where they live. Furthermore, depending on abundance, deer mice could be a significant factor in mobilizing mercury from soils into food chains. Routine monitoring for mercury in deer mouse hair could provide a valuable tool to assess future changes in environmental mercury concentrations.

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LITERATURE CITED

Burton G. V., R. J. Alley, G. L. Rasmussen, P.Orton, V. Cox , P. Jones, and D. Graff. 1977. Mercury and behavior in wild mouse populations. Environmental Research 14:30-34.

Douglass, R. J. 1984. The use of rodents in monitoring ecological impacts of oil shale development in the Piceance Basin, Colorado. *In* Issues and technology in the management of impacted western wildlife. Proceedings of a national symposium. Thorne Ecological Institute Technical Publication 14, 250 pp.

Douglass, R. J. 1989. Assessment of the use of selected rodents in ecological monitoring. Environmental Management 13:355-363.

Fortin, C., G. Beauchamp, M. Dansereau, N. Lariviere, and D. Belanger. 2001. Spatial variation in mercury concentrations in wild mink and river otter carcasses from the James Bay Territory, Quebec, Canada. Arch. Environmental Contamination Toxicology 40:121-127.

Kosatsky, T., R. Przybysz and B. Armstrong. 2000. Mercury exposure in Montrealers who eat St. Lawrence River sportfish. Environmental Research 84:36-43.

Matsubara, J. and K. Machida. 1985. Significance of elemental analysis of hair as a means of detecting environmental pollution. Environmental Research 38:225-238.

Peterson, H. and M. Madden. 2006. Development of a new biomonitoring technique using domestic pets as sentinel species. Intermountain Journal of Sciences 12:27-43.

Phelps, D., and P.R. Buseck. 1980. Distribution of soil mercury and the development of soil mercury anomalies in the Yellowstone geothermal area, Wyoming. Economic Geology and the Bulletin of the Society of Economic Geologists.75:730-741.

Reynolds, K. D., M.S. Schwarz, C. A. McFarland, T. McBride, B. Adair, R. E. Strauss, G. P. Cobb, M. J. Hooper, and S. T. McMurry. 2006. Northern pocket gophers (*Thonomys talpoides*) as biomonitors of environmental metal contamination. Environmental Toxicology and Chemistry 25:458-469.

Skalski, J. 1984. Towards the use of faunal populations as cost-effective biomonitors. *In* Issues and technology in the management of impacted western wildlife. Proceedings of a national symposium. Thorne Ecological Institute Technical Publication 14. 250 pp.

Smith, D. B., W. F Cannon,. L. G. Woodruff, R.G. Garrett, R. Klassen, J. E. Kilburn, J. D. Horton, H. D.King, M .B. Goldhaber, and J. M. Morrison. 2005. Major-and trace-element concentrations in soils from two continental-scale transects of the United States and Canada. U.S. Geological Survey Open-File Report 2005-1253, 22pp.

U.S. Environmental Protection Agency. 1991. Methods for the Determination of Metals in Environmental Samples. EPA-600/4-91-010.

U.S. Environmental Protection Agency. 1997. Mercury Study Report to Congress. EPA- 452/R-97-0003.

U.S. Geological Survey. 1970. Mercury in the environment. USGS Professional Paper 713.

Waring, T. and K. Waring. 2006 Mercury Levels in Vegetation Growing on Contaminated Soils in Southwestern Montana. Intermountain Journal of Sciences 12:18-26.

Warren, H. V., R. E. Delavault, and J. Barakso. 1966. Some observations on the geochemistry or mercury as applied to prospecting. Economic Geology 61:1010-1028.

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