# Mercury Toxicity in Wildland Firefighters: A Progress Report

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# ✦ ABSTRACT

After the sudden emergence of mercury (Hg) poisoning in bald eagles in the Greater Yellowstone Ecosystem in December 2005, we began a preliminary study to investigate if Hg accumulated at toxic levels in wildland firefighters who were exposed to smoke and other particulates while fighting fires in the western United States during summer 2007. Deviating from our original design, we were able to analyze blood from 12 subjects, and repeated blood draws occurred for only four of those subjects. Three of the subjects had measurable Hg levels that approached the limit of a nontoxic Hg concentration (<10 mcg/L). A fourth subject had a measurable level of 4 mcg/L. All other subjects had levels designated by <4 mcg/L. For the four subjects with repeated blood draws, two demonstrated an increase in mercury levels over time (<4 to 7 mcg/L, and 5 to 8 mcg/L), one showed no change over time (<4 to <4 mcg/L), and one demonstrated a decrease in mercury levels over time (4 to <4 Beside Hg, blood analyses were mcg/L). performed for the presence of four other metals:

lead, cadmium, cobalt, and thallium. Levels of these metals were well-below toxic thresholds and within normal range for all subjects. Although we recorded times of exposure to smoke for all subjects, our sample was too small to investigate any statistical inference about the relationship between the duration of exposure to smoke and changes in blood Hg concentration. As forest fires continue to ignite in the western U.S. at unprecedented levels, burning areas such as dried bogs and marshes, we highly recommend continued research and a mercurymonitoring program to ensure the continued health and safety of our firefighting crews.

#### INTRODUCTION

Since December 2005, approximately 15 bald eagles and one golden eagle (Aquila chrysaetos) were submitted for treatment to the Montana Raptor Conservation Center (MRCC). Analysis revealed that eagles contained toxic levels of Hg in their blood ( $\geq 0.4$ ppm wet weight,. Six died, one was released, and the rest

1

remain in treatment but most likely will not be releasable. Symptoms of Hg toxicity were expressed by at least three other eagles submitted prior to December 2005, but their blood was not analyzed specifically for this metal. We suspect that Hg poisoning may have emerged prior to December 2005, but was not diagnosed. The presence of Hg or other contaminants in bald eagles suggests environmental contamination that may eventually manifest itself in the human population.

Since summer 2006, blood samples from more than 100 nestling, migratory (fall and spring), and wintering eagles in Montana and Wyoming were collected in an attempt to monitor and locate the source of the mercury poisonings (Harmata 2006, Montopoli et al. 2008). They expected to locate origins of the contaminants, but none materialized. All eagles had detectable levels of contaminants in their blood, most notably Hg. For example, during fall 2007, Harmata et al. trapped 22 wintering bald eagles in southwestern Montana, and results indicated that Hg loads in the bald eagles were very high (geometric mean = 10.0 mcg/L; toxicity level > 4 mcg/L; and, during summers 2006 and 2007, nestlings in northwestern WY (10 and 15, respectively) were sampled for contaminants and results suggested elevated levels of Hg that increased by 64% over the two summers.

Natural degassing of the earth's crust is the major source of environmental Hg worldwide (Heinz 1996) and coal-fired utilities are the largest single unregulated anthropogenic source of Hg emissions in the United States (USEPA 1997). However, recent data indicate wildfires are responsible for massive aerosols of Hg (Friedli et al. 2003, Wiedinmyer and Friedli 2007) and could release 15 times more Hg into the air than every U.S. coal-fired power plant combined (Friedli et al. 2001). Biswas et al. (2003) indicated combustion of litter and green vegetation resulted in virtually complete release of Hg stored in forests in the Rocky Mountain region. Montana and Wyoming forests may contain large reservoirs of Hg deposited during the industrial age that can now be released into the atmosphere during fires. Also, Hg concentrations in fish are influenced by the extent (size) of clear-cut forests in relation to area of lakes in the Canadian boreal forests (Garcia and Carignan 2005). These data suggest large scale logging operations contribute to Hg

contamination and bioaccumulate in higher trophic level piscivorous predators (Driscoll *et al.* 1994).

Harmata (2006) speculated that "... Perhaps higher concentrations in Wyoming nestlings are a function of their proximity to Yellowstone National Park where large, extensive forest fires occur regularly and geothermal activity abounds...These fires release Hg into the atmosphere not only from trees consumed but especially peat that absorbed disproportionate amounts of atmospheric Hg emitted during the industrial age (Turetsky et al. 2006). Advancing global climate change and associated desiccation and emolation of temperate and boreal forests, exacerbated by extensive clear-cutting, may increase poisoning of aquatic ecosystems with high levels of Hg in the future."

In late May 2007, while discussing the issue of Hg poisoning in bald eagles, we theorized that, if forest fires are the source of Hg contamination in the bald eagles, the contaminant could also manifest itself in other species, most notably wildland firefighters who occupy the immediate environment while combating forest fires. Exposure of firefighters to Hg may occur: 1) after its release into the atmosphere as a result of combustion of mercury-laden tree bark and other organic plants; and, 2) while firefighters inhale particulates resulting from activities such as digging fire line in unburned areas, especially peat bogs where microorganisms methylized the inorganic mercurial ion under riparian conditions.

During summer 2007, we therefore initiated a preliminary study to investigate if Hg accumulated at toxic levels in wildland firefighters who were exposed to smoke and other particulates while fighting fires in the western United States.

### ANALYSIS AND RESULTS

The null and alternative research hypotheses were defined by:

H<sub>0</sub>: There are no statistically discernible differences in Hg levels in blood of firefighters after exposure to smoke-related contaminants.

 $H_1$ : There is a statistically discernible increase in Hg levels in blood of firefighters

after exposure to smoke-related contaminants.

The original, proposed design involved the collection and analysis of 10mL blood samples drawn from 26 subjects that were involved in fighting wildland fires during summer 2007. Full-time employees (seasonal or permanent) of Grand Teton National Park and Bridger Teton National Forest qualified as potential subjects in the study. We intended to take 2 draws per subject (pre- and postcontaminant exposure) and analyze the results using a related-samples t-test based on the repeated-measures design. A power analysis based on the difference score (post-Hg level minus pre-Hg level) allowed the detection of a medium effect due to Hg (Cohen's d = 0.5, alpha = 0.05 and power = 0.8; Cohen 1988). All tests were performed by a lab certified for the detection of Hg (St. John's Medical Center, P.O. Box 428 Jackson, WY 83001).

Participants were also asked to answer a brief questionnaire containing questions about demographics, prior mercury exposure, immediate exposure to smoke and particulates, and contact information.

Circumstances which we did not anticipate required us to substantially deviate from our original design. We were able to analyze blood from 12 subjects, and repeated blood draws occurred for only four of those subjects. Table 1 summarizes data obtained in our study.

Although our study specifically investigated Hg, analyses were performed for four other metals (lead, cadmium, cobalt, and thallium). Levels of these metals were wellbelow toxic thresholds and within normal ranges for all subjects.

Eleven of the 12 subjects were males, and the average age of all subjects was 32.5 years. Prior to the first blood draw, each subject was exposed to smoke for 20.1 days, at 11.6 hours per day on average. Prior to the second blood draw, each subject was exposed to smoke for 21.9 days, at 10.8 hours per day on average.

			Exposure to Smoke			
	Hg Level (mcg/L)		Draw 1		Draw 2	
	Draw	Draw		Hours/		Hours/
Subject	#1	#2	Days	day	Days	day
1	<4	7	6	12	30	12
2	4	<4	?	?	21	14
3	<4	<4	14	6	14	6
4	<4	*	3	15	*	*
5	<4	*	40	14	*	*
6	<4	*	34	16	*	*
7	5	8	14	8	14	8
8	<4	*	30	10	*	*
9	*	7	*	*	14	16
10	*	<4	*	*	25	14
11	*	<4	*	*	12	8
12	*	<4	*	*	45	8

Table 1. Blood Hg Level (mcg/L) of Firefighters and Their Exposure to Smoke

? Indicates missing information

\* Indicates no blood draw for the subject

# DISCUSSION

This study was motivated by the sudden emergence of Hg poisoning in bald eagles in the Greater Yellowstone Ecosystem, specifically southwestern Montana in December 2005. Subsequent research of nestling, migratory and wintering bald eagles of southern Montana and northwestern Wyoming starting summer 2006 and continuing through the present further indicated abnormally high, and sometimes toxic, levels of Hg and other contaminants in these populations. Investigation into possible sources of contamination led us to the hypothesis that the high levels of Hg encountered in bald eagles originated from the extensive forest fires that the western United States is currently experiencing. These fires are releasing smoke and other particulates containing Hg at unprecedented levels from trees contaminated with Hg during our industrialization, and from peat bogs containing biota that absorbed Hg and have recently dried out due to our current warming climate trend.

During May 2007, we speculated that wildland firefighters in the western United States were being exposed to Hg as a result of the combustion of mercury-laden tree bark and peat bogs. Realizing the significance of Hg contamination to our firefighters and environment, we proposed to investigate if Hg accumulated at toxic levels in the blood of the firefighters.

Circumstances which we did not anticipate required us to substantially deviate from our original design. The Institutional Review Board (IRB) process, a required procedure when conducting human-oriented research, was substantially more involved than anticipated. After realizing the research topic in late May and assembling the research team in mid-June, we obtained substantial assistance from the University of Washington's Medical School in procuring IRB approval in late July. Consequently, we were not able to obtain blood samples for subjects prior to the start of the fire season, nor were we able to sample 26 subjects as originally proposed (the fire season had ended for many of the seasonal employees). We were, however, able to analyze blood from 12 subjects, and repeated blood draws occurred for four of those subjects.

Conclusions drawn from such a small sample are tenuous at best. However, the following results merit attention:

- Beside Hg, blood analyses were performed for the presence of four other metals (lead, cadmium, cobalt, and thallium). Levels of these metals, though not precisely reported (<3.0 mcg/dL, <0.5 mcg/L, <1.0 mcg/L, and</li>
   1.0 mcg/L, respectively, for all subjects), were well-below toxic thresholds and within normal range for all subjects.
- 2) Three of the subjects had measurable Hg levels (7 mcg/L, 7 mcg/L, and 8 mcg/L) that approached the limit of a non-toxic Hg concentration (<10 mcg/L). A fourth subject had a measurable level of 4 mcg/L. All other subjects had levels designated by <4 mcg/L.</p>
- 3) For the four subjects with repeated blood draws, two demonstrated an increase in mercury levels over time (<4 to 7 mcg/L, and 5 to 8 mcg/L), one showed no change over time (<4 to <4 mcg/L), and one demonstrated a decrease in mercury levels over time (4 to <4 mcg/L).</p>
- 4) Although we recorded times of exposure to smoke for all subjects, our sample was too small to investigate any statistical inference about the relationship between the duration of exposure to smoke and changes in blood Hg concentration.

We initiated this preliminary study to investigate if Hg was accumulating at toxic levels in wildland firefighters who were exposed to smoke and other particulates while fighting fires in the western United States. We experienced limitations to our original design because we sampled only 12 subjects who had lower exposure to smoke than anticipated. However. we still encountered Hg at measureable levels in four subjects, while no other metals were even precisely measureable in any of the subjects. Consequently, we feel this research merits further investigation with the following modifications:

- 1) The study should be expanded to a significantly larger sample of wildland firefighters in the western United States (at least 150, contingent on funding). A majority of the firefighters should belong to hot-shot crews that are extensively exposed fire contaminants (smoke to and particulates) over the duration of the Other firefighters with less summer. exposure can be used as a comparative sample.
- 2) It is essential that Hg levels in each subject are analyzed a minimum of two times during the firefighting season, optimally:
  i) prior to commencement of the fire season; and
  ii) well into, or at the end of, the fire season after considerable exposure to fire particulates.
- 3) Time of exposure to smoke particulates by firefighters should be estimated more precisely.
- 4) Hg levels in subjects should be analyzed precisely, perhaps by an alternate method. Dr. Redeem Sumicab (pers. comm. 2007) has suggested a new procedure that analyzes urine from subjects drawn immediately upon awakening in the morning.
- 5) If the budget permits, hair samples from the back of the neck (which are fast growing) could be easily harvested to determine if mercury levels are due to chronic or acute exposure.

Analyses of data from ongoing bald eagle research indicate that elevated and toxic levels of Hg in nestling, migrating, and wintering eagles of southern Montana and northern Wyoming are persisting – even increasing – in the environment. Nestling bald eagles in Grand Teton National Park have experienced a 64% increase in mercury blood levels (Montopoli et al. 2008). As evidenced by the bald eagles in the

4

rehabilitation center, once Hg toxicity fully manifests itself, there is poor prognosis for recovery. The same is true for humans.

Symptoms of elemental Hg toxicity in humans include central nervous system (CNS), renal, and pulmonary dysfunction: tremors: irritability: insomnia: memory loss; neuromuscular changes; headaches; slowed sensory, motor and cognitive function; mild transient proteinuria; acute renal failure; chest pains; dypsnea; cough; pulmonary function impairment; and interstitial pneumonia (ATSDR 1999, U.S. EPA 1997). Acute inhalation of methyl mercury results in severe CNS effects including blindness, deafness, and impaired level of consciousness (WHO 1990).

If research supports our hypotheses, we can implement immediate actions to prevent Hg toxicity and neurological compromise in wildland firefighters, such as: 1) the use of specialized equipment such as a wildland firefighter's mask; 2) periodic urine exams to monitor Hg concentration in body tissues; and/or, 3) if Hg concentrations become elevated, the use of DMSA (meso-2,3-dimercaptosuccinic acid) to remove the Hg. As forest fires continue to ignite in the western U.S. at unprecedented levels, burning areas such as dried bogs and marshes, we highly recommend a mercurymonitoring program to ensure the continued health and safety of our firefighting crews.

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