

Mercury exposure and effects at a thermometer factory

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RICHTER ED, PELED N, LURIA M. Mercury exposure and effects at a thermometer factory. *Scand j work environ health* 8 (1982): suppl 1, 161—166. Mercury levels in air, urine, blood, and hair were studied for workers (14 women, 2 men, ages 18—44 a) employed in a small thermometer factory (metallic mercury vapor exposures) with generally inadequate engineering and hygienic arrangements. At exposure levels of 50—99 $\mu\text{g}/\text{m}^3$ (5 workers), 100—149 $\mu\text{g}/\text{m}^3$ (3 workers) and 150—200 $\mu\text{g}/\text{m}^3$ (7 workers), respectively, the mean mercury levels were 299, 449 and 628 nmol/l in urine; 105, 122 and 143 nmol/l in blood, and 4.2, 8.5 and 12.2 $\mu\text{mol}/\text{kg}$ in hair (1 cm from base). Headache, irritability-hair loss, and wrist and ankle pain were the most frequently occurring symptoms. The correlation coefficients between the measured mercury levels in air for individual workers and mercury in urine, blood, and hair (1 cm from base) were $r = 0.92$, $r = 0.79$, and $r = 0.42$, respectively. Mercury determinations for segmental hair cuts indicated peaks and drops in absorption/deposition consistent with data on the vacations of the individual workers. The data on exposure-absorption-deposition and symptoms present at urinary mercury levels of 150—770 nmol/l may be helpful when current thresholds of exposure/absorption are reconsidered.

Key terms: elemental mercury, exposure-absorption-symptom relationships.

For inorganic mercury, data on exposure-absorption relationships (9) and on absorption levels and medical findings (3, 10) from defined work populations have been the basis for the setting of permissible exposure levels (PEL) for defined work populations. In 1973, the US National Institute for Occupational Safety and Health recommended that an 8-h (time-weighted average) PEL or threshold limit value (TLV) for inorganic metallic mercury be adopted (8, 13). There has been concern as to the effects on central and peripheral neurological functions (1, 11, 12) and, in addition, on reproductive function,

although data on the latter are lacking for humans.

The present paper reports findings from a study (May—July 1979) made on occupational airborne mercury exposure, the levels of mercury in urine, blood and hair, and the symptoms of exposed workers in a small thermometer factory. The data are of concern in light of the continued need for information on exposure-absorption-effect relationships, and they are relevant to some of the practical problems associated with the monitoring of specific worksites.

Materials and methods

Workforce

All the workers in the factory were examined (16 workers, 2 males and 14 females). The age range was 18—44 a (mean 28 a), and seniority ranged from 2 months to 20 a. Two women and one man smoked during work time.

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Description of worksite

The factory was a small building, approximately 290 m² (10 × 29 m), partially divided into two work areas; within each area there were rows of work benches on each side of a middle aisle. In work area A there was an office, toilet and small washroom, and several work benches for assembling the outer and inner thermometer tubes and scale markings. In work area B, the following processes were carried out: pouring of liquid metallic mercury into the thermometer tubes, flame-closing of the thermometer glass tips, and etching of the outer glass with lines for 37°C and 41°C. This work area had four windows along one wall, three windows along another, a ventilation exhaust system of ducts suspended from the ceiling, and exhaust to the outside. There were no showers in the factory, nor were separate lockers provided for work and street clothes.

Measurement of mercury in workplace air

Mercury in the workplace air [Hg(A)] was measured at the worksites of 14 women and 1 man. (The male foreman was excluded.) We used a portable mercury vapor meter (Beckman model K-23B) — atomic absorption 253.7 nm, range 0—1.0 mg/m³, and accuracy 10 % of meter reading or ± 1 minimum scale division, whichever was larger. Calibration and zero level settings were carried out at a site away from the worksite. The Hg(A) concentrations reported in this paper represent the average of two to three determinations at each site, each reading taking about 60—90 s.

Measurement of mercury in urine

Midworkday samples of urine were collected from 15 workers (one female worker excluded) in sterile capped bottles, acidified with sulfuric acid (H₂SO₄) down to a pH of 1.7 (0.2 ml of H₂SO₄ 50 %, to 5 ml of urine), and analyzed with a Coleman MAS-50 mercury analyzer with a Thomas reagent injection bubbler (atomic absorption 253.7 nm wavelength, reproducibility ± 3 %, sensitivity 0.01 µg or less than 0.1

parts per billion) using an analytical procedure developed by Magos (5, 6) for determining total urinary mercury [total Hg(U)] and inorganic urinary mercury [inorganic Hg(U)]. Laboratory studies in which methyl-mercuric chloride was added to urine indicated that the "recovery" of the analytical procedure was 89—94 %.

Measurement of mercury in blood

All blood for the measurement of mercury in blood [Hg(B)] was drawn at a makeshift site set up in the front yard of the factory. Each worker's antecubital fossa was washed with soap and water, and the puncture site was swabbed with alcohol. The samples were collected from 10 workers by venipuncture with veno-ject EDTA (ethylenediaminetetraacetate) vacuum collecting tubes (Jintan-Terumo), transferred in an icebox, and frozen within 5 h of collection. The specimens were air shipped in the frozen state to the United States where they were analyzed by the method of Magos & Clarkson (7).

Measurement of mercury in hair

From eight workers, cuts of hair were taken from the hair base at the scalp, stapled at the end near the hair roots and put in a polyethylene bag for the analysis of hair mercury [Hg(H)] deposition (as opposed to external mercury contamination). The samples were transferred to the United States and were analyzed by the method described by Greenwood et al (4).

Symptoms and questionnaire

The workers filled out, in their homes, a checklist on personal and occupational data, work practices and symptoms, including those considered to be associated with mercury exposure.

Statistical methods

The data were hand-calculated and tabulated, and an electronic calculator was used for computing the regression equations.

Results

Table 1 reveals that the Hg(A) values exceeded 50 $\mu\text{g}/\text{m}^3$ at all worksites except the manager's office, dining room, storeroom, and toilet-washroom. The Hg(A) levels were higher in section B, where work processes involving mercury were carried out. Additional data showed that the Hg(A) levels were higher everywhere by some 10–30 % at the floor level than at face level, and traces of mercury were detected at the floor level in the manager's office and dining room.

Mercury in urine

For all workers, the total Hg(U) far exceeded the 100 nmol/l level generally seen in nonexposed persons. While higher Hg(U) levels were seen in workers whose work was directly involved with mercury, all determinations but one were beneath the biological limit value of 750 nmol/l recommended by the US National Institute for Occupational Safety and Health (8).

The fourteen university students and personnel without known exposure to mer-

cury and chosen as a reference group had Hg(U) levels between 0.075 and 0.165 nmol/l (mean = 0.100 nmol/l).

Mercury in blood

In nonexposed populations, Hg(B) levels have been reported to be less than 50 nmol/l in 85 % of those examined. For the 10 workers for whom Hg(B) was measured in the present study, Hg(B) was in the range of 99–178 nmol/l (mean 123 nmol/l). For one worker, the Hg(B) value exceeded the 150 nmol/l which has been suggested as a biological limit value (3).

Mercury in hair

The hair analysis indicated that, except for hair from one worker, the mercury burdens were less than 25 $\mu\text{mol}/\text{kg}$ for all the 1-cm segments of hair. For one worker, the Hg(H) content in one segment was 50 $\mu\text{mol}/\text{kg}$. Usually, the majority of the Hg(H) was in the inorganic form.

Segmental (1-cm) hair cuts indicated that there were peaks and drops in hair

Table 1. Mercury in urine [Hg(U)], blood [Hg(B)], and hair [Hg(H)] in relation to mercury in air [Hg(A)].

Hg (A) levels	Total Hg(U) ^a (nmol/l)	Hg(B) (nmol/l) ^b		Hg(H) levels ($\mu\text{mol}/\text{kg}$) ^c					
		Total Inorganic		Total			Inorganic		
				1 cm	3 cm	Total length	1 cm	3 cm	Total length
50–99 $\mu\text{g}/\text{m}^3$									
Minimum	150	99	75						
Maximum	444	109	91						
Mean	299	105	76	4.2	7.5	8.4	3.5	5.6	4.8
100–149 $\mu\text{g}/\text{m}^3$									
Minimum	374	105	77						
Maximum	528	138	113						
Mean	449	122	95	8.2	9.7	10.3	5.3	7.8	7.1
150–200 $\mu\text{g}/\text{m}^3$									
Minimum	483	120	91						
Maximum	770	178	138						
Mean	628	143	102	12.2	10.4	15.2	5.9	5.7	10.3

^a Number of workers from whom specimens were taken was 5, 2, and 7 for exposure levels 50–99, 100–149, and 150–200 $\mu\text{g}/\text{m}^3$, respectively [The male foreman, no Hg(A) data, and one female worker, no Hg (U) data, excluded.]

^b Number of workers from whom specimens were taken was 4, 2, and 4 for exposure levels 50–99, 100–149, and 150–200 $\mu\text{g}/\text{m}^3$, respectively.

^c Number of workers from whom specimens were taken was 1, 3, and 4 for exposure levels 50–99, 100–149, and 150–200 $\mu\text{g}/\text{m}^3$, respectively; 1 cm, 3 cm and total length = length of hair from base.

Table 2. Relationships between symptoms and the urinary mercury [Hg(U)] level of 15 workers (13 women, 2 men).^a

Symptom	Number of workers			
	150—249 nmol/l (N = 3)	250—499 nmol/l (N = 5)	500—799 nmol/l (N = 7)	150—799 nmol/l (N = 15)
Headache	1	5	6	12
Wrist and ankle pain	1	4	7	12
Irritability	1	4	4	4
Hair loss	3	2	4	9
Sweating	0	3	3	6
Metallic taste	0	2	4	6
Loss of appetite	1	1	3	5
Nausea	1	2	2	5
Abdominal pain	0	0	5	5
Constipation	0	1	3	4
Diarrhea	0	0	2	2
Depression/insomnia	1	0	3	4
Eye pain	0	1	2	3
Tremor	0	0	1	1
Bleeding gums	0	0	1	1

^a Hg(U) not available for one female worker.

Table 3. Correlation coefficients between mercury in the air [Hg(A)] and mercury in the urine [Hg(U)], blood [Hg(B)], and hair [Hg(H)] of the examined workers.

	Hg(A)	Hg(U)	Hg(B)
Hg(U)	0.92 (N ^a = 14)	—	0.68 (N = 9)
Hg(B)	0.79 (N = 10)	0.68 (N = 9)	—
Hg(H)			
1-cm length	0.42 (N = 8)	0.45 (N = 7)	0.43 (N = 6)
3-cm length	0.18 (N = 8)	0.23 (N = 7)	0.24 (N = 6)
Total length	0.52 (N = 8)	0.44 (N = 7)	0.88 (N = 6)

^a N = number of specimens taken.

segments roughly consistent with data on leaves-of-absence — called “mercury vacations” by the workers — and the onset of employment. Overall, the hair data suggested seasonal or episodic fluctuations in exposure to mercury for this group.

Symptoms

Headache, wrist and ankle pain, irritability, hair loss, sweating, and metallic taste in the mouth were the most frequently occurring symptoms. Table 2 indicates that

individual symptoms were more apt to occur in those persons with higher Hg(U) levels.

Hair loss, interestingly, was seen with both lower and higher levels of exposure. While older women were more prone to this symptom, low-level exposure for as little as two to three months could be associated with this complaint. This symptom, once well-known among laboratory workers exposed to mercury (Horowitz, personal communication), is not included in descriptions (8, 9, 13) of mercury toxicity. The possibility of exposure to thallium, which is alloyed with mercury in low-temperature thermometers, was not investigated.

The male foreman, who had worked in this factory for 20 a, was observed to have frequent temper outbursts, like those of the “mad hatter” syndrome, and he complained of irritability, depression, headache, metallic taste in the mouth, abdominal pain, and pain in his joints.

Interrelationships between mercury in the air and mercury in urine, blood and hair

From the data in table 1, at mean exposure levels of 50—99 $\mu\text{g}/\text{m}^3$ (5 workers), 100—149 $\mu\text{g}/\text{m}^3$ (2 workers), and 150—200

$\mu\text{g}/\text{m}^3$ (7 workers), respectively, the mean Hg(U) levels were 299, 449, and 628 nmol/l; the mean Hg(B) values were 105, 122, and 143 nmol/l; and the mean Hg(H) contents (base 1-cm) were 4.2, 8.2, and 12.2 $\mu\text{mol}/\text{kg}$. Table 3 presents data on the interrelationships between Hg(A), Hg(U), Hg(B), and Hg(H). It shows that, except for Hg(B)-Hg(H) (total length), the correlation coefficients (r) were lower for Hg(H) than for those between Hg(A) and Hg(B) and Hg(U).

Discussion

The findings, considered together with the inappropriate design of the work area and exhaust arrangements, add up to a fairly coherent picture of excessive exposure to mercury in this factory and medically unacceptable findings for its workers.

Despite the fact that the work compartments were not separate and self-contained units and the workers moved around, there nevertheless appeared to be gradients of exposure that did not change greatly from day to day. This conclusion is suggested by the high degrees of correlation between Hg(A), Hg(B), and Hg(U).

The vexing industrial hygiene problems associated with the use of inorganic mercury are well known. The venting shafts themselves become reservoirs of recirculable mercury; there may be sequestration of mercury in crevices, cracks and joints, which serve as "hot spots." In addition mercury contamination of workers' homes, laundries, and waste disposal sites may occur (2, 11). These problems have to be dealt with in a control program.

The need for long-term follow-up of the health status of all who have ever worked in the factory is evident.

The stepwise increase in the occurrence of symptoms from "low" to "medium" to "high" in the Hg(U) groups (table 2) suggests that this spectrum of exposure/absorption is above the biological threshold for clinically apparent effects.

A comparison of our data with those of Smith (9) indicated that the exposure levels in the factory of our investigation were in a lower range than those of Smith's. For the Hg(A) levels in the range of 50–180 $\mu\text{g}/\text{m}^3$, the Hg(U) levels of the individual workers in our study were

somewhat lower than those reported by Smith, but symptoms were somewhat more frequent; however, the Hg(B)-Hg(U) relationships appeared to be in the same range.

In conclusion, our data describe an increasing frequency of symptoms with gradients of exposure starting from 50 $\mu\text{g}/\text{m}^3$, even though the Hg(U), Hg(H), and Hg(B) levels were "subthreshold." These findings, taken together with the suggested possibility of neurotoxic effects at "tolerable" levels of mercury absorption, may be of interest in a reconsideration of the adequacy of a threshold limit value of 50 $\mu\text{g}/\text{m}^3$. In the case of the factory in our study, the data, together with the concern over the possible reproductive hazards of mercury exposure, call for urgent measures to eliminate the admittedly difficult problems associated with exposure to this agent.

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