

## Indoor Air Mercury Concentrations Following Application of Interior Latex Paint

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**Abstract.** Mercury vapors are released from paint containing mercury compounds used to prolong the shelf-life of interior latex paint. To determine whether homes recently painted with paint containing mercury had elevated indoor-air mercury concentrations, we studied 37 Ohio homes. Twenty-one homes painted with mercury-containing paint a median of 86 days earlier were compared with 16 homes not recently painted with mercury-containing paint. Paint samples from the exposed homes contained a median of 210 mg Hg/L (range 120-610 mg/L). The median air mercury concentration was higher in the exposed homes ( $0.3 \mu\text{g}/\text{m}^3$ ; range nondetectable- $1.5 \mu\text{g}/\text{m}^3$ ) than in the unexposed homes (nondetectable; range nondetectable- $0.3 \mu\text{g}/\text{m}^3$ ,  $P < 0.0001$ ). Among the exposed homes there were seven in which paint containing  $<200 \text{ mg}/\text{L}$  had been applied. In these homes, the median air mercury concentration was  $0.2 \mu\text{g}/\text{m}^3$  (range nondetectable- $1 \mu\text{g}/\text{m}^3$ ). Six (33%) exposed homes had air mercury concentrations  $>0.5 \mu\text{g}/\text{m}^3$ , the acceptable indoor concentration recommended by the Agency for Toxic Substances and Disease Registry. Elemental mercury was the form of mercury released into the air. These data demonstrate that potentially hazardous mercury exposure may occur in homes recently painted with paint that contains mercury concentrations  $<200 \text{ mg}/\text{L}$ .

Mercury vaporizes readily at room temperature and is therefore a potentially dangerous metal. Inhalation of high concentrations of mercury vapor may result in tightness and pain in the chest, difficulty in breathing, coughing, nausea, abdominal pain, vomiting, diarrhea, and headaches. Long-term exposure to low concentrations of mercury vapor is associated with vasomotor disturbances, muscle tremors, and personality changes (Knight 1989). Mercury poisoning

resulting from a chronic, low-level exposure is often difficult to diagnose because the symptoms are nonspecific and variable. Despite these known adverse health effects, mercury compounds have been used by many paint manufacturers as additives in latex (water-based) paint to protect the paint from mildew and bacteria during production and storage. The most commonly used mercurial compound in water-based paints is phenylmercuric acetate (PMA) (Train 1976).

In August 1989, a Detroit-area 4-year-old was diagnosed with acrodynia, a rare manifestation of childhood mercury poisoning, 10 days after the inside of his home was painted with 17 gallons of interior latex paint (CDC 1990). The boy became irritable, suffered uncontrollable tremors and lost his ability to walk; the skin of his fingers and toes turned pink and peeled. Inhalation of mercury vapors from PMA contained in the paint was the probable route of mercury exposure. The paint contained a mercury concentration of 930-955 mg/L, exceeding the US Environmental Protection Agency's (EPA) recommended limit of 300 mg/L for mercury used as a preservative in interior latex paint. A study in selected communities in southeastern Michigan assessed mercury concentrations in the air of homes in which this same brand of paint was applied and in urine samples from persons living in these homes. Significantly higher concentrations of mercury were detected in the air of exposed homes and in urine samples from the exposed individuals than were detected in comparable samples of air and urine from families whose homes were not painted recently with mercury-containing paint (Agocs *et al.* 1990).

The purpose of our study was twofold. First, to evaluate whether homes recently painted with paint containing mercury had elevated indoor-air mercury concentrations. Second, to determine what forms of mercury are released from latex paint containing mercury compounds.

### Methods

Thirty-seven homes in the city of Columbus, Ohio, were surveyed between April 3-7, 1990. Subjects were recruited by means of television and newspaper announcements soliciting volunteers who had

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painted the inside of their homes since November 1, 1989, with interior latex paint. "Exposed" homes were defined as those painted in the last 5 months with paint containing concentrations of mercury >50 mg/L, the estimated minimum concentration of mercury additive needed to kill bacteria (Train 1976). "Unexposed" homes were those owned by employees of the Ohio Department of Health or their acquaintances that either had not been painted in the past 18 months or had been painted with paint containing no mercury.

An interviewer obtained written informed consent and administered a questionnaire about the painting history and other characteristics of the home to an adult in each family. Samples of remaining liquid paint, dust from vacuum cleaner bags, and indoor air were collected for analysis for total mercury content. Liquid paint samples were digested with nitric and sulfuric acids. Samples from vacuum cleaner bags were sifted through a 60-mesh sieve, and the resulting dust was analyzed. Indoor air samples were collected onto hopcalite tubes by use of a Gilian<sup>1</sup> personal air sampling pump run for 12 h at a flow rate of 1 L/min. Within the exposed homes, air samples were obtained from rooms that had been painted. Sampling locations in the unexposed homes were selected at random.

Air samples were also collected for mercury speciation analysis from 15 homes (10 exposed and 5 unexposed), by a technique of cryogenic gas chromatography with atomic fluorescence detection developed by Nicholas Bloom (Bloom and Fitzgerald 1988). This form of analysis separates and measures the concentrations of inorganic mercury and species of organic mercury in an air sample. The limit of mercury detection was 0.003  $\mu\text{g}/\text{m}^3$ .

Samples of liquid paint and vacuum bag dust were analyzed by cold vapor atomic absorption. The limit of mercury detection was <2.0 mg/L for the paint and <2.0 mg/kg for the vacuum dust. Atomic absorption spectrophotometry was used to analyze samples of indoor air. The limit of mercury detection was 0.1  $\mu\text{g}$  per tube and was <0.1  $\mu\text{g}/\text{m}^3$ .

Because air mercury concentrations were not normally distributed, we used the Wilcoxon signed rank-sum test to test the significance of differences between exposed and unexposed groups. Correlations were measured by the Spearman correlation coefficient.

## Results

Twenty-one exposed homes and 16 unexposed homes were identified. The exposed homes had been painted a median of 86 days before the study (range 6–155 days), and a median of two rooms (range 1–6) had been painted in each home. A median of 2 gal of paint (range 1–10) was used from 15 different brands. Exposed homes were painted for a median of 5 days (range 1–99 days).

Paint samples were obtained from 17 of the 21 exposed homes. Because paint samples were not available from four homes, an average of the values obtained from samples of the same brand of paint used in these homes was calculated and used as an estimated paint concentration for these four homes. The median mercury content of the paint applied in the 21 exposed homes was 210 mg/L (range 120–610 mg/L). Three samples of one brand of paint used in three exposed homes contained mercury concentrations above 300 mg/L.

Air samples were obtained from the 21 exposed households and from the 16 unexposed households. The median

air mercury concentration as measured by atomic absorption spectrophotometry was higher in the exposed homes (0.3  $\mu\text{g}/\text{m}^3$ ; range nondetectable–1.5  $\mu\text{g}/\text{m}^3$ ) than in the unexposed homes (nondetectable; range nondetectable–0.3  $\mu\text{g}/\text{m}^3$ ,  $P < 0.0001$ ). When the three homes in which paint containing more than 300 mg/L had been used were excluded, the median air mercury concentration in exposed homes (0.3  $\mu\text{g}/\text{m}^3$ , range nondetectable–1.5  $\mu\text{g}/\text{m}^3$ ) was still significantly higher than that in unexposed homes (nondetectable; range nondetectable–0.3  $\mu\text{g}/\text{m}^3$ ,  $P < 0.0002$ ). Six (33%) of the 18 exposed homes had air mercury concentrations >0.5  $\mu\text{g}/\text{m}^3$ . There were 7 exposed homes in which paint containing less than 200 mg/L had been used. In these homes, the median air mercury concentration was 0.2  $\mu\text{g}/\text{m}^3$  (range nondetectable–1  $\mu\text{g}/\text{m}^3$ ).

Among the exposed homes, variables measuring the number of hours windows were open and amount of paint used were not found to be significant predictors of air mercury concentrations. A negative correlation  $-0.37$  ( $P = .06$ ) was found between air concentrations and time since the home was painted. There was not a significant relationship between the paint mercury concentrations and the total air mercury concentrations.

Air samples for mercury speciation were obtained from 10 (48%) exposed households and from 4 (25%) unexposed households. Using the technique of cryogenic gas chromatography with atomic fluorescence detection, the median total air mercury concentration was higher in the exposed homes (0.225  $\mu\text{g}/\text{m}^3$ ; range 0.086–1.745  $\mu\text{g}/\text{m}^3$ ) than in the unexposed homes (0.052  $\mu\text{g}/\text{m}^3$ ; range 0.036–0.107  $\mu\text{g}/\text{m}^3$ ) ( $P = .01$ ). A correlation of 0.92 was found between total air mercury detected by the hopcalite tube samples and the speciation samples. The median concentration of elemental mercury was 0.185  $\mu\text{g}/\text{m}^3$  (range 0.077–1.702  $\mu\text{g}/\text{m}^3$ ) in the exposed homes and 0.049  $\mu\text{g}/\text{m}^3$  (range 0.036–0.097  $\mu\text{g}/\text{m}^3$ ) in the unexposed homes. Elemental mercury constituted 74%–100% of the total mercury detected in samples from exposed homes, and it constituted from 90–100% of the total mercury detected in unexposed homes. Other individual peaks identified in exposed homes included small traces of methylethylmercury in five of the samples (range 0.001–0.009  $\mu\text{g}/\text{m}^3$ ) and monomethylmercury (range 0.001–0.003  $\mu\text{g}/\text{m}^3$ ) in three samples. The median value of other "unidentified organo mercury" species, which represent all compounds not accounted for specifically, was 0.004  $\mu\text{g}/\text{m}^3$  (range 0.01–0.074  $\mu\text{g}/\text{m}^3$ ) in the exposed homes and nondetectable (range nondetectable–0.01  $\mu\text{g}/\text{m}^3$ ) in the unexposed homes. Only elemental mercury was detected in the air above pure phenylmercury.

Vacuum bag samples were collected from 16 (76%) exposed households and from 8 (50%) unexposed homes. The median mercury concentration in the dust from exposed homes (3.76 mg/kg; range 0.93–11.91 mg/kg) was not significantly different from that in the dust from unexposed homes (1.78 mg/kg; range 1.0–4.8 mg/kg,  $P = 0.19$ ).

## Discussion

The results show that homes recently painted with paint containing mercury compounds had significantly higher indoor air mercury concentrations than homes not painted in the

<sup>1</sup> The use of trade names is for identification only and does not constitute endorsement by the Public Health Service or the U.S. Department of Health and Human Services.

past 18 months. The median indoor concentration of 0.3  $\mu\text{g}/\text{m}^3$  measured in exposed homes was 75 times higher than the average outdoor air mercury concentration (0.004  $\mu\text{g}/\text{m}^3$ ) found in most areas of the United States, (personal communication: Mark Spittler, US EPA, New England Regional Laboratory, July 2, 1990). In addition, six of the air samples obtained from homes painted with paint containing <300 mg/L exceeded the acceptable residential indoor air mercury concentration of 0.5  $\mu\text{g}/\text{m}^3$  recommended by the Agency for Toxic Substances and Disease Registry (ATSDR 1988). Notably, one home painted with paint containing <200 mg/L had an air mercury concentration of 1  $\mu\text{g}/\text{m}^3$ .

The air mercury concentrations we detected a median of 86 days after painting are consistent with those measured by other researchers. Agocs and co-workers (1990) measured a median indoor air mercury concentration of 2.0  $\mu\text{g}/\text{m}^3$  an average of one month after homes in Michigan were painted with paint containing a median mercury concentration of 754 mg/L. Foote measured air mercury concentrations in homes painted with latex paints that ranged from 1.6  $\mu\text{g}/\text{m}^3$  seven days after painting to 0.07  $\mu\text{g}/\text{m}^3$  33 months after painting (Foote 1972). The weak correlation (-0.37) we found between air mercury concentrations and time since a room was painted is probably due to variables we did not measure, such as room ventilation.

Hirschman and co-workers (1963) calculated that a room painted with a coat of paint and ventilated at two air exchanges per hour would have an average mercury concentration of 210  $\mu\text{g}/\text{m}^3$  during the first 30 minutes and would emit mercury in decreasing amounts for six weeks. Agocs and co-workers (1990) found that having windows open fewer hours a day was associated with increased air mercury concentrations. It is not surprising that a weak association was found between air mercury concentrations and variables measuring the number of hours windows were open and the amount of paint used in our sample of 21 exposed homes. This may be due to the fact that questionnaire responses about room ventilation are relatively poor surrogates for actual measurements of air exchange.

After being applied to a wall, PMA apparently breaks down into elemental mercury, which, having a high vapor pressure, is then released from the wall. The results of the speciation analysis provide strong evidence that the major form of mercury released from painted surfaces is elemental mercury. The unidentified mercurial species probably does not represent phenylmercury, because nothing except elemental mercury was detected in the air above pure phenylmercury. This unidentified fraction is more likely to be oxidized mercury, possibly formed by recent use of oxidizers in the house, (*i.e.*, chlorine bleach), or ozone levels in ambient air, which will rapidly convert elemental mercury to Hg (II).

Although the difference in mercury concentrations in dust from the exposed and unexposed homes did not reach statistical significance at the  $P = 0.05$  level, the number of dust samples may not have been large enough to detect an important difference if it was present. An earlier study (Agocs *et al.* 1990) found significantly higher dust mercury concentrations in exposed homes than unexposed homes.

Those results suggest that mercury vapors emitted into the air may settle and accumulate in carpets, posing an increased health hazard to young children who are more likely than adults to be exposed to dust on the floor.

Mercury can be added to exterior latex paint at mercury concentrations up to 2,000 mg/L. In exterior paints, mercury kills mildew after the paint is applied, in addition to acting as a preservative in the can (Train 1976). It is not known how quickly mercury emitted from exterior latex paint dissipates into the outside air; therefore, persons who apply exterior latex paint may be exposed to mercury from this source. Persons who inadvertently, or purposely use exterior paint on the interior walls may be at considerable risk of excess mercury exposure.

On June 28, 1990, the EPA announced that mercury compounds would no longer be added to interior latex paint, effective August 20, 1990. However, paints formulated prior to August 20, 1990, which contain mercury compounds can continue to be sold. Furthermore, no restrictions currently prevent consolidated/recycled paint containing  $\leq 200$  mg/L from being sold for use as interior paint. The fact that we found air mercury concentrations as high as 1  $\mu\text{g}/\text{m}^3$  in a home painted with a paint containing <200 mg/L raises questions about the safety of these consolidated/recycled paints.

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