Mercury Flooring Testing and Mitigation: Guidance for Environmental Professionals

This guidance is for environmental testing and mitigation of exposure to mercury vapor from mercury-containing polymer floors (typically a soft poured-in-place floor in a gymnasium from 1990s or earlier). It should not be used to develop plans for handling mercury vapor from a spill.

Determine if a floor contains mercury

The Minnesota Department of Health (MDH) recommends that a sample of a floor suspected to contain mercury be analyzed by a laboratory to determine the mercury content. If the floor contains less than 1 part per million (ppm) mercury, it can be assumed that the flooring was not manufactured using a mercury-containing catalyst.

If the floor contains less than 20 ppm mercury, it is unlikely that exposures to mercury vapor in the gym could reach levels of concern. Care should be taken to limit possible exposures when these floors are removed or modified in the future. In addition, there may be state and federal disposal requirements for the flooring material due to the mercury content (see “Long-term Planning”, below).

If the floor contains 20 ppm mercury or more, the mercury vapor concentration in the gym may approach or exceed levels of health concern under some conditions. Therefore, MDH recommends testing the mercury vapor concentration in these gyms under a variety of conditions as described below.

MDH mercury vapor exposure guidelines

MDH recommends that the general public should not be exposed to short-term (acute or one hour) mercury air concentrations above 1800 ng/m³. This conservative criterion protects all people, including sensitive individuals, such as pregnant women and children.

For longer term exposures, MDH recommends that gym teachers should not be exposed to more than 750 ng/m³ mercury vapor during 40 hour work weeks averaged over the school year. Children exercising in the gym will have a greater respiration rate than teachers. Therefore, their exposure should be limited to 750 ng/m³ during 16 hours or less per week averaged over the school year.

MDH long-term mercury vapor exposure guidelines are based on the EPA Integrated Risk Information System Reference Concentration of 300 ng/m³ for chronic exposures. These recommendations assume that students and teachers are not exposed to additional significant, long-term sources of mercury vapor other than the gym.
Mercury vapor testing

Real-time mercury vapor analyzers (e.g. some models of Lumex, Jerome) do an excellent job of detecting mercury vapor concentrations at any single point in time. The minimum detection limit for an instrument used to measure mercury vapor concentrations in a school or in an area where the public may be exposed should be 300 nanograms per cubic meter (ng/m³) or less. It is important to remember that the data describes the concentration at one point in time. At any other time, if conditions (e.g. temperature, ventilation) have changed, the mercury vapor concentration will be different.

Other methods of mercury vapor testing can be used (e.g. NIOSH 6009), but they require chemical analysis of samples that are taken over extended periods of time. Averaging mercury vapor concentrations over time, as these methods do, may result in more realistic exposure data. In addition, they may remove some sampling recording bias. However, unless sample collection is guided by real-time sampling with a real-time mercury vapor analyzer, the maximum exposure concentrations are not likely to be measured. Further, these methods can be more complex and expensive than real-time measurements.

Mercury vapor concentration is related to ventilation

Mercury evaporates very slowly from materials that contain mercury. Increasing the ventilation of the gym is an effective way to decrease mercury vapor concentrations. When the ventilation is turned off, mercury vapor concentrations will slowly increase. Figure 1 is a graph that shows how mercury vapor concentrations in a gym over a 24 hour period can change when there are changes in ventilation. After the ventilation is turned on, the mercury vapor concentration decreases relatively rapidly over a 1-2 hour period. When the ventilation is turned off, the mercury vapor concentration slowly increases. Because ventilation affects mercury vapor concentrations, it is important to stabilize air movement in a gym for some time prior to measuring mercury vapor concentrations.

Figure 1: Impact of ventilation on mercury vapor concentration in a gymnasium

This figure is a demonstration of possible air concentrations in a gym over 24 hours. It is compiled from a model suggested by available data and is not actual data from a gym.
**Mercury vapor concentration is related to temperature**

Mercury evaporates much faster when it is hot than when it is cold. An MDH study (unpublished) suggests that the rate mercury is emitted from mercury-containing floors doubles for approximately every 9°F increase in floor temperature. Therefore, measuring mercury vapor concentration in a room during different seasons is important for estimating long-term exposures to mercury.

**Seasonal changes in emission rate and ventilation**

The temperature of a gym floor and the ventilation of a gym will vary according to the seasons. This seasonal variation in temperature and ventilation will result in seasonal changes of mercury vapor concentrations. Figure 2 shows an example of mercury vapor concentrations that may be found in a gym with a mercury-containing floor over 12 months.

*Figure 2: Seasonal change in mercury vapor concentration in a gymnasium (normal ventilation)*

If a gym is tested during the winter when floor temperature is low, mercury vapor concentrations may be low. However, in the spring, summer and fall the floor temperature can be much higher. In addition, active (mechanical) ventilation may also be limited during these seasons. Due to these factors, the highest mercury vapor concentrations are typically found in the late spring, summer and early fall. The MDH ventilation calculator can help environmental professionals to predict mercury vapor concentrations under different conditions; or to suggest ventilation rates for maintaining acceptable mercury vapor concentrations at different floor temperatures. The calculator is a tool that generates an estimate from the best available model. However, it is not likely to be accurate for all gyms under all conditions. Mercury vapor concentrations used to determine possible exposures to people should only be inferred from actual sample measurements and not from model results. Figure 3 shows an example of the
effect of increasing ventilation in the gym on the mercury vapor concentrations in the spring, summer and fall. In the examples shown, the average exposures from August 15 through June 15 for teachers and students would be 2275 ng/m$^3$ under normal ventilation (Figure 2) and 825 ng/m$^3$ under the increased ventilation schedule (Figure 3).

**Figure 3: Seasonal change in mercury vapor concentration in a gymnasium**  
(March to November, warm weather ventilation)

This figure is a demonstration of possible air concentrations in a gym with additional, active warm weather ventilation. It is compiled from a model suggested by available data and is not actual data from a gym.

The 10 month school day average in the non-ventilated example shown in Figure 2, of 2275 ng/m$^3$, is a long-term average exposure that exceeds MDH exposure guidelines for both short-term and long-term exposures to mercury vapor. Additional ventilation or mitigation is necessary to protect public health in this example. The 10 month school day average, of 825 ng/m$^3$, in the increased ventilation example shown in Figure 3, is an average calculated from very uncertain data. It is likely that if mercury vapor concentrations were measured a day before or a day later, the data would be different. Yet the data suggest that the 10 month average is within 10% of the MDH long-term criterion of 750 ng/m$^3$. Given the many possible sources of variability, MDH considers the exposures from this spring through fall ventilation example to be consistent with the MDH guidelines for long-term exposure. For this example, additional ventilation above the increase already in place is not necessary. However MDH does recommend that additional sampling be conducted over the next year to confirm that the mercury vapor concentrations have decreased. If increased ventilation was necessary to achieve a school year average below MDH guidelines, long-term mitigation and ventilation controls need to be in place to assure that mercury vapor concentrations remain below these levels even as staffing changes occur.

**What should be done to evaluate and mitigate exposures?**

Mercury vapor exposure calculations discussed throughout this information sheet are limited to exposures in school gyms from mercury-containing floors. They do not include additional exposures to mercury vapor, including exposures to mercury vapor from gym flooring that may
occur in rooms adjacent to a gym or to mercury vapor from unrelated mercury spills. If school year average exposures above 750 ng/m$^3$ may occur for more than 40 or 16 hours per week for teachers or students, respectively, contact the MDH Indoor Air Program (http://www.health.state.mn.us/divs/eh/air/contact.htm).

It is important to remember that exposures to mercury have been occurring since the floor was installed. A few days of additional exposure will not greatly increase risk. Actions to limit future exposures can be carefully planned. It is unlikely there would be a need for immediate intervention. However, student or teacher exposures above 1800 ng/m$^3$ should be avoided.

If sampling shows:

- Mercury vapor concentration over 1800 ng/m$^3$:
  1. Confirm that the mercury vapor analyzer is operating properly.
  2. Do not allow use of the gym until mercury vapor concentrations are shown to be below 1800 ng/m$^3$.
  3. Increase ventilation.
  4. Verify (by retesting) that increasing ventilation has reduced mercury vapor concentrations to less than 1800 ng/m$^3$. Once levels are below 1800 ng/m$^3$, the gym can be used in the short-term, so long as further testing verifies year-round average concentrations at or below 750 ng/m$^3$.
  5. Discuss long-term ventilation and mitigation options with building engineers, consulting with the MPCA and MDH as necessary.
  6. Make appropriate adjustments to the yearly ventilation schedule to assure that the school year average concentration is 750 ng/m$^3$ or below.
  7. Retest during other seasons, especially during the summer, to verify exposure concentrations and to ensure exposure criteria are met.
  8. Implement an operations and maintenance plan for the ventilation equipment to ensure ventilation rates remain consistent in future years.
  9. If ventilation adjustments do not sufficiently reduce the school year average to less than 750 ng/m$^3$, additional actions including removal of the flooring should be considered. Continue to supply adequate ventilation to maintain mercury vapor concentrations below 1800 ng/m$^3$ and to minimize mercury exposures until the flooring is removed.

- Mercury vapor concentration between 750 ng/m$^3$ and 1800 ng/m$^3$:
  1. Confirm that the mercury vapor analyzer is operating properly.
  2. Retest under similar (normal) conditions within a few days.
  3. If the concentration is still 750 – 1800 ng/m$^3$, increase ventilation to achieve 750 ng/m$^3$ or below:
     * If this is not possible due to heating costs or ventilation constraints, determine whether it may be possible to increase ventilation during certain months to keep the school year average concentration at 750 ng/m$^3$ or below.
  4. Make appropriate adjustments to the yearly ventilation schedule to assure that the school year average concentration is 750 ng/m$^3$ or below.
5. Retest at least once per season to assure that the school year average concentration is 750 ng/m\(^3\) or below.
6. If ventilation adjustments do not sufficiently reduce the school year average, additional actions including removal of the flooring should be explored. Continue to supply adequate ventilation to maintain mercury vapor concentrations below 1800 ng/m\(^3\) and to minimize mercury exposures until exposures can be sufficiently reduced (for example by: adding ventilation or by removing the flooring).

- Mercury vapor concentration 750 ng/m\(^3\) or below:
  1. Confirm that the mercury vapor analyzer is operating properly.
  2. Retest seasonally to assure that the school year average concentration is 750 ng/m\(^3\) or below:
     * Make necessary adjustments to the yearly ventilation schedule if there are exceedances.
  3. If ventilation does not maintain this school year average, additional actions including removal of the flooring should be explored.
  4. Plans should be developed to assure that an adequate ventilation schedule is maintained until the floor is removed.

**Long-term planning**

Ventilation should be maintained at levels that assure average year-round mercury vapor concentrations are less than 750 ng/m\(^3\). If changes are made to the heating, air conditioning or ventilation in the school, or if there are changes to the gym that may affect mercury emissions or ventilation, mercury vapor concentrations in the gym should be measured again. If removal of the mercury-containing floor will not occur for a number of years (regardless of mercury vapor concentrations in the gym), it is important that records are maintained and that the institutional memory of the issues related to mercury-containing floors is preserved.

Prior to removing mercury-containing flooring, the school should contact the MPCA for information on disposal. A contractor with experience in removing hazardous floorings should be engaged for removal of the flooring. Appropriate measures, including mercury vapor monitoring and maintenance of negative pressure in the gym, should be taken to assure that staff and students are not exposed during removal and replacement of the gym floor.
MEMO

To: Stephen Lee, Supervisor
   Emergency Response Team
   Minnesota Pollution Control Agency

Via: Rita Messing, PhD, Supervisor
     Site Assessment and Consultation Unit

From: Carl Herbrandson, PhD, Toxicologist
      Site Assessment and Consultation Unit

Date: January 30, 2007

Re: Mercury cleanup concentrations

This memo explains mercury vapor concentrations that have been used by MDH to give advice at various mercury spill sites, and is a synopsis of Minnesota Department of Health rationale for mercury vapor guidance concentrations.

MDH advice is based on two health-based criteria:

1) 300 ng/m³: This is an EPA Reference concentration (RfC) and is a safe chronic exposure concentration for a lifetime. This RfC is protective of the general public, including sensitive individuals.

2) 1800 ng/m³: This is a California Reference exposure level (REL) and is a safe acute exposure concentration for 1 - 1 hour exposure per day. The acute REL was derived specifically to protect sensitive individuals – e.g. fetuses carried by pregnant women. Use of this acute number is also appropriate for other sensitive individuals such as children and women who may become pregnant.

MDH recommends that MPCA consult appropriate MDH staff if you are in doubt about application of mercury guidance.

There is no single way to clean and clear all houses or buildings where there are spills.

It is important to remember that the concentrations you measure in a room are not only a function of the amount of mercury spilled, but also a measure of:

1. ventilation
2. how recently and the degree to which a mercury source is disturbed prior to measurement
3. room temperature
4. the surface area of a mercury source
5. the age of the source
Therefore, higher concentrations will be measured in a room when there is:
1. minimum ventilation;
2. a lot of movement (especially disturbance of the source – for instance, walking on a contaminated carpet or sitting on a contaminated couch);
3. a spill with a large surface area (vacuuming or sweeping will increase surface area);
4. high temperature in the room, and;
5. a recent source.

While the concentration of mercury vapor in the “breathing zone” is important, our biggest concern (besides a spill in an oven or a heating vent!) is a source that is in a carpet, a bed, or a piece of furniture, where someone may have an extended, direct exposure. It is important to think about the behavior of people in the room. Could there be a large mercury vapor emission where they lie down and read, watch TV, or sleep? We are especially concerned about spills in locations where a child may lie down or play. Spots in a carpet may be > 10,000 ng/m³ even when the “breathing zone” concentration throughout most of a home is 500 ng/m³ or less. We have seen limited exposures to concentrations near 50,000 ng/m³, over time, lead to serious health impacts. Our concern about the potential for extended exposures to high concentrations is why we are, at times, more concerned about the tracking of a spill, than we are with exposures to the initial spill.

Does measuring the mercury vapor concentration in 5 locations in a single room assure that all hot spots will be found? No, but it probably has a better chance of finding all of the “hot spots” than traditional, static methods. If the Lumex operator is astute, understands how mercury behaves in indoor air, and considers human behaviors and how they may impact exposures, he or she can increase the chances that an appropriate cleanup will occur.

### Application of MDH Guidance numbers

Mercury toxicity depends on cumulative exposure (concentration x time = exposure). Therefore, MDH suggests the following for site-specific guidance.

**300 ng/m³ is a long term (residential) exposure limit.**

At sites, this often translates to:
- 500 ng/m³ - clearance of a residence. This is a maximum concentration at multiple locations in the breathing zone in every room (not an average concentration). This is higher than the exposure limit because it is a spot measurement, not an average; and mercury emissions from the source will decrease as an oxide skin forms (up to 50% decrease over a few months or year) – or as micro-droplets evaporate.
- 800 ng/m³ - clearance of a workplace or school. This is higher than the residential number because time of exposure is typically limited to about 40 hours per week. It should be applied to measurements taken in the breathing zone. While this number should be applied as an average, it has typically been looked at as a maximum.

For example, when applying this number: When breathing zone samples are taken in many places in a room, 1200 ng/m³ may be an OK one spot maximum for a room in a school or a workplace (similar to the residential 500
ng/m$^3$, above). This higher number could be applied and be protective depending on an evaluation of:
  - location of spill (classroom vs hallway or closet); and
  - type of contamination (big vs small spill, or large vs small area);
  - ventilation during testing (off but typically on).
300 ng/m$^3$ has been applied as a clearance concentration at some schools (based on the 2005 joint MDH, MPCA information sheet) because of the trepidation about parental concerns and having residential numbers below school numbers.

**1800 ng/m$^3$ is a short term exposure limit (1 hr average exposure) for pregnant women and children.**

At sites, this may translate to:
- for most adults (adult males and women who will not get pregnant):
  - 50,000 ng/m$^3$ – for “walking through”
  - 5-20,000 ng/m$^3$ – for a short time (15 minutes, or so)
  - 5,000 ng/m$^3$ – for up to an hour, or so
- for women who may get pregnant and all children:
  - 1800 – 5000 ng/m$^3$ – for a short time (<15 min)

**OSHA numbers** are appropriate when exposure to mercury is an expectation of someone’s job (for example a recycling facility or, possibly, a dentist office). Consult the Attorney General’s office if this needs clarification. MDH does not review OSHA numbers, and exposure of the general public to chemicals near the OSHA limits may result in adverse health effects.

**Personal Property**

Application of guidance to contaminated clothing, washing machines, jewelry, motor vehicles or other personal property can be problematic. Guidance for any cleanup should reflect the potential exposures and the likelihood that an exposed individual is sensitive to mercury toxicity. In addition, the possibility that the mercury can be cleaned (as may be the case with mercury contamination on the soles of shoes) should be considered. MDH does not have enough information about the extent of exposure that may occur, from these contaminated items, to develop consistent cleanup numbers. But caution is advised.

**Workplace exposures for State employees:**

OSHA standards allow 40 hr/week exposures to mercury vapor at up to 50,000 ng/m$^3$, without PPE (MN OSHA Standard). However, OSHA standards do not apply to MDH (and MPCA) employee exposures to mercury. Exposure guidelines for MDH (and MPCA) employees are the same as exposure guidelines for the general public. This is because mercury exposure is not an expectation for state agency jobs.
Personal on-the-job exposure:

While longterm exposure limits are typically yearly exposure averages, it is usually easier to break exposures down into weekly or monthly time blocks. Therefore, think about your own personal exposure in terms of your weekly average work exposure (40 hour). To keep your average exposure below the recommended 300 ng/m$^3$ (24/7) exposure, workplace exposures (adjusted for differences in breathing rates and ambient air mercury at and away from work) should be limited to about 800 ng/m$^3$ for a 40 hour work week. This is approximately equivalent to 30,000 ng/m$^3$ for 1 hour; 10,000 ng/m$^3$ for 3 hours; 1000 ng/m$^3$ for 30 hours. This conversion to higher exposures over shorter time periods may not be protective for a sensitive individual (see section below).

If you are pregnant – or plan to be pregnant:

Your weekly work exposure should not exceed the longterm 800 ng/m$^3$ average for a 40 hour week, and, in addition, you should limit your 1 hour maximum exposures to 1800 ng/m$^3$. Also, limit the number of 1 hour exposures near 1800 ng/m$^3$ to 1 per 24 hours. Another way to estimate an acceptable exposure is to calculate your exposure in 2 hour averages and to keep the average below 800 ng/m$^3$. This would assure that an hourly exposure is below 1800 ng/m$^3$ and that your longterm exposure average is below 800 ng/m$^3$. 
DATE: August 23, 2007

TO: School Administrators

FROM: Dale F. Dorschner, Supervisor, Indoor Air Unit
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Rita Messing, PhD, Supervisor, Site Assessment and Consultation Unit
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SUBJECT: High Levels of Mercury

We are writing to notify you about possible high levels of mercury in air caused by off-gassing of mercury from some synthetic (rubber-like, polyurethane) floors, most commonly found in gyms. Concentrations of mercury in air that exceed levels of health concern have been observed in several gyms with these floors. Determining the actual exposures that may occur in a gym is not always simple. However, the levels of mercury vapor in air can be reduced to levels below health concern by mechanical ventilation with fresh air (for example, in one situation, 2 air exchanges per hour was enough to reduce the concentrations of mercury).

Merely opening windows and doors, without an active system pulling in outside air, does not appear to provide sufficient ventilation to reduce the mercury vapor to safe levels. We recommend that gyms be actively ventilated with fresh air beginning at least two hours before the gym is occupied and continuing throughout the period of use.

Mercury was used as a catalyst (up to 0.2% by weight) in the curing process for some synthetic gym floors manufactured from the 1960s until the mid-1990’s. These floors give off mercury vapor continuously. The mercury vapors can accumulate to relatively high levels in poorly ventilated spaces, even in large spaces such as gyms. Increases in mercury vapor to levels of health concern, is especially problematic in the summer because higher temperatures increase the amount of mercury off-gassing from the flooring material.

MPCA and MDH will be giving a presentation on mercury in schools, including mercury issues associated with these synthetic gym floors, at the Minnesota Association of School Administrators Conference this fall; however because the highest levels of mercury in gyms have been found in the summer, we are notifying you about this problem now.

MDH published a Health Consultation about a year ago with some preliminary findings. This document is available at http://www.atsdr.cdc.gov/HAC/pha/MercuryVaporReleaseAthleticPolymerFloors/MercuryVaporReleaseFloorsHC092806.pdf or http://www.health.state.mn.us/divs/eh/hazardous/topics/mercuryvapor.pdf

We are continuing to investigate this problem and will inform you as new information becomes available. If you have questions or concerns, please feel free to contact us.

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For directions to any of the MDH locations, call (651) 201-5000 * An equal opportunity employer

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