Health Consultation

Mercury-Containing Polyurethane Floors in Minnesota Schools

MERCURY VAPOR RELEASE/ATHLETIC POLYMER FLOORS

SEPTEMBER 28, 2006

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

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HEALTH CONSULTATION

Mercury-Containing Polyurethane Floors in Minnesota Schools

MERCURY VAPOR RELEASE/ATHLETIC POLYMER FLOORS

Prepared By:

Minnesota Department of Health
Environmental Health Division
Under a Cooperative Agreement with the
U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry

FOREWORD

This document summarizes public health concerns related to potential exposures to mercury-containing polyurethane floorings in Minnesota schools. It is based on a formal evaluation prepared by the Minnesota Department of Health (MDH). For a formal evaluation, a number of steps are necessary:

- *Evaluating exposure:* MDH scientists begin by reviewing available information about environmental conditions. The first task is to find out how much contamination is present, where it is found, and how people might be exposed to it. Usually, MDH does not collect its own environmental data. Rather, MDH relies on information provided by the Minnesota Pollution Control Agency (MPCA), the US Environmental Protection Agency (EPA), and other government agencies, private businesses, and the general public.

- *Evaluating health effects:* If there is evidence that people are being exposed—or could be exposed—to hazardous substances, MDH scientists will take steps to determine whether that exposure could be harmful to human health. MDH's report focuses on public health— that is, the health impact on the community as a whole. The report is based on existing scientific information.

- *Developing recommendations:* In the evaluation report, MDH outlines its conclusions regarding any potential health threat posed and offers recommendations for reducing or eliminating human exposure to pollutants. The role of MDH is primarily advisory. For that reason, the evaluation report will typically recommend actions to be taken by other agencies—including EPA and MPCA. If, however, an immediate health threat exists, MDH will issue a public health advisory to warn people of the danger and will work to resolve the problem.

- *Soliciting community input*: The evaluation process is interactive. MDH starts by soliciting and evaluating information from various government agencies, the individuals or organizations responsible at a location, and community members. Any conclusions are shared with the individuals, groups, and organizations that provided the information. Once an evaluation report has been prepared, MDH seeks feedback from the public. *If you have questions or comments about this report, we encourage you to contact us.*

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Purpose

In July 2005 the Minnesota Department of Health (MDH) received a request from the Minnesota Pollution Control Agency (MPCA) to evaluate the potential health hazard that may accompany exposures to mercury vapor in gymnasiums in schools with mercury-containing polyurethane floors. Data from the MPCA was subsequently received by MDH in October 2005. This Health Consultation describes potential exposures to mercury vapor from these floors and documents recommendations by the Minnesota Department of Health to prevent adverse health impacts.

Background

Some polyurethane or rubber-like floorings manufactured from about 1960 through at least 1980 contained up to 1,000 milligrams per kilogram (mg/kg) mercury in phenyl mercuric acetate (Reiner 2005) or other organo-mercuric salts, which were used as catalysts. Polyurethane floors that may have contained organo-mercuric salts were manufactured by 3M, Robbins Sports Surfaces, American Biltrite Rubber Co., Inc., Athletic Polymer Systems, Crossfield Products, Mondo Rubber, Pitzer Inc., Selby Battersby & Company, and Sportan Surfaces, Inc. (Boyle 2006; Gandee 2003).

Within the past few years it has been shown that some of these floors release significant amounts of elemental mercury into the air (ATSDR 2003a; 2004). The mechanism of this release is not understood. However, releases have been shown to elevate the concentration of mercury in air in rooms with these floorings. In addition, floors abraded during resurfacing or removal may release more mercury than floors that are in use (Boyle 2006). Apparently, polyurethane floors were mostly used in gymnasiums of schools, but they have also been seen in school and prison cafeterias. Polyurethane use in non-public facilities, including private schools, health clubs or other athletic facilities, has not been investigated.

Two additional issues have not been investigated and will not be discussed in this document.

- There is no information on whether mercury can be rubbed off of the surface of the floorings or if there is mercury in dust on the floors. The bioavailability of any mercury from polyurethane floorings in the non-vapor form is not known.
- Mercuric salts are reported to have been used as catalysts in the production of other polyurethane products including athletic equipment, mats and medical training aids. These products have not been studied.

Elemental mercury: a human health hazard

Most human exposure to mercury is from the consumption of fish containing small amounts of methyl mercury. Exposure to elemental mercury is less frequent, but for some individuals may be significant. Considerable information is available on the MPCA website about the hazards of mercury in the environment, contamination and cleanup (http://www.pca.state.mn.us/air/mercury.html).

Mercury in the environment

Elemental mercury can be found in soil, water, and air. Elemental mercury is the only metal that is a liquid at room temperature. In addition, elemental mercury is volatile. Mercury volatilizes very slowly. If air overlying elemental mercury is replaced rapidly, the mercury concentration will not build up to dangerous levels. On the other hand, in a closed room, mercury vapor concentrations from even a small amount of mercury can reach dangerous levels.

Methods for measuring mercury vapor in the environment

Historically, mercury vapor has been measured by drawing air through a cell, or tube, that changes color relative to the mercury concentration in the air. These hopcalite cells are not very sensitive and require large volumes of air to measure a mercury concentration in air. Using hopcalite cells, measuring air concentrations at a single location in a house can take 8 hours. In addition, hopcalite cells are expensive, and each hopcalite cell can only be used once.

The development of sensitive realtime mercury vapor analyzers has allowed investigators to repeatedly measure mercury vapor concentrations in seconds. A Lumex (RA-915+) Mercury Vapor Analyzer, used by the MPCA's Mercury-free Zone Program to survey schools, is capable of reporting concentrations down to 10 nanograms per cubic meter (ng/m^3) to an attached display in 3 different time intervals: 1second sampling; 10-second mean, and; the mean of 3 x 10-second readings. While 1 second reporting intervals are handy for scanning an area and trying to locate a spill, MDH recommends recording 30-second results when characterizing mercury vapor concentrations at any specific location. The Lumex requires about 20 liters of air per minute for analysis.

Locating and cleaning mercury contamination

Realtime mercury vapor analyzers, such as the Lumex, are very useful for finding mercury sources. If there is some air movement in a room, it is likely that mercury vapor concentration inches from a mercury source will be much higher than mercury vapor concentrations in the breathing zone or in other places in a room. Once the source is located, it should be cleaned following recommended procedures. Cleanup instructions are available from the MPCA at: http://www.moea.state.mn.us/publications/hhw-mercuryspills.pdf
In addition the New York State Department of Health has good cleanup information at: http://www.health.state.ny.us/nysdoh/environ/hsees/mercury_brochures/cleanup.htm or http://www.health.state.ny.us/nysdoh/environ/hsees/mercury_brochures/docs/cleanup.pdf

Pinpointing the source of contamination and removing the source is the best way to lower mercury vapor concentrations indoors. Scrubbing an entire carpet, or cleaning walls may not decrease mercury vapor concentrations within a building. On the other hand, removing a floor that is offgasing (including contaminated sublayers), or even removing a small source, may result in a rapid decrease in the mercury vapor concentration. When elemental mercury vapor is released from a spill, a floor or a coal-burning power plant, it will stay in the air until it is converted to a reactive gaseous species and is stripped from the atmosphere by wet or dry particulates and aerosols (EPA 1997). The half-life of mercury vapor in the atmosphere is about 1 year.

Elemental mercury exposures and health

Dermal (skin) exposure to elemental mercury and ingestion (swallowing) of elemental mercury are unlikely to be significant sources of exposure, because dermal and gastrointestinal absorption of elemental mercury is limited (ATSDR 1999). For elemental mercury, vapor exposures are of greatest concern.

MDH develops safe chemical exposure criteria for the general public and individuals with no expectation of workplace exposure. MDH uses health-based reference values from different organizations, based on availability, in the following preferential order: MDH Health Risk Values (HRVs) promulgated in rule, EPA Integrated Risk Information System (IRIS) reference concentrations (RfCs), and other health-based values, such as Agency for Toxic Substances and Disease Registry (ATSDR) Minimum Risk Levels (MRLs) and California Reference Exposure Levels (RELs).

Chronic Air Exposure Reference Values for Elemental Mercury

EPA's integrated risk information system (IRIS) database specifies an RfC for chronic exposure to mercury vapor of 300 ng/m^3 (EPA IRIS 2004). An RfC is an exposure concentration that is not expected to result in adverse health effects to most people, including sensitive subpopulations, exposed over a lifetime. The mercury RfC is derived from multiple studies of occupational exposures. Most studies were conducted with employees in chlor-alkali or fluorescent light bulb plants who were exposed to mercury vapor. The observed critical effects included hand tremors, memory disturbances, and slight subjective and objective evidence of autonomic nervous system dysfunction. The lowest observable adverse effects concentration (LOAEC) in the occupational studies used by EPA to develop the RfC was 25,000 ng/m^3. Affected workers had mean whole blood mercury concentrations of 10–12 micrograms per liter (µg/L). When adjustment is made from a worker exposure of 8 hours per day for 5 days per week to a maximum residential exposure of 24 hour a day, 7 days per week, the adjusted lowest observable adverse effect concentration ($LOAEC_{adj}$) = 9,000 ng/m^3. An uncertainty factor of 10 was applied to compensate for the use of a LOAEC (as opposed to a concentration at which no effects are seen) and for variations in human sensitivity, and an uncertainty factor of 3 for lack of studies on the reproductive and developmental effects of elemental mercury. The resulting RfC (300 ng/m^3) is assumed to be a safe average exposure level for a lifetime. The calculation of an RfC assumes that there is a threshold level for effects. A threshold for toxicity from mercury vapor exposure is presumed in the standard model used by EPA for noncarcinogens.

The California Office of Environmental Health Hazard Assessment (CA OEHHA) derived a Reference Exposure Level (REL) for chronic inhalation exposure to mercury from the same studies used to develop the IRIS RfC. However, instead of using the cumulative uncertainty factor of 30 used by EPA, CA OEHHA has adopted an uncertainty factor of 100. This is based on a factor of 10 for the uncertainty of using an LOAEC exposure instead of a "no observable adverse effects concentration" (NOAEC) when calculating the REL. It also includes a factor of 10 for human intraspecies variability. The California REL for mercury (elemental and inorganic) is 90 ng/m^3 (CA OEHHA 2004).

The Agency for Toxic Substances and Disease Registry (ATSDR) has a health-based chronic minimum risk level (MRL) for mercury of 200 ng/m^3 (ATSDR 1999). This MRL is calculated from the same data used to calculate the IRIS RfC. However, the MRL calculation assumes that in an occupational exposure, one third of the daily inhaled air each working day is contaminated. The EPA RfC assumes that half of the daily inhalation, five days a week, is contaminated.

MDH uses IRIS RfCs for giving exposure advice when there is not an HRV. MDH has some concern that the EPA RfC uncertainty factor of 30 may not sufficiently protect sensitive subpopulations given that the basis of the underlying value is an LOAEC. The California chronic mercury REL does provide this additional protection. However, practical application of the mercury REL at contaminated sites may be problematic because personal exposure to mercury from other sources, including dental amalgams, may be in the range of the REL. MDH therefore recommends the EPA criterion (300 ng/m^3) over the MRL and REL.

Acute Air Exposure Reference Value for Elemental Mercury and Inorganic Salts

California OEHHA developed an acute REL for mercury vapor based on developmental effects in the offspring of exposed rats. Central nervous system effects in pups were noted following exposure of dams to 1.8 mg/m^3 for 1 hour/day during gestation. A cumulative uncertainty factor of 1,000 is attached to this REL because it is based on a LOAEC (10x), the primary study was an animal study (10x), and human response to all chemicals is variable (10x).

The CA OEHHA acute REL for mercury vapor is 1,800 ng/m^3, with a critical endpoint of reproductive or developmental effects (CA OEHHA 2004).

Discussion

Identification of mercury-containing floors

No protocol has been published for determining whether a floor contains mercury. However, experience suggests that it is likely that a room with a mercury-containing floor will have mercury vapor concentrations throughout the room greater than 50 – 100 ng/m^3. Confirmation of the floor content can be obtained by analyzing a small sample of the floor.

Application of health criterion to potential exposures in school gyms

Because the neurodevelopmental endpoint for elemental mercury toxicity is likely the most sensitive, concern for exposure is focused on the exposure of a pregnant, or soon to be pregnant, gym teacher or teenage student. EPA RfCs are intended to be protective exposure concentrations for student, teacher and their fetuses, over the school year, for a lifetime. Table 1 shows calculations of weekly mercury inhalation for a teacher and a student.

Mercury inhalation (ng/wk) =

$$\sum \text{Exposure duration (hr/wk) x Exposure concentration (ng/m}^3\text{) x Ventilation rate (m}^3\text{/hr)}$$

Total inhalation exposure at the RfC, assuming a normal set of exposures and receptor inhalation (ventilation) rates, are about 25,800 and 25,500 ng/week for a teacher and a student, respectively. Exposure at these levels are not expected to pose any health risk. When outdoor, indoor and sleeping exposure concentrations are assumed to be central tendency values, the gym mercury vapor concentration criteria are 740 and 1200 ng/m^3 for teachers and students, respectively. The teacher criterion is very similar to previous MDH recommended exposure criterion for workplace exposure (800 ng/m^3) for an individual with no expectation of occupational mercury exposure (ATSDR 2003b). The difference is mainly the result of assumptions in this document that exposures, other than workplace exposures, occur.

If a teacher may be in the gym 40 hours per week, gym mercury vapor concentrations should be limited to 740 ng/m^3. Given the behavior of mercury in the environment, it is likely that a single sample will not accurately represent the integrated exposure of a teacher or a student during a day or a week. A device that measures personal exposures (dosimeter badge) down to 400 – 800 ng/m^3 (24 and 8 hour exposures) would be useful. But currently the minimum detection limit of personal dosimeters is around 1,500 - 10,000 ng/m^3 (48 and 8 hour exposures). Alternatively, time-weighted factoring of measured concentrations at many different locations can be used to conservatively estimate possible exposures.

Table 1: Calculated weekly mercury exposures

		Exposure Duration (hr/wk)				Exposure Concentration (ng/m^3)				Ventilation Rate (m^3/hr)				Hg Inhalation (ng/wk)
		Gym	Outdoor	Indoor	Sleeping	Gym	Outdoor	Indoor	Sleeping	Gym	Outdoor	Indoor	Sleeping	
Teacher	RfC exposure	40	14	58	56	300	300	300	300	0.8	1	0.4	0.3	25,800
	Potential Exposure					**736 ***	4	55	55					25,808
Student	RfC exposure	10	14	88	56	300	300	300	300	1.9	1	0.4	0.3	25,500
	Potential Exposure					**1189 ***	4	55	55					25,507

* Exposure limits for teacher and student at 40 and 10 hours exposure per week, respectively

Mercury product disposal

RCRA Land Disposal Restrictions Third Final Rule establishes a high-mercury treatment subcategory for wastes with total mercury content greater than 260 milligrams per kilogram (mg/kg). High-mercury wastes must be roasted or retorted (RMERC) or incinerated (IMERC) if organics are present. RMERC residues must meet the Toxicity Characteristic Leaching Procedure (TCLP) standard of 0.20 mg/liter (mg/l), and IMERC residues must meet the TCLP standard of 0.025 mg/l prior to land disposal. Low-mercury wastes are not subject to a specific treatment requirement but must meet a numerical treatment standard of 0.025 mg/l TCLP. [64 FR 28951] In Minnesota, the MPCA should be contacted before removing a mercury-containing polyurethane floor.

Flooring containing mercury may be below the mercury concentration limit for the Resource Conservation and Recovery Act (RCRA) control, and some flooring material samples may pass the TCLP (ATSDR 2003a; 2006). Therefore upon removal, some or all of these polyurethane floors may not be considered hazardous waste. Because formulations, installation and post-application care for each floor may have been different, each floor should be tested on removal. Removed polyurethane flooring not characterized as hazardous waste, may be discarded in a lined landfill maintaining good leachate control. Mercury in the environment can be washed into aquatic systems, or it can volatilize and be transported to other watersheds where it can be deposited. Once in the aquatic environment, mercury is methylated by sulfate-reducing bacteria and may enter aquatic food chains. Methylmercury accumulates in the food chain, especially in fish that are then consumed by people (see Chapter 6 EPA 2001 for review). This indirect route-of-exposure to mercury in the environment is the largest source of mercury exposure for most people (excluding individuals exposed to high concentrations as a result of an elemental mercury spill). MDH and MPCA along with other state and federal agencies support a general policy of minimizing mercury releases to the environment.

Mercury-free Zone Program and mercury vapor data from Minnesota schools

Surveys of mercury vapor concentrations have been conducted in a large number of schools in Minnesota as part of the Mercury-free Zone Program, sponsored by the MPCA (http://www.pca.state.mn.us/programs/mercury-free/index.html). The goal of this program has been to remove elemental mercury from schools, and to date the program has removed over 1100 pounds of mercury from over 500 schools. In addition, over 200 schools have been assessed for contamination and missed mercury. MDH has been advising this program on the human health concerns related to mercury exposure, and on issues related to risk communication and environmental chemistry since the program's inception in 2001.

The Mercury-free Zone Program is focused on removal of mercury from school infirmaries and science classrooms. Some school gymnasiums have also been monitored by MPCA Mercury-free Zone staff when they have visited schools. However, coverage has been irregular, and data are incomplete. The Mercury-free Zone has only 1 full–time staff person, so resources are limited. There has been no coordinated effort to identify mercury-containing polyurethane floors in Minnesota or to compile data on these floors. Data available to MDH are shown in Table 2.

Table 2: Mercury vapor concentrations in Minnesota School gyms

School Name	City	Date	Mercury Vapor Concentration (ng/m^3)	Location of reading
Brainerd HS (Main Gym)	Brainerd	7/7/2004	**380 - 420**	**ambient**
			42,300	hatch in floor closest to gymnastics balcony
			32,600	hatch at opposite end of gym
			1,200	blue rubber flooring outside of weight room
Brainerd HS (Gymnastics Rm)	Brainerd	7/7/2004	**700**	**ambient**
			1200	some of the tumbling mats in gymnastics room
			2500	protective wraps on balance beam
Highland Park HS (Fieldhouse)	St. Paul	8/22/2002	**130**	**ambient**
			1490	floor along west side of room
			77,190	wrap on foot of balance beam
Arlington HS (Aux Gym)	St. Paul	4/4/2005	**700**	**ambient**
			818	middle of poly floor
			3208	in volley ball support pole hole
Harding HS (Fieldhouse)	St. Paul	10/21/2004	**1369**	**ambient (no ventilation running)**
		10/29/2004	**319**	**ambient (ventilation running)**
Como High (Fieldhouse)	St. Paul	4/6/2005	**2900**	**ambient (no ventilation running)**
			12,000	volleyball support pole hole

Table 2 shows data from 5 schools in Minnesota with polyurethane gym floors (6 rooms) that apparently offgas elemental mercury. Data from these gyms are similar to data seen in other states. Four of the schools are in the St. Paul School District.

MPCA has worked with the Health and Safety (H&S) Coordinator at the St. Paul City Schools to control mercury vapor concentrations in St. Paul City Schools since the MPCA and MDH's first visit to Highland Park High School in August 2002. At that time there were elevated mercury vapor concentrations in a science classroom. The classroom was cleaned to safe levels (less than 300 ng/m^3 in breathing zones). Additional sampling at the school showed that the gym had ambient mercury vapor concentrations of about 130 ng/m^3. Higher concentrations were noted in small enclosed areas where air circulation was minimal, but exposures were also unlikely in these areas (e.g. protective wraps on a balance beam, directly on the floor on one side of the gym). The H&S Coordinator was advised that air circulation and ventilation would likely keep exposures to levels below those of concern. The MPCA Mercury-free Zone staff has worked with the St. Paul School's H&S Coordinator over the past few years to assure that student and teacher exposures to mercury remain below 800 ng/m^3 over extended periods and do not exceed 1,800 ng/m^3 for any 1 hour period.

The highest ambient mercury vapor concentration reported for a MN school gym was 2,900 ng/m^3. This was measured in a gym without ventilation running. Data from another school where measurements were taken with ventilation off and then 8 days later with ventilation on, showed a reduction of 77% in mercury vapor concentration. These data suggest that significant reduction in mercury vapor concentrations can be achieved by running ventilation in a gym.

Completion of an exposure pathway

In order to have a completed exposure pathway there must be: a source of contamination; a mechanism or media of environmental transport; a point of exposure in the environment; a route of exposure to a person; and an actual exposed receptor population. Mercury-containing floors: contain mercury; emit elemental mercury into the air; mercury vapor can concentrate in rooms (gymnasiums) with mercury-containing floors; students, teachers and visitors can and do breath this mercury vapor at measured concentrations. For these completed exposures to impact health, mercury concentrations in a gymnasium must exceed the health criterion calculated above, and the exposure frequency and duration for a woman of child-bearing age must be greater than or equal than the exposure presumed when calculating the health criterion. Data suggest that if the ventilation systems are not running, exposures in gyms with mercury-containing floors may exceed levels of health concern.

Children's Health Considerations

As part of MDHs and ATSDR's commitment to protect children, children's health issues are addressed explicitly in health consultations. Mercury vapor toxicity criteria developed by the EPA (chronic RfC) and California OEHHA (acute REL) are intended to be protective of adults, children, pregnant women and fetuses. In addition, the exposure scenarios used in this health consultation included reasonable maximum exposures for pregnant women and pregnant teenagers. These result in conservative exposure recommendations that should be protective of children.

Summary / Conclusions

Currently, when a floor is identified as a source of mercury vapor by the MPCA Mercury-free Zone program, MPCA recommends the school use the ventilation system in the room to reduce air concentrations. In addition, the school is informed that emissions from the floor as well as disposal of the floor in the future may be an issue. MPCA / MDH recommendations have been that longterm air concentrations should be kept below 800 ng/m^3 and that exposures of one hour or more to levels at or above 1,800 ng/m^3 should not occur.

Data from Minnesota, Michigan, Oregon and Ohio suggest that a gym with a mercury-containing polyurethane floor and with no ventilation running may reach concentrations up to 3,000 ng/m^3 mercury vapor in ambient air (higher concentrations have not been observed, but may be possible). When ventilation is turned on, the mercury vapor concentrations decrease significantly. In one school in Minnesota where testing was conducted with ventilation off and on, the decrease in mercury vapor concentration with the ventilation on was 77%.

Available information and data suggest that it is likely that there are additional schools in Minnesota that have mercury-containing polyurethane floors. In addition, MPCA has been contacted by a consultant for the Minnesota Department of Corrections for advice on replacing a Tartan floor in the cafeteria of a state prison. There are no mercury vapor data from this site.

MDH Recommendations

- Teachers (especially teachers who are or may become pregnant) should not be exposed to mercury concentrations greater than 740 ng/m^3 for 40 hours per week, and students (especially students who are or may become pregnant) should not exercise in a gym with greater than 1200 ng/m^3 for 10 hours or more per week.
- MPCA should develop a protocol to assure consistent collection of information from affected facilities.
- Data acquired by the Mercury-free Zone program on mercury-containing floors should be compiled.
- MPCA should work with the Department of Education to notify schools
    - about concerns related to mercury-containing polyurethane floors;
    - about how to identify floorings that may be of this type; and,
    - about ventilating rooms with mercury-containing polyurethane floors.

Public Health Action Plan

- MDH will continue to provide public health advice to schools with mercury contamination and will assist the MPCA and the Department of Education with developing informational materials.

This Public Health Consultation was prepared by:

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Certification

This Minnesota Public Health Consultation on Mercury-containing polyurethane floors in Minnesota schools was prepared by the Minnesota Department of Health under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It was completed in accordance with approved methodologies and procedures existing at the time the health consultation was initiated. Editorial review was completed by the Cooperative Agreement partner.

Technical Project Officer, CAT, SPAB, DHAC

The Division of Health Assessment and Consultation (DHAC), ATSDR, has reviewed this health consultation and concurs with its findings.

Team Lead, CAT, SPAB, DHAC, ATSDR