Public Health Consequences of Mercury Spills: Hazardous Substances Emergency Events Surveillance System, 1993–1998

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We analyzed data from states that participated in the Hazardous Substances Emergency Events Surveillance (HSEES) system maintained by the Agency for Toxic Substances and Disease Registry to describe the public health consequences of mercury releases. From 1993 through 1998, HSEES captured 406 events in which mercury was the only substance released. Schools and universities, private residences, and health care facilities were the most frequent locations involved in mercury events, and human error was the contributing factor for most of the releases. Fourteen persons experienced adverse health effects as a result of the releases. An additional 31 persons had documented elevated levels of mercury in the blood. No fatalities resulted. Evacuations were ordered in 90 (22%) of the events, and the length of evacuation ranged from 1 hr to 46 days. Mercury spills have a significant public health impact and economic burden. Some actions that could potentially lessen the consequences of mercury spills are to switch to mercury-free alternatives, train people in the safe handling and disposal of mercury, and keep mercury securely stored when it is necessary to have it on hand. ***Key words*****: acute exposure, chemical spills, hazardous substances, mercury, surveillance.** ***Environ Health Perspect*** **110:129–132 (2002). [Online 10 January 2002]** ***http://ehpnet1.niehs.nih.gov/docs/2002/110p129-132zeitz/abstract.html***

With increased media reporting of mercury spills has come increased awareness of and interest in preventing spills and their associated public health impact (*1–6*). Preventing mercury spills will help lessen the total amount of mercury available to bioaccumulate in the environment. We analyzed data from the Agency for Toxic Substances and Disease Registry's (ATSDR) Hazardous Substances Emergency Events Surveillance (HSEES) system to describe mercury releases and their adverse public health consequences in participating states.

Mercury is commonly found in high school and university laboratories, health care facilities, and old industrial sites, as well as in the home (*6–8*). Products containing mercury include thermometers, thermostats, batteries, fluorescent light bulbs, dental amalgams, blood pressure devices, reagents, electrical equipment, and switches (*8–10*). Mercury exists in several forms, but these can be grouped into three major categories: metallic mercury, inorganic mercury, and organic mercury. Metallic mercury, also known as elemental mercury, is the shiny, silver-white metallic liquid found in thermometers (*9*). Because spills generally involve the release of metallic mercury, we focus here on metallic mercury, hereafter referred to simply as mercury.

Exposure to mercury can occur through inhalation, dermal absorption, or ingestion (*8*); however, it is absorbed well only via inhalation (*9*). Acute exposure can cause respiratory symptoms (cough, burning sensation in the lungs), gastrointestinal symptoms (nausea, vomiting, diarrhea, metallic taste in the mouth), increased blood pressure and heart rate, skin rashes, eye irritation, and fever (*7,9,11*). Acute exposure to extremely high levels of mercury can affect the kidneys and developing fetuses. Additionally, inhalation of sufficiently high concentrations of mercury can be fatal. Children and pregnant women are especially sensitive to mercury exposure (*9*).

Methods

Since 1990, the ATSDR has maintained an active, state-based surveillance system to collect and analyze information on hazardous substances emergency events. The pilot phase of the surveillance system took place from 1 January 1990 through 31 December 1992. We analyzed data from 1993–1998, the most recent time period for which complete data are available. Ten states participated in HSEES for the entire time period: Alabama, Colorado, Iowa, New York, North Carolina, Oregon, Rhode Island, Texas, Washington, and Wisconsin. An additional four states participated during portions of the time period: Minnesota (1995–1998), Missouri (1994–1998), Mississippi (1995–1998), and New Hampshire (1993–1996).

HSEES events are defined as sudden, uncontrolled, or illegal releases of at least one hazardous substance that had to be removed, cleaned up, or neutralized according to federal, state, or local law. A substance is considered hazardous if it might reasonably be expected to cause adverse human health outcomes. Threatened releases also are included in HSEES if *a*) the amount threatened to be released would have required removal, cleanup, or neutralization under federal, state, or local law and *b*) the threat led to an action to protect the public health (e.g., rerouting traffic, closing a road, or ordering an evacuation). Events involving only petroleum are excluded from HSEES.

Standardized data-collection forms were used to obtain information on each event, including chemicals released, number of victims, and evacuations. A victim is defined as a person experiencing at least one documented adverse health effect (such as respiratory irritation or chemical burns) that likely resulted from the event and occurred within 24 hr of the release. The HSEES system does not identify the immediate cause of the adverse health effect other than the event itself. State health department personnel used a variety of sources (e.g., records and oral reports of state environmental agencies, police and fire departments, and hospitals) to collect information about the hazardous events. All data were entered into a computerized data entry system designed by ATSDR, and data were transmitted quarterly to ATSDR for quality control checks and analysis. ATSDR provided the states with a training manual to ensure uniformity.

The analyses were restricted to events in which mercury was the only chemical released. During 1993–1998, 94.6% of the events involved only one chemical. The data were analyzed using SAS for Windows (*12*). Descriptive statistics are presented for the number of mercury events per year, locations involved in mercury releases, causal factors contributing to the releases, categories of victims, types of adverse health effects, severity and disposition of the victims, types of personal protective equipment (PPE) worn, decontaminations, and evacuations. A more detailed analysis of causal factors was done

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for events occurring in schools and private residences where children were likely to be involved in the release. We used the 1990 industrial classification system to categorize the locations (*13*). When information on a variable was missing for less than 10% of the events, the number of those missing was not specified.

Results

From 1993 to 1998, participating state health departments reported 413 events involving mercury to the HSEES system; 405 of these events involved mercury only. Of these 405 events, 389 (96%) occurred in fixed facilities, and 16 (4%) were transportation related (Table 1). The largest number of mercury events (n = 125) occurred in 1998. Half of the events occurred in two states, Colorado (n = 105) and New York (n = 98) (Table 2). The amount of mercury released ranged from 1 mL to 300 gallons.

Schools and universities (n = 79, 20.3%), private residences (n = 65, 16.7%), and health care facilities (n = 64, 16.5%) were the most frequent locations involved in fixed-facility events, accounting for about half of all events (Table 3). Causal factors contributing to fixed-facility releases included human error resulting from mistakes made by a person handling mercury (n = 155, 66.5%), equipment failure (such as a broken gas regulator, blood pressure device, thermometer, or electrical equipment; n = 53, 22.7%), deliberate damage (n = 10, 4.3%), illegal or unauthorized dumping (n = 5, 2.1%), and other (n = 10, 4.3%). (Causal factor information was not collected until mid-1995.) Of the 16 transportation-related events, 12 (75%) occurred during ground transport (i.e., truck, van, tractor, or automobile), and four (25%) occurred during air transport. Most of the events occurred between 0601 hr and 1800 hr (88%) and most occurred on a weekday (87%). Information on the time of day the event occurred was missing for 86 (21%) of the events.

Victims. Six mercury events (1.5% of all mercury events) produced 14 victims. Thirty-six percent of the victims (n = 5) were employees, 36% (n = 5) were students, and 29% (n = 4) were members of the general public. No responder-victims were reported in mercury events. The five employee-victims resulted from one event involving air transportation. Five students were victims in two events at elementary or secondary schools, and four victims who were members of the general public were involved in three events in private residences. Slightly more victims were male than were female (54% vs. 46%). Age information was missing for nine (64%) of the victims.

The 14 victims sustained a total of 18 injuries or symptoms, but most victims (71%) suffered only one injury or symptom as a result of a mercury release. Seven (39%) victims had nausea, five (28%) had skin irritation, four (22%) had headaches, and two (11%) had hyperventilation.

Most victims (n = 12, 86%) were transported to a hospital; nine were treated and released, and three were kept for observation but did not receive treatment. Two victims (14%) were seen by private physicians within 24 hr of the event. None of the victims died. At the time of event occurrence, none of the five employee victims wore any type of PPE.

Additionally, 31 persons had documented elevated levels of mercury in the blood. Thirty (97%) were members of the general public who were exposed in four events in private residences, and one (3%) was an employee who was exposed in an event in an agricultural facility. Twenty-four members of the general public were exposed in one event involving private residences after a group of children found mercury in an alley and took it to their homes. Most of the persons with documented mercury exposure (n = 28, 90%) were treated at a hospital and released, two (7%) were kept at a hospital for observation but did not receive treatment, and one (3%) was admitted to a hospital. Slightly more of the persons exposed to mercury were male than were female (56% vs. 44%), and their mean age was 16.5 years (range 2–39 years).

Decontamination, evacuation, and in-place sheltering. Of the 405 mercury events, decontamination was more likely at the scene than at a medical facility (86 events vs. 5 events; Table 4). Some persons may have been decontaminated at both locations. Evacuations were ordered in 90 (22%) of the 405 events (89 in fixed facilities and one in a transportation-related event). Eighty-four (93%) of the evacuations were of a building or an affected part of a building; the other six (7%) evacuations involved criteria other than an affected building. The median number of persons evacuated was 10 (range 1–2,080). Information on the number of persons evacuated was missing for 18 (20%) of the events. The duration of evacuation ranged from 1 hr to 46 days.

Actions were taken to mitigate, contain, or control the release in 355 (88%) of the events. Follow-up health investigations were initiated after 10 (2.5%) of the events. A contingency plan was followed during 351 (87%) events. The type of contingency plan that was followed was reported for 313 of these events. Sixty-two percent (n = 194) used a hazardous materials (HazMat) team's or other response team's standard operating procedure, 17% (n = 53) used an incident-specific ad hoc plan, 16% (n = 50) used a company's standard operating procedure, 1% (n = 4) used the Superfund Amendments and Reauthorization Act (SARA) Title III incident command system (*14*), and 4% (n = 12) used some other type of plan.

Table 1. Number of mercury events, by year and type of event, HSEES, 1993–1998.

Year	Type of mercury event: Fixed facility no. (%)	Type of mercury event: Transport no. (%)	No. mercury events	No. total events	Total mercury events (%)
1993	38 (97.4)	1 (2.7)	39	3,834	1.0
1994	58 (95.1)	3 (4.9)	61	4,215	1.4
1995	48 (98.0)	1 (2.0)	49	5,311	0.9
1996	51 (91.1)	5 (8.9)	56	5,486	1.0
1997	72 (96.0)	3 (4.0)	75	5,513	1.4
1998	122 (97.6)	3 (2.4)	125	5,986	2.1
Total	389 (96.0)	16 (4.0)	405	30,345	1.3

Table 2. Number of mercury events, by state and type of event, HSEES, 1993–1998.

State	Type of event: Fixed facility (no.)	Type of event: Transport (no.)	Total events: No.	Total events: Percent
Alabama	2	0	2	0.5
Colorado	98	7	105	25.9
Iowa	12	0	12	3.0
Minnesota	21	0	21	5.2
Mississippi	2	0	2	0.5
Missouri	20	0	20	4.9
New Hampshire	2	0	2	0.5
New York	96	2	98	24.2
North Carolina	12	1	13	3.2
Oregon	8	1	9	2.2
Rhode Island	8	0	8	2.0
Texas	36	3	39	9.6
Washington	46	2	48	11.9
Wisconsin	26	0	26	6.4
Total	389	16	405	100.0

Schools and universities. Causal factor information was available for 9 (39%) of the 23 events occurring in universities. Human error was most often reported as the contributing factor (n = 5, 56%). Other factors were equipment failure (n = 2, 22%), illegal or unauthorized dumping (n = 1, 11%), and other (n = 1, 11%). For events occurring in elementary or secondary schools (n = 56), a more detailed analysis of causal factors showed that children playing with mercury most frequently caused the event (n = 25, 45%), followed by a dropped or spilled vial, instrument, or container (n = 18, 32%). Other causes of events occurring in elementary or secondary schools were equipment failure or broken equipment (n = 3, 5%) or were unknown (n = 10, 18%).

Most events (n = 76, 96%) occurred on a weekday. The time of day the event occurred was reported for 62 (78%) of the events. All 62 events occurred between 0601 hr and 1800 hr. Thirty-five evacuations were ordered (more than one-third of all evacuations; 44% of all school or university events). The median number of persons evacuated was 32 (range 3–2,080), and the duration of evacuation ranged from 1 to 78 hr. Information on the number of persons evacuated was reported as unknown for 8 (23%) of the 35 events.

Private residences. Detailed information on causal factors contributing to releases in private residences was available for 53 (82%) of the 65 events. A dropped or spilled vial, instrument, or container contributed to 42% (n = 22) of the releases. Other factors contributing to the releases included children playing with mercury (n = 17, 32%), equipment failure or broken equipment (n = 9, 17%), deliberate damage (n = 2, 4%), and other (n = 3, 6%). Most events occurred between 0601 hr and 1800 hr (n = 34, 76%) and most occurred on a weekday (n = 48, 74%). Time of day the event occurred was missing for 20 (31%) of the 65 events. Nineteen evacuations were ordered (more than one-fifth of all evacuations; 29% of all private-residence events). The median number of persons evacuated was 4 (range 2–58), and the length of evacuation ranged from 4 hr to 46 days. Information on duration of evacuation was unknown for 3 (16%) of the events.

Health care facilities. Causal factors contributing to releases at health care facilities were available for 42 (66%) of the 64 events. Human error accounted for most of the releases (n = 32, 76%). Other factors were equipment failure (n = 8, 19%), improper mixing, and other (n = 1, 2% each). Most events occurred between 0601 hr and 1800 hr (n = 40, 89%) and most occurred on a weekday (n = 56, 88%). The time of day the event occurred was missing for 19 (30%) of the 64 events. No victims were reported in mercury events occurring in health care facilities. Eighteen evacuations were ordered (20% of all evacuations, 28% of all health care facility events). The median number of persons evacuated was 3 (range 2–42), and the duration of evacuation ranged from 1 hr to 132 hr. Information on the number of persons evacuated was unknown for 7 (39%) of the events.

Table 3. Fixed-facility mercury events, by location type, HSEES, 1993–1998.

Location	Frequency	Percent
School/university	79	20.3
Private residence	65	16.7
Health care facility	64	16.5
Public utilities	49	12.6
Manufacturing	39	10.0
Public administration	19	4.9
Transportation[a]	13	3.3
Wholesale or retail trade	8	2.1
Agriculture/mining/construction	6	1.5
Entertainment and recreational services	6	1.5
Professional and related services[b]	6	1.5
Finance, insurance and real estate	5	1.3
Business and repair services	5	1.3
Active military duty	4	1.0
Lodging place	1	0.3
Unknown	20	5.1
Total[c]	389	99.9

[a]Includes warehousing/storage, postal service, and air transportation facilities. [b]Includes libraries, museums, and research and development facilities. [c]Percentages may not total 100% due to rounding.

Table 4. Number of events with decontamination, by population group and location of decontamination, HSEES, 1993–1998.

Location of decontamination	Frequency	Percent of total events (n = 405)
Employees at scene	37	9.1
Responders at scene	37	9.1
General public at scene	12	3.0
Employees at medical facility	2	0.5
Responders at medical facility	0	0
General public at medical facility	3	0.7

Discussion

The number of mercury events captured by the HSEES system has been increasing since 1995, and in 1998 mercury was one of the 10 most commonly released substances reported to HSEES. The total number of HSEES events has also been increasing. It is unclear why the number of mercury events has been increasing in recent years. Possible reasons include increased awareness of the mercury problem, enhanced reporting, or changes in the incidence of mercury spills. Colorado reported the largest number of mercury events during 1993–1998. This is most likely attributable to Colorado's mercury response program, which provided monitoring and cleanup assistance to schools and hospitals that contacted the state health department. This project ceased in 1998, and in the last 2 years the number of reported mercury events in Colorado has fallen. During 1993–1998, most mercury releases occurred in nonindustrial areas. Schools and universities, private residences, and health care facilities were the most common locations where mercury releases occurred. Human error, such as mishandling mercury-containing instruments, was the contributing factor for most mercury releases.

Mercury events were less likely to result in victims than nonmercury, single-substance events (1.5% vs. 7.5%). No responders were victims of mercury events; however, more than 9% of the victims of nonmercury events were responders. The most common adverse health effects experienced by victims in nonmercury events were respiratory irritation (35.5%) and eye irritation (14.6%); these types of adverse health effects were not reported by victims of mercury events. No deaths were associated with mercury events. However, the HSEES system documents acute health effects, and acute health effects of mercury are generally not fatal, unlike events involving other chemicals such as ammonia and chlorine, where acute exposure can be fatal. About one-quarter of all mercury events required an evacuation, compared with 9% of nonmercury events. The maximum length of evacuation for mercury events was longer than for nonmercury events (46 days and 34 days, respectively), but the median number of persons evacuated in mercury events was half that of nonmercury events (10 and 20 persons, respectively). The longer evacuation

times in mercury events are necessary most likely because it is difficult to remove mercury from furniture, carpet, floors, and walls (*9*).

The HSEES system collected data in only 14 states during 1993–1998. Each state has different reporting requirements for the amount of hazardous substances released that has to be removed, cleaned up, or neutralized. Therefore, a lot of the smaller releases, such as releases occurring in private residences, may not be captured by the system. The number of persons with documented elevated levels of mercury in the blood is most likely underestimated because many of the exposed persons were probably not tested. However, HSEES is the only federal hazardous substances release database designed specifically to assess and record the public health consequences of hazardous substances emergency events.

Children playing with mercury cause many of the incidents in schools and homes. Because of mercury's shiny color and ability to form into little balls or beads, it is often appealing to children (*9*). When mercury is spilled, it forms small beads and spreads, making it more difficult to find and remove (*9*). It is especially difficult to remove mercury spills from carpets, which usually must be disposed of as hazardous waste (*11,15*). If a mercury spill is not properly cleaned up, the mercury can remain in cracks and crevices for long periods of time and cause continuous exposure to mercury vapors (*9*).

According to the HSEES state coordinators, cleanup of small mercury spills is generally handled by the spiller (*16*). For larger mercury spills, the parties responsible for cleanup vary by state. In Minnesota, the spiller (the responsible party) is required to clean up a spill regardless of the amount spilled. If the responsible party is not identified or does not have the means to do the clean up, the U.S. Environmental Protection Agency (EPA) would be called for assistance if the Minnesota Pollution Control Agency did not have the capability to do the cleanup or if there were other extenuating circumstances. In New York, the spiller is responsible for cleaning up a mercury spill regardless of the amount spilled. For small spills, such as a thermometer, the New York State Department of Health (NYSDOH) provides technical guidance on how to conduct the cleanup. For larger spills, NYSDOH recommends that the spiller retain a professional environmental remediation service that is experienced in mercury cleanup.

Cleanup of mercury spills can be costly (*10*). Eight ounces of mercury spilled in a school in Minnesota cost $3,780 to clean up (*16*). In New York, students playing with a jar of mercury and spreading it around a classroom caused a spill that cost $24,000 to clean up (*16*). Children playing with and breaking open hundreds of mercury switches in yards and alleys in Springfield, Ohio, necessitated an 8-day cleanup by the EPA costing approximately $100,000 (*6*). The spill was reported to the U.S. EPA by the local fire department and county emergency management agency. In Wisconsin, a school, bus, fast food restaurant, and bowling alley were contaminated with mercury by students on a field trip. Cleanup for this incident cost approximately $240,000 (*16*).

Many schools and hospitals are working to reduce or eliminate mercury, and some states are currently discussing a legislative ban on mercury in schools (*5,6,11,15,17*). The Mercury in Schools Project was developed by the University of Wisconsin Solid and Hazardous Waste Education Center (SHWEC) under a grant from the EPA's Great Lakes National Program Office. Information on mercury, such as fact sheets and mercury curricula, can be easily accessed from the project website (*6*).

In September 2000, 11 national retailers jointly issued a press release in which they pledged to stop selling mercury thermometers and instead offer mercury-free alternatives such as digital electric thermometers, glass gallium–indium–tin thermometers, and flexible forehead and ear canal thermometers (*5*). The nation's largest manufacturer of glass mercury thermometers plans to stop production of mercury thermometers (*5*).

Besides reducing exposure and adverse health effects, switching to mercury-free alternatives can have economic benefits for health care facilities and industries by lowering disposal costs (*15,17*). Disposing of one 55-gallon drum of contaminated mercury and mercury waste costs approximately $3,500 (*15*). Evacuations of long duration after a mercury spill may have a negative financial effect (e.g., lost productivity) as well as a negative emotional effect on evacuees (*4*).

Although there is growing concern about cultural and religious uses of mercury as a potential source of exposure to mercury (*9*), to our knowledge, there are no documented cases of religious, ethnic, or ritualistic uses of mercury in the HSEES database. However, there is a recent increased trend in spills from necklaces made in Mexico that contain mercury in a glass pendant (*18,19*). The mercury is spilled when the glass is broken or the mercury leaks from the pendant. The HSEES system documented five events involving a necklace with a broken mercury pendant during 1993–1998 (*16*).

There is a continued need to follow good public health practices such as *a)* using mercury-free alternatives when feasible; *b)* if no alternatives are available, ensuring that students, health care workers, and others who might work with mercury are taught safety precautions in use and disposal of mercury (*10*); *c)* if no alternatives are available and a school must have mercury on site, storing mercury in a locked container in an area out of the children's sight (*9*); and *d)* teaching children about the dangers of playing with mercury to prevent mercury exposures in the home. In addition, mercury should be stored in a secured area, and proper care must be taken when disposing of mercury-containing products in the home (*9*).

Conclusion

Proper handling of mercury is unlikely to cause adverse health effects, but improper handling can cause a substantial public health impact and economic burden (*10,15*). Identifying and recognizing risk factors for mercury spills will help to reduce and prevent the number of spills. Health care facilities and schools as well as other facilities and private homeowners should investigate switching to mercury-free alternatives.

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