

# National Elemental Mercury Response Guidebook August 2018



# **National Elemental Mercury Response Guidebook**

**August 2018**

**“This memorandum is intended solely for guidance of EPA personnel. It is not a rule and does not create any legal requirements, substantive or procedural. EPA reserves the right to act in variance with this document and to change it at any time without public notice.”**

*This page intentionally left blank.*

## Table of Contents

1	Introduction.....	1
1.1	Purpose of Guidebook.....	1
1.2	Intended Audience .....	1
1.3	History of Action Level Development, Chemical-Specific Health Consultation for Joint EPA/ ATSDR National Mercury Cleanup Policy Workgroup: Action Levels for Elemental Mercury Spills, March 22, 2012 .....	2
1.4	Forms of Mercury.....	2
1.4.1	Mercury Diffusion in the Indoor Environment.....	4
1.5	Description, Physical Properties and Classification of Elemental Mercury.....	4
1.6	Sources and Uses of Mercury.....	5
1.6.1	Sources of Elemental Mercury .....	5
1.6.2	Uses of Elemental Mercury .....	5
1.6.3	Mercury in Products Raising Public Concern .....	6
1.6.3.1	Skin Cream.....	7
1.6.3.2	Compact Fluorescent Light Bulbs (CFLs).....	7
1.6.3.3	Rubberized Gym Floors .....	7
2	Human Health Effects.....	8
2.1	Pathways of Exposure .....	8
2.2	Symptoms of Exposure.....	8
2.2.1	Acute Health Effects.....	8
2.2.2	Chronic Health Effects.....	9
2.2.3	Concerns for Pregnant Women and Children .....	10
2.3	First Aid for Exposure .....	11
2.4	Biological Sampling for Exposure .....	11
3	Initiation of the Response .....	11
3.1	Investigating Agency .....	11
3.2	Role of Public Health Department.....	12
3.3	EPA Response Authority to Elemental Mercury Spills.....	12
3.4	Request for EPA Assistance .....	13
4	OSC Initial Response.....	13
4.1	Before Leaving the Office .....	13
4.1.1	Initial Coordination .....	13

4.1.2	Other Response Support Sources .....	14
4.1.3	Other Appropriate Response Resources.....	14
4.2	Arriving at Spill Location.....	15
4.2.1	Conduct Responding State/Local Agency Debrief and Interview Property Owner .....	15
4.2.2	Obtain Signed Access Agreement .....	15
4.2.3	EPA Accounting Practices.....	16
4.2.4	EPA Enforcement Considerations .....	16
4.2.5	Public Outreach and Information.....	17
5	Initial Assessment and Screening/Sampling of Air with a Handheld MVA.....	17
5.1	MVA Startup and Performance .....	21
5.2	Initial Screening for Mercury Vapor .....	22
5.2.1	Potentially Exposed Humans and Animals.....	23
5.2.2	Residential.....	23
5.2.3	Non-Residential.....	25
5.2.4	Vehicle.....	25
5.2.5	Outdoors .....	26
5.3	Screening of Potentially Contaminated Items.....	26
5.4	Monitoring throughout all Stages of the Response .....	26
5.5	Clearance Screening/Sampling.....	27
6	Additional Media Screening, Sampling and Analytical Methods .....	27
6.1	General Discussion .....	28
6.2	Solids .....	28
6.2.1	Bulk Solids (soil, sediment, sludge, etc.) .....	28
6.2.1.1	Field Screening with MVA .....	29
6.2.1.1.1	In Situ Screening.....	29
6.2.1.1.2	Sampling and Field Screening.....	29
6.2.1.2	Sampling and Field Screening with Lumex RP-19C Attachment .....	30
6.2.1.3	Sampling and Laboratory Analysis.....	30
6.2.2	Residue (surface dust/film).....	31
6.3	Liquids (groundwater, surface water, etc.) .....	31
6.3.1	Sampling and Field Screening with MVA .....	32
6.3.2	Sampling and Field Screening with Lumex RP-91 Attachment .....	32
6.3.3	Sampling and Laboratory Analysis .....	32

6.4	Investigation-Derived Waste.....	34
6.4.1	Solid Samples .....	34
6.4.2	Liquid Samples .....	34
7	Exposure Limits.....	36
7.1	Mercury Vapor Inhalation Exposure and Limits.....	36
7.1.1	NIOSH .....	37
7.1.2	OSHA .....	37
7.1.3	ACGIH .....	37
7.1.4	ATSDR.....	37
7.1.5	EPA .....	37
7.2	Ingestion Exposure .....	38
7.3	Dermal Exposure .....	38
8	Relocation of Residents.....	38
8.1	Relocation Options.....	38
8.2	EPA Relocation Program.....	39
8.3	Release of Residential Clothing and Household Items.....	40
8.4	Site Security.....	41
9	Cleanup Process.....	41
9.1	Pre-Decontamination Procedures.....	42
9.1.1	Pre-Decontamination Documentation.....	42
9.1.2	House Tracking Database .....	43
9.2	Establishing Work Zones and Containment Operations .....	43
9.2.1	Establish Control Zones and Ingress / Egress Routes.....	44
9.2.2	Establish Ventilation / Air Management.....	44
9.2.3	Isolate Impacted Areas.....	45
9.2.4	Establish a Liquid Waste Management Plan .....	45
9.3	Specialized Products and Cleanup Tools .....	46
9.3.1	Elemental Mercury Response Products .....	46
9.3.1.1	Mercury Indicator Powder .....	46
9.3.1.2	Mercury Vapor Absorbent.....	46
9.3.1.3	Merconvap™ .....	47
9.3.1.4	Merconwipes™ .....	47
9.3.1.5	Hg Absorb™ .....	47

9.3.1.6	HgX® .....	47
9.3.1.7	DeconGel™ .....	47
9.3.1.8	Mercury Magnate™ Amalgamation Spill Powder .....	48
9.3.1.9	Powdered Sulfur .....	48
9.3.1.10	Shampoos .....	48
9.3.1.11	Products to Avoid .....	48
9.3.2	Elemental Mercury Cleanup Tools .....	49
9.3.2.1	Mercury Spill Kits .....	49
9.3.2.2	Mercury Vacuums.....	49
9.3.2.3	Mercury Hand Pumps.....	49
9.3.2.4	Small Spill Cleanup Tools.....	49
9.4	Removal Procedures.....	50
9.4.1	Screening Residential Clothing and Household Items .....	50
9.4.2	Removal of Elemental Mercury from Hard Surfaces .....	51
9.4.2.1	Physical Removal .....	51
9.4.2.2	Residual Treatment and Wash .....	54
9.4.2.3	Heat and Ventilation .....	54
9.4.2.4	Screen Interior Air Space .....	57
9.4.2.5	Optional Steps .....	57
9.4.3	Removal of Elemental Mercury from Carpeted Surfaces .....	58
9.4.4	Removal of Elemental Mercury from Wooden Floors .....	60
9.4.5	Removal of Elemental Mercury from Personal Items.....	61
9.4.5.1	Alternative Decontamination Methods for Porous Items.....	62
9.4.6	Removal of Elemental Mercury from Washers and Dryers .....	64
9.4.7	Removal of Elemental Mercury from Vehicles .....	65
9.4.8	Removal of Elemental Mercury in Plumbing.....	65
9.4.9	Removal of Dermal Mercury Contamination from Humans and Animals .....	65
9.4.10	Removal of Elemental Mercury from Soils and Other Outdoor Surfaces .....	67
9.4.11	Removal of Elemental Mercury Containers .....	72
9.4.12	Removal of Contaminated Soils and Sediments on Industrial Sites .....	72
9.5	Post-Cleanup Procedures .....	73
9.5.1	Air Sampling and Confirmation of Cleanup.....	73
9.5.2	Confirmation of Cleanup in Soils.....	73

9.6	Best Practices and Recommendations .....	74
9.7	Avoiding Common Mistakes.....	74
10	Disposal .....	75
10.1	Hazardous Waste versus Non-Hazardous Waste .....	75
10.1.1	Characteristically Hazardous Wastes .....	75
10.1.2	Household Hazardous Waste .....	75
10.1.3	Universal Waste .....	76
10.1.4	Non-Hazardous Waste .....	76
10.1.5	Listed Hazardous Wastes .....	76
10.2	RCRA Requirements .....	78
10.3	Transportation/Shipping .....	78
10.4	Disposal .....	80
10.5	Compliance with the Mercury Export Ban Act (MEBA).....	82
11	Restoration, Replacement and Reimbursement.....	83
11.1	Restoration.....	83
11.1.1	Post-Restoration Documentation .....	84
11.2	Replacement .....	84
11.3	Reimbursement.....	84
11.4	Demolition.....	84
12	Reoccupation.....	85
12.1	Obtaining Health Concurrence .....	85
12.2	De-List Letter from U.S. EPA.....	85
12.3	De-List Letter from Local Health Department.....	86
12.4	Assisting Residents in Reoccupying Homes.....	86
13	Responder Health and Safety .....	86
13.1	Personal Protective Equipment (PPE) .....	86
13.1.1	Respirators .....	87
13.1.2	Gloves, Booties and Suits .....	89
13.2	Controlling Ingestion .....	89
13.3	Worker Exposure Levels .....	89
13.4	Health and Safety Plan .....	90
13.5	Responder Decontamination .....	90



- Appendices ..... 92
- Appendix A ..... 93
- ATSDR Chemical Specific Health Consultation and Suggested Action Levels ..... 93
  - 1.0 Introduction..... 94
  - 2.0 Discussion..... 97
  - 3.0 Conclusions..... 107
  - 4.0 Recommendations ..... 108
  - 5.0 Appendices ..... 109
    - Table 1: Suggested Action Levels for Residential Settings ..... 109
    - Table 2: Suggested Action Levels for Other Locations ..... 111
  - 6.0 References..... 116
- Appendix B ..... 122
  - ERT SOP for Clearance Sampling ..... 123
- Appendix C..... 144
  - 1. Action Levels for Evacuation of Work Zone Pending Reassessment of Conditions ..... 145
  - 2. Air Sampling Data Sheet..... 147
  - 3. Air Sampling Decision Tree..... 148
  - 4. Consent for Entry and Access to Property ..... 150
  - 5. Contaminated Items Documentation Log..... 152
  - 6. Daily Safety Meeting Record ..... 153
  - 7. Decontamination Checklist ..... 154
  - 8. Example De-List Letter from Local Health Department ..... 156
  - 9. Example De-List Letters from U.S. EPA..... 157
    - a. Residence that was sampled but did not require decontamination..... 157
    - b. Residence that required decontamination ..... 158
  - 10. Equipment Supplies Checklist ..... 159
  - 11. Example Letter to Request U.S. EPA Assistance..... 161
  - 12. Mercury Screening Form for Land or Structures..... 162
  - 13. Residential Post-Decontamination Team Checklist ..... 164
  - 14. Example Post-Evacuation Letter to Health Department..... 165
  - 15. Example Public Outreach Documents ..... 166
    - a. Press Release..... 166
    - b. Letter to Resident..... 167

c.	Fact Sheet.....	168
16.	Residential Mercury Contamination Screening Checklist .....	169
17.	Example Relocation Letter .....	170
18.	Mercury Specific Vacuum Comparison Table.....	171
Appendix D .....		174
1.	EPA.....	175
a.	National Mercury Website .....	175
b.	Environmental Response Team (ERT) .....	175
c.	Emergency Response Technical Group (ERTG) .....	175
d.	Temporary Relocation Guidance.....	175
2.	ATSDR .....	175
a.	Chemical Specific Health Consultation and Suggested Action Levels.....	175
b.	ATSDR Mercury Website .....	175
c.	Toxic Substances Portal: Mercury .....	175
3.	National Institute for Occupational Safety and Health (NIOSH) .....	175
4.	Occupational Safety and Health Administration (OSHA) .....	175
5.	American Conference of Government Industrial Hygienists (ACGIH).....	176
6.	Centers for Disease Control and Prevention (CDC).....	176
7.	Find a Recycling Center .....	176
8.	Materials Safety Data Sheet (MSDS) for Mercury (Metal).....	176
9.	Companies that Recycle Mercury.....	176
10.	Federal Hazardous Waste Regulations: 40 CFR 261.5(e) .....	176
11.	Occupational Safety and Health Administration’s Safety and Health Standard for Protective Gear: 29 CFR 1910.134.....	176
12.	Comprehensive Environmental Response, Compensation Act’s Reportable Quantities, Mercury Releases: 40 CFR 302.6 (b) .....	176
13.	Mercury in Schools .....	176
Appendix E.....		179

## **Disclaimer**

The U.S. Environmental Protection Agency (EPA) expects to update this Guidebook as needed to ensure that it reflects the most current available residential elemental mercury cleanup technologies and best practices. While EPA will attempt to keep information in this Guidebook timely and accurate, the Agency makes no expressed or implied guarantees.

This Guidebook includes links to documents and information on non-EPA sites. Links to non-EPA sites and documents do not imply any official EPA endorsement of, or responsibility for, the opinions, ideas, data, or products presented at those locations, or guarantee the validity of the information provided. Links to non-EPA websites and documents are provided solely as pointers to information on topics related to residential elemental mercury cleanup that may be useful to EPA staff and cleanup contractors as well as state, county, and local responders.

## **1 Introduction**

The United States (U.S.) Environmental Protection Agency's (EPA) National Mercury Workgroup was formed in 2011 with representatives from the Office of Emergency Management (OEM), all ten Regions, the Environmental Response Team (ERT), and the Agency for Toxic Substances and Disease Registry (ATSDR). Prior to the formation of this workgroup, several Regions and ERT had developed various types of mercury response documents, including complete guidebooks with appendices, field guides, and fact sheets. Consistent with the National Approach to Response, the mission assigned to the National Mercury Workgroup was to develop a national elemental mercury spill response guidebook for Federal On-Scene Coordinators (OSC) and EPA's Special Teams across the country.

### **1.1 Purpose of Guidebook**

The National Elemental Mercury Guidebook is intended to be a nationally consistent, user-friendly guide that primarily addresses technical and administrative practices, specifically for EPA, for elemental mercury responses, including:

- communicating with property owners and residents,
- identifying response resources,
- conducting initial assessment,
- determining the extent of contamination,
- conducting monitoring and sampling,
- ascertaining action levels,
- determining mitigation options,
- establishing clearance and occupancy levels, and
- disposing of elemental mercury waste.

The primary focus of the guide is residential response, though much of the information can be applied to elemental mercury responses in schools and vehicles, as well as commercial elemental mercury spills. There are also resources in the appendices for elemental mercury cleanups of various types as well as links to mercury resources outside of EPA.

### **1.2 Intended Audience**

The National Elemental Mercury Guidebook is designed for OSCs, but may also be used by EPA cleanup contractors.

### **1.3 History of Action Level Development, Chemical-Specific Health Consultation for Joint EPA/ATSDR National Mercury Cleanup Policy Workgroup: Action Levels for Elemental Mercury Spills, March 22, 2012**

In 2000, ATSDR provided tables of action level guidelines for indoor air concentrations of elemental or metallic mercury in response to a request from both EPA and the state of Michigan. The action levels had previously been developed for individual sites and situations, but the tables summarized these guidelines in a succinct package for use by field personnel. The request was prompted by several small spills in homes caused by replacing or relocating natural gas regulators containing elemental mercury. The guidelines were designed to help risk managers at spill scenes in homes or other locations specific to elemental mercury gas regulators make decisions regarding cleanup, relocation, etc. A site-specific cleanup level for elemental mercury gas regulators in residential settings was set at 1.0 microgram per cubic meter ( $\mu\text{g}/\text{m}^3$ ) compared to the previously established “any use” residential action level of 0.3  $\mu\text{g}/\text{m}^3$ . Since their publication in 2000, these guidelines have been widely disseminated by users. As mentioned above, the National Mercury Workgroup was formed by EPA to develop consistent cleanup guidance for elemental mercury spills, including not only public health actions but also cleanup and sampling methods. As part of that effort, EPA requested that ATSDR update the 2000 guidelines to be included in a more comprehensive guidance. This health consultation, Chemical-Specific Health Consultation for Joint EPA/ATSDR National Mercury Cleanup Policy Workgroup: Action Levels for Elemental Mercury Spills, March 22, 2012, is hereafter referred to as the “health consultation.”

The health consultation (found in Appendix A) provides detailed justifications for action levels based on the ATSDR Chronic Minimal Risk Level (MRL) and EPA Reference Concentration (RfC). The recommended action levels for mercury vapor in residential settings were increased from 0.3  $\mu\text{g}/\text{m}^3$  to 1.0  $\mu\text{g}/\text{m}^3$  for normal occupancy and 10  $\mu\text{g}/\text{m}^3$  for isolation (e.g., evacuation, limited access) to limit or prevent exposure to the elemental mercury. Action levels for settings other than residential (e.g., schools, vehicles) are also based on ATSDR and EPA toxicity factors and adjusted to account for specific conditions as well as the assumed frequency and duration of exposure. Sections that describe when action levels should be adjusted to meet site specific conditions are included. The most useful features of the 2000 tables have been retained; new sections have been added that address issues related to the tables that have recurred during the past 17 years. Additional information to help On-Scene Coordinators and/or risk managers communicate risk is provided. Technological advances in detecting environmental mercury are also considered.

### **1.4 Forms of Mercury**

There are three forms of mercury: elemental mercury (described below), inorganic, and organic mercury. Elemental mercury and some types of mercury compounds are Comprehensive Environmental Response Compensation and Liability Act (CERCLA) hazardous substances but all mercury compounds are thought to be hazardous and can cause serious health problems.

This guidebook focuses on elemental mercury (also referred to as liquid or metallic mercury in this document) rather than the potential hazards associated with inorganic and organic mercury compounds. For information on inorganic or organic mercury please visit <http://www.epa.gov/mercury/>.

Elemental mercury is a shiny, silver-white, odorless liquid that is used in thermometers and other medical and industrial instruments, thermostats, electrical switches, dental fillings, and is also used industrially to produce chlorine gas and caustic soda. Elemental mercury is also used in herbal and religious remedies associated within certain spiritual practices and folk remedies in Latin American, Caribbean, and Asian cultures.

Elemental mercury will volatilize at any temperature above -38 degrees Fahrenheit (°F) and readily volatilizes at room temperature, creating an invisible odorless vapor. Since it volatilizes into the air, exposure to elemental mercury is mainly a concern for inhalation of vapors. This is of particular concern when elemental mercury is spilled in homes, where even a relatively small amount of elemental mercury can result in the accumulation of high levels of mercury vapors in the indoor air. In addition, elemental mercury can be easily tracked out to cause inhalation risks in other locations or to the environment.

As mentioned above, temperature has a profound effect on mercury vapor concentration. As a rough rule of thumb, mercury vapor pressures will double for every 10°F increase in temperature. As shown in Figure 1-1, the vapor pressure of mercury more than doubles between 50 to 68°F. If a structure where elemental mercury was spilled were re-inhabited and heated to normal levels, mercury levels would increase to over 1 µg/m<sup>3</sup>.

**Figure 1-1: Properties of Elemental Mercury**

Relative Vapor Density Air = 1	Freezing Point	Boiling Point	Vapor Pressure (mmHg)				
			32°F	50°F	68°F	86°F	104°F
7	-38°F	674°F	0.000185	0.000490	0.001201	0.002777	0.006079

Source: CRC 1969

Key:

mmHg = millimeters mercury

°F = degrees Fahrenheit

### 1.4.1 Mercury Diffusion in the Indoor Environment

Elemental mercury evaporates and spreads indoors in complex ways, which responders must understand in order to choose hypotheses and interpret measurements. First, responders must consider how much the mercury has been disturbed, since evaporation rate increases dramatically with increased disturbance (Figure 1-2). In addition, since mercury may not diffuse rapidly, detectors must be held close to surfaces that may contain elemental mercury. Also, heating and ventilation will not effectively rid materials visibly contaminated with liquid mercury; a drop 3 millimeters (mm) in diameter with a mass of 0.2 grams (g) would last at least three years indoors.

**GENERAL RULE OF THUMB:** At temperatures above 60°F, the elemental mercury concentration in the ambient air doubles for every 10 degrees of temperature increase.

**Figure 1-2: Effect of Disturbance on Evaporation of a Constant Total Volume of Elemental Mercury at 68°F**

Number of Drops	Volume per Drop (cm <sup>3</sup> )	Surface per Drop (cm <sup>2</sup> )	Surface Total (cm <sup>2</sup> )	Evaporation Rate (µg/h)
1	1	4.84	4.84	271
1,000	0.001	0.0484	48.4	2,710
10,000	0.0001	0.0104	104.2	5,835

Source: Euro Chlor 1998

Key:

cm<sup>2</sup> = centimeters squared

cm<sup>3</sup> = cubic centimeters

µg/h = micrograms per hour

In sum, elemental mercury can be challenging for responders because: (1) it is a liquid under conditions normally encountered and thus spreads and volatilizes rapidly, (2) it mixes with air slowly, (3) relatively small temperature increases lead to relatively large increases in evaporation, and (4) in extreme cases, vapors can recondense on surfaces away from the spill.

### 1.5 Description, Physical Properties and Classification of Elemental Mercury

Mercury (CAS# 7439-97-6, DOT# UN 2809, Hazard Class 8 (corrosive), chemical symbol Hg) is a metallic element. It is also known as quicksilver, azogue, or hydrargyrum. Elemental mercury is a dense [13.534 grams per cubic centimeters (gms/c<sup>3</sup>)], silver-white liquid at room temperature. Elemental mercury droplets that have been undisturbed may have a thin black oxide or sulfide coating on the surface. Unlike other metals, elemental mercury can volatilize, having a vapor pressure under ambient conditions of 0.0012 millimeters (mm). This property presents the greatest hazard because mercury enters the human bloodstream more readily through inhalation of the vapor than through ingestion or skin contact.

Elemental mercury vapor cannot be seen with the naked eye and is odorless to humans. Small amounts of spilled elemental mercury may produce enough vapors to reach hazardous levels in the immediate area of the spill. Liquid elemental mercury is insoluble in water by definition, however, it will continue to volatilize within the water column allowing for ecological and human uptake by ingestion. It is not flammable, but it may form toxic or explosive compounds at high temperatures.



**Photograph 1-1**

Elemental mercury forms alloys, known as amalgams, with most metals except iron, often releasing large quantities of heat in the process.

Due to the potential hazards posed by elemental mercury, there are special regulatory requirements for the management and disposal of elemental mercury, mercury-containing devices, and items contaminated by elemental mercury after a spill (see Chapter 10).

## **1.6 Sources and Uses of Mercury**

Mercury is and has been used in a variety of manufactured products and manufacturing processes. Many applications have been discontinued in recent years because of the health hazards associated with using mercury.

### **1.6.1 Sources of Elemental Mercury**

Natural sources of mercury include volcanoes, hot springs, and ore minerals (such as cinnabar). Elemental mercury is rarely found in nature as pure, liquid metal; most naturally occurring forms of mercury are organic or inorganic compounds. Industrial sources of mercury are present in industrial settings in the form of chemical intermediates and catalysts. It is or has been used in chlor-alkali plants (chlorine and caustic soda manufacturing) and in the cement, ink, paper, pharmaceutical, leather, and textile manufacturing industries. Elemental mercury is used in various mining operations, including gold extraction. Coal-fired power plants and copper and zinc smelters were significant sources of mercury releases to the atmosphere.

### **1.6.2 Uses of Elemental Mercury**

Metallic mercury is still used in household and workplace products including batteries, fluorescent bulbs, mercury arc lamps, and vapor lamps. Mercury lighting is used in advertising signs. Elemental mercury can be used as a reflective coating for mirrors. Elemental mercury is also used for motion-sensitive electrical switches such as those used for car alarms and light-up sneakers.



Because these products are often discarded and disposed of as mixed waste, metallic mercury is also found in municipal incinerator ash, sludge, and landfill wastes.

Many scientific and medical measuring devices use elemental mercury gauges. These devices include thermometers, barometers, blood pressure measuring devices (sphygmomanometers), hydrometers, and pyrometers.

Elemental mercury-containing instruments are found in hospitals and doctors' offices, industrial laboratories, and school laboratories. Some scientific instruments are equipped with mercury shutters. Elemental mercury is also used in diffusion pumps and as a lubricant for turbines.

Although a variety of materials are now used for dental fillings, amalgam (mercury alloy) fillings are still common. These fillings may release a small amount of mercury vapor into the mouth over a long period of time.

Elemental mercury is also used in traditional religious practices and folk medicine, especially in certain areas of Mexico, the Caribbean, and in some Asian countries. Mercury is referred to as "azogue" in regions with Spanish-speaking populations. Within some Hispanic, Caribbean, and Asian communities in the United States, metallic mercury may be worn in sealed pouches, sprinkled in homes or automobiles, mixed with bath water or perfume, or placed in devotional candles to ward off evil spirits and bring good luck.

Use the following link for a list of companies that manufacture appliances (or components used in appliances) that contain mercury: <http://www.newmoa.org/prevention/mercury/imerc.cfm>. Use the following link for the Interstate Mercury Education and Reduction Clearinghouse (IMERC) mercury-added products database, which contains a summary of IMERC data for products, including legacy and novice products:  
[http://www.p2rx.org/topicubs/index.cfm?page=subsection&hub\\_id=22&subsec\\_id=19](http://www.p2rx.org/topicubs/index.cfm?page=subsection&hub_id=22&subsec_id=19).

### **1.6.3 Mercury in Products Raising Public Concern**

As mentioned above, the focus of this guidebook is on residential mercury responses caused by liquid mercury. There are several other mercury sources causing public concern which OSCs are commonly asked to assist with. The three most notable are briefly described below and will not be addressed in detail in this guidebook. EPA has been asked to lend technical assistance in assessing these potential health concerns, but may not have the authority to go beyond assessment if the sources do not cause a release or threat of release to the environment. Other agencies may need to retain the lead on addressing potential health threats caused by these sources. A discussion of EPA's authority to address elemental mercury is provided in Section 3.3 of this guidebook.

### **1.6.3.1 Skin Cream**

A growing number of referrals have been noted due to what is referred to as “skin lightening cream” that is generally imported into the United States. These creams generally have a high concentration of mercury that may cause an inhalation risk as well as the obvious dermal absorption risk. However, they are unlikely to cause a threat to the environment and may not be eligible to be addressed under CERCLA.

For more information please visit the following websites:

<http://www.fda.gov/forconsumers/consumerupdates/ucm294849.htm>

<https://response.epa.gov/Region9Training>

<https://response.epa.gov/Hgcream>

### **1.6.3.2 Compact Fluorescent Light Bulbs (CFLs)**

The Energy Independence and Security Act of 2007 increased energy efficiency requirements (i.e., less energy use) for household light bulbs between 40 and 100 watts, leading to a significant increase in the purchase of compact fluorescent light bulbs (CFLs) in the U.S. CFLs contain a small quantity of mercury and may initially cause an elevated concentration of mercury vapor in indoor air when broken.

However, they are unlikely to cause a threat of release to the environment when broken indoors and may not be eligible to be addressed under CERCLA. For more information please visit:

<http://www.epa.gov/cfl>.

### **1.6.3.3 Rubberized Gym Floors**

Starting in the 1970s, rubberized material was commonly used in gym floors, tennis courts, multipurpose rooms, and playgrounds. Mercury was used in the polymerization process of these rubberized surfaces and as the flooring material weathers and ages, small concentrations of mercury vapor are released. The expected lifespan of these floors was generally considered to be 20 to 40 years. When those responsible for these floors began trying to remove and replace the worn material it was discovered that the material failed Toxicity Characteristic Leaching Procedure (TCLP) requiring it to be treated as a characteristic hazardous waste. EPA has provided technical assistance assessing rubberized floor removals over the years, but may not have the authority to conduct a removal action of the material as it generally does not pose a threat to the environment. For more information please visit:

<http://www.atsdr.cdc.gov/HAC/pha/MilwaukeePublicSchool/MPSGymFloorMercuryHC12162010.pdf>

## **2 Human Health Effects**

Adverse human health effects can result from acute or chronic exposure to mercury. Even a small amount of elemental mercury remaining in a room after a spill can continue to volatilize slowly over time, resulting in elevated concentrations of mercury vapor in the air, thus presenting the threat of chronic exposure. Refer to Appendix A for specific information from the health consultation.

### **2.1 Pathways of Exposure**

Mercury can enter the body through three pathways: ingestion, dermal absorption, and inhalation. However, inhalation of elemental mercury vapor poses a great risk to health and safety because mercury is absorbed more rapidly through the lungs than through the digestive tract or skin. Metallic mercury vapors are highly lipophilic (has a high affinity for body fat) and is absorbed almost completely by the lungs upon inhalation. Inhaled elemental mercury enters the bloodstream, where it can accumulate and stay in the kidney and brain for weeks or months.

Although dermal absorption is not a significant pathway of exposure, dermal exposure may produce skin irritations and allergic reactions. Ingested elemental mercury is not well absorbed, and is mostly expelled in the feces.

### **2.2 Symptoms of Exposure**

Adverse human health effects can result from acute or chronic exposure to mercury. Mercury that is absorbed can accumulate in the brain and kidney, and be excreted slowly from the body. Because mercury can accumulate in the kidneys, the kidneys are particularly sensitive to damage. Pets can also be affected by mercury exposure in ways similar to humans. They can also track elemental mercury to humans, residences, and the environment.

#### **2.2.1 Acute Health Effects**

Acute mercury poisoning can produce a wide variety of symptoms. These include irritation and burning of the skin and eyes, skin allergies and hypersensitivity, including a condition known as acrodynia, or pink disease. Acrodynia is a syndrome characterized by red peeling skin, especially on the hands, feet, and nose. Exposure may also include symptoms such as weakness, fretfulness, sleeplessness, excessive salivation or sweating, itching, swelling, fever, memory loss, and elevated blood pressure. Exposure to elemental mercury vapor may also produce kidney damage and symptoms of respiratory distress, including lung irritation with coughing, sore throat, chest pain or chest tightness, shortness of breath, pulmonary edema (excessive fluid buildup in the lungs), which may later turn into bronchitis, and, after repeated high exposure, pneumonitis (scarring of the lungs). Mercury poisoning may lead to chemical pneumonia, which can be fatal.

Acute mercury poisoning can also produce symptoms of neurological damage, including tremors, insomnia, headache, irritability, lassitude (weakness, exhaustion), sores inside the mouth (stomatitis), salivation, colic (stomach cramps), and disturbances in vision. Like many metals, mercury also concentrates in the kidneys and kills kidney cells. Exposed individuals may also experience a metallic taste, abdominal pain, diarrhea, nausea, and vomiting. In the most severe cases, mercury exposure can result in death.

### **2.2.2 Chronic Health Effects**

Chronic mercury poisoning may develop gradually without conspicuous warning signs as mercury accumulates in body tissues. Mercury has not been shown to cause cancer in animals, but it produces a variety of other types of damage, often irreversible. Symptoms of repeated exposure may include anxiety, excessive shyness, anorexia (weight loss), insomnia, loss of appetite, irritability, fatigue, forgetfulness, tremors, changes in vision and changes in hearing. Exposed individuals may experience digestive disturbances, skin irritation, eye damage, leg cramps, loss of sensation around the lips, ataxia (inability to control voluntary muscle movements), and tunnel vision.

Symptoms of acute and chronic mercury poisoning are listed in Figure 2-1.

**Figure 2-1: General Symptoms of Mercury Poisoning**

Acute Mercury Poisoning	Acute Elemental Mercury Vapor Poisoning	Chronic Mercury Poisoning
<ul style="list-style-type: none"> <li>•Irritation &amp; burning of the skin/eyes</li> <li>•Fever</li> <li>•Colic</li> <li>•Skin allergies &amp; hypersensitivity</li> <li>•Memory loss</li> <li>•Disturbances in vision</li> <li>•Acrodynia</li> <li>•Elevated blood pressure</li> <li>•Metallic taste</li> <li>•Weakness</li> <li>•Tremors</li> <li>•Abdominal pain</li> <li>•Fretfulness</li> <li>•Insomnia</li> <li>•Diarrhea</li> <li>•Sleeplessness</li> <li>•Headache</li> <li>•Nausea</li> <li>•Excessive salivation/sweating</li> <li>•Irritability</li> <li>•Vomiting</li> <li>•Itching</li> <li>•Lassitude</li> <li>•Swelling</li> <li>•Stomatitis</li> </ul>	<ul style="list-style-type: none"> <li>•Kidney damage</li> <li>•Pulmonary edema</li> <li>•Lung irritation with coughing</li> <li>•Bronchitis</li> <li>•Sorethroat</li> <li>•Pneumonitis</li> <li>•Chest pain or tightness</li> <li>•Shortness of breath</li> </ul>	<ul style="list-style-type: none"> <li>•Anxiety</li> <li>•Irritability</li> <li>•Changes in hearing</li> <li>•Excessive shyness</li> <li>•Fatigue</li> <li>•Weight loss</li> <li>•Forgetfulness</li> <li>•Insomnia</li> <li>•Tremors</li> <li>•Loss of appetite</li> <li>•Changes in vision</li> </ul>

### 2.2.3 Concerns for Pregnant Women and Children

Mercury exposure is of particular concern to pregnant women because mercury readily passes across the placenta and can accumulate in higher concentrations in the developing fetus. Young children are also susceptible to the effects of mercury because it affects the central nervous system, which is still developing in the first few years of life. Even low levels of mercury exposure have been associated with learning problems in children.

## **2.3 First Aid for Exposure**

It is important to move the mercury-exposed victims to fresh air. If necessary, call emergency medical services. The victim's exposed skin should be washed thoroughly with soap and water. If the victim's eyes have been in contact with elemental mercury, the eyes should be flushed with water for at least 20 minutes. Consult health officials to determine if medical follow up is warranted. Victims may want to consult with their physician.

Generally, first responders are not directly at risk from individuals exposed to mercury vapor. However, first responders may be exposed through direct contact or off-gassing of mercury vapor from contaminated clothing.

## **2.4 Biological Sampling for Exposure**

It is essential to coordinate with and rely on experienced medical personnel to make biological sampling determinations.

According to the CDC, elemental mercury that is absorbed undergoes distribution to most tissues, with the highest concentrations in the kidneys. Blood concentrations decline initially with a rapid half-life of approximately 1 to 3 days followed by a slower half-life of approximately 1 to 3 weeks. After exposure to elemental mercury, excretion of mercury occurs predominantly through the kidney, and peak urine levels can lag behind peak blood levels by days to a few weeks. Thus, if it has been more than a few days since exposure to mercury, a 24-hour urine sample is generally considered better than blood samples for evaluation. [http://www.cdc.gov/biomonitoring/Mercury\\_BiomonitoringSummary.html](http://www.cdc.gov/biomonitoring/Mercury_BiomonitoringSummary.html)

# **3 Initiation of the Response**

## **3.1 Investigating Agency**

The investigation phase of an elemental mercury response is generally conducted by the agency first notified of the spill (often the local hazmat team, local health department, state environmental protection agency, or EPA). Whenever possible, the local health department should be consulted or included in the initial investigation of a spill. However, local health departments do not always have the resources for extensive involvement in such efforts. In some cases, the environmental program of the state health department is better positioned to respond to environmental health issues such as elemental mercury spills. County emergency management agencies and local fire departments may also be able to support elemental mercury responses.

### 3.2 Role of Public Health Department

The role of the public health department is to determine: (1) if potentially exposed individuals should be referred for clinical assessment, (2) if biological testing should be conducted, and (3) whether to post a residence “Unfit for Human Habitation.” The public health department can potentially arrange for biological and medical testing and interpret the results. The public health department may also assist in determining whether relocation is needed and should be consulted on cleanup levels. The health department may also conduct health education and outreach. Health departments at the Federal, state, and local levels will determine their respective roles in these tasks, as well as issue alerts and help to establish legal authority for actions when needed. Because they are best positioned to know and access local resources, the local health department should be informed of all activities and should be involved to the extent possible. Some local and state health departments have tools (e.g., mercury vapor analyzers) to conduct initial assessments at sites of suspected elemental mercury spills.

### 3.3 EPA Response Authority to Elemental Mercury Spills

Authority under the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) provides that EPA can respond to releases that may present an imminent and substantial endangerment to public health. That authority does not extend to releases where exposure is solely within a residential building or other structure. When state or local resources are not available to fully address an elemental mercury response, EPA can provide technical assistance and mobilize assets to support the response. EPA does not typically respond to breaks involving thermometers or thermostats; local or state assistance should be available for those situations. In general, small releases (e.g., broken CFLs, thermometers and thermostats) can be addressed through technical advice to the resident, property owner, or responding agency or entity over the phone. The Duty Officer or EPA OSC should provide the spiller or responding agency/entity with information about the proper cleanup and disposal of elemental mercury and mercury-contamination materials. This information can be found at [www.epa.gov/mercury/](https://www.epa.gov/mercury/). Many industrial suppliers carry elemental mercury specific cleanup kits for small spills.

*EPA often receives phone calls regarding broken CFLs. EPA established a help guide for those situations that can be found at: <https://www.epa.gov/cfl>.*

An uncontained spill larger than one pound (approximately two tablespoons) that is released to the environment requires a notification to the National Response Center (NRC), (800) 424-8802.

### **3.4 Request for EPA Assistance**

When the investigating agency recognizes that the mercury situation likely poses a risk to human health and the environment, rapid assessment of the spill should be conducted. If EPA response is requested, the request for assistance should initially be made verbally.

A documentation of request should follow and should be included in the Administrative Record when preparing an Action Memorandum if a removal action is to be conducted. Examples of request letters are provided in Appendix C.

## **4 OSC Initial Response**

Suggested practices of responding OSCs include but are not limited to those described below. Each response is unique, and OSC practices are based on various plausible scenarios. When EPA is the lead, the OSC should serve as the liaison to the property owners during the entirety of the response.

Good communication with all parties is imperative. Information on the threats of elemental mercury and its physical properties, explanation of access agreements, air monitoring results, and plans for a removal action should be discussed with the affected parties.

In advance of any action, EPA should make the following recommendations to the local responding agency:

- Persons in the spill area should be advised not to remove any elemental mercury from the spill site and, if possible, to isolate known impacted areas (close doors).
- Remove shoes if they are likely to be contaminated.
- Do not attempt to clean up the elemental mercury without expert support or guidance.
- Under no circumstances should anyone attempt to vacuum an elemental mercury spill.

### **4.1 Before Leaving the Office**

#### **4.1.1 Initial Coordination**

After gathering relevant situational information, the OSC or phone Duty Officer will initiate appropriate response measures, including coordination of internal and external notifications. If warranted, EPA will mobilize its Superfund Technical Assessment and Response Team (START) to assist in assessment, monitoring and documentation. In most cases, the OSC will coordinate the development of a site health and safety plan and a Quality Assurance Project Plan/Field Sampling and Analysis Plan (QAPP/SAP).



#### 4.1.2 Other Response Support Sources

Technical assistance may also be provided by EPA Special Teams. Contact other response support sources as necessary:

1. ERT (24 hours/day) 732-321-6660
2. CDC 770-488-7100 (State that you are with EPA and ask to speak with the CDC Duty Officer, or contact your regional ATSDR representative)
3. State emergency response program/agency
4. County health department/emergency management agency
5. START
6. Emergency and Rapid Response Services (ERRS)
7. Other OSCs and Regional points of contact with mercury experience (please refer to the contact list under the documents link at [http://www.response.epa.org/site/site\\_profile.aspx?site\\_id=6544](http://www.response.epa.org/site/site_profile.aspx?site_id=6544))
8. Regional public affairs (Community Involvement Coordinator [CIC] or Press Officer)
9. U.S. Coast Guard Strike Team

#### 4.1.3 Other Appropriate Response Resources

Although not inclusive, the following is a list of physical resources that may be needed:

1. Personal Protective Equipment (PPE): chemical protective clothing, booties, gloves, air purifying respirator (APR), Mercury vapor cartridges, and self-contained breathing apparatus (SCBA) air packs, in addition to your personal response gear bag. Refer to Section 13.1 for more information on PPE.
2. Monitoring equipment: mercury vapor analyzer, multi gas indicator, and radiation meter.
3. Cleanup equipment (partial list): flashlight, tents, chairs, tables, heaters, thermometers, thermo-gun temperature meter, and exhaust fans with filters, mercury vacuum, zinc or sulfur cleanup compounds. START or ERRS can supply this equipment.
4. Data management tools (e.g., spreadsheet for personal items, laptop, camera, video camera). These tools can be supplied by START.
5. Guidance and mercury-specific documents.

## 4.2 Arriving at Spill Location

### 4.2.1 Conduct Responding State/Local Agency Debrief and Interview Property Owner

At a minimum, responders should determine the following:

1. How did the spill occur, including estimated volume and time since spill occurred?
2. Was a cleanup attempted?
3. How was the cleanup conducted?
4. What actions have been taken, including instruments used?
5. Who handled the spill or who was present during the spill?
6. Where did the mercury originate?
7. Where was the mercury detected?
8. Was the mercury taken to another location?
9. Was the mercury container opened or was the mercury handled anywhere else?
10. Has any individual been in direct contact with mercury? If so, please refer to Section 2.3 for common first aid recommendations.
11. What is the number, ages, and ethnicities of people living in the home (understand sensitive populations: ATSDR will ask for this information if you call them)?
12. Who rents, leases or owns the property and is it insured?
13. For businesses or schools, has a qualified environmental cleanup contractor been contacted? If so, does the contractor have mercury cleanup experience?

### 4.2.2 Obtain Signed Access Agreement



**Photograph 4-1**

Before EPA conducts an environmental reconnaissance or environmental sampling in the home, residents, including owners and tenants of the home, must grant access to EPA. Written agreements, signed by the residents, should be obtained whenever possible. Written agreements allow EPA and its authorized representatives to enter the residence or building and conduct air sampling to determine the extent of contamination. If cleanup becomes necessary, additional access agreements must be obtained.

Access agreements are typically obtained by EPA OSCs, CICs or Office of Public Affairs personnel. In some cases, state representatives have assisted in obtaining access agreement signatures. Sample EPA access agreements are provided in Appendix C. Depending on the scenario, there could be one access agreement for the assessment and a separate agreement for a removal, or there could be one access agreement that combines the assessment and removal.

### 4.2.3 EPA Accounting Practices

If a spill is from a single source, EPA generally uses one accounting string. However, when multiple homes or schools are impacted, and action levels are exceeded, individual Regions may decide to form multiple operational units. In this case, multiple site accounts would be established. When contractors are utilized, it is necessary to track individual spill locations regardless of EPA accounting strings.

### 4.2.4 EPA Enforcement Considerations

Under CERCLA, the owners of a contaminated property are considered potentially responsible parties. In addition, residential spills are often caused by building occupants. Potentially responsible parties are expected to take responsibility for the cleanup under EPA's "enforcement first" policies.

Regional financial disclosure forms are generally utilized during this process. There are three common situations that EPA encounters with indoor elemental mercury responses related to enforcement (i.e., "who pays?"):

1. Spill in an active non-residential building. Spills that occur where viable businesses or occupants exist are classic enforcement situations where the owners/operators in the building are expected to take action and/or hire a contractor to clean-up the spill. Often, EPA provides technical assistance to ensure proper safety and clean-up practices are conducted. In situations involving schools, EPA may take on a more active role in the response due to heightened concerns.
2. Spill in a residence where the occupants are renters. In owner/renter situations, EPA considers the owner of the building a responsible party and a viable business. As such, the owner should take responsibility for the cleanup. In some situations, the owner may claim to be non-viable and unable to fund the cleanup. EPA should then ensure all standard enforcement practices are conducted while addressing any emergency actions. This can be a challenging coordination situation, especially if the occupant of the dwelling caused the spill.
3. Spill in a residence where the occupants are the owners. When spills occur in homes that are owned by the occupants, enforcement coordination is usually straight-forward. In most cases, the spill was caused by the occupants. EPA's enforcement team should do a rapid review of the occupants "ability to pay." Usually, the occupants will demonstrate that they do not have the means to take on a cleanup that will cost tens of thousands of dollars. In these cases, EPA will generally fund the cleanup. The OSC should ensure that the occupants understand that EPA will do a thorough review of their ability to pay and may pursue reimbursement. In addition, the OSC should inform the owners, when they are the potentially responsible party, that the amount of replacement/reimbursement for contaminated property will be limited (see Chapter 11 for more information).

In all cases, insurance may be an option to fund a cleanup action. The OSC should discuss this possibility with the potentially responsible parties. Most residential insurance policies specifically exclude spills of hazardous materials. However, in some cases the insurance companies take responsibility for their policy holders, even when hazardous materials exclusions exist.

#### **4.2.5 Public Outreach and Information**

Elemental mercury spills often become newsworthy events, especially when schools are involved and where one spill results in multiple residences being affected. Even with small spills that may affect only one property or dwelling, if the media becomes aware, there is a good chance that news organizations will cover the story and reporters may appear on-scene. Responding OSCs should be prepared to engage community outreach support resources and ensure that CICs, and public affairs specialists are knowledgeable on the unique features of responding to elemental mercury spills.

For small spills, the OSC will often handle the community involvement responsibilities, if needed. For large, complex responses, CIC support is integral to ensure the public receives accurate information quickly. Integrating local emergency management and public health specialists is also important to assisting with outreach. In many cases, the source and extent of the elemental mercury contamination may initially be unknown. A robust outreach approach may be the key to gathering information and ensuring all potentially contaminated properties are identified.

When a residential property is identified as being contaminated, it is critical to not only explain the details of the spill, threat, and cleanup, but, also to provide written information to the residents to ensure that they have and understand all the details.

Finally, if media interest is high, the OSC should notify the Regional Public Affairs Office to discuss how it plans to approach and manage dissemination of public information. Examples of public outreach documents can be found in Appendix C.

## **5 Initial Assessment and Screening/Sampling of Air with a Handheld MVA**

There are currently several methods that may be used to measure mercury vapor concentrations in air. These tools have varying sensitivities and potential applications. More recently, the common method used by EPA personnel and contractors was using the MVA, followed up with confirmation air samples per NIOSH method 6009 (see Appendix B). Recent technological advancements and extensive experiences with MVAs have led to laboratory equivalent results now being achieved with the handheld instruments. Actions and decisions can be based solely on the MVA readings, as long as proper methods and procedures are followed. Within the past ten years, all EPA regions purchased Lumex 915+ MVAs, although several other MVAs are available and are in use in the regions. Consult with EPA ERT for the most current applicable MVAs. See Figure 5-1 for a comparison of MVAs.

**Figure 5-1: Comparison of Real-Time Monitoring Instruments**

INSTRUMENT	JEROME 431	JEROME J505	NIPPON MERCURY/EMP-1	VM-3000	TRACKER 300IP	LUMEX RA-915+	LUMEX RA-915 Light
Manufacturer	Arizona Instrument LLC	Arizona Instrument LLC	Nippon Instruments Corporation, Japan	Mercury Instruments GmbH, Germany	Mercury Instruments GmbH	Lumex, Russia	Lumex, Russia
Distributor	Arizona Instrument LLC	Arizona Instrument LLC	Brandt Instruments Inc., LA	ST2 Service Technologies, Inc., CO	ST2 Service Technologies, Inc., CO	Ohio Lumex Co., OH	Ohio Lumex Co., OH
Units	mg/m <sup>3</sup>	ng/m <sup>3</sup> , µg/m <sup>3</sup> , or mg/m <sup>3</sup> user selectable	mg/m <sup>3</sup>	µg/m <sup>3</sup>	µg/m <sup>3</sup>	ng/m <sup>3</sup>	µg/m <sup>3</sup>
Range	Zero to 0.999	0.05 - 500 µg/m <sup>3</sup>	Zero to 0.999 1 to 5.00	Zero to 100 Zero to 1000 Zero to 2000	0.1 to 100 0.1 to 1000 0.1 to 2000	20 to 20000 (multi-path cell) 500 to 200000 (single-path cell)	0.1 - 100
Methodology	Change in resistance of gold after mercury absorption	Atomic Fluorescence Spectroscopy (AFS)	Ultraviolet absorption "cold vapor measuring technique"	Ultraviolet absorption "cold vapor measuring technique"	Cold Vapor Atomic Absorption Spectroscopy (CVAAS)	Zeeman Atomic Absorption Spectrometry, High Frequency Modulation of Light Polarization	Zeeman Atomic Absorption Spectrometry, High Frequency Modulation of Light Polarization
Accuracy (%)	5	+/- 10% @ 1 µg/m <sup>3</sup>	5		NA	+/-20%	+/-10%
Detection Limit	0.003	0.01	0.001 (low range) 0.01 (high range)	0.1	0.1	2	0.1
Response Time	10 seconds	28 sec (Standard Mode) 16 sec (Quick Mode) 1 sec (Search Mode)	Instantaneous and 5 minute averages	1 second	1 - 16 sec (programmable)	1 - 255 sec (programmable)	1 - 255 sec (programmable)
Wavelength	Not applicable	254 nm	254 nm	253.7 nm	253.7 nm	254 nm	254 nm
UV Source	Not applicable	Info not available	Low pressure Hg discharge lamp	Electrodeless Hg low pressure lamp	Electrodeless Hg low pressure lamp	Glow discharge mercury lamp	Glow discharge mercury lamp
Stabilization	Not applicable	Info not available	Reference beam	Reference beam and thermal	Reference beam & thermal	light polarization	light polarization

INSTRUMENT	JEROME 431	JEROME J505	NIPPON MERCURY/EMP-1	VM-3000	TRACKER 300IP	LUMEX RA-915+	LUMEX RA-915 Light
Optical cell	Not applicable	Info not available	Info not available	Fused silica, 25 cm long	Fused silica, 25 cm long	Multi-path cell, 10-meter equivalent	Multi-path cell
Heating of cell	Not applicable	Info not available	Info not available	70°C	70°C	Info not available	Info not available
Pump	0.75 L/min	1 L/min	1.5 L/min	Membrane, 2 L/min	Membrane, 2 L/min	>15 L/min	>15 L/min
Filter	Yes	Info not available	Glass wool	PTFE, 1 µ, 47-50 mm diameter	PTFE 1: 47-50 mm diameter	Yes	Yes
Calibration Method	Manual	Factory Calibrated	Automatic, using an absorber	Factory	Factory calibrated (using MC-3000 Mercury calibration). The operator can recall actual calibration factor and enter a new calibration	Factory calibrated. Calibration parameters inaccessible to users	Factory calibrated. Calibration parameters inaccessible to users
Interferences and Correction	Chlorine, NO <sub>2</sub> , H <sub>2</sub> S, Mercaptans; interferences removed by internal filters.	Chlorine, ammonia, humidity/water vapor, gasoline, high concentrations of acetone		Benzene, Acetone, Carbon Tetrachloride, SO <sub>2</sub> , NO, NO <sub>2</sub> , Aromatic Hydrocarbons, Dust	Benzene, Acetone, Carbon Tetrachloride, SO <sub>2</sub> , NO, NO <sub>2</sub> , Aromatic Hydrocarbons, Dust	Info not available	Info not available
Power	115 V or 230 V	12V DC Power Adaptor	None	230 V / 50/60 Hz or 110-120 V / 50/60 Hz optional	230 V/ 50/60 Hz or 110-120 V / 50/60 Hz optional	220 V, 50 Hz or 110V, 60 Hz, 15W	240/110 VAC, 50/60 Hz, 12 VDC, 20W
Battery	Internal Ni-Cd batteries, (5 hr capacity)	Internal Ni-Metal_Hydride (24 hr capacity)	Integrated rechargeable battery (11 hr capacity)	Integrated 12 V batteries, (6 hr capacity)	Internal Ni-Metal-Hydride (6 hr capacity)	Built-in 6V, 6-12V DC (optional)	Built-in 6V, 6-12V DC (optional)
Weight	2.3 kg	6.5 lbs (3 Kg)	4.2 kg	Approx. 7 kg	15.5 lbs (7 Kg)	7.5kg	3.3 kg
Dimensions (L x W x H)	15.6 x 33.8 x 10.4 cm	30.5 x 15.8 x 21.3 cm	11.3 x 23.8 x 25.6 cm	45 x 15 x 35 cm	45 x 20 x 31 cm	46 x 21 x 11 cm	29 x 21 x 11 cm

<b>INSTRUMENT</b>	<b>JEROME 431</b>	<b>JEROME J505</b>	<b>NIPPON MERCURY/EMP-1</b>	<b>VM-3000</b>	<b>TRACKER 300IP</b>	<b>LUMEX RA-915+</b>	<b>LUMEX RA-915 Light</b>
Communication Interface		USB		RS-232	RS-232	RS-232	RS-232
Data Logging Number of Readings		Internal 10000			Internal 15000	External with PC Control	

For simplicity, this chapter describes the field use of a Lumex 915+ MVA, from the initiation of an elemental mercury spill response through post-cleanup final clearance of a contaminated area. These same methods and procedures should be followed regardless of which instrument is used. The chapter is broken down into the following sections:

- MVA Startup and Performance
- Initial Screening
- Screening of Contaminated Items
- Monitoring During Cleanup
- Clearance Screening/Sampling

Some sections will be further broken down by location whether residential, non-residential, vehicle, or outdoors.

The purpose of using the Lumex and other MVAs is to measure the levels of mercury vapor in air, and to use that data to make near real-time, health-based decisions on the need for cleanup of property and possessions or the relocation of occupants. The basis for comparison of the mercury vapor levels in air is the health consultation (see Appendix A) that established recommended action levels for elemental mercury spills.

## 5.1 MVA Startup and Performance

*“Bump” Test: A practice OSCs commonly use in the field to verify an instrument is responding to the presence of mercury vapor. A bump test can be conducted with a calibration canister or other low-level mercury containing source. Care should be taken when conducting a bump test to try not to saturate the instrument with mercury vapor. A bump test should not replace the equipment manufacturer’s calibration or internal test procedures.*

This section will describe common aspects of almost all elemental mercury responses with respect to mercury vapor detection. Before using an MVA, review the manufacturer’s user guide, the EPA ERTG Equipment Operating Guide (EOG), and Quick Start Guide (QSG)

([https://response.epa.gov/site/doc\\_list.aspx?site\\_id=0001](https://response.epa.gov/site/doc_list.aspx?site_id=0001))

for the appropriate model MVA. There is a minimum warm up period for all MVAs which may vary by model. The warm up period may be shorter on a warm day and longer on a cold day. Proper field calibration or an internal test should be performed daily according to manufacturer’s specifications. Results should be documented in the equipment logbook as well as the site logbook. For the Lumex 915+ MVA, there is a calibration “check” that is required prior to using the instrument. The calibration “check” is a test that is performed

in the field. The Lumex has a built-in elemental mercury test cell which can be tested to ensure that the unit is operating properly. The test cell contains an elemental mercury source, and if the relative deviation (R) of the measured value of the mercury vapor concentration in the test cell equals less than 25 percent, the device is ready for operation.



When performing this test, the results need to be recorded in the site logbook to document that the data being accumulated by the instrument are valid.

Environmental factors may affect the performance of instruments, including humidity and temperature. Although several manufacturers do not consider humidity an interference with their instrument, experience has shown that faulty readings (generally false positive readings) are common with high humidity levels or quick increases in humidity. Temperature is also not considered an interference by most manufacturers, but field experience demonstrates that erroneous readings related to temperature changes may occur. Erroneous readings can occur with quick changes in the temperature of the instrument itself, which is attributable to not allowing the instrument to acclimate to the desired temperature at which the instrument will be used. This commonly occurs during the summer months when an instrument has been sitting in a very warm vehicle and then is taken into an air-conditioned building and is not given time for the delicate electronics to acclimate to the new temperature. It can also occur when background readings are taken outdoors at one temperature, and then the instrument is quickly moved indoors at another temperature resulting in a significantly different temperature of air (generally anything greater than 15°F difference) being drawn through the instrument. Readings should stabilize and provide accurate information within 15 minutes or less.

Additional possible interferences that have been noted by experienced response personnel to cause erroneous readings are tobacco smoke, extremely dusty environments, pet litter boxes, and cleaning supplies under kitchen sinks and on storage shelves. These may be actual mercury vapor detections or interferences but are unlikely to be a mercury source of concern that EPA would be responding to. It should also be noted that the carrying case and strap for most MVAs are porous and can easily become contaminated. Elevated readings could come from the carrying case and strap from a previous response and should be checked regularly.

During calibration testing of the Lumex 915+, if the instrument R (%) is not below 25 percent, the instrument should not be used for decision-making purposes. Check the manufacturer's recommendations and allow the instrument to continue warming up before rechecking the calibration. It may be necessary to change out the multiple filters that are on the intake side of the instrument or the inlet hose/inlet filter holder. If calibration testing continues to exceed 25 percent after several hours, it may be necessary to send the unit back to the manufacturer for calibration and checking of the internal optics.

## **5.2 Initial Screening for Mercury Vapor**

Prior to any initial screening, anyone with knowledge of the spill should be interviewed in detail so that as much information is known before entering the contaminated area. This interview will also help estimate the magnitude of the spill and how far it may have spread so that a determination can be made as to whether additional personnel and equipment resources might be needed.

Initial entries are not intended to be full assessments of the spill but are intended to:

1. Verify that visible elemental mercury was released,
2. Estimate whether the spill would be considered small, medium, or large and whether the extent of the spill is small or significant,
3. Measure the average concentration of breathing zone air to determine proper level of PPE and Health and Safety procedures (if multiple MVAs are available at the site, make the initial entry using the MVA with the highest detection range),
4. Determine whether relocation should be recommended, and
5. Verify that the spill has already or has the potential to be released to the outside environment (authority to conduct a removal action due to indoor elemental mercury releases is explained in greater detail in Chapter 3).

### **5.2.1 Potentially Exposed Humans and Animals**

Upon initial arrival at an elemental mercury response, it may be necessary to conduct mercury vapor screening of humans and pets that may have walked through or been in direct contact with elemental mercury. If it is suspected that individuals or pets have elemental mercury on their exterior, MVA screening in a low wind environment can be conducted by slow methodical movement of the probe within 2 to 6 inches of the subject (think of hand-held metal detector screening at the airport). Readings greater than 3 to 6  $\mu\text{g}/\text{m}^3$  generally indicate the presence of elemental mercury in a concentration such that decontamination will be required (see Section 9.4.9).

If it is believed that direct contact did not occur but tracking through the elemental mercury spill area took place, the most common technique is to have the individual remove their shoes and place them in a plastic bag for headspace screening as described in Section 9.4.1. Another technique is referred to as the transfer test. During the transfer test, a small (approximately 2' x 2') non-contaminated towel is placed on the ground and the subject wipes their shoes on it several times. Place the towel into a plastic bag for headspace screening. A reading greater than 3 to 6  $\mu\text{g}/\text{m}^3$  micrograms ( $\mu\text{g}$ )/cubic meter ( $\text{m}^3$ ) generally indicates that the shoes have elemental mercury contamination such that decontamination will be required (see Section 9.4.5).

### **5.2.2 Residential**

After information gathering has been completed, the response team conducts an initial entry to verify conditions in the home. It is best if all occupants of the home, including free roaming pets, remain outside of the dwelling during the initial assessment.

In some elemental mercury spill responses, the source, size, timing, and extent of the spill may already be known, and all of these procedures may not be necessary (e.g., a known spill in a discrete room, a known thermostat release over a carpeted hallway).

In general, temporary relocation should be recommended when the indoor air mercury vapor concentrations exceed  $10 \mu\text{g}/\text{m}^3$ ; EPA responders should upgrade from Level D to Level C when sustained readings exceed  $25 \mu\text{g}/\text{m}^3$ . Action levels are fully described in Chapter 7 and Appendix A. If temporary relocation is recommended, refer to Chapter 8 for a detailed description of options; specifically, refer to Sections 8.2 and 8.3 for immediate needs of the occupants.

Initial entry is almost always conducted in modified Level D (Level D with multiple boot covers). It is highly recommended that all jewelry, especially gold jewelry, be removed before entering a potentially mercury-contaminated atmosphere. Boot covers should be used when entering the property to ensure that responders are not exacerbating the spill by tracking the elemental mercury (and ensuring that dirt is not tracked into the residence). Experience has shown that elemental mercury is one of the most easily tracked contaminants from foot traffic. Countless responders have spread elemental mercury contamination by making hasty entries prior to establishing proper entry and exit routes and decontamination procedures. For initial assessments, a dry decontamination process is recommended.

Document the instrument readings just outside the entry point and the initial readings when the door is first opened. Slowly proceed toward the suspected spill area, documenting readings in distinct living areas, until readings become elevated above a decision level (i.e., greater than  $10 \mu\text{g}/\text{m}^3$  for temporary relocation or greater than  $25 \mu\text{g}/\text{m}^3$  for upgrading from Level D to Level C PPE) or until visual confirmation of elemental mercury is made. At this point the five purposes of the initial screening listed above are generally accomplished.

NOTE: When assessing the spill, DO NOT extend the intake of the MVA too close to the visible elemental mercury. There is no need to use the MVA to check the mercury vapor concentrations of visible mercury. The mercury vapor concentrations volatilizing from the elemental mercury can saturate the instrument and cause the instrument to operate improperly. This can cause internal contamination of the instrument and may result in having to send the unit back to the manufacturer for costly decontamination. Since near-surface measurements are used to estimate elemental mercury on surfaces, responders must use consistent practices and consider all other factors that could influence the measurements (quantity of elemental mercury on surface, temperature of surface, airflow between the surface and the instrument, and distance between the surface and the instrument).

Additional areas of focus during the initial assessment should include high potential contamination areas and items. These include high utilization areas (i.e., bedrooms, living rooms, hallways, etc.), trash cans, garbage cans, drains, washing machines and dryers, recently used footwear and shoe storage areas, and cleaning supplies such as vacuums, mops, and brooms. By the end of the initial screening, the OSC should be able to determine and establish the exclusion zone. This zone will change as the project progresses. If multiple homes or units are being assessed, the initial assessment may not include a detailed screening as described above; rather, a second entry team may conduct a more thorough characterization. Timing of this second screening is based on priority.

Ultimately it is important to know the concentration of mercury vapor in the breathing zone; however, during an assessment and cleanup, it is generally best to monitor closer to the ground as mercury vapors are heavy and will hug the ground if undisturbed by air turbulence.

When the initial entry is complete, leave the MVA in operating mode and screen uncontaminated ambient air outside of the hot zone. Compare the instrument's current readings with the pre-entry initial readings to verify whether instrument drift has occurred. A filter or tubing replacement may be necessary.

### **5.2.3 Non-Residential**

Many initial screening aspects of non-residential elemental mercury spill responses are conducted similarly to methods described in the residential section above. This section will focus on issues that need to be considered when addressing non-residential structures.

In many instances for a non-residential elemental mercury spill, some form of cleanup may have already been attempted. It will be important to interview whoever conducted any cleanup attempts prior to conducting the initial entry.

Non-residential public buildings (i.e., schools, office buildings, etc.) tend to have higher foot traffic and even greater potential for contamination to be spread. Isolation of the spill area and anyone potentially affected as soon as possible will play a significant role in minimizing the spill area. Initial screening at a non-residential elemental mercury spill will likely involve testing shoes and clothing of those that were potentially impacted by the spill and probably isolated by the first responders. When screening shoes and clothes, each person's belongings should be placed into a separate plastic bag and labeled. Screening and custody of personal belongings is conducted as described in Sections 5.3 and 8.3. Alternative clothing or Tyvek® suits may need to be provided to people if clothing is contaminated. The team may need to contact employees and customers that may have cross-contaminated their vehicles or residences.

### **5.2.4 Vehicle**

Initial screening of vehicles is generally conducted by placing the MVA hose into the breathing zone of the vehicle followed by screening of the seats and floorboard. Doors should only be opened far enough to position the end of the probe far enough inside to obtain accurate readings. If vapor readings show greater than 3 to 6  $\mu\text{g}/\text{m}^3$ , elemental mercury beads are likely present in the vehicle (see Appendix A). If visible elemental mercury can be seen, a cleanup should be conducted. Vehicle cleanup procedures can be found in section 9.4.7.

### 5.2.5 Outdoors

If outdoor contamination is suspected or discovered, an initial visual survey should be conducted in the areas of interest. As with indoor spills, care should be taken not to spread the elemental mercury by foot traffic. MVA use during outdoor spills is difficult due to many factors including temperature, wind, and mercury vapors not being confined and allowed to concentrate.

Historically, outdoor spills were assessed with an MVA by slowly and methodically walking the area with the MVA probe near the ground surface. Once elevated readings are discovered, samples should be collected in plastic bags and allowed to warm up in the sun. The headspace of each bag should then be analyzed with the MVA. This technique generally relies on professional judgment because vapors are not confined and can migrate in all directions. A more accurate and inexpensive technique for assessing the extent of an outdoor elemental mercury release is using black plastic concrete mixing tubs (see photographs and description in Section 9.4.10).

### 5.3 Screening of Potentially Contaminated Items

As described above, potentially contaminated personal items will need to be screened to determine whether they require decontamination, or they can be returned. The process of screening residential clothing and household items is described in sections 8.3 and 9.4.1.

Prior to initiating this process, a systematic approach to itemization, accountability, and photographic documentation should be developed as described in Section 9.1. This will ensure EPA is guarded against the loss or damage of personal items.

### 5.4 Monitoring throughout all Stages of the Response

There are three main purposes for frequent monitoring of mercury vapor concentrations throughout a response: (1) to verify that the correct level of PPE is being worn for the type of activities that are currently being conducted, (2) to identify remaining source areas or “hot spots”, and (3) to determine if specific areas of indoor environments are safe for human occupancy. It should be noted that during an elemental mercury spill cleanup, the physical process of moving elemental mercury and mercury-contaminated material may significantly increase indoor air concentrations. For example, initial readings in a bathroom may have consistently read between 7 to 8  $\mu\text{g}/\text{m}^3$  leading one to think that Level D PPE would be sufficient. But in some cases, concentrations could easily increase to over 25  $\mu\text{g}/\text{m}^3$  during actual cleanup activities, which would warrant an upgrade in level of protection. It is common practice at many elemental mercury cleanups to instigate engineering controls during the removal activities in order to alter the concentration of mercury vapor in the breathing zone so that responders can downgrade from Level C to Level D PPE. The three most common ways are to: (1) significantly decrease the temperature in the area of contamination, (2) increase ventilation so that high-concentration indoor air is replaced with low-concentration outdoor air constantly (this is

different than heating and venting techniques that are used as a final cleaning technique, which is discussed in Chapter 9), and (3) use a mercury vapor suppressant. Ventilation should not be conducted during source identification or during the confirmation clearance sampling process. Frequent monitoring throughout a response will verify if engineering controls are working properly.

## **5.5 Clearance Screening/Sampling**

Once a thorough cleanup is conducted and a slow methodical MVA screening of the spill area is completed showing that readings are at or consistently below established action levels, final clearance screening and sampling can be conducted.

Integrated air sampling can be conducted in accordance with NIOSH Method 6009 or a modified NIOSH method 6009 (refer to Appendix B). There may be occasions when local health officials will refuse to release the site unless laboratory confirmation analysis is provided. Based on the data provided in Appendices A and B, EPA is not obligated to conduct laboratory confirmation for clearance.

If clearance screening will be conducted with an MVA or multiple MVAs, follow the methods as outlined in Appendix B. These methods generally involve sealing off the area from outside influence and setting up the MVA at an appropriate height, temperature and duration of time to closely match what would be established using NIOSH method 6009. This would include returning any items previously removed to their original locations. Some MVA instruments have built in software that will allow for time weighted average (TWA) to be shown at the end of the sampling period while others have the data stored on the instrument, which requires downloading and entering the data into a spreadsheet so that the final TWA can be calculated. Generally, the longer the period of data collection, the greater the air collection volume, which results in lower detection limits. When multiple rooms are affected and there are a limited number of MVAs available, instruments should initially be set up in the rooms with the highest previous readings, where the spill originated, in the room of greatest concern (e.g., child's bedroom), or in room(s) where maximum exposure to mercury vapor contamination would occur (such as bedrooms or the living room of a home) after consultation with the local, county or state health official, ATSDR, or an EPA toxicologist. This new process does not preclude utilizing traditional sampling methods.

## **6 Additional Media Screening, Sampling and Analytical Methods**

During most elemental mercury spill cleanups, air monitoring is conducted using a handheld MVA (see Chapter 5), but other equipment and sampling techniques may also be beneficial or required. This chapter describes additional screening methods and discusses collection and analyses of solid, liquid, and air samples, and investigation-derived wastes (IDW). Generally, data from these analyses are used for proper hazard classification, cleanup confirmation, and waste disposal purposes.

Complete proper documentation of relevant sampling-related information (e.g., locations, depths, field screening results, sample preservation) and appropriate chain-of-custody procedures for samples should be made in accordance with all applicable Standard Operating Procedures (SOP).

## **6.1 General Discussion**

Analytical methods described in this chapter pertain only to determination of total mercury; however, mercury speciation analysis of environmental media may also occur to identify the distribution of organic and inorganic species of mercury. These data may be useful to determine the source(s) of a mercury release if unknown, and predict mobility and toxicity of mercury within the food chain of an ecosystem.

To ensure protection of workers, adherence to a site-specific Health and Safety Plan (HASP) is necessary for activities involving sampling and field screening techniques discussed in this chapter. In addition, proper handling of samples and sampling equipment, including proper decontamination of reusable sampling supplies, is critical to limit cross-contamination and to help ensure overall accuracy of analytical data.

## **6.2 Solids**

Analyzing solid environmental media (e.g., soil, sediment, sludge and residue) for mercury may be necessary at the location(s) of a suspected release. These data would be used to identify a significant risk to human health or the environment that warrants cleanup. If visible elemental mercury beads are observed in the media, cleanup will be necessary and should occur before follow-up screening and sampling to determine whether additional cleanup is needed.

### **6.2.1 Bulk Solids (soil, sediment, sludge, etc.)**

Different methods of field screening and laboratory analysis may be appropriate for samples of bulk solids; however, choice of technique will depend on the level of accuracy required of the data. The following methods are listed in order of increasing data accuracy and include techniques involving equipment likely available for use at EPA sites. Other field screening equipment and methods may also be useful for certain applications, although supplies for those methods may not be readily available (or cost efficient) during emergency response activities.

### **6.2.1.1 Field Screening with MVA**

Two methods of preliminary field screening of solid environmental media (e.g., soil, sediment) using an MVA are described as follows. The preferred method may depend on available resources and type of media being investigated (e.g., the procedure described below in Section 6.2.1.1.1 may not be appropriate for evaluation of submerged sediment).

#### **6.2.1.1.1 In Situ Screening**

If a release to soil or other solid environmental media is suspected, in situ screening using a handheld MVA may be appropriate initially to detect any mercury vapor levels above background. To determine the areal extent of contamination across an area of concern, a grid system may be established by placing a black, plastic bus tub upside down on the ground surface at each grid node (see Photograph 9-15 in Chapter 9). After placement of the tubs at the grid nodes, the investigator should allow at least 1 hour for any mercury vapors to collect within the tubs. Then the MVA can be used to screen the air beneath each tub by inserting the MVA probe into a small hole drilled in the tub (see Photograph 9-16 in Chapter 9). If bus tubs are not available, the area(s) of concern may be covered with plastic sheeting (with edges of the sheeting secured to the ground surface) to trap any mercury vapors beneath the sheeting. Allow at least 1 hour for any mercury vapors to collect beneath the sheeting before using the MVA (insert the MVA probe beneath the edge of the sheeting or through a small slit cut into the sheeting). If readings above background are observed at any location by either of these screening methods, conduct soil sampling for more definitive determination of mercury concentrations to determine whether cleanup of the medium is warranted. Note that weather conditions (extreme cold and lack of daylight) may affect the viability of this technique and the sampling process described in the next section may be more appropriate in these circumstances. To access the effectiveness of this process, place thermometer under the tubs or plastic. The thermometer should be reading around 75 degrees F if this method is to be employed.

#### **6.2.1.1.2 Sampling and Field Screening**

Soil sampling (grab or composite) within the area of concern may be conducted to identify the extent of contamination. These samples may be collected using disposable stainless-steel spoons, trowels, slide hammers, or other appropriate means. Approximately equal quantities of these samples may be placed in containers (re-sealable plastic [e.g., Ziploc®] bags, glass jars, etc.) and allowed to warm if necessary. After headspace vapors have been allowed to equilibrate for at least 1 hour, the investigator should screen the headspace of each container using an MVA. Because of variations in matrices, moisture content, temperature, etc., accurate determinations of mercury concentrations within solid media cannot be achieved by this method, even if the samples are individually weighed in the field. This method is useful only to identify the extent of the contaminated area.



### 6.2.1.2 Sampling and Field Screening with Lumex RP-91C Attachment

A Lumex RP-91C attachment may be used in conjunction with a Lumex MVA to determine mercury concentrations within solid environmental media (e.g., soil, sediment, sludge) in the field. This instrument operates by heating a small aliquot of sample (about 50 milligrams [mg]) to approximately 1472°F to atomize any mercury in the sample before analysis with the Lumex MVA. Because this method includes instrumental calibration using a certified liquid or solid standard, accurate determinations of mercury concentrations in environmental media samples are achievable. The detection limit for this method is approximately 0.5 micrograms per kilogram (µg/kg) for total mercury. Prior familiarization with, and training on, use of the RP-91C is important to ensure (1) field users have adequate knowledge of all required equipment (e.g., RP-91C components, electronic balance, laptop with proper software, pipettes) and supplies (e.g., pipette tips, standards); and that (2) accurate results are obtained in the field. Use of the RP-91C attachment is detailed in an Equipment Operating Guide (EOG) that can be found at: [https://response.epa.gov/site/site\\_profile.aspx?site\\_id=0001](https://response.epa.gov/site/site_profile.aspx?site_id=0001).

### 6.2.1.3 Sampling and Laboratory Analysis

Collection of solid environmental media samples for laboratory analysis may be required to accurately determine the extent of contamination above an action level. This sampling may be warranted to determine whether cleanup is necessary or to assess whether cleanup goals have been achieved following response activities. Sampling should proceed in accordance with established EPA SOPs (refer to Appendix B). During subsurface sampling within areas where elemental mercury may be present, care should be taken to avoid migration of spilled mercury to greater depths. Samples should be homogenized and placed into 4- or 8-ounce, wide-mouth, glass, or polyethylene containers. A summary of EPA-approved analytical methods for mercury in soils/bulk solids is included in Figure 6-1.

**Figure 6-1: Analytical Methods for Bulk Solids**

Method	Method Description	Method Detection Limit	Preservation	Holding Time
SW-846 7471B	CVAA	0.1 mg/kg	Store at < 39.2 °F	28 days
SW-846 7472	ASV	0.0004 mg/kg	Store at < 39.2 °F	28 days
SW-846 7473	TDAAA	0.0004 mg/kg	Store at < 39.2 °F	28 days
EPA 245.5	CVAA	0.1 mg/kg	None specified	28 days

**Notes:**

- ASV      Anodic stripping voltammetry
- CVAA    Cold-vapor atomic absorption
- EPA      U.S. Environmental Protection Agency
- mg/kg    Milligrams per kilogram
- TDAAA   Thermal decomposition, amalgamation, & atomic absorption
- °F        Degrees Fahrenheit

Although not all of the preceding analytical methods were developed specifically for EPA's Superfund Program, all of the listed methods have been approved for use on EPA-funded projects. Choice of the appropriate analytical method may depend on available sampling equipment, laboratory instrumentation, and the required detection limit. If not experienced with analytical methods for bulk solids, project managers should discuss methods with experienced laboratory staff or OSCs to ensure the best method is selected for data needs. The analytical method may also be dictated if use of a Contract Laboratory Program (CLP) laboratory is necessary. Field duplicates, equipment rinse blanks, field blanks, and background samples should be collected, if necessary, to meet site-specific goals, and as required by sampling-related Quality Assurance Project Plans (QAPP), Field Sampling Plans (FSPs) and SOPs, and by the selected analytical method.

### **6.2.2 Residue (surface dust/film)**

In limited circumstances, collection of wipe samples may be warranted to evaluate the threat to human health presented by thin layers of mercury-containing dust, cosmetics, etc. Before deciding to collect wipe samples, first discuss their usefulness with the site risk assessor or ATSDR. Sterile gauze pads moistened with distilled/deionized water may be used for collection of the wipe samples. The area(s) wiped should be documented to enable determination of the mass of mercury per unit area (refer to the ERT SOPs in Appendix B). After sampling, each gauze pad should be placed into a clean, labeled container (e.g., 8-ounce glass jar), which should be stored in a cooler maintained at or below 39.2 °F until submitted to a laboratory for analysis. At least three media blanks of the wipe material (gauze pads) and one field blank (gauze pad dampened with distilled or deionized water) should be included with each sample set. Field duplicates may also be collected, as specified by sampling-related QAPPs, FSPs and SOPs. Wipe samples are typically analyzed by cold-vapor atomic absorption (CVAA) (e.g., EPA Method 7471B). The reporting limit for this method is 0.02 micrograms per wipe (refer to Appendix B for a list of EPA SOPs).

### **6.3 Liquids (groundwater, surface water, etc.)**

If an elemental mercury spill is suspected to impact liquid environmental media (e.g., groundwater, surface water), sampling for field screening or laboratory analysis may be warranted. Because of mercury's high toxicity and persistence, very small concentrations may pose a threat to drinking water wells, surface water intakes, and aquatic life. Sampling could involve collection from:

- Water hydrants, taps, or spigots into sample containers
- Streams, ponds, pools, sumps, etc., by dipping sample containers into those waters
- Greater depths of surface water bodies by use of discrete-depth water samplers
- Groundwater in temporary wells (installed by use of direct-push technology [DPT] equipment) through polyethylene tubing by use of a peristaltic pump, bladder pump, or foot valve
- Waste water from treatment facilities or impoundments

The following methods are listed in order of increasing data accuracy, and include techniques involving equipment likely available for use at EPA sites. Other field screening equipment/methods may also be used for certain applications, although supplies for those methods may not be readily available (or cost efficient) during emergency response activities.

### **6.3.1 Sampling and Field Screening with MVA**

An MVA may be used to screen the headspaces of containers (jars or bottles) with liquid samples, after allowing at least 1 hour for mercury vapors to warm and equilibrate within the containers. This technique will indicate only whether the liquid medium contains mercury (i.e., mercury that has volatilized into the container's headspace); it will not yield a concentration of mercury within the liquid medium. This procedure may be useful to determine whether sampling of liquids for more accurate field screening (see Section 6.3.2) or for laboratory analysis (see Section 6.3.3) is warranted.

### **6.3.2 Sampling and Field Screening with Lumex RP-91 Attachment**

A Lumex RP-91 attachment may be used in conjunction with a Lumex RA-915+ or Lumex 915M MVA to determine cold vapor mercury concentrations in liquid environmental media (groundwater, drinking water, surface water, etc.) in the field. This instrument operates by transferring an aliquot (1 to 2 milliliters [mL]) of sample to an impinger that contains a reducing agent which converts all forms of mercury in the sample to its elemental state; air is bubbled through the impinger and carried to the RA-915+ MVA for analysis. Because this method involves instrumental calibration using a certified liquid standard, accurate determination of mercury concentrations in liquid environmental media samples can be achieved. The detection limit for this method is approximately 0.5 nanograms per liter (ng/L) for total mercury. Note that prior familiarization and training on use of the RP-91 is important to ensure (1) field users have adequate knowledge of all required equipment (all RP-19 components, laptop with proper software, pipettes, etc.), and supplies (pipette tips, standards, etc.); and (2) accurate results are obtained in the field. Use of the RP-91 attachment is detailed in an EOG included on the ERTG website (see Appendix D).

### **6.3.3 Sampling and Laboratory Analysis**

Sampling of environmental liquids for laboratory analysis may be required to accurately determine concentrations of mercury for comparison to health-based standards or other action levels. Sampling should proceed in accordance with established EPA SOPs (refer to Appendix B). Samples should be collected in 1-liter, high-density polyethylene or glass bottles (except for analysis via EPA Method 1631E, for which samples must be collected in glass bottles or fluoropolymer bottles with fluoropolymer or fluoropolymer-lined caps). A summary of EPA-approved analytical methods for mercury in water or liquids is included in Figure 6-2.

**Figure 6-2: Analytical Methods for Liquids**

Method	Method Description	Method Detection Limit	Preservation*	Holding Time
SW-846 7470A	CVAA	0.2 µg/L	pH <2 with HNO <sub>3</sub>	28 days
SW-846 7472	ASV	0.1 µg/L	pH <2 with HNO <sub>3</sub>	28 days
SW-846 7473	TDAAA	0.1 µg/L	pH <2 with HNO <sub>3</sub>	28 days
EPA 200.8	ICP-MS	0.2 µg/L	pH <2 with HNO <sub>3</sub>	28 days
EPA 245.1/245.2	CVAA	0.2 µg/L	pH <2 with HNO <sub>3</sub>	28 days
EPA 245.7	CVAF	0.005 µg/L	5 mL 12N HCl	28 days
EPA 1631E	CVAF (w/ pre-concentration)	0.0005 µg/L	5 mL 12N HCl or 5 mL BrCl solution	90 days
Standard Methods 3500-Hg B	CVAA	1.0 µg/L	pH <2 with HNO <sub>3</sub>	28 days

**Notes:**

\* Some laboratories may also require samples to be cooled to a specific temperature (e.g., < 39.2 °F).

ASV	Anodic stripping voltammetry
BrCl	Bromine monochloride
CVAA	Cold-vapor atomic absorption
CVAF	Cold-vapor atomic fluorescence
EPA	U.S. Environmental Protection Agency
HCl	Hydrochloric acid
HNO <sub>3</sub>	Nitric acid
ICP-MS	Inductively coupled plasma-mass spectrometry
mL	Milliliters
N	Normal
TDAAA	Thermal decomposition, amalgamation, & atomic absorption
°F	Degrees Fahrenheit
µg/L	Micrograms per liter

Although not all of the preceding analytical methods were developed specifically for EPA's Superfund Program, all of the listed methods have been approved for use on EPA-funded projects. Choice of the appropriate analytical method may depend on available sampling equipment, laboratory instrumentation, and the required detection limit. The analytical method may also be dictated if use of a CLP laboratory is necessary. Collection of samples for analyses for both dissolved and total mercury may be warranted, especially for turbid liquids. Field duplicates, equipment rinsate blanks, field blanks, and background samples should be collected if necessary to meet site-specific goals, and as required by sampling-related QAPPs, FSPs and SOPs, as well as by the selected analytical method.

## **6.4 Investigation-Derived Waste**

Investigation-Derived Waste (IDW) from elemental mercury spills may include recovered liquid mercury, used mercury vacuum filters, used cleaning/decontamination solutions, used personal protective equipment (PPE), and other discarded items that may be contaminated with mercury (e.g., clothes, bedding, paperwork, furniture, carpet). Disposal of recovered liquid mercury is addressed in Chapter 10. Sampling of other IDW for laboratory analysis may be required to coordinate proper disposal. Considerations for sampling and analysis of those materials are discussed in the following sections.

### **6.4.1 Solid Samples**

Typically, composite samples of solid IDW are collected for analysis for metals (including mercury) via the Toxicity Characteristic Leaching Procedures (TCLP) to determine leachability of metals from the materials when exposed to a mildly acidic extraction liquid typical of a landfill environment. Techniques for sampling this type of IDW must be adequate to enable collection of representative samples (follow ERT SOP for Representative Sampling of Waste Piles). Use of hand tools (e.g., scissors, saw, tin snips or utility knife) may be required to collect aliquots of the various materials comprising the IDW. Field QC samples (e.g., field duplicates and equipment rinsate blanks) are not required by the TCLP method; however, these may be specified in site-specific QAPPs, FSPs or agency-specific SOPs. Proper disposal is described in Chapter 10.

### **6.4.2 Liquid Samples**

EPA SW-846 Method (1311) for the TCLP extraction specifies that if a sample is less than 0.5 percent solids, the filtrate may be analyzed as the sample extract. Therefore, liquid IDW samples meeting that criterion likely will not have to undergo the 18-hour extraction procedure. Because liquids are banned from land disposal, TCLP analysis may not be the most appropriate analytical method for these types of media. Instead, analysis for total RCRA metals (including mercury) may provide the most useful data to coordinate proper disposal of the IDW. These results will help determine whether the liquid IDW can be disposed of at a publicly owned treatment works (POTW) facility or by other appropriate

means. Addition of a gelling agent to transform the IDW into a semi-solid material with no free liquids may also warrant consideration to facilitate disposal of the material at a landfill (after the solidified material has been sampled for paint filter analysis and for TCLP analysis as previously described).

Techniques for sampling this type of IDW must be adequate to enable collection of representative samples. Thieving rods or Coliwasas may be used to collect samples from drums or other containers, or sample jars may be dipped directly into the liquid if deemed appropriate to provide a representative sample of the liquid for disposal purposes. Field QC samples (e.g., field duplicates, field blanks, equipment rinsate blanks) should be collected as specified in site-specific QAPPs, FSPs or agency-specific SOPs.

Figure 6-3 lists analytical methods and associated sampling-related information regarding solid and liquid IDW.

**Figure 6-3: Analytical Methods for Investigation-Derived Waste**

Matrix	Description of Method	Analytical Method (SW-846)	Container	Preservation <sup>a</sup>	Holding Time
Solid	TCLP	6010/6020, 7470A <sup>b</sup>	16-ounce jar (or larger) <sup>c</sup>	None	See below <sup>d</sup>
Liquid (>0.5% solids)	TCLP	6010/6020, 7470A <sup>b</sup>	4-liter glass or plastic container	None	See below <sup>d</sup>
Liquid (<0.5% solids)	Total RCRA Metals	6010/6020, 7470A <sup>b</sup>	2 1-liter glass or plastic containers	pH <2 with HNO <sub>3</sub>	Mercury: 28 days Other Metals: 180 days

**Notes:**

<sup>a</sup> Some laboratories may also require samples to be cooled to a specific temperature (e.g., < 39.2 °F).

<sup>b</sup> Other acceptable analytical methods for mercury are listed in Section 6.3.3.

<sup>c</sup> If sample material is very lightweight (e.g., used Tyvek® coveralls, etc.) or cannot be packed tightly into a jar (e.g., elongated wood or metal fragments, etc.), additional sample volume should be collected (up to two 32-ounce jars per sample).

<sup>d</sup> Mercury: 28 days to extraction, 28 days after extraction to analysis

Other RCRA metals: 180 days to extraction, 180 days after extraction to analysis

HNO<sub>3</sub> Nitric acid

RCRA Resource Conservation and Recovery Act

TCLP Toxicity Characteristic Leaching Procedure

°F Degrees Fahrenheit

% Percent

## 7 Exposure Limits

Several government agencies have established limits for various types of mercury vapor exposure. Many of these limits deal with the chronic exposure of workers in industries that use mercury or mercury-containing devices. Other limits deal with the effects of acute exposure, such as those that might result from an elemental mercury spill. Numeric values for cleanup and disposal purposes (e.g., soil) can be found in Chapters 9 and 10. A summary of environmental and occupational health standards is presented in Figure 7-1. More detailed information on action levels can be found in Appendix A.

**Figure 7-1: Environmental and Occupational Health Standards and Guidelines for Inhalation Exposure to Mercury Vapor**

Agency	Mercury Vapor Concentration ( $\mu\text{g}/\text{m}^3$ ) <sup>1</sup>
NIOSH IDLH	10,000
OSHA Ceiling Limit <sup>2</sup>	100
NIOSH REL <sup>3</sup>	50
ACGIH TLV <sup>4</sup>	25**
ATSDR suggested relocation Action Level	10
ATSDR suggested residential occupancy level*	1
ATSDR MRL <sup>5</sup>	0.2
EPA RfC <sup>6</sup>	0.3

\* See Final ATSDR Health Consultation (March 22, 2012) for details regarding action levels (Appendix A)

\*\*EPA's health and safety practice is to upgrade to Level C (or greater) PPE at or above 25  $\mu\text{g}/\text{m}^3$

### Notes:

<sup>1</sup> micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ )

<sup>2</sup> Ceiling Limit = exposure to the concentration of mercury vapor cannot exceed this limit at any time

<sup>3</sup> REL = Recommended Exposure Limit, a time-weighted average for an 8-hour day

<sup>4</sup> TLV = Threshold Limit Value, a time-weighted average for an 8-hour day

<sup>5</sup> MRL = Minimal Risk Level (defined in Appendix A)

<sup>6</sup> RfC = Reference Concentration (defined in Appendix A)

### 7.1 Mercury Vapor Inhalation Exposure and Limits

Below is a description of various regulatory and guidance reference concentrations for mercury vapor exposure. Refer to Appendix A for a detailed description of elemental mercury response recommended action levels.

### 7.1.1 NIOSH

NIOSH has established 10,000  $\mu\text{g}/\text{m}^3$  as the concentration that is “immediately dangerous to life or health” (IDLH) (Ashe et al. 1953 [NIOSH Pocket Guide September 2007]). The NIOSH Recommended Exposure Limit (REL) for mercury vapor is set at 50  $\mu\text{g}/\text{m}^3$  for up to a 10-hour workday during a 40-hour work week, with a skin designation (indicating that skin exposure should be prevented).

### 7.1.2 OSHA

OSHA’s legally enforceable 8-hour time weighted average limit for workplace exposure is set at 100  $\mu\text{g}/\text{m}^3$  (updated September 6, 2012). This is the Permissible Exposure Limit (PEL). PELs are applicable when mercury vapor is a known hazard in the work place. EPA would not consider PELs for residential responses.

### 7.1.3 ACGIH

The American Conference of Governmental Industrial Hygienists (ACGIH) set their Threshold Limit Value (TLV) at 25  $\mu\text{g}/\text{m}^3$  of mercury vapor (as averaged during an 8-hour workday) (ACGIH April 11, 2008).

### 7.1.4 ATSDR

ATSDR derived a chronic exposure (more than 365 days) Minimal Risk Level (MRL) of 0.2  $\mu\text{g}/\text{m}^3$  with a recommended residential action level of 1.0  $\mu\text{g}/\text{m}^3$  that should prompt environmental or health officials to implement a response action to reduce exposure (1999). ATSDR suggested a residential occupancy level of 1.0  $\mu\text{g}/\text{m}^3$  that is considered “safe and acceptable” for occupancy by the most sensitive residents of any structure after a spill, provided no visible mercury is present. ATSDR also recommended an indoor sustained action level of greater than 10  $\mu\text{g}/\text{m}^3$ , the level at which measures should be taken to relocate all occupants from potential mercury vapor exposure. Indications are that this action level may be the concentration at which urinary levels of mercury begin to increase. Other studies indicate this concentration may be the lowest toxic concentration for humans. Continued exposure may be harmful. Please refer to the health consultation in Appendix A for more information.

### 7.1.5 EPA

EPA established a reference concentration (RfC) of 0.3  $\mu\text{g}/\text{m}^3$  (June 1995) for inhalation exposure, which represents “...an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily inhalation exposure of a human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.” EPA also established that a mercury vapor concentration of 25  $\mu\text{g}/\text{m}^3$  is the level for upgrading to Level C PPE. Please refer to the health consultation in Appendix A for more information.



## 7.2 Ingestion Exposure

The EPA Maximum Contaminant Level (MCL) for mercury in drinking water is 2 parts per billion (0.002 mg/L). The Food and Drug Administration (FDA) limit for mercury in drinking water is also 2 parts per billion. Additional information on mercury in drinking water can be found at: <http://water.epa.gov/drink/contaminants/basicinformation/mercury.cfm>. Please note that these limits and the material in the referenced website are based on mercury compounds instead of elemental mercury, which is the focus of this guidebook.

## 7.3 Dermal Exposure

Generally, dermal exposure or absorption of metallic mercury through the skin is considered a minor exposure route. However, the recent introduction of skin creams containing mercury may pose a greater risk of dermal exposure.

# 8 Relocation of Residents

In cases where mercury vapor contamination exceeds the levels for safe occupancy, relocation of residents may be warranted. The OSC will consult with the appropriate public health agency personnel to determine whether relocation of residents is recommended, based on environmental screening or sampling results and the health status of individuals who may be exposed. When available, local health departments play an important role in notifying residents of the need to relocate. A letter may be issued but is not required to notify the residents of sampling results and the relocation and cleanup process. For additional information on this topic see *Superfund Response Actions: Temporary Relocations Implementation Guidance*, EPA, OSWER Directive 9230.0-97, April 2002.

*NOTE: The OSC does not have the authority, even after explaining to the residents the consequences of elemental mercury contamination, to force relocation of residents or dispose of their mercury-contaminated items, without their consent.*

## 8.1 Relocation Options

Residents often prefer to stay with friends or relatives during elemental mercury cleanups. When they are unable to do so, various service providers are available to help. Local health departments may also assist displaced residents in securing local accommodations. Resources of local health departments vary greatly, which may limit their ability to participate in elemental mercury responses. The American Red Cross is often available to assist in relocation efforts and is sometimes able to fund temporary relocations; it may receive reimbursement from EPA when the removal is complete. For smaller-scale relocations, EPA may task ERRS to provide this service. On larger responses where, multiple relocations may be required, the U.S. Army Corps of Engineers (USACE) can provide assistance. The EPA Regions

have inter-agency agreements with USACE. OSCs should coordinate with their regional support coordinators to engage USACE assistance.

If the occupants refuse to voluntarily relocate from the residence, most local jurisdictions have the authority to order a forced occupant removal or post a notice that the home is unfit for human habitation. For additional information on this topic see *Superfund Response Actions: Temporary Relocations Implementation Guidance*, EPA, OSWER Directive 9230.0-97, April 2002.

## 8.2 EPA Relocation Program

In large multi-residential elemental mercury responses, state and local relocation services may not be available. In these cases, EPA can coordinate and manage relocation of residents. The Uniform Relocation Assistance and Real Property Acquisition Policies Act (URA), 42 U.S.C. Section 4601, was enacted in 1971 to ensure uniform and equitable treatment of persons who may be displaced from their homes and businesses during Federal programs, such as disaster relief or national emergencies, or as a result of projects involving acquisition of a private property. URA provides for the issuance of relocation benefits to persons displaced in such actions. EPA is authorized under Executive Order 12580, Superfund Implementation, to temporarily relocate the threatened individuals as part of the removal action. According to the URA, the EPA OSC determines the need for relocations that are carried out in conjunction with Superfund removal actions. See *Superfund Response Actions: Temporary Relocations Implementation Guidance*, EPA, OSWER Directive 9230.0-97, April 2002 or the *Superfund Permanent Relocation Statement of Work Template and Users' Guide*, OSWER 9230.0-108, August 2004, for additional guidance.

*EXAMPLE: At an elemental mercury spill site in Region 9, the residents of the mercury contaminated house were relocated to a motel when other accommodations were unavailable. The local chapter of the Red Cross initially funded the lodging for the family. EPA was able to provide added funding because the decontamination continued for an extended amount of time.*

Under URA, persons who are temporarily relocated as part of a CERCLA removal action are eligible to receive reimbursement for all reasonable out-of-pocket expenses incurred in connection with the temporary relocation. Always ask residents if they have family or friends in the area to stay with before offering relocation. Each family is eligible to receive a housing allowance, which normally consists of paid lodging at a hotel. In addition, each family member is eligible to receive daily per diem (or food vouchers) plus incidental benefits for

miscellaneous expenses. Per diem rates will vary according to the location of the incident. The Red Cross can assist by contracting with local hotels to provide temporary relocation to evacuated residents or by issuing vouchers to families to assist in the cost of food.

Residents who relocate to the homes of friends and family members are eligible to receive relocation incidental benefits per family member. When items cannot be decontaminated and must be disposed of, residents may qualify for reimbursement. Replacement of disposed items is also an option and is discussed in Section 11.2. In past responses, the Red Cross has provided benefits in the form of a check to the head of the household. EPA may reimburse the Red Cross after the project is completed.

The assistance of a CIC will usually be needed when relocation is to occur. The CIC is an EPA employee who works with the OSC to inform the public about response actions in accordance with the interactive community involvement requirements set forth in the NCP.

### **8.3 Release of Residential Clothing and Household Items**

During relocation, all personal items should be screened for mercury vapors before removal from the site or residence in order to prevent additional locations from becoming contaminated. The relocation of residential families is a traumatic situation that will take time and patience. Generally, residents will want to take essential personal effects (e.g., toiletries, medications, work-related items) and clothing when being asked to relocate. All items must be screened following procedures described in Section 9.4.1 (Screening Residential Clothing and Household Items) before they are released to the resident.

Because some items are essential, the Red Cross or other charities may issue a cash voucher for immediate replacement of essential items. Any released or disposed items should be documented and photographed or video recorded. Residents should be instructed to select all items they plan to take out of their home while they are temporarily relocated.

No more than four to six items should be placed in a plastic bag (depending on size), and the bags should sit in a warm area for a short period of time prior to screening. Items should not be moved to a location where they may spread contamination without proper screening. The headspace of the bagged items should be screened using an MVA detector placed just inside the bag opening while attempting to not allow outside air to enter the bag (see Photograph 8-1). A consistent reading greater than 3 to 6  $\mu\text{g}/\text{m}^3$  indicates that the items should not be removed from the site and returned to residents until vapor readings are lowered. These items should be documented in writing and with photographs or video.



**Photograph 8-1**

*View of START using an MVA to analyze the headspace of bags containing potentially mercury-contaminated clothes*

## **8.4 Site Security**

EPA may request local police support or contract with local police departments to provide extra security while residences are vacant due to relocation. In addition, or alternatively, EPA may contract with private security companies to help prevent vandalism and burglary of vacant residences.

## **9 Cleanup Process**

Prior to initiating the cleanup process, the OSC should ensure that all preliminary steps, as needed and detailed in the previous chapters, have been implemented before cleanup activity begins. A Mercury Decontamination checklist of tasks is provided in Appendix C. Every response is unique. Some situations will require that all steps outlined in the checklist be completed while others may be less complex and require only a few of these tasks. In either case, reviewing the checklist on an elemental mercury response will reduce the likelihood of missing an important step in the process.

Elemental mercury spills in residences can be challenging because mercury tends to accumulate in low spots and cracks. In addition, spilled liquid mercury can easily spread because micro-beads of liquid are so small, they are difficult to see with an untrained eye. Liquid elemental mercury can resemble wet spilled paint. It adheres to everything that it comes into contact with and is easily tracked into other areas. Unlike paint, elemental mercury never dries, and it is difficult to remove from porous material and objects. It may not be possible to decontaminate porous items that have absorbed elemental mercury such as carpet, drapes, furniture, and bedding. It is generally more cost-effective to properly dispose of contaminated porous items instead of attempting to decontaminate them.

## 9.1 Pre-Decontamination Procedures

Due to the extremely intrusive nature of elemental mercury cleanups, EPA and the homeowners should thoroughly discuss the actions that are planned to be taken in their home. EPA should also describe how these actions will be documented. Ensuring the residents have a good understanding of the procedures and cleanup documentation is beneficial to the Agency as well as the homeowners.

### 9.1.1 Pre-Decontamination Documentation

Prior to decontamination, thorough video and photographic documentation of the contents and condition of the interior and exterior of the residence needs to be completed. Written notes or forms may be useful. Close coordination with the property owner and residents is critical during this step. Note date and time on video and photographs. The video should be panned slowly and thoroughly and with narration to explain details (see Photograph 9-1). The video will be used

***NOTE:** A Decontamination Checklist is provided in Appendix C. The checklist should be updated regularly to verify that work has been completed. The completed checklist should be returned to the site files. Any deviation from the plan should be noted in writing on the checklist. EPA will obtain a key for each structure to be decontaminated. All keys must be tracked and returned to the command post daily.*

during the restoration, reimbursement, and replacement processes. Any items that are removed from the home should also be documented via video, photograph, and/or written logs. There may be property that some homeowners may not want disturbed or removed, such as antiques or family heirlooms. The OSC and the resident will need to discuss options for managing and cleaning these types of items.



**Photograph 9-1**

*View of EPA personnel conducting pre-decontamination video documentation of the interior of a home*

### **9.1.2 House Tracking Database**

All information from removal activities should be tracked and organized (e.g., in a database or spreadsheet). Information to be tracked should include access agreements, temporary relocation dates, pre-decontamination documentation dates, air sampling data and results, post-decontamination documentation dates, reimbursement data, and de-list letter dates to the local health department. This is especially important when there are multiple response locations.

### **9.2 Establishing Work Zones and Containment Operations**

Hazardous materials operations must be conducted in a controlled and methodical manner to ensure contamination is not tracked to other locations and to ensure the safety of responders. Elemental mercury responses require that all contaminated items be decontaminated or removed to achieve the desired cleanup action levels. Items that cannot be removed should be decontaminated in place. All contaminated items requiring disposal should be documented in writing or with video or photographs, as described above. In addition, the Site Safety Plan must account for all potential hazards that may be encountered during cleanup operations.

### 9.2.1 Establish Control Zones and Ingress / Egress Routes

When addressing an elemental mercury cleanup at a residential or commercial property, it is important to ensure that no contamination is present on or around entry points and walkways (e.g., sidewalks, driveways). If access ways are contaminated, initial operations must be conducted to contain, remove, or treat contaminated surfaces. Specific cleanup processes are described in the sub-sections below. Once the extent of contamination is known, ingress/egress procedures should be developed in accordance with appropriate hazardous materials operations practices.

### 9.2.2 Establish Ventilation / Air Management

Establishing ventilation of a contaminated structure serves several purposes throughout the cleanup process, including:

- Decreasing ambient levels of mercury vapors within the structure to allow for identification of “hot spots”
- Reducing the potential for porous surfaces to adsorb mercury vapors
- Decreasing ambient levels of mercury vapors to allow for decreased level of personal protection
- Removing residual vapors after cleanup has been completed (see Section 9.5)

To establish ventilation, windows should be opened, and fans placed strategically to drive the mercury vapors outdoors (and cycle fresh air in). Strategic fan placement is necessary because ventilation is generally not as simple as placing a fan on the floor in the middle of the affected area as all this does is mix the air, not ventilate it to the outdoors. With proper ventilation the ambient mercury vapor concentrations will fall, and it will then be easier to determine where the source contamination is located. As cleanup operations progress, ambient mercury vapor levels should be re-checked. When checking for source areas, ventilation should be temporarily halted so that the highest concentration of vapors will be located nearest the source areas.

**NOTE:** Ventilation is critical to reduce mercury vapors and should occur as soon as possible. Ventilation reduces cross contamination via mercury vapor saturation by reducing the absorption of mercury vapors into porous materials and may reduce cleanup time by allowing the off-gassing of mercury vapors from porous materials. Ventilation will also reduce the ambient mercury vapor concentrations in the exclusion zone, possibly reducing worker PPE levels. Ventilation can be as simple as opening windows or doors to the outside (be aware of where the window's or door's vents are located) or as complex as utilizing high volume fans with charcoal filtration systems. Ventilation should not be conducted during source identification or during the confirmation sampling period.

There may be extreme cases where mercury vapor concentrations are too high to release untreated to the outside air or there may be situations where ventilation is not logistically possible. Air handling units with mercury absorbing filters may be utilized to reduce the levels of mercury vapors being released during the removal action. Activated charcoal adsorbs mercury vapors from air, but it is not particularly efficient. Charcoal treated with sulfur compounds is more efficient, but this adsorbent cannot be regenerated once it is saturated, and it must be disposed of properly. Systems have been designed using gold or silver to remove mercury vapor from air streams. Elemental mercury forms amalgams with these metals, and it can be recovered by heating the adsorption unit. The regenerated unit may be reused. Copper and zinc are also used for mercury adsorption units.

### **9.2.3 Isolate Impacted Areas**

Often elemental mercury spills occur in specific areas of a structure and can be isolated by closing off the obviously affected room(s). In some cases, the heavily contaminated areas may not be as obvious. In these situations, after full structure ventilation is established and vapor levels begin to diminish, the contaminated areas and cross-contaminated areas can be determined by using an MVA. If the heavily contaminated areas are distinctly room- or area-specific, responders should take measures to isolate these areas. Ventilation fans may need to be readjusted to ensure isolated areas do not release vapors to the rest of the structure. Isolation can be as simple as closing doors and exhausting air from the area to the outside. If necessary, plastic sheeting can be used to close off open areas (e.g., hallways) from the rest of the building. Cross-contaminated areas can then be addressed using the approaches described in this chapter.

### **9.2.4 Establish a Liquid Waste Management Plan**

Liquid waste is not typically generated during residential elemental mercury responses. In cases where liquid waste is generated during a response, it is generally most cost-effective to dispose of the liquid waste appropriately instead of trying to treat it on site. In situations where a large volume of liquid waste is generated, a cost-analysis can be conducted to determine if on-site treatment is feasible and cost-effective. Some treatment techniques are described below.

Several techniques are available for cleaning contaminated water. In the Bristol-Myers Squibb (BMS) process; chlorine is added to liquid waste, followed by BMS adsorbent (activated carbon/sulfur). Clarification and sedimentation have been proven effective in removing mercury from water. Water with a pH of 4.9 can be treated with sulfide to form a precipitate, which can then be removed by sedimentation or filtration. Duolite™ GT-73 ion-exchange resin can routinely reduce the mercury content of liquid waste from 0.2 to 70 parts per million (ppm) to between 1 and 5 parts per billion (ppb). In the Trace Mercury Removal - Immobilized Metal Affinity Chromatography (TMR IMAC™) process, chlorine is used to oxidize the elemental mercury, and the solution is passed through TMR IMAC ion-exchange resin. Peat absorbs mercury from liquid waste with pH from 5 to 5.5 and an approximate efficiency of 70%. Peanut hull charcoal can be used as a sorbent material.



Bioremediation using *Pseudomonas putida* FB1 has achieved 99 percent mercury removal efficiency in laboratory studies, but has not yet been proven or accepted as a field remediation method.

Mercury-containing brine produced by electrolytic processes in the chlor-alkali manufacturing industry can be decontaminated using a bed of activated carbon impregnated with silver. This brine may also be passed through a strong anion-exchange resin. Mercury salts can be precipitated from alkaline solutions using soluble alkali sulfides. Flocculating agents such as ferric salts, starch, or gum arabic facilitate the removal of the mercury precipitates from the aqueous medium.

## **9.3 Specialized Products and Cleanup Tools**

### **9.3.1 Elemental Mercury Response Products**

There are numerous commercially available products available for use at elemental mercury responses. However, it is important to understand the products' intended use. There are different products for different functions, including mercury indication, mercury vapor suppression, mercury amalgamation, and mercury recovery. This section is not an all-inclusive look at available products but includes some of the most commonly used products, which may be listed by their trade names. Including descriptions of these products in this guidebook is not an endorsement by EPA, but is instead intended to make responders aware of some of the product options available. All manufacturers' instructions should be read and followed as some require special application procedures (e.g., water activated). The use of these products may or may not be necessary depending on the complexity of the spill.

#### ***9.3.1.1 Mercury Indicator Powder***

Mercury indicator powder is generally used by response personnel that do not have direct access to an MVA. The indicator powder is sprinkled over the area suspected of having elemental mercury contamination and allowed to set for up to three days. If elemental mercury is present, the sulfur based powder will have a color change (generally from yellow to brown) indicating the presence of mercury contamination.

#### ***9.3.1.2 Mercury Vapor Absorbent***

Mercury vapor absorbent is a granular material generally utilized to bring overall concentrations of mercury vapor in air down enough to negate the need for upgraded respiratory protection. This activated carbon-based material will absorb mercury vapors from areas of an elemental mercury response that are hard to access (i.e., cracks and crevices). When the material is collected it should be managed with the appropriate waste stream for disposal.

#### **9.3.1.3 Merconvap™**

Merconvap™ is a chloride and sulfur based black liquid that is sprayed directly onto visible beads of mercury to suppress mercury vapors. This product can be used in areas where proper ventilation cannot be established prior to initiating physical collection of elemental mercury. It has been well-documented that the physical collection of elemental mercury will increase the mercury vapor concentrations due to agitation of the elemental mercury during the process. This product will help reduce the amount of increased mercury vapors during the physical recovery.

#### **9.3.1.4 Merconwipes™**

Merconwipes™ are moistened cloths containing chloride and sulfur that are generally used as a polishing technique after an elemental mercury cleanup is completed to make sure residual mercury is not left behind. Wipes are commonly found in commercially available mercury spill kits.

#### **9.3.1.5 Hg Absorb™**

Hg Absorb™ looks like silver metal shavings that are sprinkled over an elemental mercury spill area. The granular zinc based compound will chemically react and amalgamate with the elemental mercury allowing for easier physical collection of the liquid mercury. This product must be activated with water for the amalgamation to take place. Some spill kits contain sponges encrusted with this product which can be used as a final polishing technique at the end of an elemental mercury cleanup. The sponge should be moistened prior to use.

#### **9.3.1.6 HgX®**

HgX® is a white powder that is mixed with water (generally 1.5 pounds HgX® to 5 gallons water) and is used as a final polishing technique. The solution is sprayed over the item or area and allowed to stand (sometimes overnight); plain water is used to clean it up. This process may need to be repeated more than once if concentrations remain elevated after plain water is used.

#### **9.3.1.7 DeconGel™**

DeconGel™ is a blue viscous gel material that can be brushed or sprayed onto various surfaces – allowed to dry – and then peeled off manually. Mercury beads and residue will be encapsulated into the bottom side of the polymer substance and removed from the contaminated surface area when peeled back. Since it will be bound into the polymer, there is no separating the elemental mercury from the polymer in the field and it will all require appropriate disposal. The application and removal process can be repeated if elevated air concentrations persist.

### **9.3.1.8 Mercury Magnate™ Amalgamation Spill Powder**

Mercury Magnate™ powder reacts with liquid mercury to form a solidified amalgam that not only brings the mercury vapor pressure below harmful levels, but also allows for easy pickup using a common magnet.

### **9.3.1.9 Powdered Sulfur**

Powdered sulfur is the active ingredient in many commercially available products. Powdered sulfur can be purchased at farm and garden supply stores and can be considerably less expensive than name brand products. Powdered sulfur does two things: (1) it can make the elemental mercury easier to see since there may be a color change of the powdered sulfur from yellow to brown and (2) it binds the elemental mercury so that it can be easily removed and suppresses the vapor of any remaining mercury.

It should be noted that powdered sulfur can be moderately toxic if inhaled so breathing the powder should be avoided. Powdered sulfur can also stain certain fabrics, so it should be tested on a small inconspicuous area before using over an entire item.

### **9.3.1.10 Shampoos**

During the initial stages of a response, it may be necessary to conduct decontamination of people and pets. Although EPA does not endorse any one product over another, sulfur based Selsun Blue®, Exsel®, and Head and Shoulders Intensive Treatment Dandruff Shampoo® have been used successfully on people and pets and were recommended for use on pets by the American Society for the Prevention of Cruelty to Animals (ASPCA).

### **9.3.1.11 Products to Avoid**

Many EPA responders have noted numerous ineffective products that people have attempted to use to clean up elemental mercury spills. False information is often disseminated verbally or through Internet searches. These products do not have any chemical purpose for spreading out over an elemental mercury spill area. Examples of products that should never be used for elemental mercury cleanup include: table salt, saw dust, sand, flour and kitty litter. Although not considered a product, common household vacuum cleaners should always be avoided in attempting to clean up elemental mercury spills as they will spread contamination.

## **9.3.2 Elemental Mercury Cleanup Tools**

### **9.3.2.1 Mercury Spill Kits**

Several manufacturers provide commercially available spill kits. These kits are generally stocked with supplies sufficient to conduct a small elemental mercury cleanup. Common supplies include rubber gloves, eye protection, pipettes, chemical powders, elemental mercury collection sponges, disposable plastic dust pans, and mercury-specific hand pumps.

### **9.3.2.2 Mercury Vacuums**

There are many companies that manufacture several models of mercury vacuums. High-efficiency particulate air (HEPA) vacuum should not be used on an elemental mercury spill because they lack mercury-specific features, including a liquid mercury drop-out collection jar on the hose side of the vacuum for collection of visible liquid mercury as well as a series of internal filters (up to seven) that keep mercury vapors from being exhausted back into the atmosphere. Periodic screening of the vacuum's exhaust is necessary to assure that breakthrough has not occurred. Filters should be proactively changed to keep breakthrough from occurring. Significant care must be taken at the end of all responses to ensure the vacuum and all its components are properly decontaminated per the manufacturer's specifications so that cross-contamination in the response vehicle or warehouse does not occur. Proper decontamination can take up to three hours per vacuum. Screening the vacuum with an MVA will assure that proper decontamination has been accomplished. It may be advantageous to have several vacuum hoses on hand as they have proven to be quite difficult to decontaminate and it may be more cost-effective to dispose of the hose after use on a large elemental mercury spill response.

### **9.3.2.3 Mercury Hand Pumps**

On small elemental mercury releases, a vacuum hand pump (aspirator) can be used to collect visible mercury beads up to the size of a BB. This is generally a slow, but effective process and has proven to work on stubborn beads located in shallow cracks. Many commercially available spill kits come with vacuum hand pumps.

### **9.3.2.4 Small Spill Cleanup Tools**

Several common items found around the house have proven effective in collecting visible mercury beads on flat surfaces. Plastic covered playing cards, duct tape, disposable pipettes, eyedroppers, syringes, and shaving cream have all been used successfully by responders. When using these physical recovery techniques, slow and methodical movement is required to avoid spreading the elemental mercury.

## 9.4 Removal Procedures

Most indoor responses can be quickly managed by completing the following tasks: (1) establish ventilation in the structure to bring down ambient vapor levels, (2) remove and evaluate/decontaminate potentially contaminated loose items, (3) remove visible mercury, (4) treat or remove contaminated structures, and (5) conduct heat and ventilation cycles. More complex situations may require other techniques to successfully complete the cleanup. This section details the basic techniques and processes that should be employed on all significant interior spills. It also describes methods for less common situations that may be encountered. Note that smaller spills that are relatively contained (not tracked from the spill area and on non-porous surfaces) may require fewer steps to complete the cleanup.

### 9.4.1 Screening Residential Clothing and Household Items

An MVA should be used to screen clothing and other porous items (e.g., linens, bedding and curtains) from contaminated areas of homes. All items should be bagged, sealed, and moved outside or to an uncontaminated staging area. The number of objects in the bags should be limited to minimize the quantity of material that may need to be disposed. Care should be taken not to combine items on floors, etc. with items in drawers, etc. Items that are too large to fit into trash bags are generally wrapped in plastic sheeting and allowed to sit in the sun until warm enough to screen using the same technique. With larger items, more than one location should be screened for headspace readings (e.g., headspace readings should be taken from at least three equidistant locations on a couch that has been covered in plastic). When using this technique, verify that the bags being used are not causing elevated readings themselves by randomly testing a warm empty bag as newly purchased trash bags have given elevated readings on past projects. The bags should remain sealed and allowed to reach between 80° and 90°F to allow the contents of the bag to reach equilibrium with the air volume before the bag is sampled. This process allows any mercury vapors to accumulate in the head space of the bag. The head space in the bag should then be tested by poking a small hole in the bag and inserting the wand or extension tubing of the MVA (see Photograph 9-2) to take a head-space reading.

**NOTE:** Do not overfill the plastic bags because sufficient headspace is needed to obtain accurate mercury vapor readings. The number of items placed in the bag should be limited to fill approximately one third to one-half of the plastic bag. All types of plastic bags can be used, but they should be pre-screened before use to ensure they are not giving off detectable levels of mercury vapor. It has been determined that some opaque (dark) plastic bags can give off detectable levels of mercury vapor.



**Photograph 9-2**

*View of START personnel screening bags of clothes using an MVA*

If readings are consistently above 3 to 6  $\mu\text{g}/\text{m}^3$  (please refer to Attachment A, Section 2.2.3 for additional information on the rationale behind this range of values), the items in the bags are considered to contain mercury vapors at a concentration where they should not be taken back into the homes. Concentrations above this level typically indicate that the items have been in physical contact with, or still contain, elemental mercury. If mercury vapor levels are elevated, responders may attempt to allow the items to ventilate over a period of time before rescreening, preferably in a warm location or in direct sunlight. Once the bags screen below the 3 to 6  $\mu\text{g}/\text{m}^3$  action level, the bags should remain open and in an uncontaminated area to allow them to continue to “off-gas” over time. Bags that screen well above the action level should be disposed of or otherwise treated to reduce concentrations. Any items that require disposal should be documented in a database or spreadsheet and photo-documented prior to disposal. Final rescreen of the bagged materials should be performed post-decontamination, prior to items being returned to the house. Figure 9-1 describes the process of screening bagged materials. More detailed methods for decontaminating personal items and furnishings are discussed in Section 9.4.5 below.

## **9.4.2 Removal of Elemental Mercury from Hard Surfaces**

### **9.4.2.1 Physical Removal**

This procedure is for hard surfaces such as concrete, tile, porcelain, metal, plastic, and newer hardwood floors. Physically remove all visible mercury using physical collection techniques (e.g., plastic-coated playing cards, duct tape, shaving cream, disposable pipettes or hand pumps) and/or an approved mercury-specific vacuum (see Photograph 9-3). Larger spills will always require the use of a mercury-specific vacuum.

Exercise care while vacuuming to ensure all areas are vacuumed, paying particular attention to joints, cracks, and crevices in the flooring material. A crevice tool can be attached to the mercury vacuum to assist with these hard-to-reach areas.

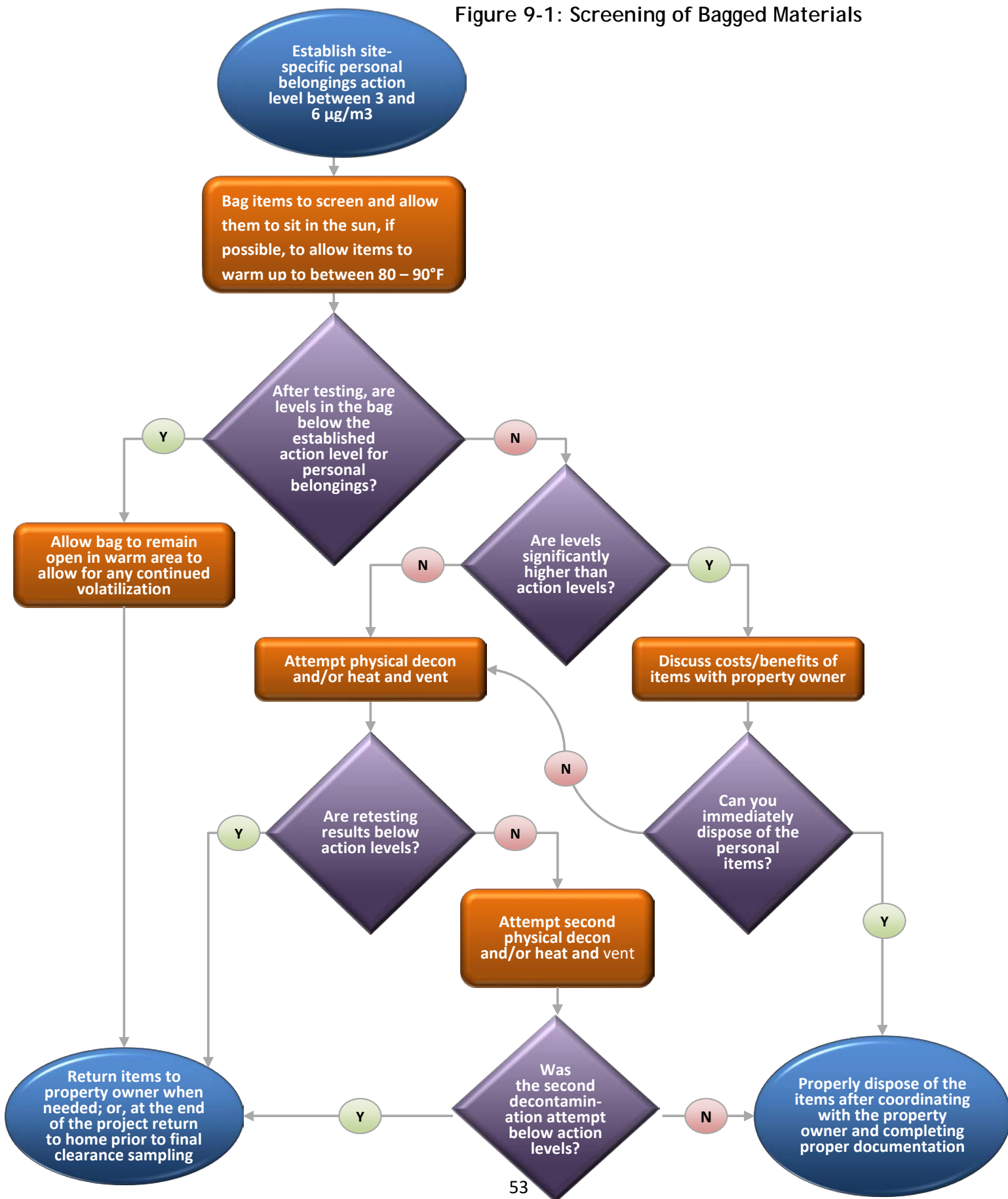
A best practice technique involves using a grid system - mark each vacuumed square with a piece of duct tape or masking tape to indicate that vacuuming has been completed (see Photograph 9-20).



**Photograph 9-3**

*Removal of elemental mercury with a mercury vacuum*

Figure 9-1: Screening of Bagged Materials





### 9.4.2.2 Residual Treatment and Wash

Before treating the floors and walls, scan the area for hidden mercury micro-beads and hot spots using an MVA. Wash the affected area with a mercury treatment solution to bind and remove the mercury residue from the surface (see Photograph 9-4). When mercury treatment solutions are used, they can reduce low levels of elemental mercury contamination into a nonhazardous inorganic salt. Follow the manufacturer's recommendations and then wash the area with clean water.



**Photograph 9-4**  
*Mopping floors with mercury treatment solution*

### 9.4.2.3 Heat and Ventilation

As ambient mercury vapor levels come down close to  $1 \mu\text{g}/\text{m}^3$  and point sources are removed from the interior space, heating/ventilation cycles will help drive off residual mercury vapors. **In residential homes, this process should not be initiated until all visible mercury has been removed.** With the area secured (windows closed, and air conditioning turned off) heat the area from  $80^\circ$  to  $90^\circ\text{F}$  for approximately four hours (the time and temperature will vary depending on site-specific circumstances) in order to volatilize any residual mercury. The temperature in the room can be regulated by the thermostat or with portable turbo heaters. For areas that are difficult to heat, turbo heaters (see Photograph 9-5) have been successful in

**NOTE:** *In some cases where it was saturated in the structure, elemental mercury may re-condense on surfaces after heating and ventilation cycles.*

raising the temperature to increase the volatilization of residual mercury. If using alternative heating sources, be sure to monitor for carbon monoxide and oxygen to ensure worker safety. In addition, when heating a residence above normal temperature, be aware of potential heat-related damage. The most common problems involve plastics, candles, and adhesives (e.g., tile, linoleum, wall paper). Once the temperature range has been achieved, ventilation can begin so that fresh air can replace the affected interior air (see Section 9.2.2). In some instances, ventilation can occur concurrently with heating and not affect achieving and maintaining the temperature goal of 80° to 90°F.



**Photograph 9-5**

*View of turbo heater applying heat to decontaminate a basement*



**Photograph 9-6**  
*View of ventilation with an industrial fan*



**Photograph 9-7**  
*View of ventilation with a blower unit*

#### 9.4.2.4 Screen Interior Air Space

After heating and venting as described in Sections 9.2.2 and 9.4.2.3, reduce thermostat to normal room temperatures, open doors and windows, and ventilate for at least one hour (the times for heating and venting cycles will vary depending on site-specific circumstances). Use blowers and ventilation fans to facilitate air movement and to completely evacuate the air column from inside to outside by replacing the indoor air with fresh outdoor air.

Then with the windows and doors closed, conduct ambient air monitoring for mercury vapor concentrations at normal indoor temperatures using an MVA or air sample pumps. Let air stabilize for 4 to 24 hours after venting before taking MVA readings (it may be as little as one to two hours for small, contained spills). Mercury vapor concentrations should be less than the desired action level (usually  $1.0 \mu\text{g}/\text{m}^3$  for residential). If ambient mercury vapor concentrations are not less than the desired action level, repeat steps beginning with residual treatment and wash. If mercury vapor levels are substantially high, elemental mercury or a saturated source likely remain in the structure.

#### 9.4.2.5 Optional Steps

These optional steps should be taken only if mercury vapor concentrations coming off surfaces or within cracks are still above the recommended cleanup level and after multiple attempts following the steps above were taken.

Seal Impacted Surfaces: Large cracks should be filled in with an epoxy joint or crack filler prior to sealing. Apply two coats of fast drying epoxy to affected surfaces (NOTE: Several products including Kilz and various epoxies have been used successfully at sites, however, DuraSeal® is a known finish product that has been tested and approved for use as a vapor barrier). Apply additional coats to cracks in the floor if necessary. After the epoxy has been applied and has cured, verify that ambient mercury vapor concentrations are less than the desired action level.

*EXAMPLE: At an EPA elemental mercury cleanup site, Lumex MVAs were used to locate any hot spots in the residence; the tile mastic was identified. ERRS crews removed the tile mastic from the kitchen and dining areas. A follow-up Lumex survey indicated mercury vapor concentrations as high as  $4 \mu\text{g}/\text{m}^3$ . Based on these levels, the ERRS crew applied two coats of concrete primer/sealer. A subsequent Lumex mercury vapor survey indicated mercury vapor concentrations below  $1 \mu\text{g}/\text{m}^3$ . A final round of air confirmation samples were collected and analyzed; results were below  $0.22 \mu\text{g}/\text{m}^3$ .*

Physical Removal of Structural Materials: There are many situations where structural material such as walls, floors, and ceilings may require removal if they are overly saturated with elemental mercury. Best practices suggest that it is likely more cost-effective to remove and replace these items rather than spending excessive amounts of time trying to treat them. In addition to the other removal techniques described later in this chapter, physical removal may be necessary if vapor levels are not adequately reduced.

Floor tiles may require removal to remediate mercury contamination. Prior to removal, samples of resilient flooring (tiles) should be analyzed for asbestos content. If the resilient flooring contains asbestos, properly trained workers should follow procedures in the Occupational Safety and Health Administration's (OSHA) Occupational Exposure to Asbestos Standard 29 CFR 1926.1101.



**Photograph 9-8**  
*View of floor cracks sealed with caulking material*

#### **9.4.3 Removal of Elemental Mercury from Carpeted Surfaces**

If elemental mercury is spilled directly on carpeting, the carpeting usually cannot be decontaminated and should be removed and properly disposed. If the carpet was impacted by cross-contamination (i.e., elemental mercury was tracked away from the initial spill to the carpet), the carpeting may not have to be removed.

For removal of grossly contaminated carpet:

1. Physically remove all visible mercury using previously described physical techniques or an approved mercury-specific vacuum. Exercise care while vacuuming to ensure that all areas are vacuumed, paying particular attention to joints between carpeting and molding. Mark each vacuumed square with a piece of duct tape or masking tape to indicate that vacuuming has been completed. Be sure to vacuum both with and against the carpeting nap to ensure mercury micro-beads are removed from the carpeting. Due to the fibrous nature of carpeting, vacuuming the beads will temporarily increase the ambient concentration of mercury vapor contamination. When removing, roll carpeting (and, if necessary, padding) inward to prevent mercury beads from releasing (see Photograph 9-9). In addition, carpeting should be bagged during transport to avoid additional spills of elemental mercury.
2. Monitor the remaining floor with an MVA.
3. If elevated levels of mercury vapor are emitting from the surface of the floor, wash the affected area with a mercury treatment solution.
4. Once surface vapors are minimized, conduct heating/ventilation cycles as described in Section 9.4.2.3 above.
5. Screen and monitor the remediated space as described in Section 9.4.2.4 above.

If the carpeting was cross-contaminated, responders may attempt to treat the carpet in lieu of removal. Using a mercury vapor suppressant wash or initiating heat/vent cycles may be considered in these situations. If a carpet wash is used, the carpeting should be cleaned again after the remediation work is completed to remove treatment residues from the carpet. After treatment, if ambient mercury vapor concentrations still exceed  $1.0 \mu\text{g}/\text{m}^3$  after one hour of ventilating, the carpeting should be removed, along with any padding beneath the carpeting. After the affected flooring has been removed, follow the procedures for removing elemental mercury from hard surfaces.



**Photograph 9-9**  
*View of carpet removal*

#### **9.4.4 Removal of Elemental Mercury from Wooden Floors**

Some wooden or laminate flooring can be cleaned using the procedures described in Section 9.4.2 (Removal of Elemental Mercury from Hard Surfaces). If the flooring has substantial cracks or grooves and behaves more like a porous material, the flooring may have to be removed. In these cases, conduct the removal of flooring in a methodical method, similar to methods used to remove carpeting, above. The difference is that wood/laminate flooring will be taken apart (not rolled up, like carpet) as seen in Photograph 9-10 below. During demolition of the floor, have a mercury vacuum with crevice tools ready to remove any visible mercury that may be present between boards or under the flooring. Like concrete, wooden structures (i.e., wall studs, floor joists, and subfloors) may be able to be sealed and painted in lieu of removal if all visible mercury has been removed.



**Photograph 9-10**

*View of removal of elemental mercury from wood flooring*

#### **9.4.5 Removal of Elemental Mercury from Personal Items**

Non- and semi-porous personal items can almost always be decontaminated using mercury treatment solutions. Depending on the level of contamination, porous personal belongings may be decontaminated using heat. Items may be put into plastic bags, labeled to identify the owners, and collected in a central area. Initial mercury vapor levels inside the bag headspace should be measured and recorded, as described in Section 9.4.1. The bag contents may be heated from approximately 80° to 90°F for 24 hours, and then vented (time and temperature will vary from spill to spill and the types of material being treated). Mercury vapor levels should then be measured, and if necessary, the process repeated until the mercury vapor levels drop below the action level. The basic procedure for removing mercury contamination from furnishings and clothing is described below, followed by two alternate methods.



1. Set up a disposable structure (tent) to hold the mercury-contaminated personal belongings and furnishings downwind from the work area. Designate a “warm zone” where personnel should not enter due to mercury vapor exhaust.
2. Place several industrial or shop grade electric, gas, or kerosene powered heaters inside the tent and place blowers at exhaust points inside the tent (verify the MVA being utilized does not have any interference issues with the fuel source of the heaters).
3. Post at least one 10-pound fire extinguisher outside of the structure and a smoke detector inside the structure.
4. Maintain the temperature inside the structure between 80° and 90°F.
5. Remove items from bags and place items inside the structure on plastic sheeting or hang from makeshift clothes lines, segregated by source or level of contamination.
6. Heat contaminated items in the structure to force the volatilization and removal of mercury vapors. Longer heating times may be required for heavily contaminated furnishings and clothing.
7. No person should enter this “decontamination structure” unless trained and protected with a minimum of Level C PPE with mercury specific cartridges.
8. Following the heating period, the structure should be ventilated.
9. All clothing and furnishings should then be placed into plastic sheeting or trash bags and screened using an MVA to verify that mercury vapor concentrations are less than the desired action level for personal effects.
10. If mercury vapor concentrations continue to exceed the established action level for personal effects, repeat step 6 or properly document and dispose of the items.
11. Appropriate decontamination and disposal of all materials and supplies, including the actual decontamination of the structure, should occur prior to dismantling the structure.

Personnel engaged in the elemental mercury cleanup operation should make sure that their personal items, such as clothing and shoes, are not contaminated before leaving the site. These items must be scanned for mercury vapors using real-time instrumentation before leaving the site.

#### ***9.4.5.1 Alternative Decontamination Methods for Porous Items***

For EPA-funded elemental mercury cleanups, it is more cost-effective in most cases to dispose of mercury-contaminated items. However, under unique circumstances, the following two alternative methods can be attempted to decontaminate mercury-contaminated items.

## Method 1

1. Clothing and furnishings may be placed on plastic sheeting in the sun and heated to volatilize the mercury vapors (see Photograph 9-11). Place in the sun for at least four hours (time will vary due to numerous variables). Longer heating times may be required for heavily contaminated furnishings and clothing.
2. All clothing and furnishings should then be placed into plastic sheeting or trash bags and screened using an MVA to verify that mercury vapor concentrations are less than 3 to 6  $\mu\text{g}/\text{m}^3$ .
3. If mercury vapor concentrations continue to exceed the action level, the items should be properly documented and disposed of.
4. Typically, this alternative method is only effective in warm to hot weather conditions.



**Photograph 9-11**

*View of mercury contaminated clothing/furnishings volatilizing in the sun*

## Method 2:

1. Clothing and furnishings such as draperies may be heated and ventilated using an ordinary clothes dryer set to the highest heat setting. Cycle items at least twice before screening, and cycle the dryer empty and on the highest heat setting between loads of contaminated clothing and furnishings.
2. All clothing and furnishings should then be placed into plastic sheeting or trash bags and screened using an MVA to verify that mercury vapor concentrations are less than the desired action level for personal effects.

3. If mercury vapor concentrations continue to exceed the action level for personal effects, the items should be properly documented and disposed of.
4. Once completed, screen the commercial or household dryer with an MVA for residual contamination. This practice may contaminate the household dryer. If the mercury vapor concentration is greater than the action level for personal effects, then the dryer should be considered contaminated and properly disposed.

#### 9.4.6 Removal of Elemental Mercury from Washers and Dryers

In residential situations where elemental mercury has been spilled long before any response action took place, contaminated clothing may have been laundered. The washing and drying machines may have become contaminated. In most cases, running empty cycles can clear out the residual mercury that is present in these machines. However, if screening with an MVA indicated that free liquid mercury is likely present, more intrusive work may need to be performed, including removing the washing or drying drum and recovering any free liquid mercury that may be present in the machine, evaluating or replacing hoses, and cleaning machine components with mercury decontamination products. In situations where the machines require additional effort to clean, it may be more cost-effective to simply dispose of the machines and replace them. If the machines are to be dismantled for cleaning, they should either be moved outdoors or placed on a containment pad to capture any liquid mercury that may be present and released.



**Photograph 9-12**

*View of START screening a household washing machine with a Lumex MVA*

#### **9.4.7 Removal of Elemental Mercury from Vehicles**

For vehicles, ATSDR recommends a mercury vapor action level in the range of 3 to 6  $\mu\text{g}/\text{m}^3$ . Some vehicles are especially difficult to clean due to the fabric materials used in flooring and seats.

The steps for cleaning vehicles include:

1. Remove all visible mercury using physical techniques or a mercury vacuum.
2. Once all visible mercury has been removed and the known affected area has been thoroughly cleaned, keep the windows and doors open for several hours to allow for venting of mercury vapor (in colder climates, this may not be possible, and the vehicle will have to be heated).
3. Once heating and venting cycles are completed as described in Sections 9.2.2, 9.4.2.3, and 9.4.2.4, close windows and doors and allow vehicle to heat up inside to above 75°F.
4. Slowly open a door and thoroughly screen the vehicles interior with an MVA.
5. If readings exceed the desired vehicle action level, repeat steps 1 through 4.
6. If readings continue to exceed the action level, carpeting and porous seating may require removal and disposal.

#### **9.4.8 Removal of Elemental Mercury in Plumbing**

Elemental mercury in plumbing is usually contained in the traps adjacent to the plumbing fixture, such as sinks, drains, and toilets. Dismantling is the preferred method of recovering elemental mercury from plumbing in this setting. After the elemental mercury is recovered from the drains, the mercury vapor concentration should be measured using an MVA.

If dismantling of the plumbing is not possible or practical (e.g., cement floor drains), a magnetic amalgam powder may be used. The magnetic amalgam powder can be gently poured into the plumbing fixture containing the elemental mercury and gently forced into the trap by use of a drain plunger. This technique should be employed with extreme caution to avoid forcing the elemental mercury farther into the plumbing system. Wait several minutes to allow the magnetic amalgam powder to react with the elemental mercury, and then introduce a plastic-covered magnet into the plumbing system. The elemental mercury is removed as the plastic-covered magnet is slowly withdrawn.

In some cases, plumbing will not respond to the cleanup techniques described above. It may be necessary to either remove or abandon (i.e., seal) floor drains to achieve appropriate ambient air mercury vapor levels. Close coordination with the property owner is essential in these situations.

#### **9.4.9 Removal of Dermal Mercury Contamination from Humans and Animals**

To assess and remove residue from humans and animals that come into direct contact with elemental mercury or with mercury contaminated items, follow the procedures described below.

### Humans:

1. Determine if a person is contaminated with mercury residue by screening them with the MVA. Start by running the MVA inlet within approximately a half inch of the person's palm-side-up hands. Then move to their shoe bottoms. Then ask if you may screen the extremities of their clothing. Generally, if mercury residue is present, it will be on the person's hands, shoes, or clothing. To get a more confident shoe reading, have the person remove their shoes and screen them in a plastic bag following the steps outlined in Section 9.4.1.
2. If detectable mercury residue is present, issue a trash bag or drum liner to each impacted individual.
3. If exposure occurred away from the individual's home, first take measures to prevent cross contamination. The person should be issued alternative clothing or a Tyvek® suit and bags should be placed over their shoes. When they are home, instruct the individual to change into non-contaminated clothing and place his or her potentially contaminated shoes and clothes into a trash bag or drum liner. Written instructions should be issued on how to proceed. Alternatively, shower facilities could be arranged for at the site.
4. As described in Section 9.4.1, screen the exposed individual's clothing and shoes with an MVA.
5. It is recommended that the exposed individual shower with warm water and wash his or her hair with sulfur-based shampoo as described in Section 9.3.1.10. A commercial product such as HgX® Hand Cream and Cleaner may also be used. Only use products that are intended for direct human use.

### Animals:

1. First determine if the animal is contaminated with mercury residue by screening them with the MVA. Start by running the MVA inlet within approximately a half inch of their fur or skin. A funnel may also be attached to the MVA inlet to assess a larger area and to prevent inlet contamination. Then move to their feet bottoms.
2. Remove collar or other items from the animal and place into a plastic bag.
3. As described in Section 9.4.1, screen the items in the bag with an MVA.
4. If the animal is contaminated the OSC must determine if the animal should be washed and treated onsite, at a veterinarian's office, or at home by the pet owner.
5. It is recommended that the exposed animal be bathed in warm water with sulfur-based shampoo as described in Section 9.3.1.10. A veterinarian should be consulted for any other actions.
6. The animal should be rescreened as described above.

#### 9.4.10 Removal of Elemental Mercury from Soils and Other Outdoor Surfaces

In most cases, elemental mercury contamination is close to the ground surface. An investigation should be conducted to determine the horizontal extent of contamination. Using a sample grid system is useful at managing sample collection in determining the area of contamination. In warm or sunny conditions, upside down black bus tubs with a small hole drilled in the top work well for grid assessments over outdoor surfaces. As shown in Photographs 9-13 and 9-14, the headspace air inside the tub is an indicator that contamination is present and must be managed. If there is visible free liquid mercury outside the structure (e.g., yard, sidewalk, street) a mercury vacuum should be used to recover the elemental mercury. On uneven surfaces, the bus tub should be modified with a plastic shroud to add surface area and seal the head space, as shown in Photograph 9-15. With soils, excavation or soil/sod cutting (see Photographs 9-16 and 9-17) may be required if the area is too large and vacuuming is not feasible. On hard surfaces (e.g., streets, parking lots), where elemental mercury is spread over an expansive area, alternative containment and removal options may be considered; however, visible mercury must be removed.



**Photograph 9-13**  
*View of a sample grid system*



**Photograph 9-14**  
*View of a sample grid system*



**Photograph 9-15**  
*View of a bus tub with shroud*



**Photograph 9-16**  
*View of a soil/sod cutting operation*



**Photograph 9-17**  
*View of a soil/sod cutting operation*



EPA has established Removal Management Levels (RMLs) for mercury contamination in soil. RMLs may be used to support the need for a removal action at a site and can be found at:

<https://www.epa.gov/risk/regional-removal-management-levels-chemicals-rmls>. In the May 2018 update, the RMLs for elemental Mercury at a Hazard Quotient of 3 were listed as:

- Residential: RML 33 mg/kg elemental Hg
- Commercial/Industrial: RML 140 mg/kg elemental Hg

State action levels may be lower than EPA's RMLs. Coordinate with your state representative for consultation on Applicable or Relevant and Appropriate Requirements (ARARs), and ensure that any ARARs used are documented in the site's Administrative Record. The OSC may want a letter from the State requesting action levels for total mercury in soil.

Disposal of contaminated materials is discussed in Chapter 10.

The following photographs (Photographs 9-18 through 9-21) provide additional views of the removal of mercury-contaminated soils and asphalt.



**Photograph 9-18**

*View of EPA ERRS contractor excavating mercury-contaminated soil*



**Photograph 9-19**

*View of mercury-contaminated soil being staged into a plastic-lined rolloff box*



**Photograph 9-20**

*View of grid system marked on asphalt where mercury vacuuming has been completed*



**Photograph 9-21**

*Using grid system to conduct initial removal of elemental mercury with a mercury vacuum and crevice tool from a temporarily closed asphalt street*

#### **9.4.11 Removal of Elemental Mercury Containers**

If a container of elemental mercury is found in a home or other location, the container should be immediately sealed (airtight) or placed inside another container that can be sealed tightly. As soon as possible, place the container in a separate container that meets appropriate shipping requirements. Wear protective gloves when handling the container to guard against contact with any elemental mercury that may be on the outside of the container. The container should then be secured to prevent theft or damage. Plastic bags should not be used to contain free liquid mercury as vapor breakthrough will occur within several days. Disposal of elemental mercury is discussed in Chapter 10.

#### **9.4.12 Removal of Contaminated Soils and Sediments on Industrial Sites**

Although this guidebook addresses elemental mercury spills in and around structures, the following is a brief description of EPA's approach to classic and large-scale cleanup sites involving mercury contamination.

Large-scale cleanup efforts may be necessary when industrial or mining operations have spilled significant amounts of elemental mercury in surface and subsurface soils, or when several years' worth of accumulation endangers surrounding land areas and waterways. The assessment of these sites should be conducted to determine the sources of the mercury contamination and delineate the pathways by which the elemental mercury is dispersed to the surrounding environment.

Dispersal pathways may include erosion and weathering of mine tailing piles, windblown soil and debris, leaching and runoff from affected areas, and mercury volatilization.

Remediation efforts can include source-control measures such as slope reduction and re-vegetation of mine tailing piles and management of water flow to and from the affected site. Pollution abatement measures include dredging or excavation, capping or covering the affected site, immobilization of contaminated media, extraction and concentration of elemental mercury, and off-site disposal. As with all large-scale remediation efforts, the cleanup process itself should not increase the hazard to public health and the environment.

## **9.5 Post-Cleanup Procedures**

After the decontamination process the following basic steps should be taken:

1. If not already conducted, heat and ventilate the structure as described above in Section 9.2.2 for two to eight hours.
2. Remove heat source and vent the structure for a minimum of two hours with open doors and windows while circulating air with fans.
3. Set the thermostat for normal living conditions and close doors and windows for a minimum of four hours to allow for ambient equilibrium of indoor air.

Section 5.5 and Appendix B detail specific procedures for conducting post-cleanup sampling and monitoring. In addition to the basic process described above, each individual site may require additional iterations of the steps.

### **9.5.1 Air Sampling and Confirmation of Cleanup**

Air sampling should be conducted to confirm that residential cleanup activities are complete. Perform air sampling for mercury vapor using an accepted MVA procedure or by collecting air samples by the NIOSH 6009 method. See Chapter 5 and Appendix B for a description of applicable procedures. Sites requiring minimal cleanup may not require confirmation air sampling.

When the results of the air screening or sampling confirm that the mercury vapor concentration is below the established action level, the OSC should inform the local public health agency who will likely indicate that the facility is ready for reoccupation and the cleanup has been completed.

### **9.5.2 Confirmation of Cleanup in Soils**

Where applicable, consult the state environmental agency for the appropriate or relevant cleanup action levels for total mercury. Frequently, separate action levels are established for residential, commercial, and industrial land uses.

Consult your state representative for consultation on ARARs. The OSC may request a letter from the State documenting the appropriate action levels for total mercury in soil.

## 9.6 Best Practices and Recommendations

The following considerations and recommendations are based on EPA OSC experiences, but may not address the full range of circumstances that may be encountered:

- Monitor aggressively—in an undisturbed environment with normal air flow, ambient air measurements tell little about the state of surfaces. Monitor as close to the surface of interest as possible without cross-contaminating the MVA. In some cases, the surface being monitored could be agitated to promote mercury volatilization.
- If aggressive monitoring shows mercury vapor contamination levels near the re-occupancy threshold under elevated temperature, decontamination via heating and ventilation may be successful.
- When in doubt, flooring should be removed. Although disruptive, this usually allows a room or structure to be returned to use sooner and substantially reduces labor time on the project, thereby reducing overall project costs.
- Mercury vapor may be masked in drains due to fresh water covering the liquid mercury. Within two to three days of stagnant water in a drain trap, there may be mercury vapor breakthrough. If drain traps are not physically removed for inspection, responders should regularly reassess drain openings with an MVA.
- Mercury vapor concentration is temperature-dependent. When temperatures are low, mercury vapor concentration may not be easily detectable.
- Age of spill is important as the older the spill the more likely the mercury vapors may have saturated areas and possibly recondensed in plenums, overhead structures, and cool areas such as concrete floors.

## 9.7 Avoiding Common Mistakes

The following recommendations are intended to assist OSCs in avoiding common mistakes during residential elemental mercury responses:

- Do not enter a residence alone or without a signed access agreement from the property owner.
- An OSC should immediately contact the local health department during a residential elemental mercury response and form a team.
- Document everything. *An OSC will probably only need 5 percent of the documented items but you just do not know what 5 percent that will be! Document it all!*

- Do not overestimate the ability to decontaminate with heating/venting cycles—if near-surface readings are over 10 µg/m<sup>3</sup>, using heat and ventilation to decontaminate to a residential standard of 1 µg/m<sup>3</sup> is not practical and is a poor use of time and money. In addition, readings this high generally indicate the presence of liquid mercury.
- As described in Section 9.6, if an elevated MVA reading is present, the best practice is to remove the item or material (“when in doubt, rip it out”).
- Call an experienced OSC or responder. Too often, a responder does not reach back for support and guidance. The best way to avoid common mistakes is to consult with those who have considerable experience in cleaning up elemental mercury sites. Each Region as well as EPA Special Teams and partner agencies provided experienced personnel in the development of this guidebook.

## 10 Disposal

As a general rule, EPA makes a hazardous waste determination for all mercury waste in accordance with 40 CFR 262.11, either through testing or applying generator knowledge. This section describes the disposal process from determining the appropriate designation of waste through transportation and final disposition of mercury containing materials.

### 10.1 Hazardous Waste versus Non-Hazardous Waste

#### 10.1.1 Characteristically Hazardous Wastes

Wastes which exhibit, or are expected to exhibit, the characteristic for toxicity of elemental mercury based on a TCLP concentration of mercury greater than or equal to 0.20 mg/L are considered D009 characteristically hazardous waste. To determine if mercury containing waste is a D009 characteristically hazardous waste, responders may either conduct testing according to the TCLP analytical method set forth in 40 CFR 261.24 or apply knowledge of the hazardous characteristic(s) of the waste ("generator knowledge").

LDR treatment standards found in 40 CFR 268.40 for U151 listed hazardous waste and for D009 characteristically toxic hazardous waste are essentially identical. See Section 10.2 (RCRA Requirements) for further discussion of mercury waste treatment and disposal standards.

#### 10.1.2 Household Hazardous Waste

If an elemental mercury spill occurs in a home, wastes generated during the cleanup would likely be considered a household hazardous waste provided the mercury waste is generated by the residents on their premises and the elemental mercury spill came from wastes generated by consumers in their home. Household hazardous waste is not regulated under RCRA as a hazardous waste (40 CFR 261.4(b)(1)) when the waste is safely managed by the homeowner. The household hazardous waste

exemption was enacted to provide for the legitimate purchase and use of chemical products that are intended for household use without triggering the cradle-to-grave requirements under RCRA Subtitle C. EPA responders should not endorse or encourage home-owners to throw away mercury containing devices or waste. Rather, if providing guidance to a homeowner, responders should encourage elemental mercury recycling options, including utilizing local household hazardous waste collection programs.

### **10.1.3 Universal Waste**

Intact (unbroken) mercury-containing equipment that is classified as hazardous waste can be collected and managed under the streamlined collection standards for universal waste set forth in 40 CFR 273. Some states also define broken mercury-containing equipment as universal waste, provided the broken equipment and the spilled liquid mercury are transferred to a container that meets the requirements of 40 CFR 262.34. However, this interpretation is not consistently applied in all states.

### **10.1.4 Non-Hazardous Waste**

If waste mercury is spilled from a source which is not a listed hazardous waste (U151), any spill residues and contaminated debris determined not to be characteristically hazardous waste (D009) either through TCLP testing or applying generator knowledge would not be classified as a hazardous waste and would not be subject to the LDRs or treatment standards prior to land disposal. Non-hazardous wastes are often referred to as “special wastes” under state regulations for purposes of identifying and tracking low-level mercury contamination through the disposal process. Some state regulations require a site-specific special waste authorization before sending mercury-contaminated non-hazardous waste to a landfill for disposal.

### **10.1.5 Listed Hazardous Wastes**

Mercury containing articles are not among the process- and industry-specific wastes found in the F and K lists in 40 CFR 261.31 and 261.32. Discarded mercury containing articles do not meet the P or U listing criteria either, because they are in a used form and do not meet the definition of a commercial chemical product as interpreted or intended by EPA. Although elemental mercury is identified in 40 CFR 261.33 under the listing U151, the materials listed in 40 CFR 261.33 include only those commercial chemical products known by the generic name of the chemicals listed (45 FR 78451, November 25, 1980). Since manufactured articles which simply contain these listed chemicals are rarely, if ever, known by the generic name of the chemical they contain (e.g., thermometer, manometer, sphygmomanometer, lamps, batteries, switches), such manufactured articles are not covered by the U151 listing. EPA considers the P and U list definition of commercial chemical product to exclude manufactured articles such as meters, switches, and lamps. (45 FR 78541; November 25, 1980).

The mercury containing articles, the elemental mercury spilled from those articles, and any related spill residues and contaminated debris, would only be subject to regulation as a hazardous waste if they exhibited a characteristic of a hazardous waste found in 40 CFR Part 261, Subpart C, or if they are a listed hazardous waste for reasons other than the mercury content. Similarly, mercury containing commercial chemical products with a different generic trade name (e.g., Thimerosal, Mercurochrome, Merthiolate) are not U151 listed waste when spilled or discarded although these formulations may be characteristically hazardous for toxicity, with the EPA hazardous waste code D009.

However, if commercial chemical product mercury is spilled (i.e., a spill directly from a container of elemental mercury which was purchased by a laboratory, manufacturer, or other entity as a commercial chemical product and is clearly labeled with the generic trade name “mercury”), the spilled elemental mercury and any spill residues and debris which come into direct contact with the mercury from the spill could be classified as U151 listed hazardous waste. In which case, the land disposal restriction (LDR) and treatment standards promulgated in 40 CFR 268.40 for U151 listed hazardous waste would apply. However, after commercial chemical product mercury is placed into a manufactured article or device (e.g., elemental mercury placed in a Honeywell™ mercury instrument, elemental mercury placed into a manometer), any mercury spilled from the article or device is excluded from the U151 definition for the reasons discussed above.

As such, there are a very limited set of circumstances that would result in a spill of U151 listed mercury waste, which are rarely encountered when handling mercury cleanup waste in typical responses and removal actions. The vast majority of responses and removal actions will involve D009 characteristically hazardous mercury waste.

When making a determination as to whether the U151 listing applies to an elemental mercury spill, consider the following excerpt from the October 1998 guidance document, “Management of Remediation Waste Under RCRA,” EPA530-F-98-026.

*“Where a facility owner/operator makes a good faith effort to determine if a material is a listed hazardous waste but cannot make such a determination because documentation regarding a source of contamination, contaminant, or waste is unavailable or inconclusive, EPA has stated that one may assume the source, contaminant or waste is not listed hazardous waste and, therefore, provided the material in question does not exhibit a characteristic of hazardous waste, RCRA requirements do not apply. This approach was first articulated in the Proposed NCP preamble which notes that it is often necessary to know the source of a waste (or contaminant) to determine whether a waste is a listed hazardous waste under RCRA and also notes that, “at many CERCLA sites no information exists on the source of the wastes.”*

*The proposed NCP preamble goes on to recommend that the lead agency use available site information such as manifests, storage records and vouchers in an effort to ascertain the sources of wastes or contaminants, but that when this documentation is not available or inconclusive the lead agency may assume that the wastes (or contaminants) are not listed RCRA hazardous wastes.*



*This approach was confirmed in the final NCP preamble. See, 53 FR 51444, December 21, 1988 for proposed NCP preamble discussion; 55 FR 8758, March 13, 1990 for final NCP preamble discussion.”*

## **10.2 RCRA Requirements**

Wastes which are known to be contaminated with elemental mercury at levels equal to or exceeding RCRA TCLP hazardous waste determining limit of 0.2 mg/L must go to a permitted RCRA incinerator or retort facility (or other form of treatment to reduce TCLP levels of mercury to below 0.02 mg/L). Hazardous waste with a total mercury concentration greater than 40 CFR 268.40 LDR Treatment Standard of 260 mg/kg must go to a permitted retort facility. Retorting is an EPA-approved treatment process during which elemental mercury is reclaimed through heating and distillation of mercury contaminated wastes. Wastes which are known to be contaminated with mercury at levels less than RCRA TCLP hazardous waste determining limit of 0.2 mg/L and land ban level of 260 mg/kg are considered non-hazardous special waste.

The flow chart below summarizes the RCRA treatment and disposal standards applicable to mercury containing waste.

## **10.3 Transportation/Shipping**

A waste profile and a Uniform Hazardous Waste Manifest should be used for all mercury-contaminated hazardous waste that is transported for off-site disposal. Typical basic shipping descriptions are as follows:

Contaminated debris or soil with mercury concentrations equal to or exceeding RCRA TCLP hazardous waste determining limit of 0.2 mg/L and land ban level of 260 mg/kg would be shipped as:

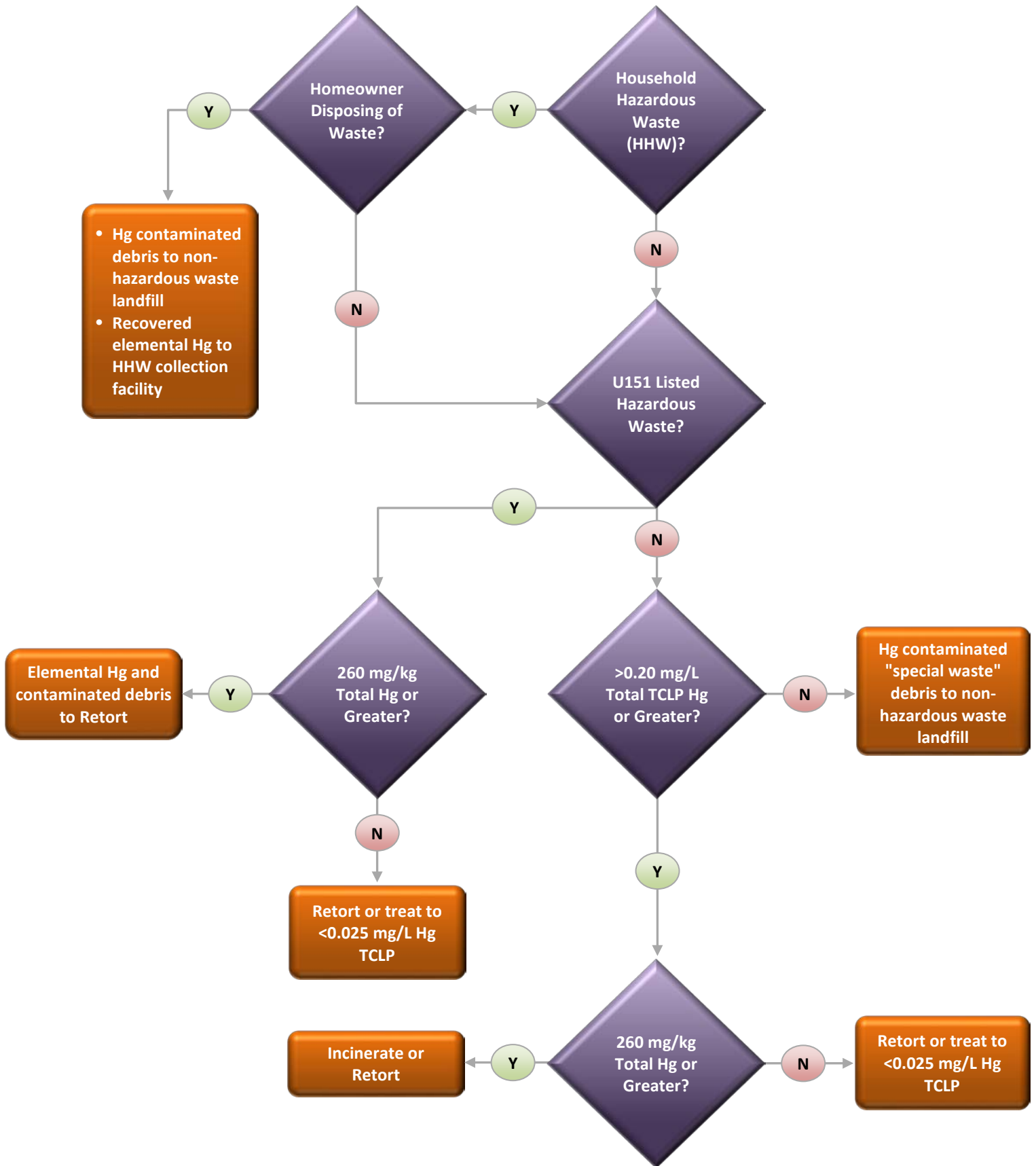
**RQ, Waste Toxic solid, inorganic, n.o.s., 6.1, UN3288, PG III (mercury contained in soil)**

or:

**R.Q., Hazardous Waste solid, nos., (D009), 9, NA3077, PGIII**

In some cases, even though analytical results indicate that waste can be classified as non-hazardous, the OSC, as the generator, may have concerns about the representativeness of the sampling. As a matter of due diligence, the OSC may choose to ship the material to a hazardous waste landfill, even though the waste was classified as non-hazardous.

Figure 10-1: RCRA Treatment and Disposal Decision Tree



## 10.4 Disposal

Household waste and personal items should be segregated by waste streams. There are wastes that have come into direct contact with liquid mercury and waste items that have only come into contact with vapors. For disposal sampling, composite samples are collected and analyzed for Total Mercury and TCLP. A Uniform Hazardous Waste Manifest must accompany all shipments of listed hazardous waste (U151) or characteristic hazardous waste (D009). If the waste is not a characteristic or listed waste, a Subtitle D landfill may accept it as non-hazardous or “special waste” dependent upon applicable state regulations.

***NOTE:** Often OSCs receive questions regarding proper disposal of CFLs. Advise callers that if the CFLs have not broken, commercial hardware or home improvement stores often accept these items for free disposal. For more information on CFLs, consult EPA’s Mercury website:  
<https://www.epa.gov/sf/>*

All contaminated items should be placed into roll-off boxes or drums. Site security should be procured to guard the roll-off boxes and drums until disposal arrangements are made. The following disposal options may be considered:

- Liquid mercury can be managed as follows (see Photograph 10-1):
  - For small residential spills (thermometers and thermostats), recovered elemental mercury can be placed and sealed in a plastic or glass container for delivery to a household hazardous waste (HHW) facility (preferred) or the resident can dispose of it as a household solid waste (not preferred, but legal). Most household hazardous waste facilities with small quantity generator (SQG) permits can accept very small quantities from residents or responders.
  - For non-residential sites (i.e., schools, hospitals, businesses), encourage the responsible party to conduct the cleanup or hire a contractor. There is no exemption for businesses to dispose of elemental mercury as a solid waste (as there is for households). If an HHW facility is a SQG, responsible parties can also deliver small quantities of liquid mercury at a minimal cost.
  - When EPA is the generator of the material, wastes must only be sent to CERCLA-approved facilities. Mercury retort facilities generally charge by transportation, rather than quantity. As a result, it costs the same to manage 1 pound of elemental mercury as it does 50 pounds.
- Low-level mercury-contaminated household debris can be transported as non-hazardous waste to a hazardous or “special waste” landfill.
  - Items containing less than 0.2 mg/L TCLP mercury are considered non-hazardous waste, or “special waste,” depending upon applicable state regulations. Most waste generated during residential responses fall under this category.

- Mercury containing wastes greater than 0.2 mg/L TCLP mercury are considered hazardous.
  - As described above, hazardous waste containing greater than 260 mg/kg of total mercury must go to a RCRA permitted retort facility.
- Disposal costs vary depending on how the waste is classified. Non-hazardous solid waste may cost up to \$40/ton for transportation and disposal. Special waste and hazardous waste may cost between \$60 and \$100 per ton for transportation and disposal (depending on the site and disposal facility location).
- Based on the generator's knowledge, the OSC may sign profiles that household debris is characterized as non-hazardous.
- ERRS Contract disposal coordinators and Regional off-site rule coordinators can assist in identifying appropriate landfill or retort facilities to accept mercury wastes.
- Universal waste is considered a RCRA hazardous waste with unique management requirements. There are companies that specialize in the management of universal wastes through the disposal process.

*NOTE: There are other resources available for information on how to manage specific mercury containing situations. The Thermostat Recycling Corporation (TRC) can accept mercury containing thermostats. Also, the National Vehicle Mercury Switch Recovery Program (NVMSRP) provides information on the management and disposal of mercury switches from vehicles. For more information, refer to <https://archive.epa.gov/mercury/archive/web/html/index-4.html>.*



**Photograph 10-1**

*View of containers used to ship liquid mercury for recycling (retorting)*

## 10.5 Compliance with the Mercury Export Ban Act (MEBA)

The Mercury Export Ban Act is intended to reduce the availability of elemental mercury in domestic and international markets. By reducing the supply of metallic mercury in commerce, MEBA aims to reduce the use of mercury in artisanal mining and for other commercial purposes globally, thereby reducing mercury pollution in the environment.

To reduce mercury in the commercial marketplace MEBA generally prohibits the export of elemental mercury and certain mercury compounds. To a similar end, MEBA aims to achieve further reductions of mercury in the marketplace by prohibiting any federal agency from conveying, selling, or distributing elemental mercury. Finally, the Act directs the Department of Energy to designate a facility that will accept elemental mercury generated within the U.S. for the purposes of long-term management and storage. The facility must become operational by January 1, 2019.

MEBA should not affect how OSCs manage and handle elemental mercury. OSCs should continue to handle and manage elemental mercury at CERCLA sites as otherwise recommended in this guidebook.



**Photograph 10-2**

*View of EPA ERRS contractor loading mercury-contaminated clothing and household items (non-hazardous “special waste”) into roll-off boxes for disposal*

## 11 Restoration, Replacement and Reimbursement

In residential situations, EPA generally has the responsibility of ensuring that properties are restored or occupants are adequately compensated for losses. However, with residential elemental mercury responses, often the contamination is a direct result of an occupant's actions. When the occupant releases elemental mercury, by rule, they are considered a potentially responsible party. Under CERCLA authority, EPA has an obligation to either ensure that the potentially responsible party takes responsibility for the cleanup or pursue cost recovery after a government-funded action has been completed. In many residential cases, the occupants demonstrate they are not viable, meaning they do not have adequate resources to pay for a cleanup. If the occupant is the potential responsible party but is found to be not viable, EPA may limit the amount of replacement or reimbursement. There are several situations where liquid mercury is brought into or spilled in a residence without the knowledge of the owner or occupant. In these cases, liability is determined on a case-by-case basis.

At a minimum, EPA should ensure that enough restoration is achieved following a cleanup to make the dwelling livable (i.e., no holes in floors or walls). As a matter of policy, EPA attempts to restore a property as close as possible to its original condition. The amount of restoration, however, may be subject to enforcement findings regarding the nature of the spill.

Replacement of personal items or reimbursement for such items should be evaluated on a case-by-case basis as part of EPA's enforcement policies and guidelines. An independent appraiser may be used. When restoration, reimbursement or replacement must be considered, the project manager should refer to EPA's *Guidance on Compensation to Private Citizens (OSWER; November 1994)* for additional information.

### 11.1 Restoration

If EPA agrees to restore a residence following a removal, the restoration phase begins when (1) the residential home has been properly decontaminated, (2) post-decontamination air sampling is completed, and (3) a public health agency has determined that air levels are appropriate for residents to reoccupy the home.

The OSC should begin the restoration phase by reviewing pre-decontamination materials (e.g. video, photographs, logs). Note any special considerations identified during the decontamination process. List all items to be restored in each residence. A restoration subcontractor should conduct a pre-restoration inspection of each residential yard or home to assess the condition of the structure and utilities and to prepare an estimate of the total cost to restore the impacted items (e.g., yard, carpet, linoleum, walls, floor tile) to their pre-contamination condition. The OSC reviews, modifies if necessary, and approves the estimate prior to initiating any restoration work. Residential restoration should return each house to its condition prior to decontamination and should repair any damage caused by the decontamination process.

As described above, the amount of restoration may be subject to enforcement decisions. Some local governments may have resources available to assist with this process. Refer to the Post-Decontamination Checklist found in Appendix C to ensure all potential operations are addressed.

#### **11.1.1 Post-Restoration Documentation**

Using the same video that was recorded to document the pre-decontamination condition of the residence, document the condition of the residence after the EPA contractor has completed removal, decontamination, and restoration activities. Details such as windows, light fixtures, and even the condition of plaster and drywall panels should be documented. A detailed video will help avoid potential disputes about the condition of the residence following decontamination.

#### **11.2 Replacement**

If EPA agrees to replace contaminated household items, a third-party appraiser should be hired to determine their value. Appraisers charge either flat fees or hourly rates. Following appraisal, EPA's contractor can be used to procure household items for comparable replacement value. At past sites, local government or the American Red Cross has agreed to replace "essential items," such as washing machines, mattresses, and clothes.

#### **11.3 Reimbursement**

If EPA agrees to reimburse residents for lost household items, a third-party appraiser should be hired to determine their value. Following appraisal, EPA may be able to utilize pre-existing contracts (i.e., ERRS or START), site-specific contracts (i.e. a Miscellaneous Obligating Document [MOD]), or utilize the USACE to provide reimbursement services. For more information on reimbursement compensation, refer to EPA's Guidance on Compensation for Property Loss in Removal Actions (September 1995). Local government and the American Red Cross may also have the ability to reimburse residents for lost household items.

#### **11.4 Demolition**

There are rare cases where structures are so heavily contaminated that they cannot be decontaminated. In some cases, the entire house is saturated with elemental mercury. In other situations, the cleanup cannot be achieved without doing major structural damage to the home. **If the OSC determines that the only course of action is abandonment or demolition, the decision should be made in consultation with the local municipality where the property is located.**

**In addition, EPA should not unilaterally take demolition action.** The OSC should consult with Regional and Headquarters management as well as Regional Counsel if they are contemplating these actions.

In some cases, the municipality or the homeowner may agree that abandonment is appropriate. After EPA ensures that mercury contamination is no longer an imminent and substantial risk to the environment, the municipality then takes responsibility for posting the structure as uninhabitable and may make longer term plans for demolition (without EPA's future involvement).

Each individual situation will determine what actions are needed to assist the occupants in finding alternate housing. EPA should coordinate with the municipality to evaluate the situation and determine what level of support can be provided to the displaced occupants. Refer to Chapter 8 for more information on temporary and permanent relocations.

## **12 Reoccupation**

Once the results of the air sampling study confirm that the mercury vapor concentration is below the action level set by local health officials/EPA/ATSDR and post cleanup procedures have been completed, the OSC or the local public health agency will indicate that the facility is ready for reoccupation.

### **12.1 Obtaining Health Concurrence**

In almost all instances, the local or county public health department will determine if a building is safe for human occupancy. After the cleanup, the OSC provides the health department with all relevant reports and data demonstrating that the cleanup was achieved by meeting agreed upon goals. The health official will often provide a written letter (or form) to demonstrate that they concur with the outcome of the cleanup. The letter will document that the structure is safe for human occupancy. In situations where local or county health officials do not have the expertise to advise on mercury contamination, they may defer to State or Federal public health officials for concurrence with EPA. In rare situations where EPA and local or state health officials disagree on cleanup levels, EPA will consult with ATSDR to evaluate the site-specific case.

### **12.2 De-List Letter from U.S. EPA**

When ATSDR or a public health agency indicates that a residence is ready for reoccupation, and restoration activities have been completed, the OSC submits a letter to the local health department stating that cleanup has been completed and clean-up levels for mercury vapor have been achieved. A copy of the air sampling and monitoring results should be attached to the letter. Based on this letter, EPA will de-list the site. Examples of letters regarding a residence that was sampled but did not require decontamination and a residence that required decontamination are provided in Appendix C.

With smaller spills, single residence situations, or at the agreement of the involved agencies, a "de-list" letter may not be necessary and all final agreements and documentation can be accomplished via the final Pollution Report (POLREP).



### 12.3 De-List Letter from Local Health Department

After an OSC submits a letter reporting analytical results and de-lists a residence, the local health department or other recipient agency should submit a letter to EPA acknowledging that the residence has been cleared for re-occupancy. An example de-list letter is provided in Appendix C.

With smaller spills, single residence situations, or at the agreement of the involved agencies, a “de-list” letter may not be necessary, and all final agreements and documentation can be accomplished via the final POLREP.

### 12.4 Assisting Residents in Reoccupying Homes

EPA, local health departments, and the American Red Cross typically assist residents in returning to their homes. These agencies are usually available to answer questions about reoccupation. Verbal or written guidance should be given to the occupants for any or all the following:

- Unpacking bagged items that were not contaminated
- Cleaning of materials that may have been decontaminated using vapor suppressant compounds
- Any structural changes to the building
- Review of what materials were disposed, adjusted or replaced
- Actions that the occupants can take to ensure residual vapors continue to dissipate
- Who to contact for future concerns about the action taken

## 13 Responder Health and Safety

As described in Chapter 7, screening levels may indicate that respiratory protection is required. Most residential responses can be conducted in Level D PPE. When respiratory protection *is* required, Section 13.1 describes the equipment options available to responders. All EPA response activities are conducted in accordance with EPA’s *Emergency Responder Health and Safety Manual*, which can be found at <https://response.epa.gov/HealthSafetyManual/index.htm>.

### 13.1 Personal Protective Equipment (PPE)

Responders may come into contact with elemental mercury via the air or by direct contact, for example, when removing and decontaminating items such as clothes, flooring, furniture, or personal items. PPE, appropriate hygiene, and operational safety all help reduce the exposure risk.

### 13.1.1 Respirators

Options for respiratory protection at mercury-contaminated sites (from least to most protective) include:

- Level D – No respirator
- Level C – Full-face air-purifying respirators (APRs) with mercury vapor-specific cartridges
- Modified Level C – Powered air-purifying respirator (PAPR)\*
- Level B – Self-contained breathing apparatus (SCBA) systems

EPA's health and safety policy establishes  $25 \mu\text{g}/\text{m}^3$  as the threshold to upgrade to Level C PPE. NIOSH allows mercury vapor cartridges to be used when air concentrations are less than  $500 \mu\text{g}/\text{m}^3$ . Concentrations exceeding  $625 \mu\text{g}/\text{m}^3$  should alert the responders to upgrade to Level B; however, upgrade from Level C to Level B PPE at greater than  $625 \mu\text{g}/\text{m}^3$  or at the upper detection limit of the MVA being used. It should also be noted that such high levels are unusual during cleanup actions due to engineered ventilation of indoor spaces.



**Photograph 13-1**  
*Scott AV-3000 APR*



**Photograph 13-2**

*Scott APR mercury vapor cartridge with P100 and ESLI*

Since mercury vapor has no warning properties (i.e., no smell, taste, irritation), end-of-service-life indicators (ESLIs) on the visual edges of the cartridges warn when it is time to change the cartridge. The ESLI is a paper strip that reacts with mercury vapor, changing from orange to dark brown. Once the reaction has taken place, responders should leave the site and the cartridge should be changed. Even if the ESLI on the cartridges are not reacted by the end of the day (after an 8- to 12-hour shift), common practice is to change the cartridges the next morning due to possible absorption of mercury vapor in the charcoal filter media overnight or in environments with high humidity.

**Figure 13-1: Recommended Respiratory Protection Based on Mercury Vapor Concentrations**

Respirator Recommendations	Air Concentration
Level D	< 25 $\mu\text{g}/\text{m}^3$
Level C with mercury vapor cartridges	25 – 625 $\mu\text{g}/\text{m}^3$
Level B*	> 625 $\mu\text{g}/\text{m}^3$

\* Upgrade from Level C to Level B at greater than 625  $\mu\text{g}/\text{m}^3$  or at the upper detection limit of the MVA being used.

If the ambient concentration of mercury vapor exceeds the exposure limits, PPE should be upgraded accordingly. NIOSH-approved mercury specific cartridges must be used with the respirators. The MSA Mersorb® - P100 Indicator Type Combination Cartridges should be used with the MSA respirators and the Mercury Vapor/Chlorine with P100 should be used with the Scott respirators.

### **13.1.2 Gloves, Booties and Suits**

Protecting feet and hands with appropriate gloves and booties is critical, as these are the areas of the body most likely to come in direct contact with elemental mercury.

PPE clothing for chemical protection must meet the permeation testing requirements of ASTM Method F 739. In this standard, a test cell is divided with a swatch of fabric. The liquid chemical is introduced on one side and monitored for permeation and breakthrough on the other. These tests have shown that nitrile, neoprene, butyl rubber, and even natural rubber protect against liquid elemental mercury. Activities that will rip these materials or force liquid mercury into the material may require additional protection in the way of outer leather gloves, thicker synthetic gloves, or additional layers of neoprene that are easily removed and replaced while sampling.

Material needed to protect the body is determined by the activity of the wearer. If the person is conducting simple sampling, monitoring, or other low-impact tasks, a Tyvek® suit may be appropriate. However, if the task requires possible contact with elemental mercury such as removal of contaminated furniture or demolition of flooring, a polymer-coated fabric such as a Saranex® or Tychem®-style suit may be needed. All materials listed in the Quick Selection Guide to Chemical Protective Clothing passed permeability tests for elemental mercury, showing protection greater than 8 hours.

### **13.2 Controlling Ingestion**

Ingestion of elemental mercury on contaminated sites typically happens by inadequate decontamination of hands followed by eating, smoking, applying cosmetics, chewing gum, or chewing tobacco in the exclusion zone. Therefore, ingestion is easily controlled by prohibiting such activities on-site or requiring hand cleaning upon every exit from the inclusion zone.

### **13.3 Worker Exposure Levels**

Figure 13-2 contains the current regulated and recommended mercury vapor exposure limits for workers. Personnel working on-site should consider the exposure limits listed in Figure 13-2 when selecting PPE.

**Figure 13-2: Worker Exposure Air Criteria or Recommendations**

Agency	Criteria/Recommendation
Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit – time weighted average	100 µg/m <sup>3</sup>
American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) - Time weighted Average	25 µg/m <sup>3</sup>
NIOSH Immediately Dangerous to Life and Health (IDLH)	10,000 µg/m <sup>3</sup>
National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL) – Time weighted average	50 µg/m <sup>3</sup>

### 13.4 Health and Safety Plan

A Health and Safety Plan (HASP) must be prepared for each response. See example HASP and guidance at <https://response.epa.gov/HealthSafetyManual/manual-index.htm>.

Components of a HASP include:

- Site Safety Plan
- Action Levels for Evacuation of Work Zone Pending Reassessment of Conditions
- Decontamination Procedures and Solutions
- Equipment and Supplies Checklist
- Emergency Contact Information
- Site-Specific Health and Safety Plan Acceptance
- Existing Site Safety Plan Addendum Form
- Daily Safety Meeting Record
- Hazard Evaluation Sheets for Major Known Contaminants – NIOSH Information

### 13.5 Responder Decontamination

A responder may have small droplets of elemental mercury adhering to gloves, boot covers, and over garments. Removing these items at the decontamination line, testing them, and disposing of them as mercury-contaminated waste off-site, if necessary, is the best way to ensure that contamination is not spread. Personnel decontamination at an elemental mercury site is straightforward.

A responder is assumed to be contaminated on all surfaces except the mask. Decontamination consists of removing gloves, booties, and overgarments without contaminating skin or street clothes. One proven process is described below:

- A decontamination line is established consisting of an approximately 2-meter by 2-meter area covered in plastic sheeting, with table, stool, and plastic trash bag;
- Radios, instruments, GPS units, and other equipment items are placed on the table and readied for the next entry. Chargers may be used during decontamination. Equipment that has come into contact with mercury-contaminated surfaces is assumed to be contaminated until its status is verified by monitoring;
- Responders leaving the exclusion zone sit on the stool, remove PPE, and place it in the contaminated trash container; the order of removal is (1) boot covers, (2) overgarments, and (3) gloves; and
- Responders take off their masks as they leave the exclusion area. Masks are assumed to be uncontaminated unless the responder has touched the mask with outer gloves.

Decontamination is most likely to fail due to lack of discipline; that is, responders failing to pass through decontamination while retrieving forgotten equipment, taking rest breaks, and so forth. Decontamination discipline should be maintained by:

- Reminding responders how easily contamination is spread;
- Providing additional required equipment at the edge of the decontamination zone; and
- Ensuring that PPE is completely removed for bathroom breaks.

In hot environments and during prolonged operations, drinks may be staged at the edge of the decontamination zone. If safety and operations concur, responders may come to the exclusion zone boundary, pull back overgarment hood, remove gloves, remove mask, wash hands, drink, remask, reglove, and return hood over mask.

Responder decontamination does not always involve monitoring for residual contamination using a monitoring instrument. Time and effort is usually better invested in ensuring that decontamination practices are adhered to rigorously. In special circumstances, such as personnel leaving the exclusion zone without PPE, monitoring may be necessary. Sometimes it is prudent to screen hands and feet. Equipment and instruments can be scanned with the Lumex.

# Appendices

Appendix A: ATSDR Chemical Specific Health Consultation and Suggested Action Levels

Appendix B: Technical Documents

Appendix C: Templates and Reference Documents

Appendix D: Additional Mercury Resources

Appendix E: Acronyms

# Appendix A

## ATSDR Chemical Specific Health Consultation and Suggested Action Levels



## **Executive Summary**

In 2000, the Agency for Toxic Substances and Disease Registry (ATSDR) provided tables of action level guidelines for indoor air concentrations of elemental or metallic mercury in response to a request from both the U.S. Environmental Protection Agency (EPA) and the state of Michigan. The action levels had been previously developed for individual sites and situations, but the tables summarized these guidelines in a succinct package for use by field personnel. The request was prompted by several small spills in homes caused by replacing or relocating natural gas regulators containing mercury. The homes affected included those serviced by utility companies in both Chicago and Detroit. The guidelines were designed to help risk managers at spill scenes in homes or other locations make decisions regarding cleanup, relocation, etc. Throughout the years, these action level guidelines have been widely disseminated by users. A workgroup has been formed jointly by EPA and ATSDR to develop consistent cleanup guidance for mercury spills, including not only public health actions but also cleanup and sampling methods. As part of that joint effort, EPA has requested that ATSDR update the 2000 guidelines to be included in a more comprehensive guidance. This health consultation is intended to provide that update.

The health consultation provides detailed justifications for action levels based on the ATSDR Chronic Minimal Risk Level and EPA Reference Concentration. The recommended action levels for mercury in residential settings remain  $1 \mu\text{g}/\text{m}^3$  for normal occupancy and  $10 \mu\text{g}/\text{m}^3$  for isolation (e.g., evacuation, limited access) of the residents from exposure to the mercury. Action levels for settings other than residential are based on residential levels and adjusted for the condition based on the presumed exposure. Sections that describe when action levels should be adjusted to meet site specific conditions are included. The most useful features of the 2000 tables have been retained; new sections have been added that address issues related to the tables that have recurred during the past 11 years. Additional information to help on-scene risk managers communicate risk is provided. Technological advances in detecting environmental mercury are also considered.

## **1.0 Introduction**

### **1.1 Background**

Elemental, also called metallic, mercury is common in our environment due in part to its unique properties and multiple uses in our daily lives [Baughman 2006; Gochfeld 2003; Risher 2007; Song 2009]. Mercury in its elemental state can pose a hazard to humans. The hazard for any person is based on how sensitive that person is to the effects of mercury, how long that person is exposed to mercury, and how much mercury is present, among other factors. These factors as they pertain to mercury spills are discussed below. Mercury is persistent in the environment, and is considered a hazard primarily under chronic exposure scenarios under most conditions. Mercury cleanups are difficult and pose substantial challenges [MacLehose 2001] to risk managers, such as the U.S. Environmental Protection Agency's (EPA) On-Scene Coordinators (OSC). Throughout the years, various EPA Regions have established guidance for conducting these cleanups. EPA's Office of Emergency Management convened a National Workgroup to harmonize this guidance and invited the Agency for Toxic Substances and Disease Registry (ATSDR) to join the Workgroup [EPA 2011]. Many of

the guidance documents developed by the various regional offices included “Suggested Action Levels for Indoor Mercury Vapors in Homes or Businesses with Indoor Gas Regulators”. This guidance was developed by ATSDR for public health and environmental professionals in 2000 [ATSDR 2000]. The National Workgroup requested that ATSDR revise these action levels to reflect advances in technology and knowledge gained through experiences since ATSDR provided them. EPA and ATSDR staff formed a Subgroup of the National Workgroup. The Subgroup determined that an ATSDR chemical-specific health consultation would be the most effective way to accomplish this task. The health consultation will be included in the National Policy upon finalization of that policy. The Subgroup requested that the list of action levels be expanded to include other exposure settings such as schools and vehicles such as school buses.

Mercury is a conductive metal and a liquid at room temperature, physical properties that make the substance a unique asset in many industrial and consumer applications [HSDB 2005]. Mercury is also used in some of the rituals and practices of certain religious sects [Alison Newby 2006; Garetano 2006, 2008; Rogers 2007, 2008]. When spilled, mercury’s viscosity is similar to that of water—it flows and collects in the same way and locations that water would if spilled. However, mercury is unusually dense compared with water; a milliliter (mL) of mercury weighs more than 13 grams (g) while a milliliter of water weighs only 1 gram. Mercury has a low vapor pressure at standard temperature and pressure, so the liquid vaporizes slowly at room temperatures [HSDB 2005; NIOSH 2007]. Elemental mercury may combine with oxygen to form a mercuric oxide skin on its outer surface. Mercuric oxide does not vaporize, but the shell formed in this manner is fragile. The slightest movement can break this oxide shell and free the elemental mercury contained inside [EPA 2005]. Mercury amalgamates with other metals and is attracted to sulfur-based compounds [Yamamoto 2007]. Mercury is unusual in the number and properties of other compounds it forms. This health consultation evaluated metallic mercury (elemental mercury or quicksilver) only. Other forms of mercury have different properties and different hazards that are not addressed here except as they relate to metallic mercury. In American homes with no known mercury spill, concentrations in the 0.01–0.1  $\mu\text{g}/\text{m}^3$  range have been reported, with typical ambient (outside air) concentrations approximately a factor of 10 less than that [Carpi 2001; Garetano 2008; Johnson 2003].

## **1.2 Health Implications**

The primary route of exposure to metallic mercury is inhalation of its colorless and odorless vapors [ATSDR 1999; Bose-O’Reilly 2008; Lee 2009]. Ingested elemental mercury can be absorbed poorly through the intestinal walls. Dermal exposure or absorption of metallic mercury through the skin is considered a minor exposure route [ATSDR 1999; Ellis 2009]. Some case studies report dermal irritation after prolonged contact with mercury [De Capitani 2009], however, this dermal irritation does not seem to cause greater absorption.

The organ or organ system in humans most sensitive to all forms of mercury changes somewhat over our life spans. For a developing fetus or young child, the most sensitive endpoint is considered to be the developing central nervous system (CNS) [Abbaslou 2006; Baughman 2006; Bensefa-Colas 2010; Bose-

O'Reilly 2008, 2010; Grant 2010]. While data about humans are limited, several animal studies report CNS effects in offspring after maternal exposure to mercury (see Section 2.2.1.6 of the ATSDR Toxicological Profile) [ATSDR 1999; Morgan 2002]. As humans mature, our CNS system completes its development and we become less sensitive to the effects of mercury on our CNS. That is, a greater exposure (i.e., higher concentration, more frequent exposure events, or longer duration of exposure events) is required to produce effects on the CNS. For this reason, our most sensitive populations are young children and developing fetuses; women who are confirmed or suspected to be pregnant also require consideration as a sensitive population to protect the fetus. The age at which young children become less sensitive to the CNS effects of mercury is unclear but the concern is usually for pre-school children. Individuals that have matured beyond this window of greater vulnerability for the CNS may experience effects on the kidneys before the effects on the CNS become evident.

Consequently, the next human organ most sensitive to the effects of mercury tends to be the kidney; inorganic forms of mercury are excreted almost exclusively through the kidneys [Baughman 2006; Bensefa-Colas 2010; Franko 2005; Opitz 1996; Samir 2011]. Generally speaking, the concentration of mercury that may pose a CNS threat to the young is less than the concentration that could affect the kidneys in older children or adults under the same conditions of exposure. In animals, acute mercury exposures (as long as 14 days in duration) of approximately 0.05 mg/m<sup>3</sup> may cause significant CNS effects; exposures in the 0.5–0.86 mg/m<sup>3</sup> range more commonly cause significant CNS effects. Typically, acute exposures of ~3 mg/m<sup>3</sup> affect the kidneys (see Figure 1A) [ATSDR 1999].

### 1.3 Guidance Values

Both ATSDR and EPA have developed health guidance values (HGVs) for inhaled mercury vapors, based on a 1983 study of workplace exposures [Fawer 1983]. The workers in the study were exposed in their workplace to mercury vapors. The workers in the Fawer cohort came from three different types of workplaces: fluorescent tube manufacture; chloralkali plants; and acetaldehyde production. The authors reported a Lowest Observed Adverse Effect Level (LOAEL) of 26 µg/m<sup>3</sup> of exposure averaged over a period of 15 years [Fawer 1983]. As discussed below, the effect noted in the study was a slight tremor in the hands. ATSDR has defined a Minimal Risk Level (MRL) for chronic exposures (more than 365 days) to mercury of 0.2 µg/m<sup>3</sup>. In developing the MRL, the workplace average from Fawer was adjusted from a 40-hour to a 168-hour exposure per week (i.e., 24 hours/day, 7 days/week), and then divided by an uncertainty factor of 30 (3 for use of a minimal LOAEL and 10 for human variability) to account for the LOAEL and individual sensitivities. {It should perhaps be noted that the concentration in the Fawer study as well as many other occupational studies was averaged over a typical workday and their results may not be completely representative of continuous or significantly longer durations of exposure such as may be found in a residential setting.} Thus, an MRL is an estimate of the level of daily exposure to a hazardous substance (in this case, metallic mercury), sustained through a specific route and duration of exposure, that is unlikely to cause measurable risk for adverse, noncancerous health effects (metallic mercury is not considered carcinogenic [cancer causing]) [ATSDR 1999]. EPA used the same study as their primary reference to develop a Reference Concentration (RfC) of 0.3 µg/m<sup>3</sup> using slightly different assumptions and somewhat

different justifications for the same uncertainty factors. EPA also cites other supporting studies in a weight of evidence approach [EPA 1995]. Please see the IRIS record available at [www.epa.gov/iris](http://www.epa.gov/iris) for the details of their derivation. The RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily inhaled exposure of the human population (including sensitive subgroups) that is unlikely to cause an appreciable risk of harmful effects during a lifetime. For further information, see Section 2.5, Chapter 7, and Appendix A of the ATSDR Toxicological Profile for Mercury and the EPA's Integrated Risk Information System (IRIS) on the Internet at [www.epa.gov/iris/](http://www.epa.gov/iris/). ATSDR considers the RfC and the MRL for chronic exposures to be within the uncertainties of the derivations and the same value for all practical purposes.

Within the limits of this health consultation, an *action level* is an indoor air concentration of mercury vapor that should prompt public health and environmental officials to consider implementing response actions. The various suggested action levels provided in this document are intended as recommendations, not as regulatory values or cleanup values, although some of the recommended action levels may correspond to present or future values adopted by regulatory authorities. The following discussion is intended to confirm that these action levels should not be considered as “bright line” indicators of toxicity or predictors of adverse health effects. These action levels are provided primarily to prevent adverse health effects by identifying environmental concentration associated with any level of toxicity. The secondary purpose is to identify when precautions should be implemented to prevent adverse health effects and when such precautions may be stopped with a reasonable expectation of no adverse effects. Risk managers, such as EPA OSCs and their state and local counterparts, should determine whether a recommended response action is necessary based on the actual conditions and circumstances they encounter at the exposure site.

## 2.0 Discussion

In the course of this discussion, the reader may find it useful to refer to Tables 1 and 2 found towards the end of this consultation. In the tables, the sections of this consultation that bear on the development of the recommended action levels are provided in the right hand column. As the discussion progresses, there are 4 key elements in this approach to bear in mind; these elements are adjusted to the assumed conditions of exposure in each scenario. These elements are explained in the various sections and summarized here:

- Visible mercury cannot be left readily accessible after a clean up is complete (Section 2.1);
- Experience has shown concentrations of 6  $\mu\text{g}/\text{m}^3$  or above are usually associated with the presence of liquid mercury that may not have been discovered (Section 2.1);
- Urinary levels in some humans begin to increase at environmental concentrations as low as 10  $\mu\text{g}/\text{m}^3$ ; this consult treats exposure to that concentration, if not terminated, as a threshold that could cause effects in some people (Section 2.2.2) ;
- The benefits to human health of cleaning transient spills to a concentration below 1  $\mu\text{g}/\text{m}^3$  under most conditions typically do not outweigh the potential consequences to overall quality of life for individuals in that environment (Section 2.2.1).

## 2.1 “Visible” Mercury

Because of metallic mercury’s unique properties and appearance, it has long attracted the attention of humans of all ages. Liquid mercury is shiny and flows easily over the hand. It flows together to make large beads and splits apart to make smaller beads—the beads can take any shape. It feels heavy to the touch, but splatters readily. For all these reasons, liquid mercury may be kept, shared, and distributed by non-professional persons who are not aware of the hazard. If visible mercury is not contained appropriately, it is a likely hazard because it may fall into the hands of our most sensitive population [Hudson 1987]. Visible mercury should therefore be considered an attractive nuisance [Azziz-Baumgartner 2007; Baughman 2006; CDC 2005; Johnson 2004; MacLehose 2001; Nickle 1999; Risher 2003].

ATSDR is often asked how much mercury is required for it to become visible to humans. While visual acuity (i.e., how well one sees objects) varies by individuals, it must be remembered that the air concentrations of mercury associated with the HGVs discussed in Section 1.3 are small and mercury is very dense. In a room that is 3 meters (roughly 10 feet) square with a 3 meter [m] ceiling, approximately 5 micrograms [ $\mu\text{g}$ ] of vaporized mercury would elevate the air concentration of mercury in the room to the ATSDR MRL ( $3\text{ m} \times 3\text{ m} \times 3\text{ m} = 27\text{ m}^3 \times 0.2\text{ }\mu\text{g}/\text{m}^3 = 5.4\text{ }\mu\text{g}$ ). Five micrograms equates to less than a nanoliter of liquid mercury ( $5 \times 10^{-6}\text{ g} \times 1\text{ mL}/13.5\text{ g} = 3.7 \times 10^{-7}\text{ mL}$  or  $\sim 0.4\text{ nL}$ ). For comparison, the most popular brand of oral thermometer in the United States contains approximately 0.3 milliliters of mercury, or about 4 grams (4,000,000 micrograms) of liquid mercury. A nanoliter (nL) of liquid would be 6 orders of magnitude or 1 million times smaller than the volume in a thermometer and effectively invisible to most humans. Therefore, if an uncontained bead of mercury can be seen in most indoor spaces, it is possible that enough vapors are present in that space for the concentration to be greater than the HGV described previously. Multiple factors such as relative humidity, surface area of the liquid, barometric pressure, and temperature can influence vaporization of a liquid. Many of these factors can change over time and by location. During an indoor release, most of these factors would likely be fairly constant in a state that would promote vaporization. Because mercury is much denser than air, stable conditions are likely to stratify (layer) the mercury vapors in a confined space like the room described previously. In addition, different materials likely to be found in indoor environments may have different affinities for mercury vapors, which can also affect how much mercury is available in the indoor air. The actual concentration at any given point in a room at any given time would be expected to vary [Lui 2011; EPA 2005; Winter 2003]. Air-monitoring instruments are required to determine the existence of, and often to find the source of, mercury in a room [CDC 2005]. The experience of EPA staff has been that concentrations as low as  $6\text{ }\mu\text{g}/\text{m}^3$  typically indicate that liquid mercury is present in a room [Nickle 1999; Nold 2011].

Because mercury is an attractive nuisance fascinating to many people and even a microscopic amount of it can contaminate many individual spaces, the initial criteria for all mercury cleanup actions must be that no visible mercury remains. This is indicated in both tables 1 and 2 in the 2 columns on the right. Removing the liquid mercury also reduces the source of the vapors in the space, meaning that any residual vapor concentrations in the area should decrease over time after the source is removed [Azziz-Baumgartner 2007; Baughman 2006; CDC 2005; Cizdziel 2011; Risher 2007; Tominack 2002]. All of the action levels [i.e.,

usually less than 1 or less than 3  $\mu\text{g}/\text{m}^3$  in Tables 1 and 2] recommended here that terminate cleanup actions as opposed to implementing protective measures assume that all visible mercury has been removed from the location of the spill. The importance of this key action in protecting public health cannot be overemphasized.

## 2.2 Residential Settings

**2.2.1 Normal Occupancy:** Because elemental mercury is primarily an inhalation hazard, any cleanup should be focused on minimizing this exposure pathway. Cleaning any area in a typical residential setting to make the indoor air concentration meet the MRL or RfC would require removing virtually every nanoliter of liquid mercury from that area. This exacting task could lead to difficult risk-management decisions, such as the considerable loss of personal property that is contaminated to the extent that cleanup is not feasible (e.g., the cleaning process would destroy the property or exceed the cost of replacing the article with similar articles). This loss of property could be severe enough to cause a substantial lifestyle change that could increase the potential for adverse health outcomes [Nickle 1999]. ATSDR prefers that no person be exposed to a concentration of a toxic substance greater than the recommended HGVs, such as the RfC or MRL. However, given the extraordinary measures required to remove enough liquid mercury to reach the HGV concentrations, the human health benefit of such a removal action may not always be warranted by the threat [ATSDR 2008; CDC 1995; Nickle 1999; Risher 2003].

The principal study (i.e, Fawer, 1983) upon which both of the HGVs for mercury discussed in Section 1.3 was based used a very sensitive method of measuring the adverse health effect in the workers. Tremor reported in the study could only be measured when a small weight was suspended from the study worker's hand. The tremor did not cause debilitating harm or contribute in any way to a lower quality of life for the workers. Because many of the participants worked in the facilities in the study before adequate protective emission controls were in place, the long-term workers likely may have been exposed to much higher levels of mercury than was reported in the study. However, the workers clearly had been exposed to sufficient mercury to cause a measurable tremor in their hands, which represents a systemic effect.

The lowest concentration of mercury reported in the scientific literature considered to be the most significant by ATSDR in the ATSDR Toxicological Profile (Table 1; ATSDR 1999) associated with adverse human health effects is 10  $\mu\text{g}/\text{m}^3$  [Ngim 1992]. This study was essentially a survey of symptoms among dentists, nurses, and aides who worked with dental amalgams that contained mercury for 8–10 hours per day during a 6-day work week. The authors of the study simulated preparing the amalgams, measured the concentration in the breathing zone, and reported the concentration from the simulation as the exposure of the survey participant. How accurately the simulation reflected both historical conditions and current practices is unknown. While both EPA and ATSDR chose to use other studies to develop their respective HGVs, both agencies agree that Ngim [1992] is an essential supporting study [ATSDR 1999; EPA 1995; Ngim 1992].

Although ATSDR and EPA have established HGVs with no appreciable risk of human harm, a range of uncertainty exists regarding the concentration at which a person may actually experience health effects.

The closer air levels are to the RfC or the MRL, the less likely any exposure is to cause adverse health effects. The closer air levels are to the lowest concentrations known to cause any level of harm to humans (the lowest toxic concentration level for humans [TCLo]), the more likely any exposure is to cause harm. In many cases, response action will be initiated quickly enough to recover the liquid mercury and stop exposures in short order. Applying HGVs, such as the RfC or MRL, that are intended for chronic exposures to situations involving shorter term exposures could be overly conservative in many cases. Historically, ATSDR has recommended  $1 \mu\text{g}/\text{m}^3$  as the residential level requiring cleanup. This concentration is a factor of 10 lower than the human TCLo [Ngim 1992], and a factor of 26 lower than the concentration which is the point of departure for the HGV of both ATSDR and EPA [Fawer 1983]. {It should be noted that the concentrations in these studies were averaged over a typical workday and their results may not be completely representative of continuous or significantly longer durations of exposure such as a residential setting.} This concentration is within a factor of 10 of the HGV concentrations described earlier. This concentration is also approximately 100 times that expected to be seen from the many other sources of mercury in our environment [ATSDR 1999; Cairns 2011; Carpi 2001; Cizdziel 2011; Garetano 2008; Johnson 2003; Lyman 2009; Song 2009]. Studies indicate that  $1 \mu\text{g}/\text{m}^3$  is approximately an order of magnitude lower than the concentration (i.e.,  $10 \mu\text{g}/\text{m}^3$ ) where results of urinary levels of mercury appear to begin to increase in concentration. [Hryhorczuk 2006; Tsuji 2003]. Experience in previous removal actions by EPA has shown an action level of  $1 \mu\text{g}/\text{m}^3$  generally causes significantly less disruption of lifestyles and fewer potential consequences for individuals or families involved in the spill event [Nickle 1999]. ATSDR's standard practice has been to recommend this value ( $1 \mu\text{g}/\text{m}^3$ ) unless the exposed population is particularly susceptible to the effects of mercury (e.g., a mercury spill in a neonatal intensive care unit or a dialysis center).

**2.2.2 Isolation/Relocation:** ATSDR is often asked at what level of mercury in indoor air persons should be isolated from the exposure to mercury. Isolation in this sense may include, but not be limited to:

- reducing the time persons spend in a particular area;
- closing the ventilation system connections leading to and from a specific portion of a building;
- reducing the emission rate of vapors from the source; or,
- relocating some or all of the persons who normally occupy the building.

All of these isolation techniques have some negative implications, whether relatively minor, such as reducing the time spent in a given room, or potentially significant, such as persons leaving their home entirely. To complicate matters further, it is common for the persons involved to be uncertain as to when the release occurred. Before isolating an area and incurring those negative implications, ATSDR suggests that, in most cases, the threat to the persons involved should be certain. Due to uncertainty about the duration of exposure before the spill was discovered, continued exposure to mercury levels that could be harmful should be minimized [Azziz-Baumgartner 2007]. Some studies have indicated that urinary levels of mercury in humans begin to increase at mercury concentration levels  $10 \mu\text{g}/\text{m}^3$  or higher. [Hryhorczuk 2006; Tsuji 2003]. Based on this and the Ngim study discussed above, ATSDR will consider the mercury concentration level of  $10 \mu\text{g}/\text{m}^3$  as the TCLo in humans for this health consultation. At the TCLo, adverse

effects are possible for susceptible persons, depending on the duration of exposure [ATSDR 1999; Cherry 2002; Hryhorczuk 2006; Ngim 1992; Tsuji 2003]. Therefore, ATSDR usually recommends risk managers consider the need to isolate humans from the spill when a concentration level  $\geq 10 \mu\text{g}/\text{m}^3$  is determined.

As with the other action levels described in Tables 1 and 2, conditions at the scene may indicate that a higher, or rarely a lower, concentration than  $10 \mu\text{g}/\text{m}^3$  is acceptable before isolation measures are truly required. In addition, the risk manager at the scene (e.g., an EPA OSC) may have reasons to seek relocation of residents other than mercury contamination, such as physical hazards caused by removal techniques or necessary curing of sealants.

**2.2.3 Personal Belongings:** The hazardous state for this form of mercury is predominantly a vapor; therefore, it can be highly mobile in the indoor environment. Both the liquid and the vapor may collect in porous materials, such as fabric, rubber, and home furnishings. The mercury may invade cracks and crevasses of appliances, flooring, and electronics. In many settings, these belongings represent a substantial investment on the part of the owner who will have an understandable desire to salvage whatever is possible. The challenge of determining what can be saved and what must be disposed of lies in the uncertainties associated with the exposure. For instance, how much time does a child spend sleeping with a favorite stuffed animal and breathing whatever vapors their companion emits? How often does a refrigerator cycle on or off, and who is normally nearby and affected by that heating? How large is the room where the home computer is off-gassing mercury? We do not have the data to answer these kinds of questions and to address all of the possible permutations without analyzing specific conditions and personal habits at a site. This level of detailed analysis, which could change from person to person or structure to structure, is not feasible for a non-site-specific health consultation. We must either dispose of everything contaminated or evaluate the potential risk of the contamination.

The ultimate goal of evaluating a contaminated belonging would be to ensure that the mercury concentration in the breathing zone of the person using the contaminated items under normal use patterns will not exceed  $1 \mu\text{g}/\text{m}^3$  for a time sufficient to cause harm. The preferred method to assess the amount of contamination is to bag small-to-medium items, heat the bag to what might be reasonably anticipated to be maximum temperatures of normal use, and take headspace readings within the bag [Baughman 2006; Nickle 1999]. Large items, such as couches, recliners, and mattresses, with porous surfaces that come in contact with mercury can raise the vapor concentrations more than smaller items in the same room. For larger items, such as appliances and electronics, typically the vapors from the cooling vents have been measured for mercury concentrations. These concentrations would normally be much higher than the readings after the vapors have dispersed into the room. The higher readings would be observed because the same number of molecules of vapor would be contained in a smaller space (e.g., at the point of emission at the vent or contained within a bag).

The suggested action levels developed in 2000 recommended that the elevated readings in the headspace or the point of emission should be less than  $10 \mu\text{g}/\text{m}^3$  [ATSDR 2000]. Because ATSDR wanted to ensure that the belongings had actually been contaminated before they were deemed a threat that suggested level was



based primarily on the human TCLo and the technical limitations of the survey instruments available at the time. Extensive field testing by EPA's Environmental Response Team has demonstrated that newer instruments are both more sensitive and less prone to yielding false positives due to interferences. Therefore, measurements can now detect lower concentrations with the same level of confidence as higher levels that were measured previously [EPA 2005].

Generally speaking, EPA's experience has shown that when liquid mercury comes in direct contact with porous objects or objects that generate heat under normal operation, those objects are not recoverable. ATSDR recommends that such objects be disposed of appropriately [Nickle 1999].

The recommended action level for the residential setting is  $\leq 1 \mu\text{g}/\text{m}^3$ ; the  $10 \mu\text{g}/\text{m}^3$  suggested in 2000 has generally worked well in reducing the vapors from belongings in a home (when belongings have been exposed only to mercury vapors) to support this action level [Nickle 1999]. When an unusually large object, such as a freezer, is used in a small room, such as a typical utility room, the contamination level in the room may exceed the  $1 \mu\text{g}/\text{m}^3$  limit even when the freezer does not exceed the  $10 \mu\text{g}/\text{m}^3$  limit for personal belongings. Likewise, when several items, such as clothing, that do not exceed the  $10 \mu\text{g}/\text{m}^3$  headspace limit are placed in a small room, such as a second bedroom in a mobile home, the home may exceed the  $1 \mu\text{g}/\text{m}^3$  limit. Obviously, appliances not in use when tested may exceed the action level during normal use.

The site risk manager's professional judgment determines when a lower action level is necessary. EPA's experience has shown that concentrations in the  $1\text{--}3 \mu\text{g}/\text{m}^3$ -range in the headspace/vent emission usually will allow levels in even smaller rooms to remain at or below  $1 \mu\text{g}/\text{m}^3$ . Experience has also shown that these action-level concentrations indicate that minimal or no contact between the contaminated item and liquid mercury has occurred. Finally, EPA's experience has also shown that concentrations  $>6 \mu\text{g}/\text{m}^3$  in indoor air usually indicate the presence of liquid mercury that may not have been discovered [Nickle 1999; Nold 2011]. Therefore, ATSDR recommends headspace readings for belongings that may have been contaminated by vapors from a mercury spill that are in the range of  $3$  to  $6 \mu\text{g}/\text{m}^3$  be considered protective of human health.

**2.2.4 Conditions when other concentrations should apply:** Under some conditions, ATSDR will consider concentrations in non-occupational settings above  $1 \mu\text{g}/\text{m}^3$  as safe for human health [ATSDR 2008]. Examples of these conditions are when other mechanisms can be put into place to reduce exposure durations for sensitive persons, or when a population is less sensitive (e.g., healthy adults). These conditions usually occur when the methods required to achieve lower concentrations may possibly cause more harm (e.g., increased property damage and potential harmful lifestyle changes as described earlier) than would the short duration of exposure to slightly higher mercury levels (when the source of the mercury vapors has been controlled [e.g., removal of visible mercury]). Conditions vary from site to site, which may suggest the need for modification; however, ATSDR has never considered an exposure level in a residential setting at a concentration  $>10 \mu\text{g}/\text{m}^3$  as acceptable for long-term use. Again, use of these higher levels normally implies that all visible mercury has been removed, indicating that all point sources are

removed or isolated. Subsequently, with no mercury source to continue vaporizing levels are expected to decline with time.

Persons in whom the CNS is developing (e.g., fetuses, infants, and young children) are the population considered most sensitive to mercury exposure and, thus, require greater protection [Bensefa-Colas 2010; Bose-O'Reilly 2008; Opitz 1996]. No evidence indicates that persons with deteriorating nervous systems are more susceptible to the effects of mercury than healthier adults; however, a person's underlying conditions may mask the more subtle effects of mercury. Prolonged exposure to mercury also affects the kidneys [ATSDR 1999; Baughman 2006; Bensefa-Colas 2010; Franko 2005; Opitz 1996; Samir 2011]. Under almost all conditions, removing visible mercury from the indoor environment until a residual concentration of 1  $\mu\text{g}/\text{m}^3$  is reached would be protective of even the most sensitive population.

If a person has an underlying condition that makes them more susceptible to the effects of mercury than healthier persons, a concentration less than 1  $\mu\text{g}/\text{m}^3$  mercury in a residential setting may be considered necessary. An invalid with poorly functioning kidneys who normally lives in a space where mercury has been spilled is an example of this situation. An infant born prematurely who is struggling to complete its development may be more susceptible to mercury contamination than an infant born at full term. When OSCs are faced with similar unusual conditions, consulting with public health officials and the healthcare provider for the person is warranted.

Inhaling elemental mercury from a spill may contribute to the overall body burden of mercury. Persons with already high systemic levels of mercury may be more susceptible to adverse effects due to the contribution of the new exposure [Goldman 2001; CDC 2001]. Persons likely to have high systemic levels of mercury include those who work with mercury in occupational settings. Other persons likely in this category are those who routinely eat more than the recommended two meals of fish per week [EPA/FDA 2004]. These persons should be advised to consult their personal healthcare provider regarding the additional exposure to mercury due to the spill. Risk managers may need to consider isolating these persons at a lower concentration of mercury than suggested in Section 2.2.2 earlier. No adverse effect would be expected at the normal occupancy level suggested in Section 2.2.1.

## **2.3 Commercial and Occupational Settings**

### **2.3.1 Workplaces covered by the Occupational Safety and Health Administration regulations in Subpart Z:**

Occupational settings where mercury exposure is anticipated are addressed by various occupational standards. The Occupational Safety and Health Administration (OSHA) does not have a specific standard for mercury in Title 29 of the Code of Federal Regulations (29 CFR). However, general requirements, such as the Hazard Communications Standard (29 CFR 1910.1200), Respiratory Protection Standards (29 CFR 1910.134), and a health and safety program for workers who might be exposed to a "Subpart Z" hazard (29 CFR 1910.1000, Table Z-2), do apply. See <http://www.osha.gov/SLTC/mercury/index.html> for a complete list of standards applicable to mercury exposure. Industrial hygiene recommendations and best practices by the American Conference of Governmental and Industrial Hygiene (ACGIH), the National Institute for Occupational Safety and Health (NIOSH), and OSHA include periodic monitoring of the workplace air,

biological exposure indices to monitor worker's individual body burdens, periodic medical monitoring, and engineering controls to reduce mercury concentration at any given workstation [HSDB 2005]. See <https://www.osha.gov/SLTC/mercury/standards.html> for these guidelines. In addition, workers are presumed to be healthy adults with exposure durations of 40-hour workweeks for 40 years. Under these conditions, which obviously include responders and others workers subject to the requirements of OSHA's Hazardous Waste Site Operations and Emergency Response Standard [29 CFR 1910.120]), the occupational standards would be expected to protect human health. OSHA established the Permissible Exposure Limit (PEL), the only legally enforceable federal U.S. standard, as a ceiling (i.e., level not to be exceeded) value of 100  $\mu\text{g}/\text{m}^3$  (actual standard is 1 mg/10 m<sup>3</sup>). NIOSH set a Recommended Exposure Limit (REL) of 50  $\mu\text{g}/\text{m}^3$  as a 10-hour, time-weighted average. The American Conference of Governmental and Industrial Hygienists (ACGIH) recommended the most recent occupational exposure standard as the Threshold Limit Value–Time Weighted Average (TLV-TWA) of 25  $\mu\text{g}/\text{m}^3$ . ACGIH has also recommended biological exposure indices (BEI) in both urine and blood [ACGIH 2008; HSDB 2005].

**2.3.2 Workplaces not covered by Subpart Z:** In some occupational settings, such as many commercial retail settings, medical offices, and schools, exposure to mercury is not an expected hazard. Which settings are covered by the various requirements in Subpart Z vary from standard to standard. For example, to quote the hazard communications standard 29 CFR 1910.1200(b)(2)), the HazComm standard applies to "...any chemical which is known to be present in the workplace in such a manner that employees may be exposed under normal conditions of use or in a foreseeable emergency." A mercury spill in an occupational setting is not likely to be a normal condition and, if the mercury is not used in the normal work at the setting, it would be unlikely to be a foreseeable emergency. A more detailed list of exemptions in 29 CFR 1910.1200(b)(6)(ii) specifically excludes any setting "...when the hazardous substance is the focus of remedial or removal action being conducted under CERCLA in accordance with the Environmental Protection Agency regulations."

In these settings, the protections associated with the occupational standards and recommended guidelines described earlier (e.g., medical monitoring, engineering controls, hazard communications) are not typically available [Risher 2003]. Without these additional protective measures, applying the occupational standards to these situations is inappropriate. However, the exposure duration in most workplaces would be roughly the same. Therefore, the underlying assumption for residential exposures (exposure for 24 hours, 7 days a week, for non-employed persons living in the home or 16 hours, 7 days a week for persons employed outside the homes and school-aged children not being homeschooled) would not reasonably apply. Adjusting the 1  $\mu\text{g}/\text{m}^3$  residential action level discussed earlier from a 168 hour exposure (24/7) or a 112 hour exposure (16/7) to a 40-hour exposure, which is more typical in a commercial or public workplace, would yield an equivalent protection in the 3–4  $\mu\text{g}/\text{m}^3$ -range (i.e., 168 hours is about 4 times longer than 40 hours and 112 is about 3 times longer). The exposure for non-employees, such as customers or clients in businesses or students in a school, would be even more transient. Although these non-employees could be more susceptible than presumably healthy adult workers, a concentration in this 3 to 4  $\mu\text{g}/\text{m}^3$ -range should be safe for them as well [CDC 1995; Nickle 1999; Ratcliffe 1996].

**2.3.3 Conditions when other concentration may apply:** The interaction between mercury and the developing CNS is poorly understood. Therefore, mercury exposures should be minimized for workers in all settings who are confirmed or suspected to be pregnant, or may become pregnant. In commercial settings, such as maternity wards, dialysis clinics, pre-kindergarten daycare, and pediatric intensive care units, susceptible populations reasonably may be expected to spend prolonged periods of time. In those cases, minimizing mercury exposures or lowering the acceptable residual concentration should be considered.

When considering response operations during a mercury spill, balancing the risks associated with specific settings may be necessary. For instance, if a mercury spill occurs in a commercial setting that provides essential life-saving services to a community and is the sole source for those services, disrupting these services may cause greater harm than exposure to the mercury. Exposure to mercury at levels as high as occupational levels for only a few hours is not likely to cause serious harm to a person, whereas missing a scheduled dialysis treatment may cause significant harm. The risk manager at the scene should consult with public health authorities in the community if this kind of circumstance is suspected.

## **2.4 Schools and Educational Settings**

Schools can pose a significant challenge during mercury cleanup. First, schools commonly provide a community setting in which many children could be exposed to a single source of liquid mercury discovered in or brought to the school. Second, the school environment can actually be a source of mercury—the fascinating chemical and physical properties of mercury can make it seem a useful teaching tool. Other potential exposure locations in a school include utility rooms and ventilation spaces where mercury may be used in temperature or pressure controls. Third, school areas, such as buses, gyms, cafeterias, and hallways, are commonly used by many people; they may walk through spilled mercury and spread contamination to other areas. Fourth, schools have multiple appliances (e.g., classroom computers and computer labs) that can produce heat. A classroom with 1–5 computers not in use may be safe; however, 5 computers turned on and producing their normal amount of heat in the air may generate enough mercury vapors in the room from a spill to pose a risk to staff and students [ATSDR 1997; CDC 1995, 2005; EPA 2010; Gordon 2004; Mercury in Schools 2004; Nickle 1999; Taueg 1992; Tominack 2002]. Additionally, the length of exposure duration may be too short to likely harm the seemingly most sensitive population (i.e., the students).

Many school systems have programs to remove hazards, including mercury, in their schools. However, students can bring mercury to the school and share it with their fellow students, a contingency that school officials must recognize and address.

The exposure scenario at most schools, even with after-school programs, is typically much closer to a workday type of exposure (i.e., 7–10 hours) than a residential setting; however, the longest time most students will spend in any given school building will be commonly 3 to 5 years. Some private schools may offer more extended instructional opportunities, both in the number of hours per day and in the number of years (i.e., number of grade levels taught). Staff at these schools may be in the same setting for a considerably longer time (e.g., a 40-year work lifetime; 10 to 12 hour days), depending on their personal

habits and regional turnover rates. Students or staff could be pregnant. Risk managers should be aware of the potential for these unique circumstances within a school.

Consideration should be given to closing or isolating areas of schools with mercury concentrations of  $\geq 10 \mu\text{g}/\text{m}^3$ , depending on the exposures, pending removal of the hazard. Given the variables associated with exposures in educational settings, ATSDR recommends a range  $\leq 3 \mu\text{g}/\text{m}^3$  before resuming normal operations of the school. This recommendation is based on the residential action levels discussed earlier and adjusted for a normal school day. Presuming all visible mercury in the setting has been removed, this action level is considered appropriate.

## **2.5 Vehicles**

The scenario for persons exposed to mercury while in vehicles is challenging to estimate because it depends on many factors. The purpose of the vehicle (e.g., a school bus versus a family van), the habits of the individual users (e.g., how much time does Mom spend in the car in a hot parking lot waiting for the kids to get out of school?), the sensitivity of the individual passengers (e.g., is Mom in the previous example pregnant?), and the number of passengers routinely in the vehicle are probably the biggest considerations. However, the intended use in any given period may greatly influence the potential hazard posed by mercury in a vehicle. For instance, a spill in a family vehicle that is used soon after for a prolonged vacation may cause more intense exposure than otherwise might be expected. Given all the possible variables, the most sensitive anticipated use of a vehicle should determine the action level for that vehicle.

For family vehicles, the exact exposure scenario depends on the habits of the principle drivers, but some exposure to most of the family is possible at some point. The duration of exposure on any given day is likely to be only a small fraction of the 24-hour period, but this could be offset by much longer duration exposures for transient periods (e.g., the family vacation). Because most of the family could be exposed while in the vehicle, the entire spectrum of sensitivities must be considered. The vehicle itself will be a fairly confined space with variable air-change rates (e.g., use of the air conditioner compared to open windows). Other than the transient exposure scenario of the family vacation, the length and intensity of the exposure duration should allow a higher spectrum of action levels than has been discussed up to this point.

For work vehicles, the exposure scenario can be either a vehicle that is used primarily to commute to a work location with a duration equal to a fraction of a full day (e.g. similar to the family vehicle above), or a vehicle that, for all intents and purposes, is the work location with a duration closer to an normal workday (e.g., sales and service vehicles, some construction equipment). In this instance, the population being exposed can be assumed to be a healthy adult. The occupied working area of the vehicle would be similar to a family vehicle or smaller and could be relatively open to the environment (e.g., an operator's seat on a piece of construction equipment), or closed similar to the family vehicle (e.g., the service van). For closed vehicles, concentrations higher than that of a family car would be acceptable generally. Without engineering controls and recommendations for settings protection when mercury is a known hazard, the acceptable concentration in these vehicles should not approach the occupational standards.

For multi-passenger vehicles, such as school buses or church vans, the exposure scenario would depend upon the underlying purpose of the vehicle. In other words, most passengers in a school bus would be students, and the characteristics of the population would be similar to that described earlier for the school being served. Population characteristics of the passengers in a city bus or a church van would be closer to that of the general population. For common carrier vehicles, such as airplanes or trains, the exposure duration would be relatively short for the passengers but closer to a workplace exposure for the crew. While space for individual persons may be limited, the interior of the multi-passenger vehicle over all would tend to be more spacious than other vehicle types. Air-change rates would vary significantly depending on the status and type of the vehicle. Given the high variability in the sensitivity of the population being transported, acceptable concentrations would be lower than most commercial or work vehicles. Exposure duration for most multi-passenger vehicle would be relatively short (e.g., measured in hours); however, exposure duration in a common carrier would vary over a fairly broad spectrum.

Visible mercury should not be present in any vehicle for all the reasons cited earlier in Section 2.1, but primarily because it could be tracked into other settings. The risk manager should be mindful that, even in a vehicle, higher concentrations mean a source of liquid mercury is likely present. If concentrations inside the vehicle do not decline significantly with cleaning and removing potential sources, a source of liquid mercury is especially likely. Concentrations  $>6 \mu\text{g}/\text{m}^3$  should raise concerns about the presence of liquid mercury in the vehicle.

Given all of these variables and concerns, ATSDR recommends an action level in the range of 3–6  $\mu\text{g}/\text{m}^3$ . This is based on concerns similar to the commercial setting (such as schools and retail establishments), adjusted for the shorter and transient exposure in the vehicles, and avoidance of tracking and the nuisance hazard of liquid mercury. Pregnant women and very young children should spend the minimum time possible in a vehicle contaminated with mercury. For a transient exposure of prolonged duration, alternative transportation should be considered for sensitive persons in the family.

### **3.0 Conclusions**

For the given scenarios requested by the Action Level Subgroup, ATSDR considers the action levels in this health consultation and summarized in the following tables appropriate to protect public health. If the action levels are exceeded, the risk managers on scene should consider appropriate response actions to protect the health of persons most likely to be exposed or more sensitive to the effects of mercury.

Before selecting any specific action level or course of action, risk managers should consider the assumptions and limitations described in this health consultation as they apply to the situation encountered when responding to a release. Risk managers should consider consulting with ATSDR staff or EPA risk assessors when unusual situations or unusually sensitive persons are involved.

In all cases where cleanup actions are terminated under these schemes, the action levels recommended are based on the assumption that all liquid mercury has been removed from the scene of the exposure.

## 4.0 Recommendations

In removal actions, ATSDR recommends that any liquid mercury at the scene be isolated and removed as expeditiously as possible to avoid tracking the mercury to other locations.

Each site may have site-specific concerns that should be considered before selecting an appropriate action level. Risk managers at the scene of a spill should consider consulting with regional risk assessors or public health officials at ATSDR, the State, or local authorities regarding unusual circumstances that they encounter.

ATSDR recommends the liberal use of field screening devices and methods to detect the presence of mercury in areas where a spill is suspected and to monitor the progress of cleanup. Environmental samples analyzed in a laboratory are generally unnecessary until all visible mercury is removed and confirmation is required that response activity is complete.

Samples to confirm final cleanup should be collected and analyzed in a manner equivalent to the modified NIOSH 6009 method. ATSDR considers readings from a properly calibrated Lumex Mercury Vapor Analyzer that are representative of 8 hours of exposure at the point of sampling, as comparable to the NIOSH 6009 method in the range of 0.1 to 10  $\mu\text{g}/\text{m}^3$  [Singhvi, 2003] and will accept these in lieu of laboratory analysis.

Application of the action levels provided in this health consultation should be modified as necessary to reflect actual conditions at the site of a mercury release. At the request of the lead agency, ATSDR is available to review site-specific situations and assist in making any decision to modify the application at the site.

The conclusions and recommendations provided in this health consultation are based on the information available to ATSDR as of the date of the document. New or additional information may necessitate a modification of our conclusions and recommendations.

## 5.0 Appendices

**Table 1: Suggested Action Levels for Residential Settings**

Action Level ( $\mu\text{g}/\text{m}^3$ )	Use of Action Level	Rationale for Action Level	Sampling Suggestions and other Considerations	Consult Section
Less than 1	Acceptable level for normal occupancy for most sensitive persons. No further response action needed	Experience has shown that response actions to reach levels lower than $1 \mu\text{g}/\text{m}^3$ can be disruptive enough to cause more harm than benefit. $1 \mu\text{g}/\text{m}^3$ is within an order of magnitude of health guidance values and indoor background levels. This concentration is 25 times lower than the concentrations referenced in the development of health guidance values.	No visible mercury; highest quality data.* Sampling in breathing zone of most sensitive person under normal conditions for use.	See Sections 2.1 and 2.2.1
3–6	Acceptable level for unrestricted use of family vehicles under most conditions.	Exposure duration in most vehicles is short compared with other settings, allowing a higher concentration as the “floor” of this range. Requirement for no visible mercury means the source of vapors has been removed and concentrations should continue to fall. The “ceiling” of the range is based on the presumption that liquid mercury may still be present but not yet discovered.	No visible mercury; highest quality data.* Sampling in the passenger compartment under normal use conditions. Unusual use of the vehicle in this case would be extended family vacations.	See Sections 2.1 and 2.5
3–6	Acceptable level to allow personal	The sampling point suggested in the column to the right tends to concentrate the vapors higher than typical exposure conditions. Exposure	Survey instrument data generally acceptable.+ Readings should be at the vents of appliances or headspace of bags. Bags should be warmed passively to ambient conditions and	See Section 2.2.3



Action Level ( $\mu\text{g}/\text{m}^3$ )	Use of Action Level	Rationale for Action Level	Sampling Suggestions and other Considerations	Consult Section
	belongings to remain in owner's possession.	frequency should be intermittent and the duration should be short. The 6 $\mu\text{g}/\text{m}^3$ is based on the possibility that liquid mercury is present but may not have been discovered.	appliances/ electronics should be at operating temperatures.	
Greater than 10	Isolation of contamination from residents or evacuation of residents	Indications are that 10 $\mu\text{g}/\text{m}^3$ may be the concentration at which urinary levels of mercury begin to increase. Other studies indicate this concentration may be the lowest toxic concentration (TCLo) for humans. Continued exposure may be harmful.	Survey instrument data acceptable. + Exposure to contaminant should be minimized.	See Section 2.2.2

\*Highest quality data is NIOSH 6009 analytic results or equivalent (e.g., Lumex reading averaged over 8 hours)

+Survey instrument data is considered any real-time monitoring equipment (e.g., Jerome, MVI, VM 300)

**Table 2: Suggested Action Levels for Other Locations**

Action Level ( $\mu\text{g}/\text{m}^3$ )	Use of Action Level	Rationale for Action Level	Sampling Suggestions and other Considerations	Consult Section/Reference
Less than 3	Normal Occupancy for commercial settings where mercury exposure is not expected in normal course of work. (e.g., 29 CFR 1910 Subpart Z does not apply)	Concentration is based on residential action level of $1 \mu\text{g}/\text{m}^3$ adjusted for a work day (i.e., 24/7 exposure reduced to 8/5 or 40 hour workweek). Persons exposed in these settings would not expect the presence of mercury as part of their normal employment.	No visible mercury; highest quality data.* Taken in breathing zone of most sensitive person under normal conditions for use. Pregnant workers should be offered alternate worksite.	See Section 2.1 and 2.3.2
1–3	Acceptable level for schools to resume normal operations.	Concentration is based on residential action level of $1 \mu\text{g}/\text{m}^3$ adjusted for a typical school day.	No visible mercury; highest quality data.* Taken in breathing zone of most sensitive person under normal conditions for use. Pregnant workers and students should be offered temporary alternatives to working or attending the school.	See Section 2.1 and 2.4
3–6	Acceptable level for unrestricted use of vehicles under most conditions.	Exposure duration in most vehicles is short compared with other settings, allowing a higher concentration as the “floor” of this range. Requirement for no visible mercury means the source of vapors has been removed and concentrations should continue to fall. The “ceiling” of the range is based on the presumption that liquid mercury may still be present but not yet discovered.	No visible mercury; highest quality data.* Sampling in passenger compartment under normal use conditions. Unusual use of the vehicle in this case would be situations where the vehicle is the workplace.	See Sections 2.1 and 2.5
Greater than 10	Isolation of contamination or	Indications are that $10 \mu\text{g}/\text{m}^3$ may be the concentration at which urinary	Survey instrument data acceptable.* Exposure to contaminant should be minimized.	See Section 2.3.2

Action Level ( $\mu\text{g}/\text{m}^3$ )	Use of Action Level	Rationale for Action Level	Sampling Suggestions and other Considerations	Consult Section/Reference
	evacuation of workers not covered by a health and safety program addressing exposure to mercury.	levels of mercury begin to increase. Other studies indicate this concentration may be the lowest concentration toxic to humans.		
25	Normal Occupancy for industrial settings where mercury exposure is expected in normal course of work. (e.g., 29 CFR 1910 Subpart Z does apply).	Based on the 1996 ACGIH TLV. Assumes hazard communications programs as required by OSHA; engineering controls as recommended by NIOSH; and medical monitoring as recommended by NIOSH and ACGIH are in place.	Survey instrument data acceptable. <sup>+</sup> Workers in these settings should be subject to OSHA standards for mercury (e.g., medical records, Subpart Z, HCS, HAZWOPER).	See Section 2.3.1
25	Upgrade responder protective ensemble to Level C during uncontrolled releases of mercury	For response, workers subject to requirements of 29 CFR 1910.120, based on the ACGIH TLV, as recommended by the 1987 NIOSH/OSHA/USCG/EPA Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities ( the" 4 agency guidance manual").	Survey instrument data acceptable. <sup>+</sup> Uncontrolled release refers to the absence of positive engineering controls on the material.	Occupational Safety and Health Guidance Manual for Hazardous Waste Site

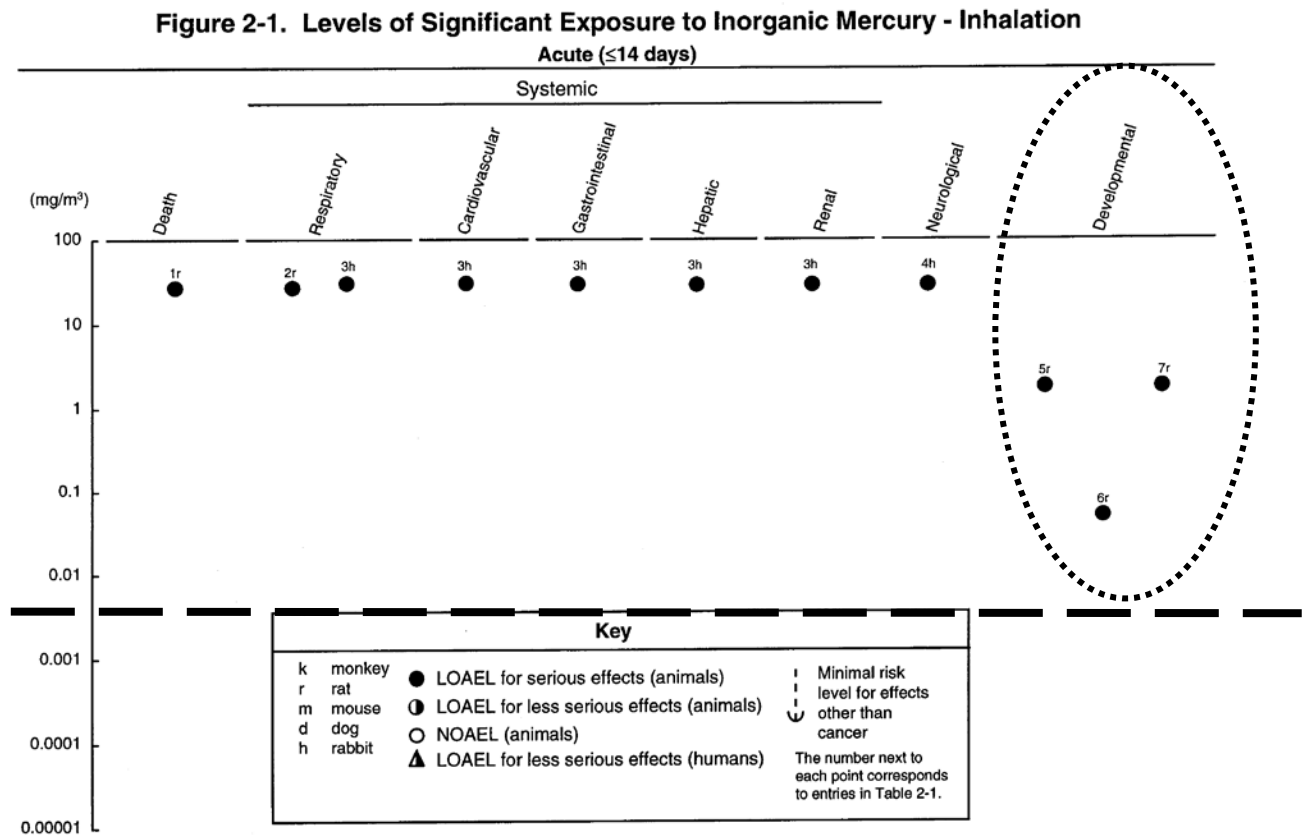
\* - Highest quality data would be NIOSH 6009 analytic results or equivalent (e.g., Lumex reading averaged over 8 hours)

+ - Survey instrument data would be considered any real time monitoring equipment (e.g., Jerome, MVI, VM 300, etc)

**Figure 1A: ATSDR Toxicological Profile Figure 2-1 Acute Exposures (Annotated)**

Developmental effects in animals

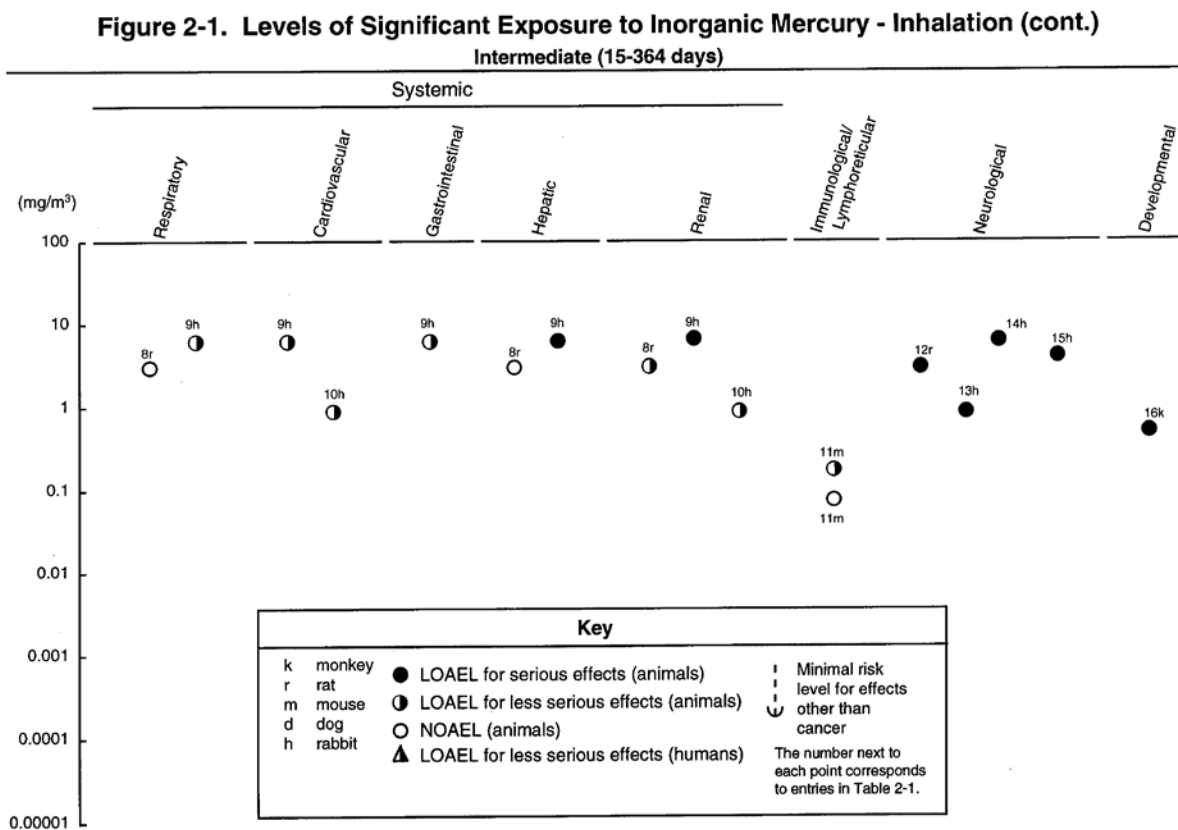
Figure 1A. Annotated insert of Figure 2-1 from the ATSDR Toxicological Profile graphing the



significant inhalation studies of inorganic mercury by health effect and concentration for exposure durations of  $\leq 14$  days. Dashed line represents the ATSDR Residential Action Level recommended in this health consultation. This figure illustrates most clearly the reason for considering developmental effects as the most sensitive endpoint.

**Figure 1B: ATSDR Toxicological Profile Figure 2-1 Intermediate Exposures (Annotated)**

Figure 1B. Annotated insert of Figure 2-1 from the ATSDR Toxicological Profile graphing the



significant inhalation studies of inorganic mercury by health effect and concentration for exposure durations of 15–364 days. Dashed line represents the ATSDR Residential Action Level recommended in this health consultation.

**Figure 1C: ATSDR Toxicological Profile Figure 2-1 Chronic Exposures (Annotated)**

Human Studies considered significant by ATSDR

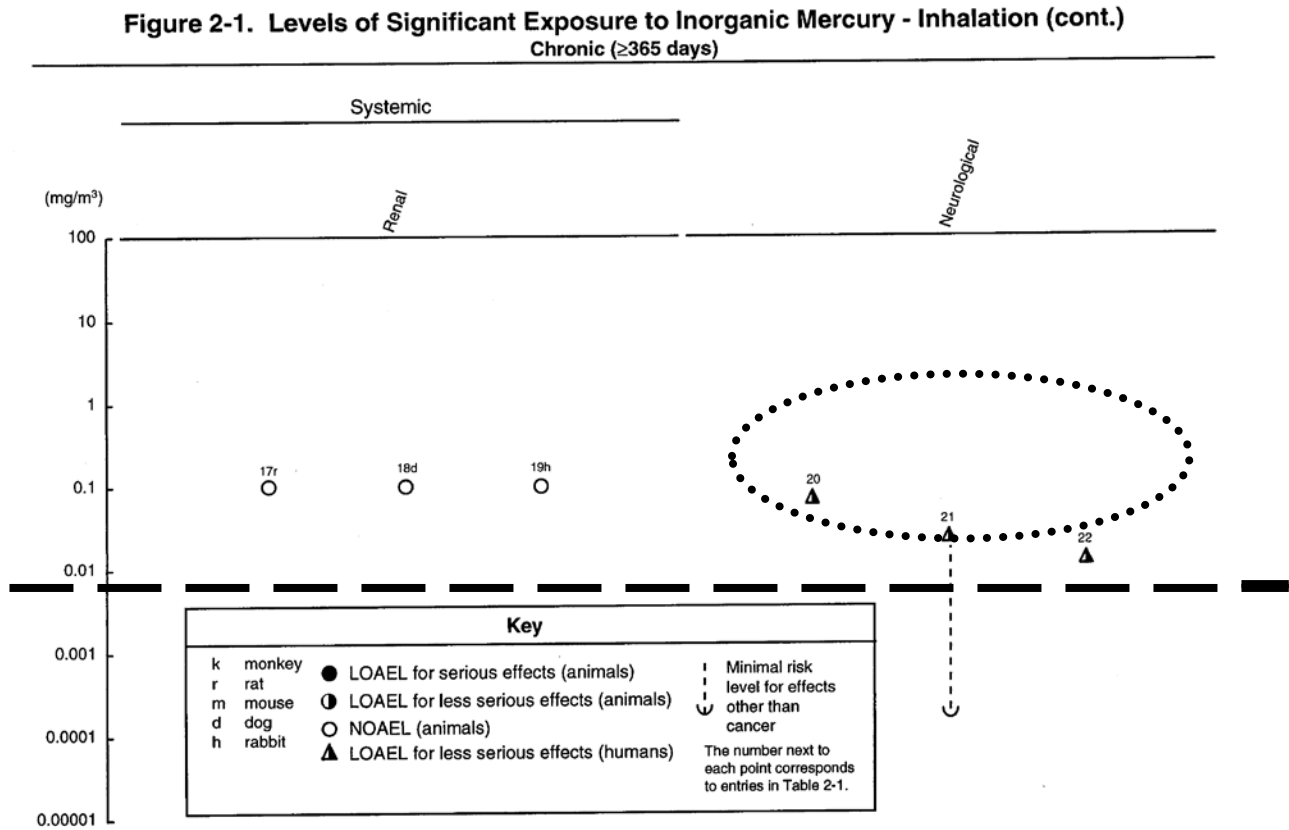


Figure 1C. Annotated insert of Figure 2-1 from the ATSDR Toxicological Profile graphing the significant inhalation studies of inorganic mercury by health effect and concentration for exposure durations of ≥365 days. Dashed line represents the ATSDR Residential Action Level recommended in this health consultation. This dotted circle indicates the three studies of humans in occupational settings that ATSDR considers most significant.

## 6.0 References

Abbaslou P, Zaman T. 2006. A Child with elemental mercury poisoning and unusual brain MRI findings. *Clin Toxicol.* 44; 1: 85-88

ACGIH 2008. TLVs and BEIs. Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. American Conference of Governmental and Industrial Hygienists. Cincinnati, OH

Alison Newby C, Riley D, Leal-Almeraz T. 2006. Mercury use and exposure among Santeria practitioners; religious vs. folk practice in Northern New Jersey, USA. *Ethn Health.* Aug. 2006 11; 3: 287-306

ATSDR/EPA, 1997 National Alert for Mercury. Available at <http://www.atsdr.cdc.gov>.

ATSDR, 1999. Agency for Toxic Substances and Disease Registry. Toxicological Profile for Mercury. Atlanta: U.S. Department of Health and Human Services.

ATSDR, 2000. Suggested Action Levels for Indoor Mercury Vapors in Homes or Businesses with Indoor Gas Regulators. Letter consultation from ATSDR to Mr. Brendan Boyle, Michigan Health, and Mr. Ralph Dollhopf, EPA Region V. December 2000

ATSDR, 2008. Health Consultation for the McAlester Mercury Site. Letter to CDR Patrick Young. Jan. 2008

Azziz-Baumgartner E, Lubber G, Schurz-Rogers H, Backer L, Belson M, Kieszak S, Caldwell K, Lee B, Jones R, Todd R, Rubin C. 2007. Exposure assessment of a mercury spill in a Nevada school -- 2004. *Clin Toxicol.* May 2007. 45; 4: 391-395.

Baughman TA. 2006. Elemental mercury spills. *Environ Health Perspect.* Feb 2006. 114; 2: 147-152.

Bensefa-Colas L, Andujar P, Descatha A. 2010. Mercury poisoning. *Rev Med Interne.* Jun 2010 [electronic publication before print].

Bose-O'Reilly S, Lettmeier B, Gothe RM, Beinhoff C, Siebert U, Drasch G. 2008. Mercury as a serious health hazard for children in gold mining areas. *Environ Res.* Mar 2008. 107; 1: 89-97

Bose-O'Reilly S, McCarty K, Steckling N, Lettmeier, B. 2010. Mercury exposure and children's health. *Curr Probl Pediatr Adolesc Health Care.* Sep 2010. 40; 8: 186-215

Cairns E, Tharumakulasingam K, Athar M, Yousaf M, Cheng J, Huang Y, Lu J, Yap D. 2011. Source, concentration, and distribution of elemental mercury in the atmosphere in Toronto, Canada. *Environ Pollut* Jan 2011 [electronic publication before print].

Carpi A, Chen Y. 2001. Gaseous elemental mercury as an indoor air pollutant. *Environ Sci Technol.* Nov 2001. 35; 21: 4170-4173.

CDC, 1995. Centers for Disease Control and Prevention. Mercury exposure in a residential community--Florida, 1994. Atlanta: U.S. Department of Health and Human Services. *MMWR.* Jun 1995. 44; 23: 436-437, 443.

CDC, 2001. Centers for Disease Control and Prevention. Blood and hair mercury levels in young children and women of childbearing age – US, 1999. Atlanta: U.S. Department of Health and Human Services *MMWR.* Mar 2001. 50; 8: 140-143.

CDC, 2005. Centers for Disease Control and Prevention. Measuring exposure to an elemental mercury spill--Dakota County, Minnesota, 2004. Atlanta: U.S. Department of Health and Human Services.

*MMWR.* Feb 2005. 54; 6: 146-149.

Cherry D, Lowry L, Velez L, Cotrell C, Keyes D. 2002. Elemental mercury poisoning in a family of seven. *Fam Community Health.* Jan 2002. 24; 4: 1-8

Cizdziel J and Jiang Y. 2011 Concentrations of gaseous elemental mercury in ambient air within an academic chemistry building. *Bull Environ Contam Toxicol.* Apr 2011. 86; 4: 419-422.

De Capitani EM, Souza EM, Vieira RJ, Madureira PR. 2009. Contact dermatitis to elemental mercury with distant lesion. *An Bras Dermatol.* Jan-Feb 2009. 84; 1: 75-77.

Ellis L, Mullins M, Galvin N, Scalzo A. 2009. Detection of elemental mercury in abdominal wall soft tissue. *J Med Toxicol.* Dec 2009. 5; 4: 205-208.

EPA. 1995. US Environmental Protection Agency. IRIS summary for elemental mercury. U.S. Environmental Protection Agency, Washington, DC. Available from: <http://www.epa.gov/iris/>. June 1995.

EPA. 2005. US Environmental Protection Agency. Ritualistic use of mercury simulation: a preliminary investigation of metallic mercury vapor fate and transport in a trailer. U.S. Environmental Protection Agency. Edison, NJ . January 2005. Available from <http://www.epa.gov/>.

EPA, 2010. US Environmental Protection Agency. Mercury in schools website. U.S. Environmental Protection Agency. Washington, DC. Available from: <http://www.epa.gov>.

EPA, 2011. US Environmental Protection Agency. National mercury cleanup policy workgroup charter. U.S. Environmental Protection Agency. Washington, DC [as transmitted via electronic mail (e-mail) by J. Kelly, EPA to R. Nickle, ATSDR on 03/04/2011 at 1:18 pm.]



EPA/FDA, 2004. US Environmental Protection Agency and the Food and Drug Administration. Advice for women who might become pregnant, women who are pregnant, nursing mothers, and young children. U.S. Environmental Protection Agency and U.S. Department of Health and Human Services, Washington, DC. EPA-823-R-04-00. Available from: <http://www.fda.gov>.

Fawer R, DeRibaupierre U, Guillemin M, Berode M, and Lobe, M. 1983. Measurement of hand tremor induced by industrial exposure to metallic mercury. *Br J Ind Med*. 40:204–208.

Franko A, Budihna MV, Dodic-Fikfak M 2005. Long-term effects of elemental mercury on renal function in miners of the Idrija Mercury Mine. *Ann Occup Hyg*. Aug 2005. 49; 6: 521-527.

Garetano G, Stern AH, Robson M, Gochfeld M. 2008 Mercury vapor in residential building common areas in communities where mercury is used for cultural purposes versus a reference community. *Sci Total Environ*. Jul 2008. 1; 397: 131-139.

Garetano G, Gochfeld M, Stern A. 2006 Comparison of indoor mercury vapor in common areas of residential buildings with outdoor levels in a community where mercury is used for cultural purposes. *Environ Health Perspect*. Jan 2006. 114; 1: 59-62.

Gochfeld M. 2003. Cases of mercury exposure, bioavailability, and absorption. *Ecotoxicol Environ Saf*. Sep 2003. 56; 1: 174-179.

Goldman L and Shannon M. 2001. Technical report: mercury in the environment: implications for pediatricians. *Pediatrics*. Jul 2001. 108; 1: 197-205.

Gordon A. 2004. Short-term elemental mercury exposures at 3 Arizona schools; public health lessons learned. *J T Clin Toxicol*. 42;2:179–187.

Grant C, Lalor G, Fletcher H, Potter T, Vutchkov M, Reid M. 2010. Elements in human placentae in Jamaica. *West Indian Med J*. Oct 2010. 59; 5: 479-485.

Hudson P, Vogt R, Brondum J, Witherell L, Myers G, Paschal D. 1987. Elemental mercury exposure among children of thermometer plant workers. *Pediatrics*. Jun 1987. 79; 6: 935-938.

Hryhorczuk D, Persky V, Piorkowski J, Davis J, Moomey C, Krantz A, Runkle K, Saxer T, Baughman T, McCann K. 2006. Residential mercury spills from gas regulators. *Environ Health Perspect*. Jun 2006. 114; 6: 848-852.

HSDB, 2005. Mercury. Hazardous Substance Databank. Toxicology Data Network. National Library of Medicine. National Institutes of Health. Bethesda, MD 2005.

Johnson C. 2003. Letter Report to EPA Region II. Mercury vapor levels in dwellings in close proximity to the World Trade Center Site.

Johnson C. 2004 Mercury in the environment: sources, toxicity, and prevention of exposure. *Pediatr Ann.* Jul 2004. 33; 7: 437-442.

Lee R, Middleton D, Caldwell K, Dearwent S, Jones S, Lewis B, Monteilh C, Mortensen ME, Nickle R, Orloff K, Reger M, Risher J, Rogers HS, Watters M. 2009. A review of events that expose children to elemental mercury in the United States. *Environ Health Perspect.* Jun 2009. 117; 6: 871-878.

Liu J, Cheney M, Wu F, Li M. 2011. Effects of chemical functional groups on elemental mercury adsorption on carbonaceous surfaces. *J Hazard Mater.* Feb. 2011. 186; 1: 108-113.

Lyman S, Gustin M. 2009. Determinants of atmospheric mercury concentrations in Reno, Nevada, U.S.A. *Sci Total Environ.* December 2009. 408; 2: 431-438.

MacLehose R, Pitt G, Will S, Jones A, Duane L, Flaherty S, Hannant D, Stuttard B, Silverwood A, Snee K, Murray V, Syed Q, House I, Bellis MA. 2001 Mercury contamination incident. *J Public Health Med.* March 2001 23; 1: 18-22.

Mercury in Schools, 2004 Webpage; supported by the University of Wisconsin at <http://www.mercuryinschools.uwex.edu/>.

Morgan D, Chanda S, Price M, Fernando R, Liu J, Brambila E, O'Connor R, Beliles R, Barone S. 2002. Disposition of inhaled mercury vapor in pregnant rats: maternal toxicity and effects on developmental outcomes. *Toxicol Sci.* April 2002. 66; 2: 261-273.

Ngim CH, Foo SC, Boey KW, et al. 1992. Chronic neurobehavioural effects of elemental mercury in dentists. *British Journal of Industrial Medicine.* 49;11:782-790.

Nickle R. 1999 Mercury: Top of the hit parade for eight years. *Drug Chem Toxicol.* February 1999. 22; 1: 129-142.

NIOSH, 2007. NIOSH Guide to Chemical Hazards. US Department of Health and Human Services. Centers for Disease Control and Prevention. National Institute for Occupational Safety and Health. Cincinnati, OH Sept. 2007. DHHS (NIOSH) Publication Number 2005-149. Available at <http://www.cdc.gov/niosh/npg/>.

Nold E, Adams G, Nickle R. 2011. Email between the authors re: levels of mercury in air associated with the presence of liquid mercury. Electronic mail string dated 7/5/2011 at 1103 am.

Opitz H, Schweinsberg F, Grossmann T, Wendt-Gallitelli M, Meyermann R 1996. Demonstration of mercury in the human brain and other organs 17 years after metallic mercury exposure. *Clin Neuropath.* May-June 1996. 15; 3: 139-144.

Orloff K, Ulirsch G, Wilder L, Block A, Fagliano J, Pasquale J 1997 Human exposure to elemental mercury in a contaminated residential building. *Arch Environ Health*. May-June 1997. 52; 3: 169-172.

Ratcliffe H, Swanson G, Fischer L 1996. Human exposure to mercury: a critical assessment of the evidence of adverse health effects. *J Toxicol Environ Health*. October 1996. 49; 3: 221-270.

Risher J, Nickle R, Amler S. 2003. Elemental mercury poisoning in occupational and residential settings. *Int J Hyg Environ Health*. August 2003. 206; 4-5: 371-379.

Risher J, De Rosa C. 2007. Inorganic: the other mercury. *J Environ Health*. Nov. 2007. 70; 4: 9-16.

Rogers HS, McCullough J, Kiesak S, Caldwell K, Jones RL, Rubin C. 2007 Exposure assessment of young children living in Chicago communities with historic reports of ritualistic use of mercury. *Clin Toxicol*. 45; 3: 240-247.

Rogers, HS, Jeffrey N, Kiesak S, Fritz P, Spliethoff H, Palmer C, Kass D, Caldwell K, Eadon G, Rubin C. 2008. Mercury exposure in young children living in New York City. *Journal of Urban Health*. Jan. 2008. 85;. 1: 39-51.

Samir A and Aref W. 2011. Impact of occupational exposure to elemental mercury on some antioxidative enzymes among dental staff. *Toxicol Ind Health*. March 2011. [Electronic Print ahead of Publication].

Singhvi R, Turpin R, Kalnicky D, and Patel J. 2001. Comparison of field and laboratory methods for monitoring metallic mercury vapor in indoor air. *J Hazard Materials* 83(1-2):1-10.

Singhvi R, Kalnicky D, Patel J, and Mehra Y. 2003. Comparison of Real-Time and Laboratory Analysis of Mercury Vapor in Indoor Air: Statistical Analysis Results. *Proceedings of the Pittsburg Conference*. 2003

Song X, Cheng J, Lu J. 2009. Annual atmospheric mercury species in downtown Toronto, Canada. *J Environ Monit*. March 2009. 11; 3: 660-669.

Taueg C, Sanfilippo D, Rowens B, Szeida J, Hesse JL: 1992. Acute and chronic poisoning from residential exposures to elemental mercury--Michigan, 1989-1990. *J Toxicol Clin Toxicol*. 1992 30; 1: 63-67.

Tominack R, Weber J, Blume C, Madhok M, Murphy T, Thompson M, Scalzo A. 2002. Elemental mercury as an attractive nuisance: multiple exposures from a pilfered school supply with severe consequences. *Pediatr Emerg Care*. April 2002. 18; 2: 97-100.

Tsuji J, Williams P, Edwards M, Allamneni K, Kelsh M, Paustenbach D, Sheehan P 2003.  
Evaluation of mercury in urine as an indicator of exposure to low levels of mercury vapor.  
*Environ Health Perspect.* April 2003. 111; 4: 623-630.

Winter T. 2003. The evaporation of a drop of mercury. *American Journal of Physics.* 71; 8: 783-786.

Yamamoto M, Charoenraks T, Pan-Hou H, Nakano A, Apilux A, Tabata M. 2007 Electrochemical behaviors of sulfhydryl compounds in the presence of elemental mercury. *Chemosphere.* Sep. 2007. 69; 4: 534-539.

# Appendix B

## Technical Documents

### EPA ERT

- ERT SOP for Clearance Sampling
- Modified NIOSH 6009
- Comparison of Real-Time and Laboratory Analysis of Mercury Vapor in Indoor Air: Statistical Analysis Results

### NIOSH

- NIOSH Method 6009

# **ERT SOP for Clearance Sampling**

## **DRAFT Indoor Mercury Spills – Area Clearance Procedure**

**11/13/2014**

1. Scope and Application
2. Technical Approach
3. Responsibilities
4. Interferences
5. Equipment / Apparatus
6. Prerequisites: Pre-Operational Checks
7. Post-Remediation Procedure
8. Calculations
9. Quality Assurance / Quality Control (QA/QC)
10. Data Validation
11. Health and Safety
12. References
13. Appendices
  - A - Hand-Held Mercury Vapor Analyzer Comparison Table
  - B - Mercury Spill Survey Testing Record
  - C - Mercury Spill Clearance Testing Record for SKC Hydrar Tube
  - D - Mercury Spill Clearance Testing Record for Direct-Reading Mercury Analyzer

## 1.0 Scope and Application

This Standard Operating Procedure (SOP) outlines indoor air testing procedures to provide adequate data for evaluation by the appropriate Health Department to determine if a residential or commercial building meets public health guidelines for occupancy following the release or spillage of elemental mercury.

The testing procedures described here may also be useful for determining mercury vapor indoor air levels in an occupational setting where mercury is released although the occupational environment is not the focus of this document. Release of mercury in an occupational situation will often warrant coordination with the appropriate OSHA regional office or an OSHA designated state agency. (OSHA testing procedures for mercury vapor can be found at <http://www.osha.gov/dts/sltc/methods/inorganic/id140/id140.html>).

## 2.0 Technical Approach

Two approaches are generally acceptable to obtain adequate data to determine if a residential building can remain occupied or be re-occupied.

2.1 **Sample Collection Approach.** Indoor air samples are collected on solid sorbent material (e.g., Hopcalite or Hydrar) contained in glass collection tubes connected to personal sampling pumps (according to NIOSH 6009). Pump flow rates are set to collect 0.15 to 0.25 L/min of air over a defined time period (typically 8 hours with 200 L air sampled)). The sorbent material from the collection tube (typically 200 mg in a single section) is digested in a mixture of concentrated nitric acid and concentrated hydrochloric acid. After preparation, the sample is analyzed by Cold Vapor Atomic Absorption (CVAA) techniques and results are reported in micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ).

2.2 **Direct Reading Analyzer Approach.** A direct-reading, portable mercury analyzer (with a detection limit of  $0.2 \mu\text{g}/\text{m}^3$  or lower) can be used to measure mercury vapor concentration in air. Results may be reported in units of nanograms of mercury per cubic meter of air ( $\text{ng}/\text{m}^3$ ) or  $\mu\text{g}/\text{m}^3$  ( $1000 \text{ ng}/\text{m}^3 = 1 \mu\text{g}/\text{m}^3$ ). The direct-reading mercury analyzer may be used to monitor mercury levels over a defined time period (typically 8 hours) to provide Time Weighted Average (TWA) values for use in determining if a building can be re-occupied by building occupants.

The following discussion outlines mercury vapor analyzers on the market. Note that the difference in detection limits among the instruments may impact their applicability for collecting the data needed for a re-occupancy determination.

2.2.1 Jerome 431, 431X, and J405: The Jerome 431, 431X, and J405 Hg vapor analyzers are based on gold film sensing technology. A thin gold film, in the presence of mercury vapor, undergoes an increase in electrical resistance proportional to the mass of mercury vapor in the sample. When the SAMPLE button is pressed, an internal pump draws ambient air through a scrubber filter and into the flow system. After 2 seconds, the sample solenoid bypass opens, closing off the scrubber filter from the flow system. The sample air passes through a gas filter that removes acidic gasses which interfere with the sensor's response to mercury. The sample air is drawn over the gold film sensor and the sensor adsorbs mercury vapor. Nine seconds after starting, the sample solenoid bypass closes, and the

remainder of the sample is drawn through the scrubber filter and flow system. The instrument determines the amount of mercury adsorbed and displays the measured concentration on the digital meter. The digital meter is automatically re-zeroed at the start of each sample cycle and the reading is frozen until the next sample cycle is activated, eliminating drift between samples.

The Jerome 431 and 431X units display results in milligrams per cubic meter ( $\text{mg}/\text{m}^3$ ) and provide detection limits of approximately  $1 \mu\text{g}/\text{m}^3$  ( $0.001 \text{ mg}/\text{m}^3$ ) with useful range of  $3 - 999 \mu\text{g}/\text{m}^3$  ( $0.003 - 0.999 \text{ mg}/\text{m}^3$ ). The Jerome J405 displays results in  $\mu\text{g}/\text{m}^3$  and provides a detection limit of  $0.5 \mu\text{g}/\text{m}^3$  with a useful range of  $0.5 - 999 \mu\text{g}/\text{m}^3$ . These detection limits may not be adequate for making re-occupancy decisions.

2.2.2 Jerome J505: The J505 uses atomic fluorescence spectroscopy (AFS) for mercury analysis. A mercury light source emits at 254nm into a sample cell. Mercury atoms present in the sample cell absorb light at 254nm and, then re-emit light at the same wavelength. A photo multiplier tube (PMT) is used to measure the light emitted at  $90^\circ$  to the source, which correlates to mercury concentration. Ambient air is drawn through the intake port by the pump at a nominal flow rate of one liter/minute. The sample air flow is controlled by a valve, and flows either through a scrubber filter and then into the sample cell or directly into the sample cell where it is exposed to 254 nm light. Any mercury present absorbs and then re-emits the light; the re-emission is measured by the PMT. The PMT response during scrubbed flow is subtracted from the response during sample flow. The result correlates to mercury vapor concentration, which is calculated and displayed. After analysis, the sample air is routed through the exhaust scrubber to absorb any mercury before the sample stream is discharged. The J505 reports results in  $\mu\text{g}/\text{m}^3$ . The detection limit is  $0.01 \mu\text{g}/\text{m}^3$  with a useful range of  $0.050 - 500 \mu\text{g}/\text{m}^3$ .

2.2.3 Nippon EMP-2: The NIC EMP-2 employs the ultraviolet (UV) Atomic Absorption Spectroscopy (AAS) method to determine mercury vapor concentration at a specific wavelength of 253.7 nm. Sample gas is drawn directly into the absorption cell and is exposed to radiation from the UV source. The decrease in signal at the detector is proportional to the amount of mercury vapor in the absorption cell, providing measurement of mercury concentration in real-time.

The NIC EMP-2 mercury survey meter reports results in  $\mu\text{g}/\text{m}^3$ . The detection limit is  $0.1 \mu\text{g}/\text{m}^3$  with a useful range of  $0.1 - 1000 \mu\text{g}/\text{m}^3$ .

2.2.4 Mercury Instruments VM3000 and Tracker 3000IP: The VM3000 and Tracker 3000IP instruments utilize the Cold Vapor Atomic Absorption Spectroscopy (CVAAS) technique. The mercury concentration is measured in an optical cell made of fused silica. A maintenance-free membrane pump continuously feeds the sample gas to the optical cell where light absorption measurement takes place at a wavelength of 253.7 nm. Radiation from a mercury lamp passes through the cell and is measured by a solid state detector. The attenuation of the UV light reaching the detector depends on the number of mercury atoms in the optical cell. The internal computer performs real-time quantification of mercury concentration in the sample. The high-frequency driven electrodeless mercury



discharge lamp (EDL) light source is controlled by a reference beam and reference detector device providing a stable baseline. Thermostatic control of the UV detector provides additional stability. To prevent temperature drift both the lamp unit and the detectors are temperature-stabilized. Because the optical cell is heated the unit is insensitive to water vapor.

The VM3000 and Tracker 3000IP units report results in  $\mu\text{g}/\text{m}^3$  with detection limit of  $0.1 \mu\text{g}/\text{m}^3$  and useful range of  $0.1 - 2000 \mu\text{g}/\text{m}^3$ .

- 2.2.5 Lumex RA 915 Light and RA-915+: The operating principle for the RA 915 Light and RA-915+ is based on the effect of differential Zeeman Atomic Absorption Spectrometry (AAS) combined with high frequency modulation of polarized light. The UV emission source (mercury lamp) is positioned in a permanent magnetic field. The resonance mercury line at 254 nm is split into three polarized Zeeman components:  $\pi$ ,  $\sigma^+$ , and  $\sigma^-$  respectively. When radiation is observed along the magnetic field lines, only the  $\sigma$  component radiation is registered. One  $\sigma$  component is within the mercury absorption line envelope and the other is outside it. In the absence of mercury vapor, the intensities of both  $\sigma$  components are equal. Mercury atoms cause a proportional, concentration-related difference in the intensity of the  $\sigma$  components. A polarization modulator is used to separate the  $\sigma$  components in time. Because the spectral shift of the  $\sigma$  components is significantly smaller than the width of molecular absorption bands and scattering spectra, the background absorption caused by interfering components generally does not affect the analyzer measurement. A multi-path cell with an effective length of 10 meters (m) is used for the RA-915+ (effective length of 3 meters for the RA 915 Light).

The Lumex RA-915+ reports results in  $\text{ng}/\text{m}^3$ . The detection limit for the Lumex RA-915+ is  $0.002 \mu\text{g}/\text{m}^3$  ( $2 \text{ ng}/\text{m}^3$ ) with a useful range of  $0.020 - 100 \mu\text{g}/\text{m}^3$  ( $20 - 100,000 \text{ ng}/\text{m}^3$ ). The Lumex RA 915 Light reports results in  $\mu\text{g}/\text{m}^3$ . The detection limit for the Lumex RA 915 Light is  $0.1 \mu\text{g}/\text{m}^3$  with a useful range of  $0.1 - 100 \mu\text{g}/\text{m}^3$ .

Appendix A contains a comparison table for hand-held Mercury Vapor Analyzers.

Based on detection limits and useful range, the Lumex Ra915+, Lumex RA915 Light, Jerome J505, Nippon EMP-2, Mercury Instruments VM3000, and Tracker 3000IP may be acceptable for making re-occupancy determinations.

### 3.0 Responsibilities

Only trained, qualified persons who thoroughly understand these procedures should take measurements and process results.

Prior to selecting a direct-reading mercury analyzer, check with the manufacturer for the latest models and detection limits to ensure that the unit selected will be acceptable for re-occupancy determinations.

## 4.0 Interferences

Direct Reading Instruments: Do not allow the direct-reading mercury analyzer to contact metallic mercury! Any direct contact of any part of the instrument with metallic mercury may result in high background noise for a prolonged period of time. Refer to the manufacturer's documentation for known interferences. There may be interferences from other contaminants not known to the manufacturer that might adversely affect mercury vapor measurement readings.

While taking measurements of mercury vapor concentrations in ambient air, observe basic safety regulations dealing with mercury and its compounds, mercury filled devices, and operating codes and safety regulations for electrical installations.

Sample Collection: Refer to NIOSH Method 6009 and SERAS SOP# 1827 for discussion of interferences in clearance sampling utilizing laboratory methods.

## 5.0 Equipment / Apparatus

### 5.1 Direct Reading Instrument

- 5.1.1 Ohio Lumex Model RA-915+ portable Mercury Vapor Analyzer or other equivalent direct-reading analyzer (must have a detection limit of 0.2  $\mu\text{g}/\text{m}^3$  or lower).
- 5.1.2 PC and Software for Lumex RA-915+ Control/Data Averaging or data logging capability with download of logged data for external data processing.

### 5.2 Sample Collection

- 5.2.1 Sampler: glass tube, 7 cm long, 6-mm OD, 4-mm ID, flame sealed ends with plastic caps, containing one section of 200 mg sorbent (typically, Hydrar) held in place by glass wool plugs (SKC, Inc., Cat. #226-17-1A, or equivalent).
- 5.2.2 Personal sampling pump, 0.15 to 0.25 L/min, with flexible connecting tubing.

### 5.3 Personal Protective Equipment (PPE)

Appropriate PPE should be used to protect the Lumex RA-915+ operator and personnel conducting sampling operations. Refer to the site-specific Health & Safety Plan for appropriate PPE.

## 6.0 Prerequisites: Pre-Operational Checks

The Lumex RA-915+ or other direct-reading mercury analyzer must have a current factory calibration with certificate or must be user calibrated according to the manufacturer's instructions. User calibrations must be documented.

Follow the operating procedures in SERAS SOP# 1729, *Operation of the Lumex RA-915+ Analyzer for Measuring Mercury Vapor Concentrations in Ambient Air*, when conducting pre-operational instrument checks and clearance testing for mercury vapor.

If using other direct-reading instruments, follow the manufacturer's instructions for pre-operational checks and instrument operation.

Follow guidelines in NIOSH 6009 and manufacturer's instructions for pre-operational checks, calibration, and operation of personal sampling pumps and for use of sampling tubes.

## 7.0 Post-Remediation Procedure

Mercury clearance testing may be started after appropriate cleanup (remediation) procedures have been performed by an authorized Contractor or Agency.

Measurements at the end of a clean-up day may indicate low to non-detectable air concentrations of mercury. However, despite the best clean-up efforts, elevated mercury vapor concentrations may be observed a day or two after remediation has been performed.

It is important to note that, during remediation sampling, all electronics should be in their normal operating mode (as when the room is occupied). For example, if there is a TV in a family room, the TV should be on during sampling.

Remediation activities are designed to remove most solid/liquid sources of metallic mercury. However, mercury vapor may become suspended in the air, especially if the room is warm. During the evening, the room typically cools, and mercury vapor may turn back into liquid and re-condense onto surfaces in different/additional locations. It then re-vaporizes when the air warms and is again detectable with air monitoring equipment. Also, if mercury beads are left behind in cracks/crevices, they may become covered with dust, which may suppress vapor formation. When the air and dust is disturbed during the next days' cleanup operations, the beads may give off vapor that is detectable with air monitoring equipment. Cleanup activities may need to be repeated. This rebound effect is normal and not an indication of an incomplete job the first time.

It is advisable to delay from several hours up to 1-2 days after the clean-up is complete before initiating clearance testing in order to verify the absence of a rebound effect. The exact time depends on site specific conditions such as the volume of mercury spilled and the size of the contaminated area. Professional judgment should be used.

The rebound effect vaporization/condensation cycle will continue as long as the vapor remains. As an alternative approach, a forced heating and venting process for 6-8 hours after liquid mercury is removed followed by approximately 8 hours of normal activity in the room, may be considered. For example, if the cleanup was finished at 3 PM, then forced heating/venting should occur until 9 - 11 PM and clearance sampling could begin around 8 AM the following day. This procedure will require less time in many circumstances and may be more effective in ensuring the room meets re-occupancy conditions.

Although not routinely performed, in some cases it may be warranted to consider a re-sampling event days to weeks after re-occupancy when the room(s) is not being used. There are obvious pros and cons to this approach but it may ensure that an effective cleanup was performed.

7.1 Visual Inspection and Mercury Source Location. Fill in the site and mercury vapor analyzer information on the Mercury Spill Survey Testing Record (MSSTR) form (Appendix B) prior to conducting the initial survey of the cleaned spill area. Inspect surfaces and crevices for visible droplets of mercury using a flashlight at a low angle to the surface (this

procedure can also be used during the initial investigation of a reported small spill). If droplets are present, advise the site manager that cleanup procedures need to be repeated.

If visible mercury is not observed, conduct a survey with the Lumex RA-915+ or other real-time mercury vapor analyzer (section 2.3) at a sampling height of 1-2 inches (2.5 – 5 cm) above the entire surface of the spill area. It may be appropriate to use a less sensitive instrument such as the Jerome 431 for an initial screening. Record location/readings on the MSSTR form. If mercury readings are consistently above  $1 \mu\text{g}/\text{m}^3$ , advise the site manager that cleanup procedures may need to be repeated. After **all visible mercury has been removed** and real-time readings are consistently below  $1 \mu\text{g}/\text{m}^3$ , initiate clearance sampling to measure very low levels of mercury.

- 7.2 Clearance Sampling Using Laboratory Methods. Clearance sampling is particularly important in the later stages of cleanup, where site responders are attempting to determine if building re-occupancy is appropriate based on public health guideline values for mercury vapor. Due to the time and resources required, it is best to conduct sampling when the responders are reasonably certain clearance values can be met. NIOSH Method 6009 can be used to measure mercury concentrations in air samples at levels down to  $0.1 \mu\text{g}/\text{m}^3$ .

Fill in the site and air sampling information (action level for clearance, date, and sampling locations) on the Mercury Spill Clearance Testing Record for SKC Hydrar Tube (MSCTR-HT) form (Appendix C).

Collect air samples (according to NIOSH 6009, typically eight hours) from the centers of rooms that are occupied a significant number of hours per day and consider doing so where field instrument readings indicate potential problem areas. In homes, samples should be collected from living and sleeping areas, with particular attention paid to those rooms occupied by the youngest residents of the home. Ideally, the following conditions should exist in order to obtain results offering a reasonable level of certainty that returning building occupants will not be exposed to mercury vapor concentrations above health-based guidelines:

1. Placement and operation of fans in the sampled areas for air circulation in the room as close to normal operation as possible. NOTE: If a fan is not normally in operation, then having one in operation during sampling may not be representative of actual exposures.
2. Temperature between 75 °F and 85 °F. NOTE: Sampling should be done at the normal room temperature if that is above 85 °F.
3. Sampling height generally at 2.5 ft (or representative height for occupant's common activities, e.g. potentially lower for very young children).
4. Constant activity over the sampling period to disturb areas that once contained liquid mercury - using a mechanical device, for example, a robotic vacuum. This agitation is to prevent oxidation of the liquid mercury surfaces, which inhibits vaporization. NOTE: The device used to disturb the mercury should be decontaminated or discarded with contaminated material after clearance sampling is completed. NOTE: Constant activity may not be needed if fans are operated during the sampling period.

- Typically, windows closed and air conditioner off as this approach likely represents the worst-case conditions for elevated mercury levels. If sampling occurs under other conditions, they should be noted on the clearance testing record form.

Ambient (background) air samples should be taken for comparative purposes. The ambient (background) samples are defined as areas of the home that are removed from circulating fans. It may also be advisable to take one or two outside samples depending on site conditions particularly if there is any potential for elevated exterior readings. Duplicate samples and blanks should be used to monitor the repeatability of the data and to check for sample contamination, respectively. Samples should be collected in common areas of multi-family dwellings (e.g., lobbies and common hallways).

Fill in the pump#, flow (L/min), time on, and time off for each sampling location on the MSCTR-HT form.

Submit samples to an accredited laboratory for mercury analysis according to NIOSH 6009. Record the mercury concentration ( $\mu\text{g}/\text{m}^3$ ) for each sampling location on the MSCTR-HT form. Provide a copy of the form to the site manager for use in determining re-occupancy status.

- 7.3 Clearance Sampling Using Portable Mercury Analyzers (MVAs). An alternate approach to the use of NIOSH Method 6009 is to monitor mercury vapor concentrations with the Lumex RA-915+. Mercury vapor concentration is monitored for a defined time period (typically 8 hours) and the average value for the time period is reported. Monitoring should be conducted in the same locations and using the same conditions (1-5) as noted above for Clearance Sampling. The Lumex RA-915+ incorporates external PC control to perform time averaging of mercury vapor results. This may also be accomplished using other direct-reading instruments (with a detection limit of  $0.2 \mu\text{g}/\text{m}^3$  or lower) that incorporate internal data logging combined with external data processing.

OPTIONAL: If continuous monitoring over the 8 hour period is not feasible due to a limited number of MVAs and/or large number of sampling areas, averaging discrete readings over the 8 hour time period (e.g., 1 reading per hour) may be considered. With this approach, 2 or 3 MVAs may be used for clearance of 10-15 areas in an 8 hour period; the standard procedure (continuous 8 hour monitoring) would require 15-20 MVAs to accomplish the same task. This optional approach may not be appropriate if the mercury vapor concentration has large fluctuations or changes rapidly over the 8 hour time period.

OPTIONAL: A second Mercury Vapor Analyzer (MVA) may be added as a Quality Assurance (QA) check. The second MVA should be co-located with the first unit to provide duplicate results for the location, which can be used to confirm that the first unit is operating properly.

NOTE: Battery power may not be sufficient to operate the Mercury Vapor Analyzers for 8 hours. In that case, an external power source is required.

Fill in the site and air sampling information (action level for clearance, date, location, time on, time off, total hours, and average mercury concentration) for each sampling location on the Mercury Spill Clearance Testing Record for Direct-Reading Mercury Analyzer

(MSCTR-DRMA) form (Appendix D). Provide a copy of the form to the site manager for use in determining re-occupancy status.

## 8.0 Calculations

Real-time, direct-reading instruments provide mercury vapor results in units of  $\text{ng}/\text{m}^3$  or  $\mu\text{g}/\text{m}^3$ . The conversion factor is  $1 \mu\text{g}/\text{m}^3 = 1000 \text{ng}/\text{m}^3$ . Additional calculations are not required. The Lumex RA-915+ (with PC control) calculates and reports the average value in  $\text{ng}/\text{m}^3$  for the time period monitored and additional calculations are not required. NIOSH 6009 results are reported in  $\mu\text{g}/\text{m}^3$  and additional calculations are not required.

For direct-reading instruments that provide data-logging (see Appendix A), the results are downloaded according to the manufacturer's instructions and then, imported into a spreadsheet where the time-averaged value is calculated.

OPTIONAL: A similar spreadsheet calculation may be used to determine the average value when multiple discrete readings from 1 or 2 MVAs have been taken over the 8 hour period.

## 9.0 Quality Assurance / Quality Control (QA/QC)

### Direct Reading MVA Instruments:

The following general QA/QC procedures apply for operation of the Lumex RA-915+ mercury analyzer (or equivalent):

1. All data must be documented on field data sheets or in site logbooks.
2. The instrument must be operated according to SERAS SOP# 1729 and/or the operating instructions supplied by the manufacturer, unless otherwise specified in the work plan. Instrument checkout activities must occur prior to operation and they must be documented.
3. Procedures must be used to ensure the accuracy and precision of mercury measurements in ambient air as specified by the manufacturer and all verification procedures must be documented.
4. Optional: Second co-located MVA to provide duplicate results. All QA/QC procedures noted above (1-3) apply to this unit.
5. Optional: Concurrent collection of NIOSH Method 6009 samples and direct reading MVA measurements. The NIOSH samples should be collected at a minimum of 5 - 10 percent of the sampling locations. Consider placing the NIOSH sampling instruments in locations where children spend considerable time and/or where initial readings were elevated.

### Sample Collection:

The QA/QC procedures outlined in NIOSH Method 6009 must be followed for clearance sampling utilizing laboratory methods.

## 10.0 Data Validation

### Direct Reading Instruments:

The analyst will ensure that the direct-reading MVA and clearance sampling equipment are operated in accordance with the manufacturer's instructions and/or the appropriate SOP, and that all operational checks have been completed and are within the specified criteria.

### Sample Collection:

Refer to SERAS SOP #1017 for Data Validation procedures applicable to samples collected/analyzed according to NIOSH method 6009.

## 11.0 Health and Safety

When cleaning up and handling mercury, follow the site-specific Health & Safety Plan prepared for the general health and safety practices of your organization.

For sample collection and analysis, refer to SERAS SOP #3013, SERAS Laboratory Safety Program.

The analyst should consult all appropriate material safety data sheets (MSDS) prior to running an analysis for the first time. If a MSDS is unavailable from the manufacturer of the material, consult other sources such as EPA, OSHA, NIOSH, etc.

## 12.0 References

National Institute for Occupational Safety and Health. 1996. NIOSH Manual of Analytical Methods. Method 6009. 4th ed. Suppl. Available at: <http://www.cdc.gov/niosh/docs/2003-154/>.

Ohio Lumex Co., Inc., 2001. Mercury Analyzer RA-915+ User's Manual.

Ohio Lumex Co., Inc., 2001. Analyzer RA-915+ User's Manual: Operation With a PC.

SERAS SOP# 1017, Data Validation Procedure for Routine Inorganic Analysis.

SERAS SOP# 1729, Operation of the Lumex RA-915+ Analyzer for Measuring Mercury Vapor Concentrations in Ambient Air.

SERAS SOP# 1827, Analysis of Mercury in Air Using Cold Vapor Atomic Absorption (CVAA) (Based on NIOSH Method 6009).

SERAS SOP #3013, SERAS Laboratory Safety Program.

## 13.0 Appendices

- A. Hand-Held Mercury Vapor Analyzer Comparison Table
- B. Mercury Spill Survey Testing Record
- C. Mercury Spill Clearance Testing Record for SKC Hydrar Tube
- D. Mercury Spill Clearance Testing Record for Direct-Reading Mercury Analyzer

APPENDIX A

Hand-Held Mercury Vapor Analyzer Comparison Table



Instrument	Jerome 431X	Jerome J405	Jerome J505	Jerome 431	Mercury / EMP-2	Mercury Vapor Monitor VM-3000	Mercury Tracker 3000 IP	Lumex RA 915 light	Lumex RA-915+
<b>Manufacturer</b>	Arizona Instrument LLC	Arizona Instrument LLC	Arizona Instrument LLC	Arizona Instrument LLC	Nippon Instruments Corporation, Japan	Mercury Instruments GmbH	Mercury Instruments GmbH	Lumex, Russia	Lumex, Russia
<b>Distributor</b>					Brandt Instruments, Inc., LA	ST2 Service Technologies, Inc., CO	ST2 Service Technologies, Inc., CO	Ohio Lumex Co., OH	Ohio Lumex Co., OH
<b>Units</b>	mg/m <sup>3</sup>	µg/m <sup>3</sup>	µg/m <sup>3</sup>	mg/m <sup>3</sup>	µg/m <sup>3</sup>	µg/m <sup>3</sup>	µg/m <sup>3</sup>	µg/m <sup>3</sup>	ng/m <sup>3</sup>
<b>Range</b>	0.003 to 0.999	0.5-999 (displayed) 0.5 - 5000 (recorded)	0.05 - 500	0.003 to 0.999	0.1 - 1000	1 to 100 1 to 1000 1 to 2000	0.1 to 100 0.1 to 1000 0.1 to 2000	0.1 to 100	20 to 20000 (multi-path cell) 500 to 200000 (single-path cell)
<b>Methodology</b>	Change in resistance of gold after mercury absorption	Change in resistance of gold after mercury absorption	Atomic Fluorescence Spectroscopy (AFS)	Change in resistance of gold after mercury absorption	Cold Vapor Atomic Absorption Spectroscopy (CVAAS)	Cold Vapor Atomic Absorption Spectroscopy (CVAAS)	Cold Vapor Atomic Absorption Spectroscopy (CVAAS)	Zeeman Atomic Absorption Spectrometry, High Frequency Modulation of Light Polarization	Zeeman Atomic Absorption Spectrometry, High Frequency Modulation of Light Polarization
<b>Accuracy (percent)</b>	+/- 5% @ 0.1 mg/m <sup>3</sup>	+/- 10% @ 1 µg/m <sup>3</sup>	+/- 10% @ 1 µg/m <sup>3</sup>	+/- 5% @ 0.1 mg/m <sup>3</sup>	+/- 5% @ 100 µg/m <sup>3</sup>	NA	NA	Info not available	+/-20%
<b>Detection Limit</b>	0.001	0.5	0.01	0.001	0.1	0.1	0.1	0.1	2
<b>Response Time</b>	12 sec (Sample Mode) 3 sec (Survey Mode)	7 sec (Sample Mode) 2 sec (Survey Mode)	28 sec (Standard Mode) 16 sec (Quick Mode) 1 sec (Search Mode)	12 sec (Sample Mode) 3 sec (Survey Mode)	1 sec manual: 5 min	1 second	1 - 16 sec (programmable)	10 - 255 sec (programmable)	1 - 255 sec (programmable)
<b>Wavelength</b>	Not applicable	Not applicable	254 nm	Not applicable	253.7 nm	253.7 nm	253.7 nm	254 nm	254 nm
<b>UV source</b>	Not applicable	Not applicable	Info not available	Not applicable	Low pressure Hg discharge lamp	Electrodeless Hg low pressure lamp	Electrodeless Hg low pressure lamp	Glow discharge mercury lamp	Glow discharge mercury lamp
<b>Stabilization</b>	Not applicable	Not applicable	Info not available	Not applicable	Reference beam	Reference beam & thermal	Reference beam & thermal		light polarization
<b>Optical cell</b>	Not applicable	Not applicable	Info not available	Not applicable	Info not available	Fused silica, 25 cm long	Fused silica, 25 cm long	Multi-path cell	Multi-path cell, 10 meter equivalent
<b>Heating of cell</b>	Not applicable	Not applicable	Info not available	Not applicable	Info not available	70°C	70°C	Info not available	Info not available
<b>Pump</b>	750 mL/min	750 mL/min	1 L/min	0.75 L/min	1.0 L/min	Membrane, 2 L/min	Membrane, 2 L/min	>15 L/min	>15 L/min
<b>Filter</b>	Yes	Yes	Info not available	Yes	Info not available	PTFE 1: 47-50 mm diameter	PTFE 1: 47-50 mm diameter	Yes	Yes
<b>Calibration Method</b>	Factory Calibrated.	Factory Calibrated.	Factory Calibrated.	Factory Calibrated.	Factory calibrated with standard gas, and this calibration value is stored in the microprocessor memory before shipping. Recalibrate at 6 month intervals.	Factory calibrated (using MC-3000 Mercury calibration). The operator can recall actual calibration factor and enter a new calibration	Factory calibrated (using MC-3000 Mercury calibration). The operator can recall actual calibration factor and enter a new calibration	Factory calibrated. Calibration parameters inaccessible to users.	Factory calibrated. Calibration parameters inaccessible to users.
<b>Interferences and Correction</b>	Chlorine, NO <sub>2</sub> , H <sub>2</sub> S, Mercaptans; interferences removed by internal filters.	Chlorine, NO <sub>2</sub> , H <sub>2</sub> S, most mercaptans; NOTE: the C/M filter removes these compounds. Special use filters available.	Chlorine, ammonia, humidity/ water vapor, gasoline	Chlorine, NO <sub>2</sub> , H <sub>2</sub> S, Mercaptans; interferences removed by internal filters.	Benzene, Acetone, Carbon Tetrachloride, SO <sub>2</sub> , NO, NO <sub>2</sub> , Aromatic Hydrocarbons, Water Vapor, Dust Automatic correction	Benzene, Acetone, Carbon Tetrachloride, SO <sub>2</sub> , NO, NO <sub>2</sub> , Aromatic Hydrocarbons, Dust	Benzene, Acetone, Carbon Tetrachloride, SO <sub>2</sub> , NO, NO <sub>2</sub> , Aromatic Hydrocarbons, Dust	Info not available	Info not available
<b>Power</b>	115 / 220 V	12V DC Power Adaptor	12V DC Power Adaptor	115 V or 230 V	100 / 240 V	110 / 240V	230 V/ 50/60 Hz or 110-120 V / 50/60 Hz optional	220 V, 50 Hz or 110V, 60 Hz, 20W	220 V, 50 Hz or 110V, 60 Hz, 20W
<b>Battery</b>	Internal Ni-Cd (6 hr capacity)	Internal Ni-Metal_Hydride (24 hr capacity)	Internal Ni-Metal_Hydride (24 hr capacity)	Internal Ni-Cd batteries (5-hr capacity)	Internal Lithium (5 hr capacity)	integrated 12 V batteries (6 h capacity)	Internal Ni-Metal-Hydride (6 hr capacity)	Built-in 6V, 6-12V DC (optional)	Built-in 6V, 6-12V DC (optional)
<b>Weight</b>	8 lbs (3.5 Kg)	5 lbs (2 Kg)	6.5 lbs (3 Kg)	7 lbs	4 lbs (1.8 Kg)	approx. 7 Kg	15.5 lbs (7 Kg)	7.5 Kg	7.5kg
<b>Dimensions (L x W x H)</b>	33 x 15 x 10 cm	28 x 16 x 16.5 cm	30.5 x 15.8 x 21.3 cm	33.8 x 15.6 x 10.0 cm	26.5 x 11 x 12.8 cm	45 x 15 x 35 cm	45 x 20 x 31 cm	46 x 21 x 11 cm	46 x 21 x 11 cm
<b>Communication Interface</b>	RS-232	USB	USB	RS-232	RS-232	RS-232	RS-232	RS-232	RS-232
<b>Data Logging Number of Readings</b>	External Box 1000	Internal 20000	Internal 10000	External Box 1000	Internal (SD card)	Internal 30000	Internal 15000	Info not available	External with PC Control

APPENDIX B

Mercury Spill Survey Testing Record

**Mercury Spill Survey Testing Record (MSSTR)**

Date: \_\_\_\_\_ Site: \_\_\_\_\_

Task Leader: \_\_\_\_\_ SERAS

Work Assignment Manager: \_\_\_\_\_ ERT/EPA

Analyst: \_\_\_\_\_

**Anticipated Contaminated Area Information:**

Building: \_\_\_\_\_ Room: \_\_\_\_\_ Dept: \_\_\_\_\_

Before/After Video (cross-reference): \_\_\_\_\_

Description of Spill and Surrounding Area:

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Photo of Spill and Surrounding Area (cross-reference): \_\_\_\_\_

**Mercury Vapor Analyzer Survey Information:**

Instrument: \_\_\_\_\_ Model: \_\_\_\_\_ Serial#: \_\_\_\_\_

Factory Calibration Date: \_\_\_\_\_ Pre Test: \_\_\_\_\_ Post Test: \_\_\_\_\_

TIME	Location	Mercury Reading ng/m <sup>3</sup> or µg/m <sup>3</sup>

**Comments & Recommendations**

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

APPENDIX C

Mercury Spill Clearance Testing Record for SKC Hydrar Tube



APPENDIX D

Mercury Spill Clearance Testing Record for Direct-Reading Mercury Analyzer



# Modified NIOSH Method 6009





# STANDARD OPERATING PROCEDURES

SOP: 1827  
PAGE: 1 of 16  
REV: 3.0  
DATE: 02/05/01

## ANALYSIS OF MERCURY IN AIR WITH A MODIFIED NIOSH 6009 METHOD

---

### CONTENTS

- 1.0 SCOPE AND APPLICATION
- 2.0 METHOD SUMMARY\*
- 3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE\*
- 4.0 INTERFERENCES AND POTENTIAL PROBLEMS\*
- 5.0 EQUIPMENT/APPARATUS
  - 5.1 Atomic Absorption Spectrophotometer
  - 5.2 Strip-Chart Recorder, Integrator, or Printer
  - 5.3 Glassware and Containers\*
- 6.0 REAGENTS
  - 6.1 Type I Water (ASTM D1193)
  - 6.2 Concentrated Nitric Acid (HNO<sub>3</sub>)
  - 6.3 Concentrated Hydrochloric Acid (HCl)
  - 6.4 Stock Mercury Solutions
  - 6.5 Stannous Chloride, 10% in 1:1 HCl
  - 6.6 Calibration Standards\*
- 7.0 PROCEDURES
  - 7.1 Sample Preparation\*
  - 7.2 Calibration Standards\*
  - 7.3 Laboratory Control Standard\*
  - 7.4 Calibration Verification Standards\*
  - 7.5 Method Detection Limit Standard\*
  - 7.6 Blank Spike/Blank Spike Duplicate\*
  - 7.7 Lot Blanks\*
  - 7.8 AA Calibration and Measurement
- 8.0 CALCULATIONS\*
- 9.0 QUALITY ASSURANCE/QUALITY CONTROL
  - 9.1 Initial Calibration/Calibration Check\*
  - 9.2 Method Detection Limit\*
  - 9.3 Continuing Calibration Verification\*
  - 9.4 BS/BSD Samples\*
  - 9.5 Dilution Analysis\*



# STANDARD OPERATING PROCEDURES

SOP: 1827  
PAGE: 2 of 16  
REV: 3.0  
DATE: 02/05/01

## ANALYSIS OF MERCURY IN AIR WITH A MODIFIED NIOSH 6009 METHOD

---

### CONTENTS (cont)

- 10.0 DATA VALIDATION\*
- 11.0 HEALTH AND SAFETY\*
- 12.0 REFERENCES
- 13.0 APPENDICES
  - A - NIOSH Method 6009\*

\*These sections affected by Revision 3.0

SUPERCEDES: SOP #1827; Revision 2.0; 05/13/99 EPA Contract EP-W-09-031.



# STANDARD OPERATING PROCEDURES

SOP: 1827  
PAGE: 3 of 16  
REV: 3.0  
DATE: 02/05/01

## ANALYSIS OF MERCURY IN AIR WITH A MODIFIED NIOSH 6009 METHOD

---

### 1.0 SCOPE AND APPLICATION

This method is a modification of NIOSH Method 6009 for mercury (Appendix A). It is applicable to the analysis of indoor air samples of volatilized elemental mercury (Hg) collected on solid sorbent material (typically Hopcalite) contained in glass collection tubes. The sorbent sample is digested and the Hg concentration is determined by the cold-vapor Atomic Absorption (AA) spectroscopy technique. The method is simple, rapid, and relatively free of matrix interferences.

Detection limits, sensitivity, and optimum ranges for Hg analysis will vary with the sorbent material, volume of air sampled, and models of atomic absorption spectrophotometers used.

These are standard operating procedures which may be varied or changed as required, depending upon site conditions, equipment limitations or limitations imposed by the procedure. In all instances, the ultimate procedures employed will be documented and associated with the final report.

Mention of trade names or commercial products does not constitute U.S. Environmental Protection Agency (U.S. EPA) endorsement or recommendation for use.

### 2.0 METHOD SUMMARY

Indoor air samples of elemental Hg are collected on solid sorbent material contained in glass tubes according to NIOSH method 6009. The sorbent material from the collection tube (typically 200 mg in a single section) is quantitatively transferred to a 100-milliliter (mL) volumetric flask. The sample is digested by first adding 2.5 mL of concentrated nitric acid followed by 2.5 mL of concentrated hydrochloric acid. After digestion is complete, the sample is diluted to volume with deionized water.

The sample is analyzed by the cold-vapor AA spectroscopy technique with no additional dilutions. The principle is essentially the same as direct aspiration AA, except a cold-vapor generator system, rather than a flame, is used to atomize the sample. Radiation from a given excited element is passed through the vapor containing ground-state atoms of that element. The intensity of the transmitted radiation decreases in proportion to the amount of the ground-state element in the vapor. A monochromator isolates the characteristic radiation from the hollow cathode lamp and a photosensitive device measures the attenuated transmitted radiation.

### 3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

Sample holding times, suggested collection volume, preservative, and type of containers are as follows:

Measurement	Volume Req. (L)	Collection Type of Containers	Holding Preservative	Time
<hr/>				
<u>Mercury in air:</u>				
Solid sorbent	10 - 200 <sup>(1)</sup>	glass tube	sorbent, 25° C	21 days

---

<sup>(1)</sup> The volume of air collected is directly related to detection limit; the larger the volume, the lower the detection limit.



# STANDARD OPERATING PROCEDURES

SOP: 1827  
PAGE: 4 of 16  
REV: 3.0  
DATE: 02/05/01

## ANALYSIS OF MERCURY IN AIR WITH A MODIFIED NIOSH 6009 METHOD

---

### 4.0 INTERFERENCES AND POTENTIAL PROBLEMS

Although the method minimizes dilution and sample matrix effects, the technique is not completely interference free. Inorganic and organic Hg compounds may cause a positive interference

Cross-contamination and contamination of the sample can be major sources of error because of the sensitivities achieved with the cold-vapor AA spectroscopy technique. The sample preparation work area should be kept scrupulously clean. All glassware should be cleaned as directed in Section 5.3.

### 5.0 EQUIPMENT/APPARATUS

#### 5.1 Atomic Absorption Spectrophotometer

A single- or dual-channel, single- or double-beam instrument having a grating monochromator, Hg hollow cathode lamp, photomultiplier detector, adjustable slits, a wavelength range of 190 to 800 nanometers (nm), and provisions for interfacing with a strip-chart recorder or computer, printer, autosampler, and Hg cold-vapor generation system.

#### 5.2 Strip-Chart Recorder, Integrator, or Printer

A recorder is useful to provide a permanent record and for easy recognition of any problems with the analysis.

#### 5.3 Glassware and Containers

All glassware, polypropylene, or Teflon containers, including sample bottles, should be washed in the following sequence: detergent, tap water, 1:1 nitric acid, tap water, 1:1 hydrochloric acid, tap water, and Type I water. If it can be documented through an active analytical quality control program, using spiked samples and reagent blanks that certain steps in the cleaning procedure are not required for routine samples, these steps may be eliminated from the procedure.

### 6.0 REAGENTS

All standard solutions are prepared and documented in accordance with ERT/SERAS SOP #1012, *Preparation of Standard Solutions*.

#### 6.1 Type I Water (ASTM D1193)

Use Type I water for the preparation of all reagents and calibration standards, and as dilution water.

#### 6.2 Concentrated Nitric Acid (HNO<sub>3</sub>)

Use commercially available high-purity, spectrograde acid certified for AA use.

#### 6.3 Concentrated Hydrochloric Acid (HCl)

Use commercially available high-purity, spectrograde acid certified for AA use.



# STANDARD OPERATING PROCEDURES

SOP: 1827  
PAGE: 5 of 16  
REV: 3.0  
DATE: 02/05/01

## ANALYSIS OF MERCURY IN AIR WITH A MODIFIED NIOSH 6009 METHOD

---

### 6.4 Stock Mercury Solutions

Use a commercially available Hg standard solution, accompanied by a certificate of analysis, or prepare a 1000 micrograms per milliliter ( $\mu\text{g/mL}$ ) stock standard solution from high purity mercuric oxide ( $\text{HgO}$ ) using Type I water and redistilled HCl. Dissolve 1.0798 grams (g) of dry  $\text{HgO}$  in 50 mL of 1:1 HCl, then dilute to one liter (1 L) with Type I water.

### 6.5 Stannous Chloride, 10% in 1:1 HCl

Dissolve 20 grams (g) reagent grade stannous chloride in 100 mL concentrated HCl. Slowly add this solution to 100 mL Type I water and mix well. Prepare fresh daily or each time calibration standards are prepared.

### 6.6 Calibration Standards

For those instruments that do not read out directly in concentration, a calibration curve is prepared to cover the appropriate concentration range. For best results, intermediate and working standards should be prepared fresh each time a batch of samples is analyzed. A blank and a minimum of five working standards must be used to calibrate the AA instrument.

Prepare all calibration and check standards using the procedures outlined in Section 7.0. Ideally, all QC standards are prepared by spiking blank sorbent media. This matches the sample matrix and, thereby, minimizes sample matrix effects. QC standards may also be prepared by spiking reagent blanks if sufficient blank sorbent media tubes are not available, or variability exists within media blanks.

## 7.0 PROCEDURES

### 7.1 Sample Preparation

1. Quantitatively transfer the sorbent and the front glass wool plug from each sampler tube into a 100-mL volumetric flask.
2. Add 2.5 mL of concentrated  $\text{HNO}_3$  followed by 2.5 mL concentrated HCl.

NOTE: The Hg must be in the oxidized state to avoid loss. For this reason, the nitric acid must be added first.

3. Allow the sample to stand for 1 hour or until the black sorbent is dissolved. The solution will turn dark brown and may contain undissolved material.
4. Carefully dilute to 100 mL with Type I water.
5. The final sample solution (blue to blue-green in color) contains 2.5 percent  $\text{HNO}_3$ , 2.5 percent HCl, and is analyzed for Hg with no additional dilution (except for samples containing high concentrations of Hg).

### 7.2 Calibration Standards



# STANDARD OPERATING PROCEDURES

SOP: 1827  
PAGE: 6 of 16  
REV: 3.0  
DATE: 02/05/01

## ANALYSIS OF MERCURY IN AIR WITH A MODIFIED NIOSH 6009 METHOD

---

Prepare a calibration blank, and a minimum of five working standards in graduated amounts in the linear part of the calibration range (0.2 to 10.0  $\mu\text{g/L}$ ) by spiking blank sorbent media (from unused sorbent tubes) with known amounts of Hg. Dissolve the blank sorbent media, using steps 1 - 3 of the procedure outlined in Section 7.1. Spike each standard solution with the appropriate amount of Hg, and dilute to volume per step 4 of the procedure outlined in Section 7.1.

NOTE: The calibration blank will also be used for the Initial Calibration Blank (ICB) and Continuing Calibration Blank (CCB) during sample analysis.

Calibration standards may also be prepared by spiking reagent blanks with known amounts of Hg to generate a calibration curve if sufficient blank sorbent media are not submitted, or variability exists within media blanks.

### 7.3 Laboratory Control Standard

Prepare the laboratory control standard (LCS) by spiking blank sorbent media (same lot and type of media) with a known amount of Hg (at or near midrange of the calibration curve). Use an independent source of Hg (different than that used to prepare calibration standards) for the LCS sample. Prepare the LCS sample using the procedure outlined in Section 7.1 at the same time the samples are prepared. A LCS will be analyzed with the frequency of one per batch.

If calibration standards are prepared by spiking reagent blanks, the LCS sample is also prepared by spiking a reagent blank with a known amount of Hg.

### 7.4 Calibration Verification Standards

Prepare the initial calibration verification (ICV) and the continuing calibration verification (CCV) standards by spiking blank sorbent media with known amounts of Hg (at or near midrange of the calibration curve). Prepare ICV and CCV standards using the procedure outlined in Section 7.1.

If calibration standards are prepared by spiking a reagent blank, the ICV and CCV standards are also prepared by spiking reagent blanks.

### 7.5 Method Detection Limit Standard

Prepare the method detection limit (MDL) standard by spiking blank sorbent media with a known amount of Hg at the expected MDL (typically half the concentration of the lowest calibration standard) using the same source used for calibration. Prepare the MDL standard using the procedure outlined in Section 7.1.

If the calibration standards are prepared by spiking the reagent blank, the MDL standard is also prepared by spiking a reagent blank.

### 7.6 Blank Spike/Blank Spike Duplicate

Prepare the media blank spike (BS) and blank spike duplicate (BSD) samples by spiking blank sorbent media with known amounts of Hg (5 to 10 times the detection limit) at a frequency of one in twenty samples or per batch. Spike blank sorbent media with appropriate amounts of Hg (near the midrange of the calibration) and prepare BS/BSD samples using the procedure outlined in Section 7.1. BS/BSD



# STANDARD OPERATING PROCEDURES

SOP: 1827  
PAGE: 7 of 16  
REV: 3.0  
DATE: 02/05/01

## ANALYSIS OF MERCURY IN AIR WITH A MODIFIED NIOSH 6009 METHOD

---

samples are prepared in the laboratory to monitor precision and accuracy of the method.

Use the BS/BSD samples delivered to the laboratory with unknown samples, or blank tubes from the same lot if none are provided with the samples.

### 7.7 Lot Blanks

This section applies only if calibration and QC standards are prepared in reagent blank. If this is the case, a minimum of three (3) lot blanks must be prepared and analyzed with the samples.

### 7.8 AA Calibration and Measurement

Differences between the various makes and models of satisfactory AA instruments and cold-vapor generators prevent the formulation of detailed instructions applicable to each system. The analyst should follow the manufacturer's operating instructions for a particular instrument and cold-vapor generator system.

Analyze the working standards together with the samples and blanks. Analyze the full set of working standards at the beginning of the run to establish the initial calibration curve. Analyze additional standards during sample analysis to confirm instrument response (see Section 9.0).

Samples with concentrations of Hg over the high standard must be diluted into the linear calibration range (see Section 9.5).

## 8.0 CALCULATIONS

For determination of concentration, read the Hg value (B) in  $\mu\text{g/L}$  from the calibration curve or directly from the read-out system of the instrument. Calculate the concentration of Hg in the sample (A) as follows:

$$A = \mu\text{g/L Hg sample} = 3 \times \frac{D + C}{D}$$

where:

- B = Concentration of Hg from the calibration curve ( $\mu\text{g/L}$ )
- C = Amount of acid blank matrix used for dilution (mL)
- D = Sample aliquot used for dilution (mL)

Note: If no dilution was required,  $C = 0$ , and  $A = B$ .

Calculate the amount of Hg (W) for each sorbent tube:

$$W = \mu\text{g/tube Hg} = A (0.1)$$

where:

- A = Concentration of Hg in the sample ( $\mu\text{g/L}$ )
- 0.1 = Final solution volume (L/tube)



# STANDARD OPERATING PROCEDURES

SOP: 1827  
PAGE: 8 of 16  
REV: 3.0  
DATE: 02/05/01

## ANALYSIS OF MERCURY IN AIR WITH A MODIFIED NIOSH 6009 METHOD

---

Calculate the concentration ( $\mu\text{g}/\text{m}^3$ ) of Hg in the air volume sampled:

$$\mu / \text{m}^3 \text{ Hg} = 000 \times \frac{W - 3\text{LK}}{V}$$

where:

- W = Amount of Hg in each sorbent tube ( $\mu\text{g}/\text{tube}$ )
- V = Volume of air sampled (L/tube)
- BLK = amount of Hg in the blank tube ( $\mu\text{g}/\text{tube}$ )
  - = zero (0) when standards are prepared by spiking blank sorbent media; or
  - = average of lot blank results when standards are prepared in reagent blanks (Section 7.7)

(For any blank value  $< \text{MDL}$ , substitute the value of 0.0 for the raw data prior to calculating the averages. The calculated average is subtracted from each sample even if this average is  $< \text{MDL}$ .)

NOTE: Report  $\mu\text{g}/\text{tube}$  results for lot blank, trip blank, field blank(s), and BS/BSD samples because no air volume is collected for these samples.

### 9.0 QUALITY ASSURANCE/QUALITY CONTROL

All quality control data should be documented and available for reference or inspection.

#### 9.1 Initial Calibration/Calibration Check

A calibration curve must be prepared each day as described in Section 7.2. The correlation coefficient ( $r$ ) must be greater than or equal to 0.995 for an acceptable calibration. The initial calibration must be verified by analysis of the ICV standard (Section 7.4), the ICB standard (Section 7.2), and the LCS sample (Section 7.3). The ICV result must be within  $\pm 10$  percent of the true value. Results for the ICB and method blank must be less than the MDL. The LCS result must be within the Performance Acceptance Limits (PALs) supplied by the vendor.

#### 9.2 Method Detection Limit

The MDL standard (Section 7.5) must be analyzed at the beginning of sample analysis to verify the Hg MDL. The results for the MDL standard must be within  $\pm 20$  percent of the true value. If the MDL standard is not within  $\pm 20$  percent, the MDL must be elevated to the concentration of the lowest calibration standard.

#### 9.3 Continuing Calibration Verification

The working standard curve must be verified by analyzing the CCV (Section 7.4) and the CCB standard after every 10 samples. CCV results must be within  $\pm 20$  percent of the true value and CCB results must be less than the MDL.

#### 9.4 BS/BSD Samples





# STANDARD OPERATING PROCEDURES

SOP: 1827  
PAGE: 9 of 16  
REV: 3.0  
DATE: 02/05/01

## ANALYSIS OF MERCURY IN AIR WITH A MODIFIED NIOSH 6009 METHOD

---

At least one BS and one BSD sample (Section 7.6) must be analyzed with each batch of samples (not to exceed 20 samples) to verify precision and accuracy of the method.

BS/BSD percent recovery (%R) should be within the advisory limit of 75-125 percent and calculated as:

$$\%R = \frac{SSR}{SA} \times 100$$

where:

SSR = Spiked (BS or BSD) sample result ( $\mu\text{g}/\text{tube}$ )  
SA = Spike added ( $\mu\text{g}/\text{tube}$ )

The Relative Percent Difference (RPD) for the BS/BSD samples should be within the advisory limit of  $\pm 20$  percent and calculated as:

$$RPD = \frac{S - D}{(S + D)/2} \times 100$$

where:

S = %R for BS sample result  
D = %R for BSD sample result

### 9.5 Dilution Analysis

If the Hg concentration of any sample exceeds the initial calibration range, that sample must be diluted and reanalyzed. Use the results of the original analysis to determine the approximate dilution factor required to get a Hg concentration within the initial linear calibration range. Dilute the sample (less than 10 mL sample required for analysis) and analyze the diluted sample aliquot. Report results for the diluted aliquot with the lowest dilution factor which produces a Hg concentration in the linear calibration range (see Section 8.0).

### 10.0 DATA VALIDATION

Data will be assessed by the Data Validation & Report Writing Group using the most current revision of the ERT/SERAS SOP #1017, Data Validation Procedure for Routine Inorganic Analysis. However, data is considered satisfactory for submission purposes when all of the requirements listed in the method are met.

### 11.0 HEALTH AND SAFETY

The toxicity or carcinogenicity of each reagent used in this method has not been precisely defined. However, each chemical compound should be treated as a potential health hazard. The laboratory is responsible for following the chemical hygiene plan and laboratory safety program regarding the safe handling of the chemicals specified in this method.

When working with potentially hazardous materials, refer to U.S. EPA, Occupational Safety and Health Administration (OSHA) and corporate health and safety practices. More specifically, refer to ERT/SERAS SOP



## STANDARD OPERATING PROCEDURES

SOP: 1827  
PAGE: 10 of 16  
REV: 3.0  
DATE: 02/05/01

### ANALYSIS OF MERCURY IN AIR WITH A MODIFIED NIOSH 6009 METHOD

---

#3013, *SERAS Laboratory Safety Program*.

The analyst should consult all appropriate MSDS information prior to running an analysis for the first time.

#### 12.0 REFERENCES

U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. 1992. *Test Methods for Evaluating Solid Waste*, SW-846. 3<sup>rd</sup> ed.

National Institute for Occupational Safety and Health. 1996. *NIOSH Manual of Analytical Methods*. Method 6009. 4<sup>th</sup> ed. Suppl.

U.S. EPA ERT/SERAS SOP #1818, *Determination of Metals by Atomic Absorption (AA) Methods*.



# STANDARD OPERATING PROCEDURES

SOP: 1827  
PAGE: 11 of 16  
REV: 3.0  
DATE: 02/05/01

## ANALYSIS OF MERCURY IN AIR WITH A MODIFIED NIOSH 6009 METHOD

---

APPENDIX A  
NIOSH Method 6009 for Mercury  
SOP #1827  
February 2001



# STANDARD OPERATING PROCEDURES

SOP: 1827  
 PAGE: 12 of 16  
 REV: 3.0  
 DATE: 02/05/01

## ANALYSIS OF MERCURY IN AIR WITH A MODIFIED NIOSH 6009 METHOD

### MERCURY

6009

Hg MW: 200.59 CAS: 7439-97-6 RTECS: OV4550000

METHOD: 6009, Issue 2 EVALUATION: PARTIAL Issue 1: 15 May 1989  
 Issue 2: 15 August 1994

OSHA : C 0.1 mg/m<sup>3</sup> (skin) PROPERTIES: liquid; d 13.55 g/mL @ 20 °C; BP 356 °C;  
 NIOSH: 0.05 mg/m<sup>3</sup> (skin) HP -39 °C; VP 0.16 Pa (0.0012mmHg);  
 ACGIH: 0.025 mg/m<sup>3</sup> (skin) 13.2 mg/m<sup>3</sup> @ 20 °C; Vapor Density  
 (air=1) 7.0

SYNONYMS: quicksilver

SAMPLING		MEASUREMENT	
<b>SAMPLER:</b>	SOLID SORBENT TUBE (Hopcalite in single section, 200 mg)	<b>TECHNIQUE:</b>	ATOMIC ABSORPTION, COLD VAPOR
<b>FLOW RATE:</b>	0.15 to 0.25 L/min	<b>ANALYTE:</b>	elemental mercury
<b>VOL-MIN:</b>	2 L @ 0.5 mg/m <sup>3</sup>	<b>DESORPTION:</b>	conc. HNO <sub>3</sub> /HCl @ 25 °C, dilute to 50 mL
<b>-MAX:</b>	100 L	<b>WAVELENGTH:</b>	253.7 nm
<b>SHIPMENT:</b>	routine	<b>CALIBRATION:</b>	standard solutions of Hg <sup>2+</sup> in 1% HNO <sub>3</sub>
<b>SAMPLE STABILITY:</b>	30 days @ 25 °C [1]	<b>RANGE:</b>	0.1 to 1.2 µg per sample
<b>FIELD BLANKS:</b>	2 to 10 field blanks per set	<b>ESTIMATED LOD:</b>	0.03 µg per sample
<b>MEDIA BLANKS:</b>	at least 3 per set	<b>PRECISION (S<sub>r</sub>):</b>	0.042 @ 0.9 to 3 µg per sample [4]
ACCURACY			
<b>RANGE STUDIED:</b>	0.002 to 0.8 mg/m <sup>3</sup> [2] (10-L samples)		
<b>BIAS:</b>	not significant		
<b>OVERALL PRECISION (S<sub>r</sub>):</b>	not determined		
<b>ACCURACY:</b>	not determined		

**APPLICABILITY:** The working range is 0.01 to 0.5 mg/m<sup>3</sup> for a 10-L air sample. The sorbent material irreversibly collects elemental mercury. A prefilter can be used to exclude particulate mercury species from the sample. The prefilter can be analyzed by similar methodology. The method has been used in numerous field surveys [3].

**INTERFERENCES:** Inorganic and organic mercury compounds may cause a positive interference. Oxidizing gases, including chlorine, do not interfere.

**OTHER METHODS:** This replaces method 6000 and its predecessors, which required a specialized desorption apparatus [4,5,6]. This method is based on the method of Rathje and Marcano [7] and is similar to the OSHA method ID 145H [2].



# STANDARD OPERATING PROCEDURES

SOP: 1827  
PAGE: 13 of 16  
REV: 3.0  
DATE: 02/05/01

## ANALYSIS OF MERCURY IN AIR WITH A MODIFIED NIOSH 6009 METHOD

MERCURY: METHOD 6009, Issue 2, dated 15 August 1994 - Page 2 of 5

### REAGENTS:

1. Water, organics-free, deionized.
2. Hydrochloric acid (HCl), conc.
3. Nitric acid (HNO<sub>3</sub>), conc.
4. Mercuric oxide, reagent grade, dry.
5. Calibration stock solution, Hg<sup>2+</sup>, 1000 µg/mL. Commercially available or dissolve 1.0798 g of dry mercuric oxide (HgO) in 50 mL of 1:1 hydrochloric acid, then dilute to 1 L with deionized water.
6. Intermediate mercury standard, 1 µg/mL. Place 0.1 mL 1000 µg/mL stock into a 100 mL volumetric containing 10 mL deionized water and 1 mL hydrochloric acid. Dilute to volume with deionized water. Prepare fresh daily.
7. Stannous chloride, reagent grade, 10% in 1:1 HCl. Dissolve 20 g stannous chloride in 100 mL conc. HCl. Slowly add this solution to 100 mL deionized water and mix well. Prepare fresh daily.
8. Nitric acid, 1% (w/v). Dilute 14 mL conc. HNO<sub>3</sub> to 1 L with deionized water.

### EQUIPMENT:

1. Sampler: glass tube, 7 cm long, 6-mm OD, 4-mm ID, flame sealed ends with plastic caps, containing one section of 200 mg Hopcalite held in place by glass wool plugs (SKC, Inc., Cat. #226-17-1A, or equivalent).  
NOTE: A 37-mm, cellulose ester membrane filter in a cassette preceding the sorbent may be used if particulate mercury is to be determined separately.
2. Personal sampling pump, 0.15 to 0.25 L/min, with flexible connecting tubing.
3. Atomic absorption spectrophotometer with cold vapor generation system (see Appendix) or cold vapor mercury analysis system.\*
4. Strip chart recorder, or integrator.
5. Flasks, volumetric, 50-mL, and 100-mL.
6. Pipet, 5-mL, 20-mL, others as needed.
7. Micropipet, 10- to 1000-µL.
8. Bottles, biological oxygen demand (BOD), 300-mL.

\* See SPECIAL PRECAUTIONS

**SPECIAL PRECAUTIONS:** Mercury is readily absorbed by inhalation and contact with the skin. Operate the mercury system in a hood, or bubble vented mercury through a mercury scrubber.

### SAMPLING:

1. Calibrate each personal sampling pump with a representative sampler in line.
2. Break ends of sampler immediately prior to sampling. Attach sampler to pump with flexible tubing.
3. Sample at an accurately known rate of 0.15 to 0.25 L/min for a total sample size between 2 and 100 L.  
NOTE: Include a minimum of three unopened sampling tubes from the same lot as the samples for use as media blanks.
4. Cap sampler and pack securely for shipment.

### SAMPLE PREPARATION:

5. Place the Hopcalite sorbent and the front glass wool plug from each sampler in separate 50-mL volumetric flasks.
6. Add 2.5 mL conc. HNO<sub>3</sub> followed by 2.5 mL conc. HCl.  
NOTE: The mercury must be in the oxidized state to avoid loss. For this reason, the nitric acid must be added first.
7. Allow the sample to stand for 1 h or until the black Hopcalite sorbent is dissolved. The solution will turn dark brown and may contain undissolved material.
8. Carefully dilute to 50 mL with deionized water. (Final solution is blue to blue-green).
9. Using a volumetric pipet, transfer 20 mL of the sample to a BOD bottle containing 80 mL of deionized water. If the amount of mercury in the sample is expected to exceed the standards, a smaller aliquot may be taken, and the volume of acid adjusted accordingly. The final volume in



# STANDARD OPERATING PROCEDURES

SOP: 1827  
PAGE: 14 of 16  
REV: 3.0  
DATE: 02/05/01

## ANALYSIS OF MERCURY IN AIR WITH A MODIFIED NIOSH 6009 METHOD

MERCURY: METHOD 6009, Issue 2, dated 15 August 1994 - Page 2 of 5

### REAGENTS:

1. Water, organics-free, deionized.
2. Hydrochloric acid (HCl), conc.
3. Nitric acid (HNO<sub>3</sub>), conc.
4. Mercuric oxide, reagent grade, dry.
5. Calibration stock solution, Hg<sup>2+</sup>, 1000 µg/mL. Commercially available or dissolve 1.0798 g of dry mercuric oxide (HgO) in 50 mL of 1:1 hydrochloric acid, then dilute to 1 L with deionized water.
6. Intermediate mercury standard, 1 µg/mL. Place 0.1 mL 1000 µg/mL stock into a 100 mL volumetric containing 10 mL deionized water and 1 mL hydrochloric acid. Dilute to volume with deionized water. Prepare fresh daily.
7. Stannous chloride, reagent grade, 10% in 1:1 HCl. Dissolve 20 g stannous chloride in 100 mL conc. HCl. Slowly add this solution to 100 mL deionized water and mix well. Prepare fresh daily.
8. Nitric acid, 1% (w/v). Dilute 14 mL conc. HNO<sub>3</sub> to 1 L with deionized water.

### EQUIPMENT:

1. Sampler: glass tube, 7 cm long, 6-mm OD, 4-mm ID, flame sealed ends with plastic caps, containing one section of 200 mg Hopcalite held in place by glass wool plugs (SKC, Inc., Cat. #226-17-1A, or equivalent).  
NOTE: A 37-mm, cellulose ester membrane filter in a cassette preceding the sorbent may be used if particulate mercury is to be determined separately.
2. Personal sampling pump, 0.15 to 0.25 L/min, with flexible connecting tubing.
3. Atomic absorption spectrophotometer with cold vapor generation system (see Appendix) or cold vapor mercury analysis system.\*
4. Strip chart recorder, or integrator.
5. Flasks, volumetric, 50-mL, and 100-mL.
6. Pipet, 5-mL, 20-mL, others as needed.
7. Micropipet, 10- to 1000-µL.
8. Bottles, biological oxygen demand (BOD), 300-mL.

\* See SPECIAL PRECAUTIONS

**SPECIAL PRECAUTIONS:** Mercury is readily absorbed by inhalation and contact with the skin. Operate the mercury system in a hood, or bubble vented mercury through a mercury scrubber.

### SAMPLING:

1. Calibrate each personal sampling pump with a representative sampler in line.
2. Break ends of sampler immediately prior to sampling. Attach sampler to pump with flexible tubing.
3. Sample at an accurately known rate of 0.15 to 0.25 L/min for a total sample size between 2 and 100 L.  
NOTE: Include a minimum of three unopened sampling tubes from the same lot as the samples for use as media blanks.
4. Cap sampler and pack securely for shipment.

### SAMPLE PREPARATION:

5. Place the Hopcalite sorbent and the front glass wool plug from each sampler in separate 50-mL volumetric flasks.
6. Add 2.5 mL conc. HNO<sub>3</sub> followed by 2.5 mL conc. HCl.  
NOTE: The mercury must be in the oxidized state to avoid loss. For this reason, the nitric acid must be added first.
7. Allow the sample to stand for 1 h or until the black Hopcalite sorbent is dissolved. The solution will turn dark brown and may contain undissolved material.
8. Carefully dilute to 50 mL with deionized water. (Final solution is blue to blue-green).
9. Using a volumetric pipet, transfer 20 mL of the sample to a BOD bottle containing 80 mL of deionized water. If the amount of mercury in the sample is expected to exceed the standards, a smaller aliquot may be taken, and the volume of acid adjusted accordingly. The final volume in



# STANDARD OPERATING PROCEDURES

SOP: 1827  
PAGE: 15 of 16  
REV: 3.0  
DATE: 02/05/01

## ANALYSIS OF MERCURY IN AIR WITH A MODIFIED NIOSH 6009 METHOD

MERCURY: METHOD 6009, Issue 2, dated 15 August 1994 - Page 4 of 5

### EVALUATION OF METHOD:

Rathje and Marcero originally used Hopcalite (MSA, Inc.) as the sorbent material [7]. Later, Hopcalite was shown superior to other methods for the determination of mercury vapor [8]. Atmospheres of mercury vapor for the study were dynamically generated in the range 0.05 to 0.2 mg/m<sup>3</sup> and an adsorbent tube loading of 1 to 7 µg was used. The Hydrar material sometimes used is similar to Hopcalite. No significant difference in the laboratory analysis of mercury collected on the two sorbent materials was observed [9]. OSHA also validated a method for mercury using Hydrar [2]. An average 99% recovery, with  $\bar{S}_r = 0.042$ , was seen for 18 samples with known amounts (0.9 to 3 µg) of mercury added (as Hg(NO<sub>3</sub>)<sub>2</sub>) [10]. No change in recovery was seen for samples stored up to 3 weeks at room temperature or up to 3 months at -15 °C; longer storage times were not investigated [10].

### REFERENCES:

- [1] Evaluation of Mercury Solid Sorbent Passive Dosimeter Backup Data Report. Inorganic Section, OSHA Analytical Laboratory, Salt Lake City, Utah, 1985.
- [2] Mercury in Workplace Atmospheres (Hydrar Tubes). Method ID 145H, Inorganic Section, OSHA Analytical Laboratory, Salt Lake City, UT, 1987.
- [3] NIOSH/MRSB. Reports for analytical Sequence Nos. 5854, 5900, 6219, and 6311, NIOSH (Unpublished, 1987-1988).
- [4] NIOSH Manual of Analytical Methods, 3rd. ed., Method 6000. (1984).
- [5] NIOSH Manual of Analytical Methods. 2nd. ed., V. 4, S199, U.S. Dept. of Health, Education, and Welfare Publ. (NIOSH) 79-141 (1979).
- [6] *Ibid.*, V. 5, P&CAM 175, Publ. (NIOSH) 79-141 (1979).
- [7] Rathje, A.O., Marcero, D.H. Improved hopcalite procedure for the determination of mercury in air by flameless atomic absorption, *Am. Ind. Hyg. Assoc. J.* **37**, 311-314 (1976).
- [8] McCammon, C.S., Edwards, S.L., Hull, R.D., Woodfin, W.J., A comparison of four personal sampling methods for the determination of mercury vapor, *Am. Ind. Hyg. Assoc. J.*, **41**, 528-531 (1980).
- [9] Internal Methods Development Research, DataChem Laboratories, Inc., Salt Lake City, UT (1982).
- [10] Eller, P.M., NIOSH, unpublished data (1987-88).

### METHOD WRITTEN BY:

Keith R. Nicholson and Michael R. Steele, DataChem Laboratories, Inc., Salt Lake City, Utah, under NIOSH contract No. 200-87-2533.

### APPENDIX: COLD VAPOR MERCURY ANALYSIS SYSTEM



## STANDARD OPERATING PROCEDURES

SOP: 1827  
PAGE: 16 of 16  
REV: 3.0  
DATE: 02/05/01

### ANALYSIS OF MERCURY IN AIR WITH A MODIFIED NIOSH 6009 METHOD

---

MERCURY: METHOD 6009, Issue 2, dated 15 August 1994 - Page 5 of 5

---

1. The valve should direct the vented vapors to a hood or to a mercury scrubber system.
2. When the valve is opened to "Vent" the peristaltic pump should draw room air. Place a Hopcalite tube in the air intake to eliminate any mercury that may be present.
3. Adjust the peristaltic pump to a flow that will create a steady stream of bubbles in the BOD bottle, but not so great that solution droplets enter the tubing to the quartz cell.
4. If water vapor condenses in the quartz cell, heat the cell slightly above room temperature by wrapping it with a heating coil and attaching a variable transformer.
5. The bubbler consists of a glass tube with a bulb at the bottom, slightly above the bottom of the BOD bottle. The bulb contains several perforations to allow air to escape into the solution (in a stream of small bubbles). A second tube is provided to allow the exit of the vapor. The open end of the second tube is well above the surface of the liquid in the bottle. The two tubes are fixed into a stoppering device (preferably ground glass) which fits into the top of the bottle. A coarse glass frit can be used in place of the bulb on the first tube. However, it is more difficult to prevent contamination when a frit is used.
6. Replace the flexible tubing (Tygon or equivalent) used to connect the bubbler, cell, and pump periodically to prevent contamination from adsorbed mercury.



# **Comparison of Real-Time and Laboratory Analysis of Mercury Vapor in Indoor Air: Statistical Analysis Results**

# Comparison of Real-Time and Laboratory Analysis of Mercury Vapor in Indoor Air: Statistical Analysis Results

Raj Singhvi

Environmental Response Team Center  
U. S. Environmental Protection Agency  
Edison, NJ 08837  
E-mail: singhvi.raj@epa.gov

D. Kalnicky, J. Patel, and Y. Mehra  
Response Engineering and Analytical Contract/Lockheed Martin, Inc.  
Edison, NJ 08837

## Abstract

Metallic mercury vapor levels in indoor air were measured under various conditions inside a van and a trailer using Lumex RA915<sup>+</sup> (Lumex) and Mercury Tracker 3000 (Tracker) real-time mercury analyzers and were confirmed by laboratory analysis using a modified National Institute for Occupational Safety and Health (NIOSH) 6009 method. Mercury monitoring data from several mercury spill sites around the United States were also used in this comparison study. Based on statistical analysis, Lumex and Tracker field analyzers provide real-time screening to assess initial extent of metallic mercury contamination, to identify “hot spots”, and to monitor progress of decontamination procedures at a spill site.

Statistical analysis showed that field and laboratory (NIOSH 6009) data for analyses of mercury in air samples were comparable for Lumex and Tracker Hg readings of about 0.03 and 0.1  $\mu\text{g}/\text{m}^3$  or greater, respectively, provided that the factory calibrations of the real-time analyzers were adjusted based on the mercury concentration measured from a standard mercury gas source in a laboratory environment. In order to meet final clean-up action levels (0.3-1.0  $\mu\text{g}/\text{m}^3$ ) for indoor mercury spills, time averaged Lumex and Tracker results may be used instead of the NIOSH method under certain circumstances, such as during emergency responses, depending on site requirements. Additional work is in progress to define the conditions when real-time metallic mercury vapor monitoring instruments, such as the Lumex or Tracker, may be used.

## 1 Introduction

The quality of indoor air and the resultant risk associated with accidental exposure to volatilized metallic mercury (Hg) is a major concern for building occupants. Indoor air monitoring programs that can provide high quality data with rapid turnaround of results are needed to effectively address these concerns. The field and laboratory analytical methods developed by the United States Environmental Protection Agency's Environmental Response Team (U.S. EPA/ERT), through its Response Engineering Analytical Contract (REAC), provide timely, cost-effective elemental Hg analysis while maintaining rigorous Quality Assurance/Quality Control (QA/QC) procedures to ensure reliability of the analytical data. Use of field analyzers provides real-time screening to assess the initial

extent of metallic mercury contamination, to identify “hot spots”, and to monitor progress of decontamination procedures at the spill site. For readings below field detection levels, the modified NIOSH 6009 method provides an effective way to measure low Hg vapor levels (Singhvi et al., 1999).

## **2 Analysis Methodology**

Real-time mercury vapor measurements were logged to data files at regular intervals (typically 2 to 15 seconds) while indoor air samples were collected for laboratory (NIOSH 6009) analysis. The Lumex was operated in software “MONITORING” mode during data logging using an external computer. The Tracker has built-in data logging capabilities and the data were downloaded after collection using an external computer. The real-time mercury analysis results were then averaged over the appropriate period (typically 2-, 4-, or 8-hours) that coincided with the indoor air sample collection time. All comparisons are based on time averaged data.

### **2.1 Real Time Monitoring**

**Lumex RA915<sup>+</sup>:** The Lumex is a portable atomic absorption spectrometer designed to detect extremely low mercury vapor concentrations and perform fast and simple analyses both at a fixed laboratory and in the field. Two modes of operation are available for ambient air analysis: “ON STREAM” and “MONITORING”. At a sample rate of 10-15 liters per minute (L/min), the Lumex can detect mercury vapor in ambient air at concentrations as low as two nano grams per cubic meter ( $\text{ng}/\text{m}^3$ ). The low mercury detection limit and the sensitivity of the instrument are achieved through a combination of 10-meter multi-path optical cells and Zeeman Atomic Absorption Spectrometry using High Frequency Modulation of polarized light. The Lumex is factory calibrated (from 1000 to 40,000  $\text{ng}/\text{m}^3$ ) and mercury vapor results are reported in  $\text{ng}/\text{m}^3$  (Ohio Lumex Co., 2000).

**Mercury Tracker 3000:** The Tracker is a portable instrument based on resonance absorption of mercury atoms at a wavelength of 253.7 nanometers (nm). The mercury sample is drawn through a 1 micron PTFE filter, at approximately 1.2 L/min, into the optical cell of the instrument by a membrane pump. Radiation from a mercury lamp passes through the cell and is measured by a solid state ultraviolet (UV) detector. The attenuation of the UV light reaching the detector depends on the number of mercury atoms in the optical cell. The internal computer performs the quantitative evaluation of the mercury concentration in the sample in real-time. The Tracker is factory calibrated (from 60 to 300  $\mu\text{g}/\text{m}^3$ ) and mercury vapor concentration is reported in micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ) (Mercury Instruments Analytical Technologies, 2000).

### **2.2 Laboratory Analysis (NIOSH 6009)**

**Indoor air Sampling:** Indoor air samples of volatilized elemental Hg are collected on solid sorbent material (typically Hopcalite<sup>TM</sup> or Hydrar<sup>TM</sup>) contained in glass tubes. Air is pumped through the sorbent with a personal sampling pump, which can be programmed for collection time and flow rate [typically 0.25 to 0.75 L/min]. Pump flow rate is initially calibrated against a rotometer reference and is measured again after sample collection. Sampling stations are typically set up in several locations within the structure.

Modified NIOSH 6009 Method: The sorbent material from the collection tube (typically 200 milligrams in a single section) is quantitatively transferred to a 100-milliliter (mL) volumetric flask. The sample is digested by first adding 2.5 mL of concentrated nitric acid followed by 2.5 mL of concentrated hydrochloric acid. After digestion, the sample is diluted to volume with deionized water and analyzed using the cold-vapor Atomic Absorption spectroscopy technique. Results are reported as  $\mu\text{g}/\text{m}^3$  based on the total air volume collected for the sample. Matrix effects are minimized by using sorbent material for preparation of blanks and calibration standards (U.S. EPA/ERTC, 2001). The modified NIOSH 6009 method incorporates more concentrated sample solutions than those of the standard method. This minimizes dilution effects while providing improved Hg detectability to meet the demanding action level requirements associated with emergency response situations.

### **3 Statistical Methods**

Several statistical analysis methods may be used for evaluating and comparing field and laboratory data (Gilbert, 1987 and Draper and Smith, 1981). A probability-value (p-value) is usually included in the output. Irrespective of the analysis being performed, the p-value is the lowest level at which the proposed hypothesis can be rejected. If the p-value is less than the given significance level (usually 0.05), the hypothesis can be rejected, otherwise, there is no statistical significance and the hypothesis cannot be rejected. Prior to performing any statistical evaluations, a test of distribution is performed on the data set to determine if parametric or non-parametric statistical methods should be utilized.

#### **3.1 Pairwise Comparisons**

Pairwise comparisons are useful for initial evaluation of field versus laboratory data sets. This is a hypothesis test, run at a significance level of 0.05, which determines if there are significant differences between two sets of paired data. During the test, one data set is subtracted from the other to get a third set of differences. A statistical analysis is performed to test the null hypothesis that the mean of the differences equals zero. If the data are not normally distributed, a test about the median as opposed to the mean is performed. In both cases, the p-value determines the significance of the analysis. If the p-value is less than the significance level, the null hypothesis is rejected and there is significant difference between the data sets. If the p-value is greater than the significance level, there is no significant difference between the data sets. This does not mean that the data sets are equal, but, rather, that they are not significantly different from each other. Even if pairwise comparisons analysis indicates that field and laboratory data sets are significantly different, it does not mean that a strong relationship cannot exist between them.

#### **3.2 Correlation Analysis**

Correlation analysis is related to regression analysis. It determines the degree of linearity between two sets of data and may be utilized prior to linear regression analysis. A correlation coefficient (R) is generated in the analysis which ranges in value from -1.0 (a perfect negative linear correlation) to 1.0 (a perfect positive linear relationship). A zero value indicates no linear relationship exists. If a strong linear relationship exists, linear

regression analysis should be used to evaluate the data sets. If a non-linear relationship exists, a non-linear regression analysis may be considered.

### **3.3 Linear Regression Analysis**

Regression analysis is used to fit a model between the independent variable (field data) and the dependant variable (laboratory data) to determine if a linear relationship exists and if that relationship is significant. Regression analysis yields the coefficient of determination (R-square), which defines the proportional amount of variability explained by the regression model. The R-square value ranges from 0.0, which means no variability to 1.0, which indicates that 100-percent of the variability is explained by the model. The regression also yields the F statistic, which determines if the model explains a significant amount of the variation in the data sets. A p-value may also be generated for the F statistic. If the p-value for the F statistic is less than the significance level (0.05), and the R-square value is high ( $> 0.7$ ), the regression model is significant.

The residuals of the regression model should be examined for potential outliers. The residuals are the differences between the predicted dependent values and the actual dependent values. A plot of residuals versus dependent values should be a random scattering of points. Anomalies or potential outliers are usually apparent. If any potential outliers are present, the regression analysis should be performed without these values to determine their impact upon the model. If the sample size for regression is small (less than 8 observations) removal of data points should be avoided, irrespective of their impact, because their removal greatly increases the error associated with the regression analysis.

## **4 Mercury Comparison Studies**

Real-time and laboratory analytical data collected from August 2001 through December 2002 were statistically evaluated to determine comparability of NIOSH vs. time averaged Lumex or Tracker mercury vapor readings. The Lumex and Tracker real-time mercury analyzers were factory calibrated. Lumex values ( $\text{ng}/\text{m}^3$ ) were converted to  $\mu\text{g}/\text{m}^3$  by dividing by 1000 prior to comparison with NIOSH values. Data for the following studies were evaluated:

- Lumex vs. NIOSH; 106 observations
- Lumex vs. NIOSH; NIOSH  $\leq 10 \mu\text{g}/\text{m}^3$ ; 100 observations
- Lumex vs. NIOSH; NIOSH  $\leq 1 \mu\text{g}/\text{m}^3$ ; 62 observations
- Tracker vs. NIOSH; 156 observations
- Tracker vs. NIOSH; NIOSH  $\leq 10 \mu\text{g}/\text{m}^3$ ; 125 observations
- Tracker vs. NIOSH; NIOSH  $\leq 1 \mu\text{g}/\text{m}^3$ ; 42 observations

### **4.1 Evaluation of Mercury Data**

All pairwise comparisons, correlation, and regression analysis evaluations were performed using the SAS<sup>TM</sup> (V 8.0) statistical analysis software package. Data plots were done using Corel Quattro Pro (V 8) and Corel Presentations (V 10). The SAS<sup>TM</sup> correlation analysis output includes two coefficients: the Pearson coefficient for normal (bell shaped) data distributions and the Spearman coefficient for non-normal distributions. The SAS<sup>TM</sup> regression output includes a Student Residual and Cook's D value for each

observation (Schlotzhauer and Little, 1987). The Student Residual is the residual divided by the standard error. The Cook's D value is a relative measure of data quality. If the Student Residual is between 2.0 and 3.0 in absolute value, the observation may be an outlier. If it is 3.0 or larger in absolute value, the observation is considered a probable outlier. When the Student Residual is larger than 2.0 in absolute value and Cook's D is outside the range of the data set, the observation may be considered a potential outlier and a new regression analysis should be performed without that observation.

#### **4.2 Statistical Analysis Results**

Figures 1 and 2 show laboratory (NIOSH) vs real-time (Lumex or Tracker) data. In general, pairwise comparisons analysis indicated that the data were not normally distributed and there was a significant difference between real-time and NIOSH data sets. The correlation coefficients indicated that the data were highly correlated and regression analysis was justified.

Regression analysis results for Lumex vs NIOSH data sets are presented in Table 1. Results without potential outliers showed that Lumex and NIOSH data were comparable. The slopes for the regressions showed that Lumex readings were low compared to laboratory analysis (about 1/2 the NIOSH value). The RMS error (0.011) and slope ( 1.975) for Lumex vs. NIOSH  $\leq 1$  indicated that corrected Lumex results of about  $0.022 \mu\text{g}/\text{m}^3$  or greater were comparable to laboratory analysis.

Regression analysis results for Tracker vs NIOSH data sets are presented in Table 2. Results without potential outliers showed that the data were highly comparable. The RMS error 0.054 for Tracker vs. NIOSH  $\leq 1$  indicated that Tracker results of about  $0.1 \mu\text{g}/\text{m}^3$  or greater were comparable to laboratory analysis results. The slopes for the regressions indicated that Tracker readings were in agreement with laboratory analysis.

### **5 Real-Time Analyzer Calibration Studies**

Statistical analysis showed a significant difference between NIOSH 6009 and real-time instrumentation results. In order to verify this difference, a Hg gas standard with a certified concentration of  $5.0 \mu\text{g}/\text{m}^3$  was obtained (Spectra Gases, Branchburg, NJ) and the Hg concentration was measured using real-time instrumentation as shown in Figure 3. The Hg gas from the cylinder was analyzed with the real-time analyzers to check/verify real-time readings. Time averaged readings were used to determine percent recovery of the standard gas concentration for the individual real-time mercury analyzer. A correction factor, based on percent recovery, was then used to calculate a new calibration factor for the analyzer. The new calibration factor was entered into the analyzer's memory to adjust real-time readings to agree with the Hg gas standard concentration ( $5 \mu\text{g}/\text{m}^3$ ). The Hg gas from the cylinder was also analyzed using the NIOSH method to check/verify the cylinder concentration. The NIOSH results (5.05 and 4.97) were in excellent agreement with the certified mercury concentration ( $5.0 \mu\text{g}/\text{m}^3$ ).

Two Tracker units (Tracker#1 and Tracker#2) and three Lumex units (Lumex#1, Lumex#2, and Lumex#3) were calibrated with the standard Hg gas. After calibration, real-time and laboratory analytical data collected during March 2003 were statistically evaluated to determine comparability of NIOSH vs. time averaged Lumex or Tracker mercury vapor

readings. Data for the following studies were evaluated:

- Tracker#1 vs. NIOSH; 33 observations
- Tracker#1 vs. NIOSH; NIOSH  $\leq 1 \mu\text{g}/\text{m}^3$ ; 25 observations
- Tracker#2 vs. NIOSH; 33 observations
- Tracker#2 vs. NIOSH; NIOSH  $\leq 1 \mu\text{g}/\text{m}^3$ ; 17 observations
- Lumex#1 vs. NIOSH; 15 observations
- Lumex#1 vs. NIOSH; NIOSH  $\leq 1 \mu\text{g}/\text{m}^3$ ; 6 observations
- Lumex#2 vs. NIOSH; 10 observations
- Lumex#2 vs. NIOSH; NIOSH  $\leq 1 \mu\text{g}/\text{m}^3$ ; 7 observations
- Lumex#3 vs. NIOSH; 4 observations

## 5.1 Statistical Analysis Results

Figures 4 - 7 show NIOSH vs calibrated real-time Hg analyzer (Lumex or Tracker) data. In general, pairwise comparisons analysis indicated that Tracker vs NIOSH data sets were not normally distributed and there was a significant difference between the data sets. Pairwise comparisons for Tracker#2 vs NIOSH, where the NIOSH value was less than or equal to  $1.0 \mu\text{g}/\text{m}^3$ , indicated that the data were not normally distributed and were not significantly different. The correlation coefficients indicated that the data were highly correlated and regression analysis was justified. Pairwise comparisons indicated that Lumex#1 or Lumex#2 vs NIOSH data were normally distributed and the data sets were significantly different. The correlation coefficients indicated that the data were highly correlated and regression analysis was justified. Pairwise comparisons and correlation analysis were not feasible for Lumex#3 vs NIOSH data due to the small sample size.

Regression analysis results without potential outliers (Table 3) showed that time averaged Hg analyzer and NIOSH data were highly comparable. The RMS errors (0.011 - 0.028) for Lumex Vs. NIOSH  $\leq 1$  indicated that Lumex results of about  $0.03 \mu\text{g}/\text{m}^3$  or greater were comparable to laboratory analysis results. The RMS errors (0.034- 0.042) for Tracker vs. NIOSH  $\leq 1$  indicated that Tracker results of about  $0.1 \mu\text{g}/\text{m}^3$  or greater were comparable to laboratory analysis. Regression results for small sample size ( $n < 7$ ) should be viewed as exploratory. The slopes for the regressions showed that readings for calibrated real-time Hg analyzers were in agreement with laboratory analysis.

## 6 Conclusions

Statistical analysis indicated that field (Lumex or Tracker) and laboratory (NIOSH 6009) data for analysis of mercury in air samples were comparable for Lumex and Tracker Hg readings of about  $0.03$  and  $0.1 \mu\text{g}/\text{m}^3$  or greater, respectively, provided that the factory calibrations of the real-time analyzers were adjusted based on the mercury concentration measured from a standard mercury gas source in a laboratory environment. Based on statistical analysis, Lumex and Tracker field analyzers provide real-time screening to assess initial extent of metallic mercury contamination, to identify "hot spots", and to monitor progress of decontamination procedures at a spill site. In order to meet final clean-up action levels ( $0.3$ - $1.0 \mu\text{g}/\text{m}^3$ ) for indoor mercury spills, time averaged Lumex and Tracker results may be used instead of the NIOSH method under certain circumstances, such as during emergency responses, depending on site requirements. Additional work is in progress to

define the conditions when real-time metallic mercury vapor monitoring instruments, such as the Lumex or Tracker, may be used.

## **7 Acknowledgments and Disclaimer**

The authors wish to thank Donna Getty of REAC for statistical analysis support, Charles Gasser of REAC for analytical support, and Miguel Trespalacios and Amy DuBois of REAC for field sampling support. The analytical methods described here were developed to meet U.S. EPA/ERT/REAC field and laboratory requirements for monitoring indoor metallic mercury vapor and may not be applicable to the activities of other organizations. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

## **8 References**

Draper, N., and H. Smith, *Applied Regression Analysis, 2nd Edition*, John Wiley & Sons, Inc., NY, 1981.

Gilbert, R. O., *Statistical Methods of Environmental Pollution Monitoring*, Van Nostrand Reinhold Co., NY, 1987.

Mercury Instruments Analytical Technologies, *Mercury Tracker 3000 Operating Manual*, March, 2000.

Ohio Lumex Co., Inc., *Lumex Multifunctional Mercury Analyzer RA-915+ Operation Manual*, 2000.

Schlotzhauer, S. D., and R. C. Little, *SAS System for Elementary Statistical Analysis*, SAS Institute Inc., Cary, North Carolina, 1987.

Singhvi, R., D. A. Johnson, J. Patel, and P. Solinski, "Analytical Method for Indoor Air Monitoring for Metallic Mercury Vapors", presented at *The 8<sup>th</sup> International Conference on Indoor Air Quality & Climate, Indoor Air 99*, Edinburgh, Scotland, August, 1999.

U.S. EPA/ERTC, Standard Operating Procedure #1827, *Analysis of Mercury in Air with a Modified NIOSH 6009 Method*, Rev. 3.0, Feb 5, 2001.



Table 1. Regression Analysis Results for Mercury Comparison Studies,  
NIOSH (dependent) vs. Lumex (independent)

Parameter	Lumex vs. NIOSH; All Data		Lumex vs. NIOSH; NIOSH $\leq$ 10		Lumex vs. NIOSH; NIOSH $\leq$ 1	
	All Data	Without Potential Outliers	All Data	Without Potential Outliers	All Data	Without Potential Outliers
n	106	101	100	91	62	55
R-square	0.9704	0.9898	0.9843	0.9958	0.9365	0.9530
slope	1.794	1.816	1.909	1.969	1.877	1.975
intercept	0.187	0.089	0.03	0.018	0.028	0.011
RMS error	0.73	0.28	0.25	0.12	0.069	0.032
F-value (p-value)	3408 (<0.0001)	9615 (<0.0001)	6159 (<0.0001)	21150 (<0.0001)	885 (<0.0001)	1074 (<0.0001)

Table 2. Regression Analysis Results for Mercury Comparison Studies,  
NIOSH (dependent) vs. Tracker (independent)

Parameter	Tracker vs. NIOSH; All Data		Tracker vs. NIOSH; NIOSH $\leq$ 10		Tracker vs. NIOSH; NIOSH $\leq$ 1	
	All Data	Without Potential Outliers	All Data	Without Potential Outliers	All Data	Without Potential Outliers
n	156	150	125	124	42	35
R-square	0.9687	0.9882	0.4416	0.9265	0.8527	0.9523
slope	1.19	1.183	0.456	1.149	1.098	1.076
intercept	-0.138	0.163	1.73	0.153	0.037	0.031
RMS error	5.29	1.57	1.98	0.71	0.1	0.054
F-value (p-value)	4767 (<0.0001)	12438 (<0.0001)	97 (<0.0001)	1539 (<0.0001)	231 (<0.0001)	659 (<0.0001)

Regression results based on factory calibration for Lumex and Tracker analyzers

n = number of observations

R-square ( $r^2$ ) = coefficient of determination for the regression model

RMS error = the standard error of the Y estimate for the regression model

Table 3. Regression Analysis Results for Real-Time Analyzer Calibration Studies, NIOSH (dependent) vs. Lumex or Tracker (independent)

Lumex vs. NIOSH					
Parameter	Lumex#1 All Data	Lumex#1 NIOSH $\leq$ 1	Lumex#2 All Data	Lumex#2 NIOSH $\leq$ 1	Lumex#3 All Data
n	15	6	9	7	4
R-square	0.9957	0.9982	0.9989	0.9501	0.9987
slope	1.24	1.254	0.9698	1.071	1.362
intercept	0.019	-0.015	-0.021	-0.068	-0.07
RMS error	0.101	0.011	0.028	0.028	0.018
F-value (p-value)	2981 (<0.0001)	2160 (<0.0001)	6109 (<0.0001)	95 (0.0002)	1545 (0.0006)

Tracker vs. NIOSH				
Parameter	Tracker#1 All Data	Tracker #1 NIOSH $\leq$ 1	Tracker#2 All Data	Tracker#2 NIOSH $\leq$ 1
n	32	23	33	14
R-square	0.9886	0.9594	0.9937	0.9802
slope	1.144	1.062	1.117	1.109
intercept	-0.034	0.008	-0.021	-0.021
RMS error	0.071	0.042	0.096	0.034
F-value (p-value)	2596 (<0.0001)	497 (<0.0001)	4866 (<0.0001)	595 (<0.0001)

Regression results excluding potential outliers based on laboratory calibration for Lumex and Tracker analyzers

n = number of observations

R-square ( $r^2$ ) = coefficient of determination for the regression model

RMS error = the standard error of the Y estimate for the regression model

## Lumex RA915+ Data

106 Observations

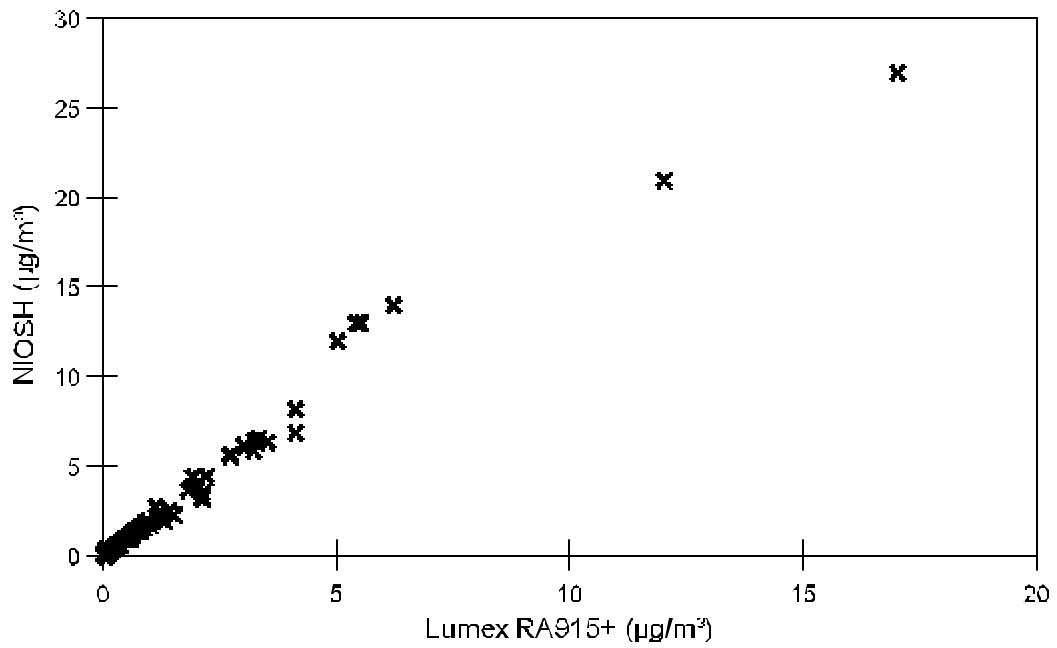


Figure 1. Laboratory (NIOSH 6009) and Field (Lumex RA915+) Mercury Results

## Tracker 3000 Data

156 Observations

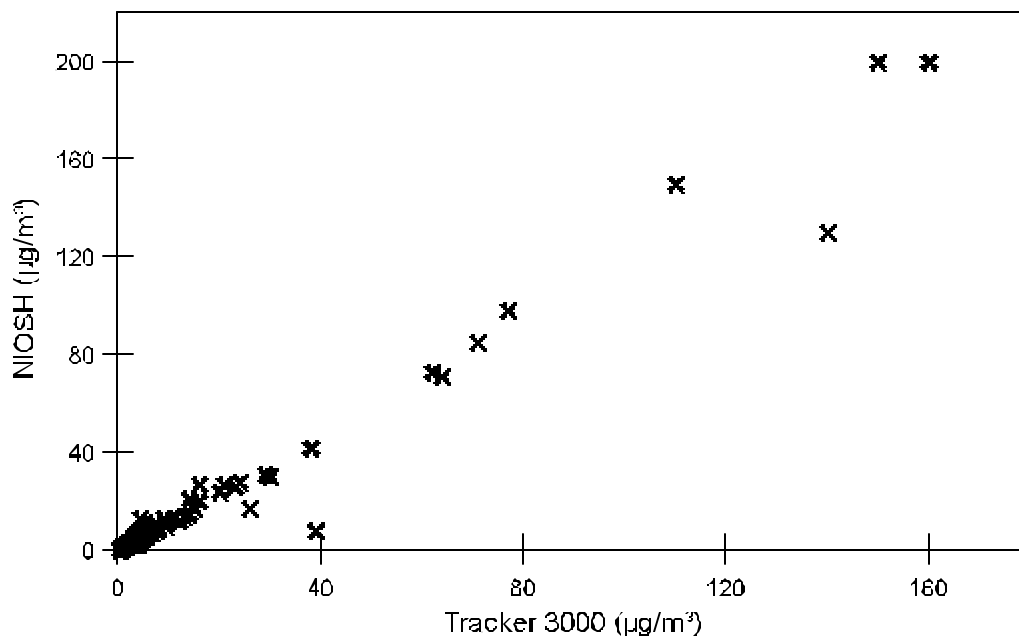


Figure 2. Laboratory (NIOSH) and Tracker 3000 Mercury Results

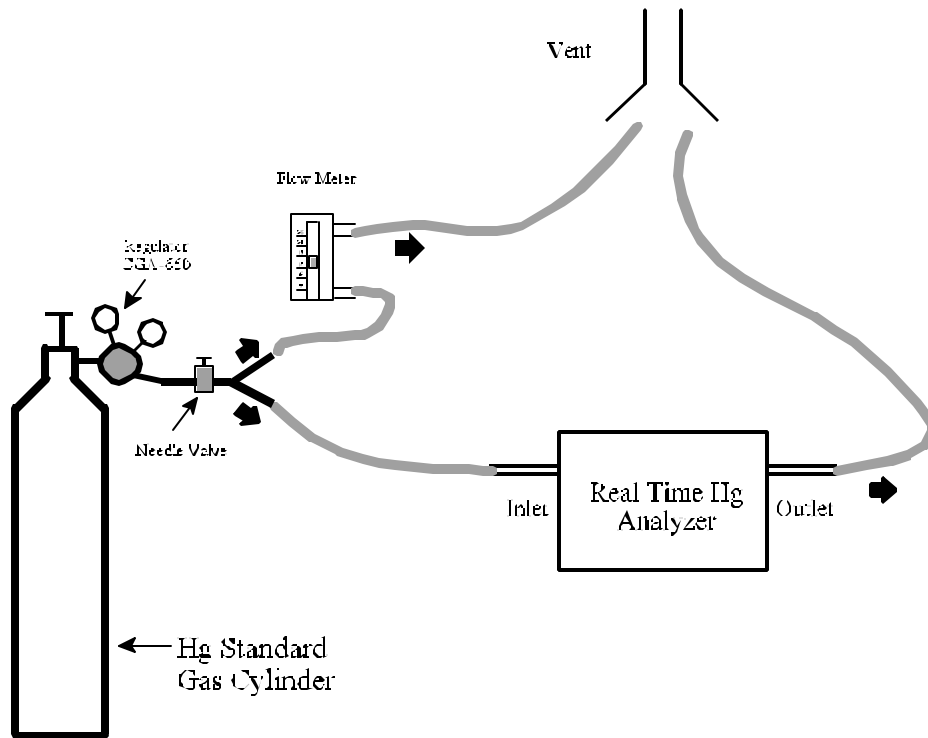


Figure 3. Setup for Calibrating Real-Time Mercury Analyzers

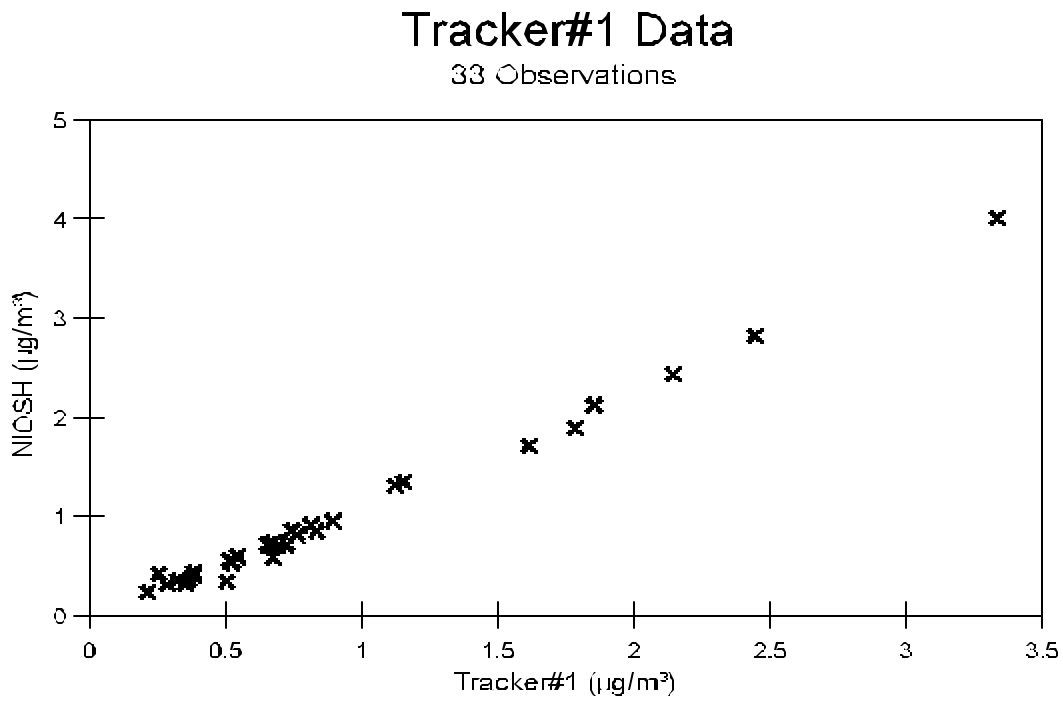


Figure 4. Laboratory and Tracker#1 (Calibrated) Mercury Results

## Tracker#2 Data

33 Observations

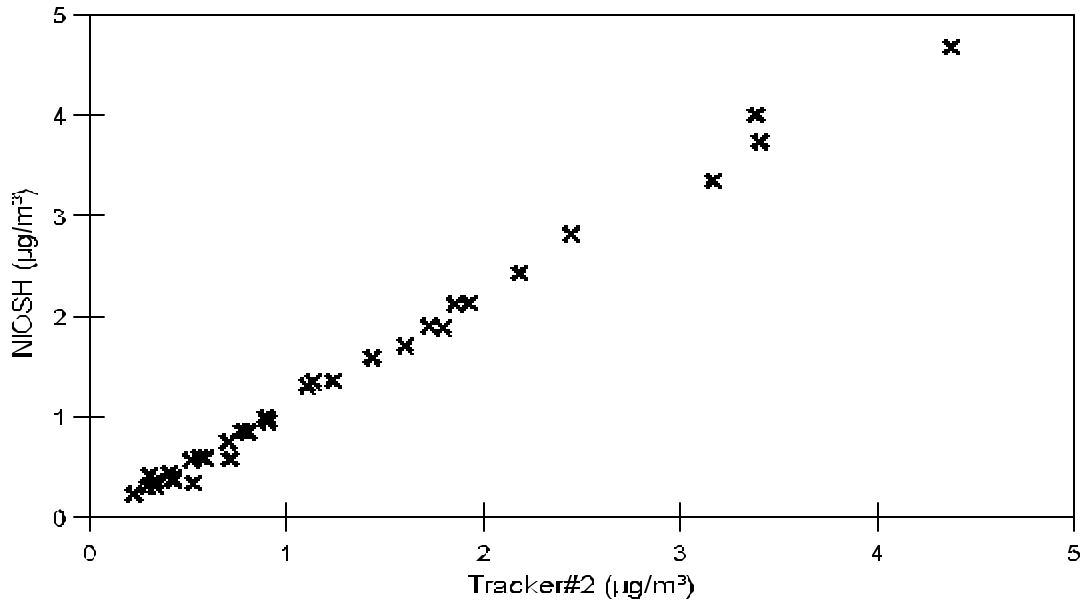


Figure 5. Laboratory and Tracker#2 (Calibrated) Mercury Results

## Lumex#1 Data

15 Observations

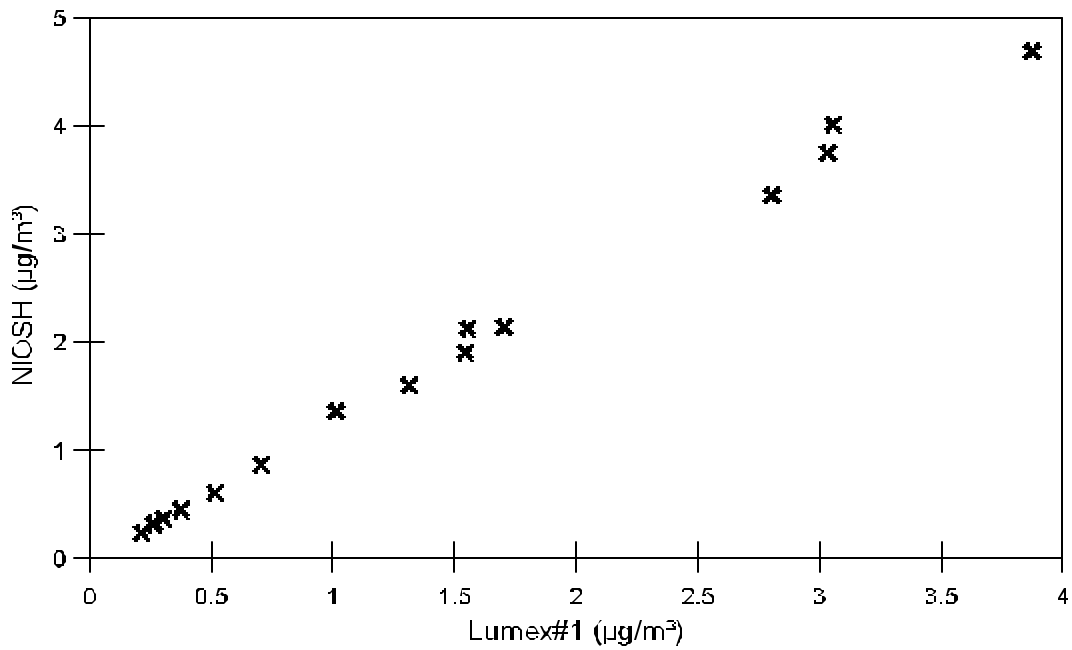


Figure 6. Laboratory and Lumex#1 (Calibrated) Mercury Results

# Lumex#2 Data

10 Observations

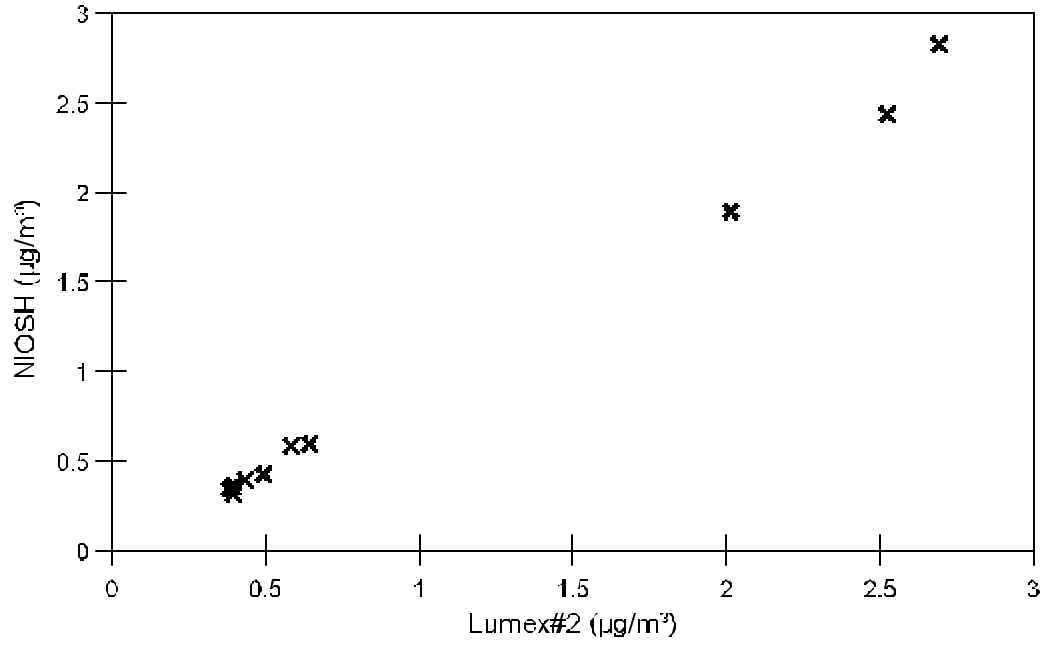


Figure 7. Laboratory and Lumex#2 (Calibrated) Mercury Results

# NIOSH Method 6009

# MERCURY

6009

Hg

MW: 200.59

CAS: 7439-97-6

RTECS: OV4550000

METHOD: 6009, Issue 2

EVALUATION: PARTIAL

Issue 1: 15 May 1989  
Issue 2: 15 August 1994

OSHA : C 0.1 mg/m<sup>3</sup> (skin)  
NIOSH: 0.05 mg/m<sup>3</sup> (skin)  
ACGIH: 0.025 mg/m<sup>3</sup> (skin)

PROPERTIES: liquid; d 13.55 g/mL @ 20 °C; BP 356 °C;  
HP -39 °C; VP 0.16 Pa (0.0012 mm Hg;  
13.2 mg/m<sup>3</sup>) @ 20 °C; Vapor Density  
(air=1) 7.0

SYNONYMS: quicksilver

SAMPLING		MEASUREMENT	
<b>SAMPLER:</b>	SOLID SORBENT TUBE (Hopcalite in single section, 200 mg)	<b>TECHNIQUE:</b>	ATOMIC ABSORPTION, COLD VAPOR
<b>FLOW RATE:</b>	0.15 to 0.25 L/min	<b>ANALYTE:</b>	elemental mercury
<b>VOL-MIN:</b>	2 L @ 0.5 mg/m <sup>3</sup>	<b>DESORPTION:</b>	conc. HNO <sub>3</sub> /HCl @ 25 °C, dilute to 50 mL
<b>-MAX:</b>	100 L	<b>WAVELENGTH:</b>	253.7 nm
<b>SHIPMENT:</b>	routine	<b>CALIBRATION:</b>	standard solutions of Hg <sup>2+</sup> in 1% HNO <sub>3</sub>
<b>SAMPLE STABILITY:</b>	30 days @ 25 °C [1]	<b>RANGE:</b>	0.1 to 1.2 µg per sample
<b>FIELD BLANKS:</b>	2 to 10 field blanks per set	<b>ESTIMATED LOD:</b>	0.03 µg per sample
<b>MEDIA BLANKS:</b>	at least 3 per set	<b>PRECISION (<math>\hat{S}_r</math>):</b>	0.042 @ 0.9 to 3 µg per sample [4]
ACCURACY			
<b>RANGE STUDIED:</b>	0.002 to 0.8 mg/m <sup>3</sup> [2] (10-L samples)		
<b>BIAS:</b>	not significant		
<b>OVERALL PRECISION (<math>\hat{S}_{rT}</math>):</b>	not determined		
<b>ACCURACY:</b>	not determined		

**APPLICABILITY:** The working range is 0.01 to 0.5 mg/m<sup>3</sup> for a 10-L air sample. The sorbent material irreversibly collects elemental mercury. A prefilter can be used to exclude particulate mercury species from the sample. The prefilter can be analyzed by similar methodology. The method has been used in numerous field surveys [3].

**INTERFERENCES:** Inorganic and organic mercury compounds may cause a positive interference. Oxidizing gases, including chlorine, do not interfere.

**OTHER METHODS:** This replaces method 6000 and its predecessors, which required a specialized desorption apparatus [4,5,6]. This method is based on the method of Rathje and Marcero [7] and is similar to the OSHA method ID 145H [2].



**REAGENTS:**

1. Water, organics-free, deionized.
2. Hydrochloric acid (HCl), conc.
3. Nitric acid (HNO<sub>3</sub>), conc.
4. Mercuric oxide, reagent grade, dry.
5. Calibration stock solution, Hg<sup>2+</sup>, 1000 µg/mL. Commercially available or dissolve 1.0798 g of dry mercuric oxide (HgO) in 50 mL of 1:1 hydrochloric acid, then dilute to 1 L with deionized water.
6. Intermediate mercury standard, 1 µg/mL. Place 0.1 mL 1000 µg/mL stock into a 100 mL volumetric containing 10 mL deionized water and 1 mL hydrochloric acid. Dilute to volume with deionized water. Prepare fresh daily.
7. Stannous chloride, reagent grade, 10% in 1:1 HCl. Dissolve 20 g stannous chloride in 100 mL conc. HCl. Slowly add this solution to 100 mL deionized water and mix well. Prepare fresh daily.
8. Nitric acid, 1% (w/v). Dilute 14 mL conc. HNO<sub>3</sub> to 1 L with deionized water.

**EQUIPMENT:**

1. Sampler: glass tube, 7 cm long, 6-mm OD, 4-mm ID, flame sealed ends with plastic caps, containing one section of 200 mg Hopcalite held in place by glass wool plugs (SKC, Inc., Cat. #226-17-1A, or equivalent).  
NOTE: A 37-mm, cellulose ester membrane filter in a cassette preceding the sorbent may be used if particulate mercury is to be determined separately.
2. Personal sampling pump, 0.15 to 0.25 L/min, with flexible connecting tubing.
3. Atomic absorption spectrophotometer with cold vapor generation system (see Appendix) or cold vapor mercury analysis system.\*
4. Strip chart recorder, or integrator.
5. Flasks, volumetric, 50-mL, and 100-mL.
6. Pipet, 5-mL, 20-mL, others as needed.
7. Micropipet, 10- to 1000-µL.
8. Bottles, biological oxygen demand (BOD), 300-mL.

\* See SPECIAL PRECAUTIONS

**SPECIAL PRECAUTIONS:** Mercury is readily absorbed by inhalation and contact with the skin. Operate the mercury system in a hood, or bubble vented mercury through a mercury scrubber.

**SAMPLING:**

1. Calibrate each personal sampling pump with a representative sampler in line.
2. Break ends of sampler immediately prior to sampling. Attach sampler to pump with flexible tubing.
3. Sample at an accurately known rate of 0.15 to 0.25 L/min for a total sample size between 2 and 100 L.  
NOTE: Include a minimum of three unopened sampling tubes from the same lot as the samples for use as media blanks.
4. Cap sampler and pack securely for shipment.

**SAMPLE PREPARATION:**

5. Place the Hopcalite sorbent and the front glass wool plug from each sampler in separate 50-mL volumetric flasks.
6. Add 2.5 mL conc. HNO<sub>3</sub> followed by 2.5 mL conc. HCl.  
NOTE: The mercury must be in the oxidized state to avoid loss. For this reason, the nitric acid must be added first.
7. Allow the sample to stand for 1 h or until the black Hopcalite sorbent is dissolved. The solution will turn dark brown and may contain undissolved material.
8. Carefully dilute to 50 mL with deionized water. (Final solution is blue to blue-green).
9. Using a volumetric pipet, transfer 20 mL of the sample to a BOD bottle containing 80 mL of deionized water. If the amount of mercury in the sample is expected to exceed the standards, a smaller aliquot may be taken, and the volume of acid adjusted accordingly. The final volume in

the BOD bottle must be 100 mL. To prevent possible loss of mercury during transfer, place the pipet tip below the surface of the liquid in the BOD bottle.

#### CALIBRATION AND QUALITY CONTROL:

10. Prepare a minimum of two series (six levels each) of working standards covering the range 0.01 to 0.5 µg Hg per aliquot by adding known amounts of the intermediate standard to BOD bottles containing enough 1% nitric acid to bring the final volume to 100 mL.
11. Analyze the working standards together with the samples and blanks (steps 13 through 16). Analyze full set of standards at the beginning of the run, and a second set at the end of the run. Additional standards may be run intermediately during the analysis to confirm instrument response.
12. Prepare calibration graph (peak height vs. solution concentration, µg/sample).

#### MEASUREMENT:

13. Zero the spectrophotometer by removing the bubbler from the BOD bottle, allowing the baseline on the recorder to stabilize.
14. Place the bubbler in a BOD bottle containing 0.5 µg mercury in 100 mL 1% nitric acid. Adjust the spectrophotometer so that it will give a 75% to full-scale deflection of the recorder.
15. Vent the mercury vapor from the system.
16. Analyze standards, samples and blanks (including media blanks).
  - a. Remove the bubbler from the BOD bottle.
  - b. Rinse the bubbler with deionized water.
  - c. Allow the recorder tracing to establish a stable baseline.
  - d. Remove the stopper from the BOD bottle containing the next sample to be analyzed. Gently swirl the BOD bottle.
  - e. Quickly add 5 mL 10% stannous chloride solution.
  - f. Quickly place the bubbler into the BOD bottle.
  - g. Allow the spectrophotometer to attain maximum absorbance.
  - h. Vent the mercury vapor from the system.
  - i. Place the bubbler into an empty BOD bottle. Continue venting the mercury until a stable baseline is obtained.
  - j. Close the mercury vent.

#### CALCULATIONS:

17. Calculate the amount of mercury in the sample aliquot ( $W$ , µg) from the calibration graph.
18. Calculate the concentration  $C$  (mg/m<sup>3</sup>), of mercury in the air volume sampled,  $V$  (L):

$$C = \frac{W \cdot \frac{V_s}{V_a} - B}{V}$$

Where:  $V_s$  = original sample volume (step 8; normally 50 mL)

$V_a$  = aliquot volume (step 9; normally 20 mL)

$B$  = average amount of mercury present in the media blanks

**EVALUATION OF METHOD:**

Rathje and Marcero originally used Hopcalite (MSA, Inc.) as the sorbent material [7]. Later, Hopcalite was shown superior to other methods for the determination of mercury vapor [8]. Atmospheres of mercury vapor for the study were dynamically generated in the range 0.05 to 0.2 mg/m<sup>3</sup> and an adsorbent tube loading of 1 to 7 µg was used. The Hydrar material sometimes used is similar to Hopcalite. No significant difference in the laboratory analysis of mercury collected on the two sorbent materials was observed [9]. OSHA also validated a method for mercury using Hydrar [2]. An average 99% recovery, with  $\bar{S}_r = 0.042$ , was seen for 18 samples with known amounts (0.9 to 3 µg) of mercury added (as Hg(NO<sub>3</sub>)<sub>2</sub>) [10]. No change in recovery was seen for samples stored up to 3 weeks at room temperature or up to 3 months at -15 °C; longer storage times were not investigated [10].

**REFERENCES:**

- [1] Evaluation of Mercury Solid Sorbent Passive Dosimeter, Backup Data Report. Inorganic Section, OSHA Analytical Laboratory, Salt Lake City, Utah, 1985.
- [2] Mercury in Workplace Atmospheres (Hydrar Tubes). Method ID 145H, Inorganic Section, OSHA Analytical Laboratory, Salt Lake City, UT, 1987.
- [3] NIOSH/MRSB. Reports for analytical Sequence Nos. 5854, 5900, 6219, and 6311, NIOSH (Unpublished, 1987-1988).
- [4] NIOSH Manual of Analytical Methods, 3rd. ed., Method 6000. (1984).
- [5] NIOSH Manual of Analytical Methods. 2nd. ed., V. 4, S199, U.S. Dept. of Health, Education, and Welfare Publ. (NIOSH) 79-141 (1979).
- [6] Ibid., V. 5, P&CAM 175, Publ. (NIOSH) 79-141 (1979).
- [7] Rathje, A.O., Marcero, D.H. Improved hopcalite procedure for the determination of mercury in air by flameless atomic absorption, *Am. Ind. Hyg. Assoc. J.* **37**, 311-314 (1976).
- [8] McCammon, C.S., Edwards, S.L., Hull, R.D., Woodfin, W.J., A comparison of four personal sampling methods for the determination of mercury vapor, *Am. Ind. Hyg. Assoc. J.*, **41**, 528-531 (1980).
- [9] Internal Methods Development Research, DataChem Laboratories, Inc., Salt Lake City, UT (1982).
- [10] Eller, P.M., NIOSH, unpublished data (1987-88).

**METHOD WRITTEN BY:**

Keith R. Nicholson and Michael R. Steele, DataChem Laboratories, Inc., Salt Lake City, Utah, under NIOSH contract No. 200-87-2533.

**APPENDIX: COLD VAPOR MERCURY ANALYSIS SYSTEM**

1. The valve should direct the vented vapors to a hood or to a mercury scrubber system.
2. When the valve is opened to "Vent" the peristaltic pump should draw room air. Place a Hopcalite tube in the air intake to eliminate any mercury that may be present.
3. Adjust the peristaltic pump to a flow that will create a steady stream of bubbles in the BOD bottle, but not so great that solution droplets enter the tubing to the quartz cell.
4. If water vapor condenses in the quartz cell, heat the cell slightly above room temperature by wrapping it with a heating coil and attaching a variable transformer.
5. The bubbler consists of a glass tube with a bulb at the bottom, slightly above the bottom of the BOD bottle. The bulb contains several perforations to allow air to escape into the solution (in a stream of small bubbles). A second tube is provided to allow the exit of the vapor. The open end of the second tube is well above the surface of the liquid in the bottle. The two tubes are fixed into a stoppering device (preferably ground glass) which fits into the top of the bottle. A coarse glass frit can be used in place of the bulb on the first tube. However, it is more difficult to prevent contamination when a frit is used.
6. Replace the flexible tubing (Tygon or equivalent) used to connect the bubbler, cell, and pump periodically to prevent contamination from adsorbed mercury.

# Appendix C

## Templates and Reference Documents

The attached forms are examples from EPA's ten Regions that can be used to help ensure all key actions are taken in a residential mercury response. In most cases, formal documentation between local/State jurisdictions and EPA is not necessary; however, in multi-residential responses or large/complex responses, formal documentation is encouraged. All forms can be modified for Regional use. The check-lists should be used as a best-practice.

### 1. Action Levels for Evacuation of Work Zone Pending Reassessment of Conditions

HEALTH AND SAFETY MONITORING						
Instrument	Task Number	Contaminant(s)	Monitoring Location	Monitoring Frequency	Action Levels	
PID (e.g., MultiRAE, TVA-1000B) FID (e.g., TVA-1000B)					<b>Unknown Vapors</b> Background to 1 ppm: Level D 1 to 5 ppm above background: Level C 5 to 500 ppm above background: Level B >500 ppm above background: Level A	<b>Contaminant-Specific</b>
Oxygen Meter/Explosimeter (e.g., MultiRAE, MultiWarn)					<b>Oxygen</b> <19.5% or >25.0%: Evacuate area; eliminate ignition sources; reassess conditions. 19.5 to 25.0%: Continue work in accordance with action levels  for other instruments.	<b>Explosivity</b> <10% LEL: Continue work in accordance with action levels for other instruments; monitor continuously for combustible atmospheres. >10% LEL: Evacuate area; eliminate ignition sources; reassess conditions.
Radiation Alert Monitor (Rad-mini or RAM-4)					<0.1 mR/hr: Continue work in accordance with action levels for other instruments. >0.1 mR/hr: Evacuate area; reassess work plan and contact radiation safety specialist.	
Mini-Ram Particulate Monitor					<b>General/Unknown</b> Evaluate health and safety measures when dust levels exceed 2.5 milligrams per cubic meter.	<b>Contaminant-Specific</b>
Draeger Colorimetric Tubes					<b>Tube Action Level Action</b>	

**HEALTH AND SAFETY MONITORING**

<b>Instrument</b>	<b>Task Number</b>	<b>Contaminant(s)</b>	<b>Monitoring Location</b>	<b>Monitoring Frequency</b>	<b>Action Levels</b>
					<b>Action Level Action</b>
Air Monitor/Sampler Type: _____ Sampling medium:					
Micro R Meter (Ludlum 192,)					<2 mR/hr: Continue work in accordance with action levels for other instruments. 2 to 5 mR/hr: In conjunction with a radiation safety specialist, continue work and perform stay-time calculations to ensure compliance with dose limits and ALARA policy. >5 mR/hr: Evacuate area to reassess work plan and evaluate options to maintain personnel exposures ALARA and within dose limits.
Ion Chamber (Ludlum 2241)					See micro R meter action levels above.
Radiation Survey Ratemeter/Scaler with External Detector(s)					<b>Detector Action Level Action</b>
Noise Dosimeter (Sound Level Meter)					<85 decibels as measured using the A-weighted network (dBA): Use hearing protection if exposure will be sustained throughout work shift. >85 dBA: Use hearing protection. >120 dBA: Leave area and consult with safety personnel.
Other: Lumex mercury Vapor Analyzer	1	Mercury	Residence, yards, storm drain	Continuous	Level B – >100,000 ng/m <sup>3</sup> Level C - >25,000 ng/m <sup>3</sup> Residential occupancy levels - <1,000 ng/m <sup>3</sup> Residents isolation level - >10,000 ng/m <sup>3</sup> Re-occupancy levels - <3,000 ng/m <sup>3</sup>

**2. Air Sampling Data Sheet**

**Air Sampling Data Sheet**

Site: \_\_\_\_\_

Project Number: \_\_\_\_\_

Date: \_\_\_\_\_

Page: \_\_\_\_\_ of \_\_\_\_\_

Sample Description/Location	Sample No.	Pump ID No.	Flow rate, L/min			Time		Duration, minutes	Air volume, Liters
			Start	Stop	Avg.	Start	Stop		
<b>Entries by:</b> _____						<b>Date:</b> _____			

**Note:** Follow appropriate SOP and/or manufacturer’s instructions for instrument use.

**Comment:** \_\_\_\_\_





**Key:**

+	Positive Result Above Background	HP	Health Physicist
α	Alpha	IO	Inorganics
β	Beta	JPO	Joint Program Office
γ	Gamma	LAT	Level-A Truck (Seattle)
A	Anchorage Warehouse	LEL	Lower Explosive Limit
ALI	Annual Limit Intake	L/Min	Liters/Minute
APD	Advanced Portable Detector	MCE	Methyl Cellulose Ester
ASTM	American Society for Testing and Materials	mR/hr	Milliroentgen Per Hour
BTA	Bio Threat Analyzer	NH <sub>3</sub>	Ammonia
BTEX	Benzene, Toluene, Ethylbenzene, Xylene	NIOSH	National Institute of Occupational Safety and Health
C	Cassette Media for SKC Pumps	O <sub>2</sub>	Oxygen
CGI	Combustible Gas Indicator	OSHA	Occupational Safety and Health Administration
Cl	Chlorine	P	Portland Warehouse
CMS	Chip Measuring System Draeger	PCB	Polychlorinated Biphenyl
CO	Carbon Monoxide	PCM	Phase Contrast Microscopy
CSI	Chemical Sampling Information	PDR	Personal Data Ram
CWA	Chemical Warfare Agent	PID	Photoionization Detector
DAC	Data Chem	PNA and PAH	Polynuclear Aromatic Hydrocarbons
DoD	Department of Defense	ppm	Parts Per Million
FP	Filter Paper	PUF	Polyurethane Foam
FTIR	Hazmat Identification System	R	Response Truck Located at Warehouse (Seattle)
GC-MS	Gas Chromatograph Mass Spectrometer/HAPSITE	SAM	Surveillance and Monitoring
GFF	Glass Fiber Filter	SO <sub>2</sub>	Sulfur Dioxide
H <sub>2</sub> S	Hydrogen Sulfide	ST	Sorbent Tube Media for SKC Pumps
H <sub>2</sub> SO <sub>4</sub>	Sulfuric Acid	START	Superfund Technical Assessment and Response Team
H <sub>3</sub> PO <sub>4</sub>	Phosphoric Acid	SVOC	Semi Volatile Organic Compound
HazCat™	Hazardous Materials Categorization	TEM	Transmission Electron Microscopy
HCl	Hydrochloric Acid	TO	Toxic Organics
HCN	Hydrogen Cyanide	TVA	Toxic Vapor Analyzer
HEPA Filter	High Efficiency Particulate Air Filter	μR/hr	Milliroentgen Per Hour
HF	Hydrofluoric Acid	VOC	Volatile Organic Compound
HHA	Hand Held Assay	W	Warehouse South Park (Seattle)
Hj-Vol	High-Volume Sampler	WMD HazCat	Weapons of Mass Destruction Hazardous Materials Categorization



**Equipment Representatives:**

Alexeter – Tom Fryzel (877) 591-5571  
 Draeger - Tech Support – (800) 858-1739  
 HAPSITE Orders and Technical – (315) 434-1100  
 HiVolume Air Sampling Support – Jerry Winberry (919) 467-2785  
 Ludlum – (800) 622-0828  
 Lumex – Joseph Siperstein (888) 876-2611  
 Rae Systems – Shawn Ralton (253) 330-2141  
 SKC Pump – Ken Walter (206) 979-8352  
 Scott – Shaun Endsley (208) 818-0122 or (800) 247-7257 (tech support)  
 Thermo (Formerly Altura) – (978) 657-5555 (Option #, then 1)

**Laboratories:**

ALS – Rand Potter (801) 884-7712  
 Test America – Darla Powell (206) 255-8508  
 Air Toxics – Karen Stempson (916) 439-3111  
 Pace Analytical – Michael King (877) 859-7778  
 Washington State Department of Health – Denny Russell (206) 418-5562 (Biologicals)

**Action Levels:**

Oxygen Enriched/Deficient Environment  
 23.5% < O<sub>2</sub> < 19.5%

Flammable/Explosive Environment  
 CGI ≥ 10% LEL

Unknown Volatile Organic Compound  
 1ppm Sustained, Level-C  
 5ppm Sustained, Level-B

Radiation  
 ≥1 mR/hr Withdraw, Only Continue Monitoring with Health Physicist Advice  
 <1 mR/hr Continue Monitoring for Radiation  
 .01 - .02 mR/hr Typical Background Levels

**Disclaimer**

This multimedia document was developed by field personnel for utilization by the US EPA and their contractors, and is to be used by trained personnel only. Neither the US EPA nor any of their contractors assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed herein. Reference to any specific commercial products, process, or service by trade name, trademark, manufacturer or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the US EPA.

#### 4. Consent for Entry and Access to Property



### UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

#### Consent for Entry and Access to Property -- Mercury

<b>Name:</b>	<b>Phone:</b>
<b>Address:</b>	
<b>Address of property for which consent to access is granted:</b>	
<b>Relationship to property (i.e., owner, 5-year tenant, etc.):</b>	

I consent to officers, employees, and authorized representatives of the United States Environmental Protection Agency (EPA) entering and having continued access to my property for the following purposes:

1. air sampling;
2. decontamination of structures, furnishings and/or personal belongings contaminated by mercury;
3. stabilization and disposal of contaminated furnishings and/or personal belongings that remain contaminated;
4. removal and disposal of carpets, baseboards, furnace filters and of drapes, blinds, and other window dressings pursuant to health department recommendations;
5. removal and disposal of food products pursuant to health department recommendations; and
6. such other actions as the EPA On-Scene Coordinator determines necessary to protect human health or welfare or the environment.

In some cases, EPA may compensate for the actual value of property disposed of by EPA. The value will be determined by an independent certified appraiser retained by EPA.

I realize that these actions by EPA are undertaken pursuant to its response authorities under the comprehensive Environmental Response, Compensation and Liability Act of 1980, as amended (CERCLA), 42 U.S.C, § 9601 et seq.

I also realize that there may be loss of or damage to property during these actions. In addition, I realize EPA will be using my utilities, including heat, water, and electricity.

To the extent that U.S. EPA does replace any item determined to be contaminated, I acknowledge that it makes no representations about the quality, aesthetics, safety, use or character of such item or its

installation. Furthermore, U.S. EPA makes no warranties as to such item or its installation, including, but not limited to, merchantable warranties or warranties of fitness for purpose.

This written permission is given by me voluntarily with knowledge of my right to refuse and without threats or promises of any kind.

I certify that I am not insured under any policy that might cover costs associated with responding to mercury contamination on my property.

I certify that this Consent for Entry and Access is entered into voluntarily and constitutes an unconditional consent and grant of permission for access to the property by officers, employees and authorized representatives of EPA at reasonable times.

I have not intentionally applied mercury in order to obtain relocation-related benefits. I have not requested or permitted anyone else to release mercury so that I could obtain relocation-related benefits. I understand that intentionally applying (or arranging for the application or mercury in order to obtain relocation-related benefits is a crime punishable by a fine and/or imprisonment. I understand that making any misrepresentation in order to obtain relocation-related benefits is a crime punishable by a fine and/or imprisonment.

All statement in this document are true and correct to the best of my knowledge. I understand that intentionally making false or fraudulent statements in this document is a criminal offense punishable by a fine and/or imprisonment.

---

**Date**

---

**Signature**

---

**Print Name**



## 6. Daily Safety Meeting Record

Daily Safety Meeting Record		
General Information		
Project:		
Project No:	T.O. No.:	
Project Location:		
Date:	Time:	Weather:
Specific Location:		
Planned Activities:		
Safety Topics Presented		
Chemical Hazards Update:		
Physical Hazards Update:		
Radiation Hazards Update:		
Review of Previous Monitoring Results:		
Protective Clothing/Equipment Modifications:		
Special Equipment/Procedures: Mercury vapor analyzer as gas monitoring.		
Drilling Safety Issues (including testing the operation of drill rig emergency stop switches):		
Emergency Procedures: In case of emergency, all team members will meet at:		
Additional Topics/Observations:		
Team Members' Comments/Suggestions:		
Initial Project Safety Checklist		
1. Emergency information reviewed? _____ Made familiar to all team members? _____		

## 7. Decontamination Checklist



### UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

#### Mercury Decontamination Plan

<b>Address:</b>	
<b>Date:</b>	<b>Time Started/Ended:</b>

- \_\_\_\_\_ Health Department issues evaluation letter to resident. Health Department to post sign stating: "Unfit for Human Habitation."
- \_\_\_\_\_ OSC obtains keys from residents and forwards to command post/IC.
- \_\_\_\_\_ May request local police support or contract with local police departments to provide extra security while residences are vacant due to relocation. In addition, or alternatively, EPA may contract with private security companies to help prevent vandalism and burglary of vacant residences.
- \_\_\_\_\_ Pre-document conditions in the house with thorough video footage and photos of the contents and condition of the interior and exterior of the residence. Note date and time on video and photos. The video should be panned slowly and thoroughly and with narration to explain details.
- \_\_\_\_\_ Residents bag select clothes, personal items, medicine for relocation. All personal items should be screened for mercury vapors before removal from the site/residence in order to prevent additional locations from becoming mercury contaminated.
- \_\_\_\_\_ Bag all remaining clothes, shoes, rugs, bedding, and porous items. Screen with a mercury vapor analyzer. Screen washing machines/dryer, replace air filters, and screen vacuums. Place bags of contaminated items in a non-contaminated area.
- \_\_\_\_\_ Compile a detailed inventory and photo/video documentation of contaminated items once they are bagged and placed in a non-contaminated area.
- \_\_\_\_\_ Remove all visible mercury using physical techniques and/or a mercury vacuum.
- \_\_\_\_\_ Remove & contain all porous contaminated materials (i.e. carpet) that cannot be deconned.

\_\_\_\_\_ Wash the affected area with a mercury treatment solution to bind and remove the mercury residue from the surface. Follow the manufacturer's recommendations and then wash the area with clean water.

\_\_\_\_\_ Close the windows, turn off the air conditioning and heat the area from 80°-90°F for approximately 4 hours in order to volatilize any residual mercury. The temperature in the room can be regulated by the thermostat or with portable turbo heaters.

\_\_\_\_\_ Reduce thermostat to normal room temperatures, open doors and windows, and ventilate for at least 1 hour. Use blowers and ventilation fans to facilitate air movement and to completely evacuate the air column from inside to outside by replacing the indoor air with fresh outdoor air.

\_\_\_\_\_ Perform post air sampling for mercury vapor using an accepted MVA procedure or by collecting air samples by the NIOSH 6009 method. Prepare by:

- Sealing off area from outside influence
- Returning any items previously removed to their original locations
- Setting up MVA at an appropriate height, temperature and duration of time to closely match what would be established using NIOSH method 6009

\_\_\_\_\_ Place waste and bags of PPE into appropriate waste containers for proper disposal.

NOTE: Decontamination checklist may be modified if alternate methods for decontaminating contaminated clothing and other porous items are preferred over immediate disposal.



## 8. Example De-List Letter from Local Health Department

**Name County Combined  
Health District Logo**

**Health Commissioner:**  
Robert Brown, R.S., M.P.A.  
*Community Service Provider*

**Board of Health:**  
Barbara Johnson, MD  
Michael Green, PhD

March 10, 2014  
John Q. Smith  
On-Scene Coordinator  
U.S. EPA Region X  
Superfund Division (X-1)  
Emergency Response Section X  
123 Main Street  
City, State 12345

Dear Mr. Smith:

The <Name> County Health District has received information from your office that the following homes have completed the clean-up and reconstruction phase or required no action regarding the mercury incident. Upon reviewing the post-cleanup sampling results, I am requesting that these homes be removed from the action list.

Sincerely,

*Robert Q. Brown*

Robert Q. Brown, R.S., M.P.A.  
Health Commissioner

456 E. 1<sup>st</sup> Avenue, City, State 67890  
Phone: 123-456-7890  
Fax: 987-654-3210

## 9. Example De-List Letters from U.S. EPA

### a. Residence that was sampled but did not require decontamination



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY  
CITY, STATE 12345

March 8, 2014

Robert Q. Brown, R.S., M.P.A.  
Health Commissioner  
Name County Combined Health District  
456 E. 1st Avenue  
City, State 67890

Dear Mr. Brown:

On March 6, 2014, the following locations were referred to U.S. EPA for mercury characterization and potential cleanup:

- Address 1
- Address 2
- Address 3
- Address 4
- Address 5
- Address 6
- Address 7
- Address 8
- Address 9
- Address 10

Completion of initial air sampling for mercury by U.S. EPA at these locations occurred on March 6, 2014. A copy of the sample analyses confirming that mercury levels are below the long-term action levels provided by State Department of Health and the Agency for Toxic Substances and Disease Registry is attached. The addresses noted above did not require indoor decontamination and U.S. EPA has no plans for further activity at these locations. Please contact me if you have any questions at 333-333-3333.

Sincerely,

*John Q. Smith*

John Q. Smith  
U.S. EPA Region X  
On-Scene Coordinator

Cc: Site File

**b. Residence that required decontamination**



**UNITED STATES ENVIRONMENTAL PROTECTION AGENCY**  
CITY, STATE 12345

March 10, 2014

Robert Q. Brown, R.S., M.P.A.  
Health Commissioner  
Name County Combined Health District  
456 E. 1st Avenue  
City, State 67890

Dear Mr. Brown:

On March 6, 2014, the following locations were referred to U.S. EPA for mercury characterization and potential cleanup:

- Address 1
- Address 2

Completion of post decontamination air sampling for mercury by U.S. EPA at these locations occurred on March 9, 2014. A copy of the sample analyses confirming that mercury levels are below the long-term action levels provided by State Department of Health and the Agency for Toxic Substances and Disease Registry is attached. The addresses noted above required indoor decontamination, and U.S. EPA has no plans for further activity at these locations. Please contact me if you have any questions at 333-333-3333.

Sincerely,

*John Q. Smith*

John Q. Smith  
U.S. EPA Region X  
On-Scene Coordinator

Cc: Site File

## 10. Equipment Supplies Checklist

EQUIPMENT/SUPPLIES CHECKLIST			
INSTRUMENTATION	No.	RESPIRATORS	No.
Multi-gas monitor (MultiRAE Plus, AreaRAE, Multirwarn)		Air purifying	
Sensors: O <sub>2</sub> , LEL, H <sub>2</sub> S, CO, NH <sub>3</sub> , Cl <sub>2</sub> , NO <sub>2</sub> , SO <sub>2</sub> , HCN, PH <sub>3</sub>		Cartridges:	
Gas Calibration Kit		SCBAs	
PID/FID (MultiRAE Plus, TVA-1000B) (probe: _____eV)		Cascade system	
Real-time cyanide monitor		<b>EMERGENCY EQUIPMENT</b>	
Real-time ammonia/chlorine (NH <sub>3</sub> , Cl <sub>2</sub> ) monitor		Medical monitoring kit	
Chemical weapon detector (AP2Ce, APD2000)		Blood pressure monitor (with sphygmomanometer)	
Draeger tube kit (tubes: _____)		Thermometer (medical)	
Hazard Categorization Kits (First Step, Orange, WMD)		Fire extinguisher	
Field Spetrometers (HazMat ID, First Defender)		Spill kit	
Personal dust monitor (MiniRam)		Portable eye wash	
Area dust monitor (DataRam 4000)		Stretcher	
Mercury monitor (Lumex, Jerome)			
Personal air sampling pumps, supplies and cal kit		<b>DECONTAMINATION EQUIPMENT</b>	
Infrared monitor (MSA Evolution 5000, Minolta Campac 3)		Wash tubs	
Weather station		Buckets	
GPS Unit (Garmon)		Scrub brushes	
Spare batteries (type: _____)		Pressurized sprayer	
		Spray bottle	
<b>RADIATION EQUIPMENT/SUPPLIES</b>		Detergent (type: _____)	
TLD badges		Solvent (type: _____)	
Ludlum 192 survey meter (Micro R)		Plastic sheeting	
Ludlum 2241-2 survey meter		Tarps and poles	
Probes: GM pancake, 2" Nal gamma, ZnS alpha		Trash bags	
Electronic dosimeters (Canberra MRAD 103)		Trash cans	
Eberline R020		Masking tape	
SAM 935 gamma spectrometer		Duct tape	
Documentation forms		Paper towels	
		Face mask	
<b>PERSONAL PROTECTIVE EQUIPMENT</b>		Face mask sanitizer	
Steel-toed boots		Step ladders	
Hard hat		Distilled water	
Eye protection		Deionized water	



## 11. Example Letter to Request U.S. EPA Assistance

### State EPA Logo

State of Name Environmental Protection Agency

Mr. John Q. Smith  
Emergency Response Branch, Chief  
U.S. EPA, Room X  
123 Main Street  
City, State 12345

Re: 2014 City Mercury Spill

Dear Mr. Smith:

<State> EPA requests U.S. EPA's assistance in conducting an emergency removal action involving mercury contamination in City, State. ER was notified Saturday, March 4<sup>th</sup>, by the City Fire Department that several children had smashed switches containing mercury from an old abandoned drum located at 456 Street in City. On Saturday, representatives from <State EPA> Emergency Response, Special Investigations, and Barbara Q. Johnson from U.S. EPA began investigations as to the extent and severity of the contamination. State EPA's contractor was activated to place plastic over contaminated areas while <State EPA> staff worked with U.S. EPA to screen houses for contamination. At present, six houses have levels exceeding removal standards and several areas outside have been identified for cleanup. Barbara Q. Johnson is currently conducting emergency cleanup activities.

Meanwhile, <State EPA> and the <City Health Department> collected names of individuals possibly exposed to the mercury. Testing of those individuals exposed to mercury was conducted by the <Health Department>.

<State EPA> is formally requesting U.S. EPA's assistance in assessing contamination and conducting the appropriate removal actions.

Please let me know if you have any questions and feel free to call me at 555-555-5555 with any questions. Bob Q. Green, <State EPA> OSC is the contact for this site.

Sincerely

*Jane Q. Davis*

Jane Q. Davis, Manager  
Emergency Response & Special Investigations

Cc: Bob Q. Green ER, SSWDO

## 12. Mercury Screening Form for Land or Structures

### MERCURY SCREENING FORM FOR LAND OR STRUCTURES

Site Name: \_\_\_\_\_ TDD #: \_\_\_\_\_

Date of Screening: \_\_\_\_\_ Time initiated: \_\_\_\_\_

Name of Contact: \_\_\_\_\_ Phone: \_\_\_\_\_

Address: \_\_\_\_\_

Type of structure (circle one): Residential, commercial, school, other (specify) \_\_\_\_\_

Number of occupants: \_\_\_\_\_ Ages (if a residence): \_\_\_\_\_

Suspected date of spill: \_\_\_\_\_

Current outdoor ambient temperature: \_\_\_\_\_

Status of ventilation (check one):  
 1. Outside windows/doors open.  
 2. Windows closed, interior doors open.  
 3. Door and windows to spill area closed.

Was there any attempt to clean spill? Y N

Any mercury-related illnesses reported? Y N

**Screening:** Instrument (check): Jerome \_\_\_\_\_ Lumex \_\_\_\_\_ Other \_\_\_\_\_

Write peak reading for each room listed below. Specify units.

Room Type: \_\_\_\_\_ Specific Location: \_\_\_\_\_

Floors: \_\_\_\_\_

Breathing Zone: \_\_\_\_\_

Vents: \_\_\_\_\_

Other: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

--





### 13. Residential Post-Decontamination Team Checklist



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

#### Residential Post-Decontamination Team

<b>Address:</b>	
<b>Date:</b>	<b>Time Started/Ended:</b>

- \_\_\_\_\_ Ambient air levels are below the ATSDR level of 1.0 µg/m<sup>3</sup>.
- \_\_\_\_\_ Obtain house key from Command Post lock box and U-haul boxes from ERRS contractor. Obtain initial predocumentation video and inventory sheets.
- \_\_\_\_\_ Post-decontamination team unpack indoor “clean” bags into boxes. Leave filled boxes on floor.
- \_\_\_\_\_ Gather used “clean” bags from house for disposal at Command Post rolloff boxes.
- \_\_\_\_\_ Utilizing initial pre-documentation video, post-document all rooms in house and outdoor areas.
- \_\_\_\_\_ Photodocument and provide a detailed inventory of contaminated items (in bags located on back porch or back of house); less than or equal to four items per photo. If a mattress is contaminated, measure the mattress. Provide good details on the items. For example: one twin mattress measuring 6 feet by 4 feet by 8 inches, or one pair of boys Levi jeans size medium. After documenting the items, place back into the bags.
- \_\_\_\_\_ Call ERRS contractor to transfer bagged contaminated items to Command Post rolloff boxes.
- \_\_\_\_\_ Inform U.S. EPA OSC of completion of post-documentation of house.
- \_\_\_\_\_ Return house key, video, and inventory log to Command Post.
- \_\_\_\_\_ Forward copy of contaminated item log and photolog to local health department.

## 14. Example Post-Evacuation Letter to Health Department



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY  
CITY, STATE 12345

March 23, 2014

Jane Q. Smith, RN, BSN  
Director of Nursing  
Name County Combined Health District  
456 E. 1st Avenue  
City, State 67890

Dear Ms. Smith:

U.S. EPA completed soil excavation activities at the Name Street Mercury site on March 10 and 13, 2014. The following areas contained soil contaminated with mercury and were excavated:

- The property located at 123 Name Street (Sample ID: S-1)
- A small portion of soil adjacent to the detached garage of the home at 123 Name Avenue and the alley (Sample ID: S-2)
- The east/west alley between 123 Name Lane and 123 Name Drive (Sample ID: S-3 and S-4)
- The backyard of 456 Name Street (Sample ID: S-5)
- The east/west alley between 456 Name Avenue and the 1<sup>st</sup> east/west cross alley (Sample ID: S-6)
- The backyard of 456 Name Lane (Sample ID: S-7)
- A small portion of soil located near the 456 Name Drive backyard fence gate and the alley (Sample ID: S-8)
- A portion of the front yard under a tree located between the homes 789 and 791 Name Street (Sample ID: S-9)
- A small portion of soil in the rear of the backyard of 789 Name Avenue adjacent to the dividing metal fence (Sample ID: S-10)

U.S. EPA technical consultants collected post excavation soil samples for total mercury analysis. The samples were prepared and analyzed in accordance with U.S. EPA method 7471 using a Varian SpectrAA 300. The results can be found in Attachment A.

All samples showed total mercury concentrations below the State EPA residential soil action level of X milligrams per kilogram. U.S. EPA has no plans for further activity at these locations. Please contact me if you have any questions at 333-333-3333.

Sincerely,

*John Q. Smith*

John Q. Smith  
U.S. EPA Region X  
On-Scene Coordinator

Cc: Site File

## 15. Example Public Outreach Documents

The following are examples of documents from a previous mercury response distributed to local residents for informational purposes:

### a. Press Release

**For Immediate Release: April 30, 2014**

Name County Health Department (NCHD)

Health Contacts: John Q. Smith

Solid Waste Coordinator

Name County Health Department

888-888-8888

Name County Medical Director, Dr. Barbara Q. Johnson said today, "The preliminary results of sampling at the Name School found low levels of mercury contamination in several isolated areas. Several agencies and school officials are working rapidly but carefully to ensure a safe condition for the return of the students and faculty."

On April 19<sup>th</sup>, 2014, a U.S. EPA Emergency Response Team and a Name County Health Department Official visited a house that had been contaminated after the owner's child brought mercury home from school.

Representatives from U.S. EPA and officials from State and County health departments have been aggressively investigating the situation, taking advantage of the schools being closed for spring vacation. As of April 28, 2014, thirty-four buses have been inspected for mercury vapors. Four buses have been found with small amounts of mercury. The school hired contractors to clean up the contamination on four buses. EPA and health officials are continuing to conduct air sampling and evaluating the results for the entire Name School building.

Mercury is a naturally occurring metal that has several forms. Metallic mercury is a shiny, silver, odorless liquid metal, which if heated, is a colorless, odorless gas. Mercury is a highly toxic, cumulative poison and a major health threat to humans. Exposure usually occurs by inhalation or by skin contact, but there is also a small risk of exposure through ingestion. Children living in or frequenting contaminated buildings are particularly at risk of exposure. At high levels, mercury may damage the brain, kidneys, and a developing fetus, according to the Agency for Toxic Substances and Disease Registry.

The Name County Health Department is encouraging the public to properly dispose of any mercury they may have in their home. The Health Department will accept mercury by appointment and properly dispose of it free of charge, with no questions asked. John Q. Smith, Name County Solid Waste Coordinator said "mercury poses a threat to human health and should never be kept in your home or garage." Residents who may have mercury are encouraged to call the Name County Health Department at 888-888-8888 to make arrangements for free disposal.

The officials involved with this cleanup are concerned about the health risks to community members who may not even know they are being exposed to mercury in their homes or vehicles. The school says there will be no action taken against students who help take care of this unfortunate situation. "We don't want to give out punishment, we want absolute safety to return to the Name School," said Mary Q. Davis, Assistant Superintendent of Name School District.

**b. Letter to Resident**



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY  
REGION X  
EMERGENCY RESPONSE BRANCH  
1234 MAIN STREET, ROOM 123  
CITY, STATE 12345

REPLY TO ATTENTION OF:

NAME MERCURY SPILL  
MAY 2014

Dear Resident,

As you may be aware, the United States Environmental Protection Agency (U.S. EPA) is in the process of decontaminating a home in Name County, State, that has been contaminated with mercury. U.S. EPA would like to discuss with you the cleanup that may take place in your home.

In April 2014, metallic mercury was taken from a middle school in Name County, State, and was used in and outside of Name School by a group of students. As a result, your home may also be contaminated with small amounts of mercury.

Representatives from U.S. EPA, Name school officials, and state and county health departments have been aggressively investigating the situation, taking advantage of the schools being closed for spring vacation. As of April 28, 2014, thirty-four buses have been inspected for mercury vapors. Three buses have been found with small amounts of mercury. The school hired contractors to clean up the contamination on the buses and in the school. U.S. EPA is conducting air sampling and are evaluating the results for the entire Name School building and the buses.

The involved agencies screened and conducted air sampling at two homes. As of today, one home has been qualified for decontamination. Additional homes will be screened for mercury as they are identified.

Mercury is a naturally occurring metal that has several forms. Metallic mercury, also known as quick silver, is a shiny, silver, odorless liquid metal, which if heated, is a colorless, odorless gas. Mercury is a highly toxic, cumulative poison and a major health threat to humans. Exposure usually occurs by inhalation or by skin contact, but there is also a small risk of exposure through ingestion. Children living in or frequenting contaminated buildings are particularly at risk of exposure. At high levels, mercury may damage the brain, kidneys, and a developing fetus, according to the Agency for Toxic Substances and Disease Registry.

Clean up of your home is expected to take approximately one week after work begins. Clean up may take longer if mercury contamination levels are higher than expected, or if the mercury has spread to other areas of your home. The cleanup team working in your home will work from about 7:00 am to 7:00 pm Monday through Saturday.

Every precaution is being taken to insure that public health and safety throughout the cleanup is a priority. As you will see, the workers will be wearing protective clothing during the cleanup project. U.S. EPA will be particularly careful in making sure your home is cleaned as safely and quickly as possible.

Thank you for your patience and cooperation on this matter. If you have any questions or concerns about this clean up action, please call Michael Q. Smith at 222-222-2222 or Jane Q. Johnson of the Name County Health Department at 888-888-8888.

Matthew Q. Green,  
Public Affairs

## c. Fact Sheet

# Mercury Incident Fact Sheet

Name County, State

May 3, 2014

## Introduction

The purpose of this fact sheet is to provide information regarding the Name School Mercury Incident. Also included are phone numbers of the Name School Offices, Name County Health Department, and the U.S. EPA representatives should the public have further health or environmental concerns about the incident.

## History

On April 6<sup>th</sup>, a family notified the Name County Health Department about some mercury that their child brought home from school. Since this event, the Health Department and the U.S. EPA have been aggressively working with the Name School Officials, investigating the situation by interviewing students and residents to determine the extent of contamination. Additionally, the U.S. EPA provided air monitoring and took air samples for confirmatory analysis. The U.S. EPA also tested all 34 buses used by the Name schools. Three buses had levels of mercury that required decontamination. Some mercury was also detected in the school. Name school officials hired an environmental contractor to decontaminate the buses and the school. The U.S. EPA is continuing to investigate and test all of the schools in the Name school district for mercury.

Mercury was also detected in one home and it needs to be decontaminated.

## What is Mercury? And the Health Risks

Mercury is a naturally occurring metal that has several forms. Metallic mercury is a shiny, silver odorless liquid metal, which if heated, becomes a colorless, odorless gas. Mercury is a highly toxic, cumulative poison and a major health threat to humans. Exposure usually occurs by inhalation or by skin contact, but there is also a small risk of exposure through ingestion. Children living in or frequenting contaminated buildings are particularly at risk of exposure. At high levels, mercury may damage the brain, kidneys, and a developing fetus, according to the agency for Toxic Substance and Disease Registry. The Name County Health Department is accepting mercury from residents who may have mercury stored in their home. The disposal is free and no questions will be asked about how the mercury was obtained.

## Current Status

As a result of mercury contamination, some items in the school have been disposed. They include lockers, vacuum cleaners and sink traps. Lab data on air samples collected in the school building have shown that no mercury contamination remains. There is no human health or environmental threat. Three buses are currently being decontaminated.

## Next Steps

The Health Department will continue to encourage parents to report any incidences of mercury that they may have knowledge of. The U.S. EPA will clean up the home that has elevated levels of mercury and will work with school and health officials and continue to offer assistance during the ongoing investigation.

## 16. Residential Mercury Contamination Screening Checklist



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

### Residential Mercury Contamination Screening Checklist

(to be used when residence is known to be contaminated)

(v) or (N/A)			
Vacuum cleaner (bag)		Car (both sides floor and seat in front and back)	
Furnace filter		Tool boxes	
Heating ducts		Baseboard areas	
Clothing (bag and screen)		Tile crevices	
Shoes (especially tongue areas)		Cracks in floor	
Clothes hamper		Concrete floors	
Bedding (between sheets, especially at level of feet)		Near bottom of brick wall	
Clothes washer (inside)		Lower shelving and items on shelf	
Clothes dryer (inside and lint trap)		Dusty areas	
Heavy traffic areas of floor		Under edge of linoleum or vinyl tile	
Heavy traffic areas of carpet (especially near bed, TV viewing area)		Crevices of hardwood flooring	
Sink drains		Above drop ceiling tiles (especially if spill occurred on floor above)	
Jewelry (bag and screen)		All garage areas	
Porous items (books, wooden objects, etc.)		Throw rugs	
Coins (bag and screen)		Welcome mats	
Food-related items in contaminated areas (bag and screen)		Furniture	
Electronics		Under major appliances	
Floor Drains			

## 17. Example Relocation Letter

**Name County Combined  
Health District Logo**

**Health Commissioner:**  
Robert Brown, R.S., M.P.A.  
*Community Service Provider*

**Board of Health:**  
Barbara Johnson, MD  
Michael Green, PhD

March 7, 2014

To the residents of 123 Main Street:

We have received the air sampling results from the U.S. EPA taken at your home. The results of the air sampling have shown mercury levels above the acceptable levels for a residential setting. Therefore, we are asking for your cooperation so that we may decontaminate your home.

You will be asked to leave your home for a period of approximately 1 day. You will be allowed to take enough clothing and personal items for this period. Anything you take must be screened by the U.S. EPA to assure that you are not taking anything which might be contaminated with mercury.

The Red Cross will provide housing and a food allowance for those individuals who are being evacuated if needed. If you have other family members or friends that you wish to stay with during this time that is also acceptable. If you choose to stay with family or friends, the food allowance cannot be offered.








The City Police Department will be notified and additional security checks will be performed during this time period. We will need a set of keys to gain access to your home for the decontamination process. The keys will be kept secure with the U.S. EPA.

In an effort to help you with the evacuation of your home, we will be giving you plastic bags to put clothing and any other items you wish to take with you. Please put those items in the bags and twist them shut. A representative from the U.S. EPA will come by and check these bags with an instrument as you are leaving your home to assure you are not taking any mercury or mercury vapors with you. Please take any valuables, rings, jewelry, etc.










To briefly explain the decontamination process, a team of professionals from the U.S. EPA will perform an initial screening of your home by putting clothes into plastic bags and checking them with their equipment. Any clothing that has tested positive for mercury will be removed from the home. A list of anything removed will be given to you. When you go back into your home you will find your clothes in bags up off the floor.

456 E. 1<sup>st</sup> Avenue, City, State 67890  
Phone: 123-456-7890  
Fax: 987-654-3210

## 18. Mercury Specific Vacuum Comparison Table

							
<b>Manufacturer</b>	Minuteman International					Nilfisk Advance	
<b>Web Address</b>	www.minutemanintl.com					www.pa.nilfisk-advance.com	
<b>Model Number</b>	MRS-1	MRS-2	MRS-3	MRS-4	MRS-6 (Maxi-Guard II)	SS Mercury Vac	VT Mercury Vac
<b>Static Lift</b>	110 Inches	110 Inches	110 Inches	110 Inches	88 Inches	102 Inches	117 Inches
<b>Airflow</b>	115 CFM	115 CFM	115 CFM	115 CFM	95 CFM	99 CFM	99 CFM
<b>Power (Watts)</b>	1480	1480	1480	1480	1480	1100	1000
<b>Cord</b>	16/3' - 50'	16/3' - 50'	16/3' - 50'	16/3' - 50'	16/3' - 50'	30 Feet	30 Feet
<b>Wet Capacity</b>	N/A	N/A	N/A	10 Gallon	N/A	N/A	N/A
<b>Dry Capacity</b>	.82 ft <sup>2</sup>	.82 ft <sup>2</sup>	.82 ft <sup>2</sup>	2.1 ft <sup>2</sup>	.62 ft <sup>2</sup>	2.25 Gallons/1 quart	12 Gallon
<b>Filter Area</b>	3,234 in <sup>2</sup>	3,234 in <sup>2</sup>	3,234 in <sup>2</sup>	N/A	552 in <sup>2</sup>	DNP "Honeycomb" Design	DNP "Honeycomb" Design
<b>Height</b>	41 Inches	48 Inches	46 Inches	46 Inches	25 Inches	30 Inches	40 Inches
<b>Width</b>	21 Inches	21 Inches	21 Inches	21 Inches	21 Inches	18.5 inches	21 Inches
<b>Voltage</b>	115 (220)	115 (220)	115 (220)	115 (220)	115 (220)	110-120/220	110-120/220
<b>Wet / Dry</b>	No	No	No	Yes	No	No	No
<b>Weight</b>	62 Pounds	73 Pounds	78 Pounds	70 Pounds	24 Pounds	44 Pounds	107 Pounds
<b>Design</b>	Liquid Mercury	Mercury Contaminated Dust	Liquid Mercury & Dust	Mercury Contaminated Liquids (Wet Only)	Liquid Mercury & Dust	Liquid Mercury & Granular Compounds	Liquid Mercury & Granular Compounds
<b>Stages of Filtration</b>	5	5	5	5	5	4	4
<b>Disposable Bag Capacity</b>	15 Gallon	15 Gallon	15 Gallon	15 Gallon	6 Gallon	2.25 Gallon	12 Gallon
<b>Mercury Separator</b>	Yes	Yes	Yes	Yes	Yes	No	Yes
<b>Accessories Available</b>	Yes	Yes	Yes	Yes	Yes	Yes	Yes
<b>Hour Meter</b>	Yes	Yes	Yes	Yes	No	No	No
<b>Carbon Filter Weight</b>	DNP	DNP	DNP	DNP	DNP	31 Pounds	54 Pounds
<b>Other</b>	DNP	DNP	DNP	DNP	DNP	DNP	DNP
<b>Photo Use</b>	Photos courtesy of Minuteman International					Photos courtesy of Nilfisk Advance	



									
<b>Manufacturer</b>	Nikro Industries				Tiger-Vac				
<b>Web Address</b>	www.nikro.com				www.tiger-vac.com				
<b>Model Number</b>	MV00688-SS	MV15110-PLY	MV15110-PTD	MV15110-SS	MRV-8 Poly	MRV-8 Poly Tank Air	MRV-8 CR Air	MRV-15 (Electric)	MRV-16 (4W) SS
<b>Static Lift</b>	88 Inches	110 Inches	110 Inches	110 Inches	95 Inches	DNP	DNP	110 Inches	110 Inches
<b>Airflow</b>	95 CFM	115 CFM	115 CFM	115 CFM	120 CFM	120 CFM	120 CFM	110 CFM	110 CFM
<b>Power (Watts)</b>	DNP	DNP	DNP	DNP	1000	DNP	DNP	1050	1050
<b>Cord</b>	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
<b>Wet Capacity</b>	N/A	N/A	N/A	N/A	DNP	DNP	DNP	20 Gallons	20 Gallons
<b>Dry Capacity</b>	DNP	DNP	DNP	DNP	4 Gallons	4 Gallons	4 Gallons	10 Gallons	10 Gallons
<b>Filter Area</b>	DNP	DNP	DNP	DNP	1368 in <sup>2</sup>	DNP	DNP	DNP	DNP
<b>Height</b>	DNP	DNP	DNP	DNP	26 Inches	DNP	DNP	48 Inches	DNP
<b>Width</b>	DNP	DNP	DNP	DNP	18 Inches	DNP	DNP	24 Inches	DNP
<b>Voltage</b>	115 (220 Optional)	115 (220 Optional)	115 (220 Optional)	115 (220 Optional)	120/240	DNP	DNP	120/240	120/240
<b>Wet / Dry</b>	No	No	No	No	DNP	DNP	DNP	Yes	Yes
<b>Weight</b>	20 Pounds	32 Pounds	32 Pounds	32 Pounds	44 Pounds	DNP	DNP	92 Pounds	DNP
<b>Design</b>	Liquid Mercury & Granular Compounds	Liquid Mercury & Granular Compounds	Liquid Mercury & Granular Compounds	Liquid Mercury & Granular Compounds	Liquid Mercury	DNP	DNP	Liquid Mercury, Mercury Contaminated Debris & Liquids	Liquid Mercury, Mercury Contaminated Debris & Liquids
<b>Stages of Filtration</b>	5	5	5	5	3	DNP	DNP	4	4
<b>Disposable Bag Capacity</b>	6 Gallon	15 Gallon	15 Gallon	15 Gallon	DNP	DNP	DNP	5 Gallons	5 Gallons
<b>Mercury Separator</b>	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
<b>Accessories Available</b>	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
<b>Hour Meter</b>	DNP	DNP	DNP	DNP	Yes	DNP	DNP	Yes	Yes
<b>Carbon Filter Weight</b>	20 Pounds	32 Pounds	32 Pounds	32 Pounds	7.5 Pounds	DNP	DNP	DNP	DNP
<b>Other</b>	DNP	DNP	DNP	DNP	DNP	DNP	DNP	Available in Electric & Air	DNP
<b>Photo Use</b>	Photos courtesy of Nikro Industries				Photos courtesy of Tiger-Vac				

DNP = Manufacturer did not provide information

NOTE: This list is not inclusive of all commercially available mercury-specific vacuums. This comparison is provided for informational purposes only and is not a certification, endorsement, recommendation, claim, or declaration of any company or of the products and services they provide or claim to provide. EPA makes no guarantees regarding the accuracy of the information provided in this table.

\*Source: ESCO

# Appendix D

## Additional Mercury Resources

1. EPA
2. ATSDR
3. NIOSH
4. OSHA
5. ACGIH
6. CDC
7. Find a Recycling Center
8. MSDS for Mercury (Metal)
9. Companies that Recycle Mercury
10. Federal Hazardous Waste Regulations
11. Occupational Safety and Health Administration's Safety and Health Standard for protective gear
12. Comprehensive Environmental Response, Compensation Act's Reportable Quantities, Mercury Releases
13. Mercury in Schools

## 1. EPA

### a. National Mercury Website

- [www.epa.gov/mercury/](http://www.epa.gov/mercury/)

### b. Environmental Response Team (ERT)

- [https://response.epa.gov/site/site\\_profile.aspx?site\\_id=ERTMERCURY](https://response.epa.gov/site/site_profile.aspx?site_id=ERTMERCURY)

### c. Emergency Response Technical Group (ERTG)

- [https://response.epa.gov/site/site\\_profile.aspx?site\\_id=0001](https://response.epa.gov/site/site_profile.aspx?site_id=0001)

### d. Temporary Relocation Guidance

- <https://semspub.epa.gov/work/HQ/174943.pdf>

### e. Office of Research and Development (ORD)

- <https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=211003>

## 2. ATSDR

### a. Chemical Specific Health Consultation and Suggested Action Levels

- [http://www.atsdr.cdc.gov/emergency\\_response/Action\\_Levels\\_for\\_Elemental\\_Mercury\\_Spills\\_2012.pdf](http://www.atsdr.cdc.gov/emergency_response/Action_Levels_for_Elemental_Mercury_Spills_2012.pdf)

### b. ATSDR Mercury Website

- <http://www.atsdr.cdc.gov/mercury/>

### c. Toxic Substances Portal: Mercury

- <http://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=24>

## 3. National Institute for Occupational Safety and Health (NIOSH)

- NIOSH 6009: <http://www.cdc.gov/niosh/docs/2003-154/pdfs/6009.pdf>
- Safety and Health Topic – Mercury: <http://www.cdc.gov/niosh/topics/mercury/>
- Criteria for a Recommended Standard: Occupational Exposure to Inorganic Mercury: NIOSH Document #73-11024: <https://www.cdc.gov/niosh/docs/73-11024/>

## 4. Occupational Safety and Health Administration (OSHA)

- Safety and Health Topics – Mercury: <https://www.osha.gov/SLTC/mercury/index.html>

## **5. American Conference of Government Industrial Hygienists (ACGIH)**

- Threshold Limit Values (TLVs®) and Biological Exposure Indices (BEIs®):  
<http://www.acgih.org/>

## **6. Centers for Disease Control and Prevention (CDC)**

- Elemental Mercury Releases Attributed to Antiques:  
[http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5623a2.htm?s\\_cid=mm5623a2\\_e](http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5623a2.htm?s_cid=mm5623a2_e)

## **7. Find a Recycling Center**

- Earth 911: <http://earth911.org/>

## **8. Materials Safety Data Sheet (MSDS) for Mercury (Metal)**

- <http://www.bethlehemapparatus.com/pdf/MSDS.pdf>

## **9. Companies that Recycle Mercury**

- Waste Management: <http://www.wmsolutions.com/>
- Thermostat Recycling Corporation: <http://www.thermostat-recycle.org/>

## **10. Federal Hazardous Waste Regulations: 40 CFR 261.5(e)**

- [http://www.ecfr.gov/cgi-bin/text-idx?SID=ac3b3fcd29b1ccada4b884912f743b5e&node=se40.26.261\\_15&rgn=div8](http://www.ecfr.gov/cgi-bin/text-idx?SID=ac3b3fcd29b1ccada4b884912f743b5e&node=se40.26.261_15&rgn=div8)

## **11. Occupational Safety and Health Administration's Safety and Health Standard for Protective Gear: 29 CFR 1910.134**

- [http://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_id=12716&p\\_table=standards](http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=12716&p_table=standards)

## **12. Comprehensive Environmental Response, Compensation Act's Reportable Quantities, Mercury Releases: 40 CFR 302.6 (b)**

- [http://www.ecfr.gov/cgi-bin/text-idx?SID=cd3072655eecaf06ad54116e6f5be8cf&node=se40.28.302\\_16&rgn=div8](http://www.ecfr.gov/cgi-bin/text-idx?SID=cd3072655eecaf06ad54116e6f5be8cf&node=se40.28.302_16&rgn=div8)

## **13. Mercury in Schools**

- ATSDR's Mercury Report – Children's Exposure to Elemental Mercury  
[http://www.atsdr.cdc.gov/mercury/mercury\\_report.html](http://www.atsdr.cdc.gov/mercury/mercury_report.html)

A former industrial building in New Jersey used to manufacture mercury thermometers was converted in 2004 to a children's day care facility. Children and adults at the facility were exposed to residual amounts of mercury. As a result, Congress directed the U.S. Agency for Toxic Substances and Disease Registry (ATSDR) to further investigate and characterize these kinds of exposures.

- **ATSDR's Mercury Quick Facts for School Nurses**

[http://www.atsdr.cdc.gov/mercury/docs/Mercury\\_School\\_Nurse\\_Brochure.pdf](http://www.atsdr.cdc.gov/mercury/docs/Mercury_School_Nurse_Brochure.pdf)

Information on health effects of mercury exposure, steps to take when a spill occurs, and reducing the risk of exposure in schools.

- **EPA's Schools and Mercury**

<https://www.epa.gov/schools-healthy-buildings/mercury-concerns-during-renovations-healthy-school-environment>

EPA's website includes links to websites that provide information for school administrators, faculty, staff, local health jurisdictions, and parent groups on how to reduce the hazards of mercury on children's health, avoid chemical liabilities, develop planning tools, and establish collection programs for mercury.

- **EPA's Chemical Management Resource Guide for School Administrators**

<https://www.epa.gov/chemicals-under-tsca>

This website can help your school reduce the use of dangerous chemicals and install safer chemical management practices. The website will help school administrators set policies that protect against dangerous chemical exposures, and parents and concerned citizens determine if their children's schools are minimizing potential exposure to dangerous chemicals.

- **Northeast Waste Management Officials' Association (NWMOA)'s Mercury in Schools and Communities**

<http://www.newmoa.org/prevention/mercury/schools/>

NEWMOA developed outreach and assistance materials to assist communities in identifying and removing elemental mercury and products containing mercury from schools and from homes.

- **Healthy School Environments: Toolkit for Safe Chemical Management**

<https://www.epa.gov/schools-chemicals>

<https://www.epa.gov/schools-chemicals/toolkit-safe-chemical-management-k-12-schools>

Helps schools and school districts start or improve a chemical management program to reduce chemical hazards and prevent future chemical mismanagement issues.

# Appendix E

## Acronyms



**µg/L:** micrograms per liter

**µg/m<sup>3</sup>:** micrograms per cubic meter

**ACGIH:** American Conference of Governmental Industrial Hygienists

**APR:** Air Purifying Respirator

**ARARs:** Applicable or Relevant and Appropriate Requirements

**ASTM:** American Society for Testing and Materials

**ATSDR:** Agency for Toxic Substances and Disease Registry

**BEIs<sup>®</sup>:** Biological Exposure Indices

**BMS:** Bristol-Myers Squibb

**CDC:** Centers for Disease Control and Prevention

**CIC:** Community Involvement Coordinator

**DOE:** U.S. Department of Energy

**EERS:** Emergency and Rapid Response Services

**EPA:** U.S. Environmental Protection Agency

**ERT:** Environmental Response Team

**ESLI:** End-of-Service-Life Indicators

**FDA:** U.S. Food and Drug Administration

**gms/cc:** grams per cubic centimeters

**HASP:** Health and Safety Plan

**H<sub>2</sub>SO<sub>4</sub>:** Sulfuric Acid

**HCl:** Hydrochloric Acid

**HGV:** Health Guidance Values

**HNO<sub>3</sub>:** Nitric Acid

**HQ:** Headquarters

**IAG:** Inter-Agency Agreement

**IDLH:** Immediately Dangerous to Life or Health

**IRIS:** Integrated Risk Information System

**LOAEL:** Lowest Observed Adverse Effect Level

**mg/day:** milligrams per day

**ml:** milliliters

**mm:** millimeters

**MEBA:** Mercury Export Ban Act

**MRL:** Minimal Risk Level

**MSDS:** Materials Safety Data Sheet

**MVA:** Mercury Vapor Analyzer

**NIOSH:** National Institute for Occupational Safety and Health

**NWMOA:** Northeast Waste Management Officials' Association

**OEM:** Office of Emergency Management

**OSC:** On-Scene Coordinator

**OSHA:** Occupational Safety and Health Administration

**PAPR:** Powered Air-Purifying Respirator

**PPE:** Personal Protective Equipment

**ppb:** parts per billion

**ppm:** parts per million

**REL:** Recommended Exposure Limit

**RCRA:** Resource Conservation and Recovery Act

**RfC:** Reference Concentration

**SCBA:** Self-contained Breathing Apparatus

**SQG:** Small Quantity Generator

**START:** Superfund Technical Assessment and Response Team

**TCLP:** Toxicity Characteristic Leaching Procedure

**TDD:** Technical Direction Document

**TLVs®:** Threshold Limit Values

**TMR IMACTM:** Trace Mercury Removal - Immobilized Metal Affinity Chromatography

**TWA:** Time-weighted Average

**URA:** Uniform Relocation Assistance and Real Property Acquisition Policies Act

**USACE:** U.S. Army Corp of Engineers