Metallic Mercury Emergency Spill Response Field Guide

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1.0 Introduction

Metallic mercury (chemical symbol Hg) occurs naturally in the environment as mercuric sulfide (cinnabar). Mercury is a silvery white metal, liquid at room temperature, that easily breaks up into small droplets and evaporates to form toxic, colorless and odorless mercury vapor. This emergency response field guide is a condensed version of the *Metallic Mercury Spill Response Guide.* The field guide is suitable for use by On-Scene Coordinators (OSC) and other response personnel in the field; refer to the *Metallic Mercury Spill Response Guide* for more detailed information. Mention of trade names or commercial products does not constitute endorsement or recommendation for their use.

This field guide contains sections on:

- **Emergency Response and Protective Measures for Responders**
- **Remediation**
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2.0 Emergency Response and Protective Measures for Responders

Under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) regulations, any mercury release of greater than or equal to one pound (lb) or 0.454 kilograms (kg) is a reportable quantity. The person in charge of the vessel or facility involved in the release must notify the National Response Center at 800-424-8802 (or 202-426-2675 in the Washington DC metropolitan area). See the Occupational Safety and Health Administration (OSHA) 40 Code of Federal Regulations (CFR) 302.6 (section IV.D.3.b) for additional information.[1]

2.1 Assessment of Spill

The level of response to a reported mercury spill will depend on the size of the spill, the number and ages of the persons in the vicinity of the spill (small children are especially susceptible to harm), the amount of time elapsed since the spill occurred, and the speed and extent of contaminant dispersion. Site responders should advise residents and/or workers not to attempt clean up with a conventional vacuum cleaner or broom. These techniques can disperse liquid mercury and mercury vapors into previously uncontaminated areas.

Responders must assess whether the spill is in an open area or a confined space, and whether the release site is a workplace or a residence. Response measures will depend on whether a large amount of mercury was released suddenly, or if the mercury has been released slowly over a period of time. Inhaled mercury vapors pose the greatest threat to human health, with even small spills potentially producing enough mercury vapor to pose a serious health hazard. Intense heat and fire increase the hazard level because mercury may form toxic or explosive compounds when exposed to heat.[2]

For indoor spills, remove people from the room and close door. For outdoor spills, site responders should restrict entry to spill areas, evacuating all unauthorized persons at least 10 to 25 meters (m) (30 to 80 feet) in all directions, and moving them upwind of the spill.[3,4] For large spills, evacuate an area at least 100 m (300 feet) downwind. In case of fire, evacuate the area recommended by the local health and safety personnel.

Site responders should wear chemical protective clothing (see Appendix A or consult manufacturers' specifications).[3,5] Respirators should be worn during emergencies and confined-space entries. Consult National Institute of Occupational Safety and Health (NIOSH) document #73-11024 or OSHA Safety and Health Standards, 29 CFR 1910.134 for lists of respirator specifications (Appendix A). The *Metallic Mercury Spill Response Guide* provides names and contact information for various mercury spill cleanup products. Government regulations concerning exposure limits are discussed in Section 10.

Section 13 also provides a list of contact information for various government and private agencies that assist in mercury spill responses.

2.1.1 Small Spill

If the mercury spill is very small, (e.g., a broken thermometer), follow the directions below to consolidate and contain the spill.[6] The use of protective gloves (nitrile rubber) and shoe covers is preferred.[7]

- Visible, indoor mercury spills can be covered with epsom salts, chelating resins, alum (potassium aluminum sulfate), calcium sulfide, sodium thiosulfate, sulfur and lime, and other mercury vapor adsorbents available through commercial laboratory supply houses, to lower the mercury vapor concentration in the indoor air. This must be done before any attempt is made to remove the mercury.[8,10]
- Roll the mercury beads onto paper or suction them up with an eyedropper, syringe, hand-held mercury aspirator, or a specially equipped vacuum cleaner (NILFISK or MINUTEMAN™, Lab Safety Supply). Commercially-available mercury spill kits may also be used. Pay special attention to floor cracks and spaces between tiles. Avoid bringing metal jewelry in contact with the mercury because mercury forms compounds with most metals, generating heat in the process.

- Mercury on carpeting, upholstery or bedding may be difficult to remove; these items may need to be discarded properly if they cannot be decontaminated.
- Place the mercury into a leak-proof, airtight container, such as a glass jar.
- Place the paper or eyedropper and the gloves in the container as well, and seal it tightly.
- Open the doors and windows.
- Apply mercury indicator powder (commercially available) over the area of the spill.
- Close off the room from the rest of the building. Use fans for a minimum of four hour to ventilate the room.
- Leave mercury indicator powder in place for several hours. A color change indicates that additional mercury is present and additional cleanup is needed. Lack of color change indicates all mercury was removed. Unchanged powder is uncontaminated and may be removed by wet-mopping.
- Consult the local health department on the proper procedure for disposal of the collected mercury. Do not dispose of mercury with other household or office-waste products.
- Contaminated clothing and shoes must not be worn off-site.

2.1.2 Intermediate-Size Spill

Intermediate-sized spills in the workplace may be cleaned up by workers themselves if they have been trained to use spill kits and protective clothing. Gloves, eye protection, shoe covers and laboratory coats are sufficient when cleaning up a spill of a few milliliters (mL) of mercury.[8]

- Keep the area clear of all persons except those cleaning up the spill.
- Make sure the spill area is well ventilated.
- Do not walk through the spilled mercury nor touch it with bare hands.
- Use procedures listed in 2.1.1 to clean up spill.
- Contact the appropriate state or federal agency for disposal instructions. Do not dispose of mercury-containing waste with other workplace waste products.
- Contaminated clothing and shoes must not be worn off-site.

2.1.3 Large Spill

For larger spills, especially those with exposed victims, professional help is essential.[2,3,4,5,8] Upon receiving a report of a large mercury spill responders should take the following actions:

- Contact appropriate Agency (Section 13).
- Advise residents or workers not to disperse mercury or mercury vapors by attempting to sweep up the mercury spill or by attempting to clean up the spill by any other means.

- Move all unauthorized persons, especially children, away from the spill area. If possible, isolate operations, using local exhaust ventilation at the site of the mercury release.
- Close windows and doors and seal off the area. Insure that the ventilation system to the contaminated area is isolated and sealed off as well.
- Vent the contaminated area to the outdoors to maintain negative pressure (when compared to other parts of the building) in the contaminated area.
- Cover large outdoor spills with earth, sand, or other non-combustible materials, followed by plastic sheeting for rain protection.

2.2 First Aid Procedures

Victims of exposure may exhibit any of a variety of symptoms (discussed in Section 9). It is important to move the mercury-exposed victims to fresh air, and call emergency medical services; inform medical responders that mercury is involved.[8] A trained responder should wash the victim's exposed skin thoroughly with soap and water. If the victim's eyes have been in contact with the mercury, flush the eyes with water for at least 20 minutes. If the victim has ingested a large amount of mercury and is still conscious, give the victim a large amount of water to drink, then induce vomiting by having the victim touch the back of their throat with a finger.[12,16] Keep the victim warm and at rest. Get immediate medical attention.

Rescuers are not directly at risk from individuals exposed to mercury vapor, although contaminated clothing can expose rescuers through direct contact or off-gassing of mercury vapor.[2]

Victims or suspected victims of mercury exposure should remain under medical observation for 24 to 48 hours.[3,4] Each victim should get a neurological exam (especially a handwriting test to detect tremors, an early sign of neurological damage). Kidney function and mercury levels in the urine should also be measured. The victims should get chest X-rays to detect signs of chemical pneumonia. An allergist should evaluate the victims' skin for reaction.

3.0 Remediation

Remediation alternatives should be evaluated for timeliness, cost-effectiveness, reliability, duration of useful life, and health and safety considerations. The remediation process and the resulting remediated site should meet regulatory requirements for contaminant removal and disposal, and the removal process should not entail undue noise, dust, odors, or traffic in surrounding neighborhoods.

3.1 Contaminated Air

Mercury vapors inside buildings can be dispersed to the outside atmosphere, where the concentrations quickly fall to acceptable levels, as set by the local health agency/U.S. EPA in consultation with ATSDR for the specific site. Closing off the affected room and heating it to 80-90^{o} F can accelerate the vapor release and dispersal process. Windows should then be opened and

fans turned on in the room to drive the released mercury outside. Mercury vapor levels should be re-checked, and the procedure repeated until the mercury levels drop below the acceptable level.[22]

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 from air streams. 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. Aqueous scrubbers are used to remove organic mercury from the atmosphere.[15]

3.2 Contaminated Personal Belongings

Personnel engaged in the 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. If clothing or shoes are contaminated, personal belongings may be decontaminated using heat, depending on level of contamination. Items may be put into plastic bags, labeled to identify the owners, and collected in a central area. Initial mercury levels inside the bag headspace should be measured and recorded. The bag contents may be heated from approximately 90^{o} F to 140^{o} F for 24 hours, and then vented. Mercury vapor levels should then be measured, and if necessary, the process is repeated until the mercury levels drop below a defined acceptable level.[23]

3.3 Contaminated Water

Several techniques are available for cleaning mercury-contaminated water, as described in the *Metallic Mercury Spill Response Guide*.[1,4,11, 1524]

3.4 Contaminated Soils and Sediments

Large-scale cleanup efforts may be necessary when industrial or mining operations have spilled significant amounts of mercury in surface and subsurface soils, or when several years' worth of accumulation endangers surrounding land areas and waterways. Different types of remediation efforts are discussed in the *Metallic Mercury Spill Response Guide*.[25,26] As with all large-scale remediation efforts, the cleanup process itself should not increase the hazard to public health or to the environment.

3.5 Contaminated Containers

If a container of mercury is found in a home or other unauthorized location, contact the local health department or hazardous material team for instructions on proper disposal.[6] Any disposal container should be airtight or placed inside another container that can be sealed tightly. Wear protective (rubber) gloves when handling the container to guard against contact with any mercury that may be

on the outside of the container. If the mercury has been spilled, leave the area and contact the local health or hazardous material team.

4.0 Post-Cleanup Procedures

At the conclusion of the decontamination procedures the following steps should be taken:

- Facility should be warmed up to 80^{o} F to 85^{o} F for a minimum of eight hours.
- Vent the facility for a minimum of two hours with open door and windows and circulate air with fans.
- Thermostat should then be set for normal living conditions and doors and windows closed for four hours.
- Perform air sampling for mercury vapor, and analyze collected air samples by NIOSH 6009 method.

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

Persons in the spill area should be advised not to remove any mercury from the spill site. Children and adults may be tempted to take some of the mercury home with them or to roll the beads around on desktops or tabletops. This behavior is not only dangerous for the persons directly involved, but it greatly increases the chance of spreading the contamination to hard-to-reach locations away from the area of the spill.

5.0 Disposal

The United States Environmental Protection Agency (U.S. EPA) Hazardous Waste classification for mercury is U 151 (toxic waste).[12] All mercury waste must be managed as a hazardous waste according to federal or state regulations.[11] Any container or inner liner used to hold this waste, any residue, contaminated soil or water, or other debris resulting from cleaning up a mercury spill must be treated as hazardous waste as well. A list of mercury disposal and recycling companies can be found in the *Metallic Mercury Spill Response Guide*.

6.0 Physical Properties of Metallic Mercury[1,2,3,4,7,9,10]

Mercury (CAS# 7439-97-6, DOT# UN 2809, chemical symbol Hg) is a dense (13.59 grams per cubic centimeters [g/cc]), silver-white liquid at room temperature.[9] Unlike other metals, mercury has a significant vapor pressure under ambient conditions (0.002 millimeters [mm]).[9] It is this property that presents the greatest hazard because mercury enters the human bloodstream more readily through inhalation of the vapor than through ingestion of or skin contact with the liquid. Mercury vapor is colorless and odorless. Small amounts of spilled mercury may produce enough vapors to reach hazardous levels in the immediate area of the spill.

Mercury is not flammable, but it generates toxic or explosive compounds at high temperatures.[2,3,10] Mercury

corrodes copper and copper alloys. This may cause structural failure of copper plumbing or electrical wiring and contact materials. Mercury forms explosive compounds with acetylene and its compounds, chlorine, chlorine dioxide, methyl azide, chlorates, nitrates, and ethylene oxide. Mercury is insoluble in water, but dissolves in nitric acid (HNO_3) and hot concentrated sulfuric acid (H_2SO_4). It does not react with dilute hydrochloric acid (HCl), cold H_2SO_4 or alkalies. Mercury forms amalgams (alloys) with most metals (for example, aluminum, calcium, potassium, sodium, and rubidium) except iron, with evolution of large amounts of heat.[9] The heat released can present an additional hazard if there are heat-sensitive materials in the area. Prolonged contact of mercury with ammonia may yield an explosive solid. For this reason, mercury manometers should not be used with ammonia. Mercury also reacts violently with dry bromine.

If there is a fire in addition to a spill, use a fire extinguisher suited to the type of fire (e.g., ordinary combustibles, electrical, flammable liquids).[8,16] Water should not be sprayed directly at the heated mercury, but may be used to cool fire-exposed containers. Minimize the spread of the spill by preventing mercury from entering sewers, waterways, basements, or confined spaces. Do not use steel or aluminum tools or metal equipment, because mercury forms alloys with these metals on contact.

7.0 Anthropogenic Sources of Mercury

Mercury is used in a variety of manufactured products and manufacturing processes.[2] Many applications have been discontinued in recent years because of the health hazards associated with mercury. Metallic mercury is still used in household and workplace products including batteries, fluorescent bulbs, mercury arc lamps, and vapor lamps,[6,10] and in motion-sensitive electrical switches such as those used for car alarms and light-up sneakers.[6] Mercury is present in industrial settings in the form of chemical intermediates and catalysts.[2,4,10,13,14,15] It is used in chlor-alkali plants (chlorine and caustic soda manufacturing) and in the cement, ink, paper, pharmaceutical, leather, and textile manufacturing industries. Mercury is used in various mining operations, including gold extraction.

Coal-fired power plants and copper and zinc smelters are significant sources of mercury releases to the atmosphere. Elevated mercury concentrations in air have been observed near point sources including mines and agricultural fields treated with fungicides.

Mercury is present in many scientific and medical devices, including thermometers, barometers, sphygmomanometers (blood pressure measuring devices), hydrometers, and pyrometers.[2,6] Mercury-containing instruments are found in hospitals and doctors' offices, industrial laboratories, and school laboratories. Amalgam (mercury alloy) dental fillings are also still common.[1,10,13] Medical waste incinerator emissions, medical equipment and general medical waste may be a significant source of environmental mercury.[13]

Other anthropogenic sources of mercury in the soil include organic and inorganic fertilizers (sewage sludge, compost), lime, and fungicides. Because mercury-containing consumer products are often discarded as mixed (household) waste, metallic mercury is also found in municipal incinerator ash, sludge, and landfill wastes.[2,4]

8.0 Exposure to Metallic Mercury[2,6,13,14,17]

Inhalation of mercury in the workplace is the main route of occupational exposure, according to a survey conducted by NIOSH from 1980 to 1983. Most potentially exposed workers are employed in health services, business services, or special trades industries as contractors, chemical technicians, science technicians, registered nurses, or machine operators. Children of workers who are occupationally exposed to mercury are at an increased risk of mercury exposure if their parents wear contaminated clothing home.

Exposure to mercury may be associated with traditional folk medicine and religious practices in Mexican, Caribbean, and Asian communities within the U.S.,[6,13] where it is 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.

Inhalation of mercury vapor poses the greatest risk to health and safety because mercury is absorbed more rapidly through the lungs than through the digestive tract or skin. Metallic mercury is highly lipophilic (has a high affinity for body fat) and is absorbed almost completely by the lungs upon inhalation. Inhaled mercury rapidly diffuses across the lung alveolar membranes and enters the bloodstream. Mercury can accumulate in the kidney and brain over time.[17] A few drops of mercury can raise the vapor concentration in surrounding indoor air to a dangerous level. Air saturated with mercury vapor at 20°C contains a concentration that greatly exceeds toxic limits for humans.

9.0 Health Effects of Mercury Exposure

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.[2,5] The symptoms of acrodynia include flushing, itching, swelling, pink palms and soles of the feet, excess perspiration, elevated blood pressure, sleepiness, irritability and rashes.[6] Exposure to mercury vapor may also produce kidney damage and symptoms of respiratory distress, including lung irritation with coughing, chest pain or chest tightness, shortness of breath, and pulmonary edema (excess fluid buildup in the lungs).[2,17] Mercury-induced chemical pneumonia can be fatal.[6] Victims may experience a metallic taste, abdominal pain, diarrhea, nausea, and vomiting.[2] If the damage is severe, death usually occurs within ten days.[9] Similar neurologic effects are observed after acute, subchronic and chronic exposures, but symptoms intensify and may become irreversible as exposure duration and/or concentration increases.[13] Nervous system effects include tremors, irritability, weakness, chills, headaches, disturbances in vision (changes in visual field or tunnel vision), memory and concentration problems, loss of sensation or paresthesias (abnormal sensation) in extremities, mood and personality changes, ataxia and muscle incoordination.[2,3,6,10] [2,6]

Chronic mercury poisoning may develop gradually without conspicuous warning signs as mercury accumulates in body tissues.[15] Symptoms of repeated exposure include gray skin color and gum problems. Both genders may experience reproductive problems, and there is some limited evidence for spontaneous abortions in women whose husbands were exposed to metallic mercury.[3,17] Developing fetuses may be damaged if the mother is exposed to mercury. Although data are inadequate to classify mercury as to

carcinogenicity, no correlation has been observed between mercury exposure and cancer in animal or epidemiological studies[31].

10.0 Exposure Limits

Several government agencies have established limits for various types of mercury exposure.[2,3,10,13] 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 situations, such as a mercury spill (Table 1).

NIOSH has established 10,000 µg/m^3 as the concentration that is "immediately dangerous to life or health" (IDLH). OSHA's legally enforceable ceiling limit for workplace exposure is set at 100 micrograms per cubic meter (µg/m^3). At no time should the mercury concentration exceed this level. The NIOSH Recommended Exposure Limit (REL) for mercury vapor is set at 50 µg/m^3 as an eight-hour time-weighted average (TWA), with a skin designation (indicating that skin exposure should be prevented).

The American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) for mercury vapor is 25 µg/m^3 (eight-hour time-weighted average).

The U.S. EPA has established a reference concentration (RfC) of 0.3 µg/m^3 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."[29] The Agency for Toxic Substances and Disease Registry (ATSDR) has derived a similar chronic Minimal Risk Level (MRL) of 0.2 µg/m^3. ATSDR has proposed a residential occupancy level of 1.0 µg/m^3 that is considered "safe and acceptable" for occupancy of any structure after a spill, provided no visible mercury is present. ATSDR has also proposed an indoor action level of 10 µg/m^3 at which measures should be taken to isolate residents from potential mercury exposure. This action level approaches levels reported in the literature to cause subtle human health effects. Assuming a short-term exposure duration, it "allows for interventions before health effects would be expected".[32]

Ingestion of 0.3 g of mercury can be fatal to humans, as is 75 milligrams per day (mg/day) in drinking water. The U.S. EPA and Food and Drug Administration (FDA) limit for mercury in drinking water is two ppb. The RCRA limit for mercury in leachate is 200 µg/L.[13] A summary of environmental and occupational health standards and guidelines is presented in Table 1.

11.0 Sampling and Analysis

The *Metallic Mercury Spill Response Guide* provides details on the various methods available for measuring mercury in the environment. Mercury concentrations in air can be determined by real-time portable field instruments, or by air sampling followed by laboratory analysis.

TABLE 1 Environmental and Occupational Health Standards and Guidelines for Inhalation Exposure to Mercury Vapor	
AGENCY	**MERCURY CONCENTRATION (µg/m^3)**
NIOSH IDLH	**10,000**
OSHA Ceiling Limit	**100**
NIOSH REL	**50**
ACGIH TLV	**25**
ATSDR proposed Action Level	**10**
ATSDR proposed residential occupancy level	**1**
ATSDR MRL	**0.2**
U.S. EPA RfC	**0.3**

11.1 Air

11.1.1 Real-Time Air Monitoring

Field instruments are useful for providing real-time surveys of affected areas and identifying "hot spots" that require immediate attention. Real-time mercury vapor monitoring before and after decontamination procedures provides useful information on the progress of the cleanup efforts and helps to identify problem areas that require further attention.

Ambient air monitoring with real-time instruments at outdoor work sites help determine hazards to persons working in the area and to the surrounding community. Air monitoring should be performed in the immediate work area, upwind, downwind, at the fence line or other perimeter, and in the surrounding neighborhood.

The Jerome™ Gold Film Mercury Vapor Analyzer (Arizona Instruments, Inc., Arizona, Model 411 or Model 431) is often used for real-time air monitoring.[13,18] The instrument has a high detection limit of approximately 3 µg/m^3, but is extremely useful for conducting an initial extent of contamination survey. Jerome instruments may be used for indoor or ambient air. The Jerome is factory calibrated (from 0.01 to 0.1 mg/m^3) and mercury vapor results are reported in mg/m^3.

The Lumex RA-915$^+$ (Ohio-Lumex Co., Ohio) 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. The Lumex is factory calibrated (from 1,000 to 40,000 ng/m^3) and mercury vapor results are reported in ng/m^3. See Appendix C for instructions on the use of this instrument.

The Mercury Tracker 3000 is a portable instrument based on resonance absorption of mercury atoms at a wavelength of 253.7 nanometers (nm). The internal computer performs the quantitative evaluation of the real-time mercury concentration in the sample. The Tracker is factory calibrated (from 60 to 300 µg/m^3) and mercury vapor concentration is reported in µg/m^3. See Appendix C for instructions on the use of this instrument.

Table 2 of the *Metallic Mercury Spill Response Guide* provides a comparison of these instruments.

11.1.2 Air Sampling and Analysis

Measurement of low levels of mercury vapor can best be accomplished using laboratory analysis.[15,18,20] This is particularly important in the later stages of cleanup, where site responders are checking for compliance with state and federal regulations or with health risk-based values. Indoor air samples are generally collected on solid sorbent materials (e.g., Hopcalite or silvered Chromosorb P) contained in glass collection tubes connected to personal sampling pumps. Pump flow rates are set to collect 0.25 to 0.50 L/min of air over a period of six to eight hours. No preservatives or special storage conditions are required. However, filter samples should be stored with the filters upright and transported at or near ambient conditions to prevent significant deterioration. Impact and vibration should be avoided during transport because this can dislodge particulates from the filters. Before analyzing the samples, the sorbent material is digested in acid to release the analyte.[21]

Ambient (background) air samples should be taken for comparative purposes. Indoor air samples can be collected under normal conditions of air conditioning or heating.[18] Samples should be collected from the centers of rooms that are occupied a significant number of hours per day, or where field instrument readings indicate potential problem areas. In homes, samples should be collected from living and sleeping areas, with particular attention paid to the sleeping areas of the youngest occupants of the residence. 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).

The most commonly used laboratory analysis method is NIOSH Method 6009: *Mercury*.[20] This method uses cold vapor atomic absorption (CVAA) to measure mercury concentrations in air samples at levels down to 0.1 µg/m^3. Neutron activation analysis is capable of detecting mercury levels down to 0.05 µg/m^3.[15]

11.2 Soil, Sludge and Dust Sampling, Geophysical Detection and Analysis

When it is suspected that mercury has penetrated the soil near a spill area, soil-core sampling may be necessary to determine the extent of contamination. Samples should be collected near the surface and at several depths, depending on the depth of fill material, the geological features of the

site, and the suspected depth of penetration.

A geophysical survey may be necessary at the site of a spill if there is any indication that there may be buried metal containers such as drums or tanks. Various instruments are available to help identify rock fractures, buried objects, and migration of a plume of electrically conductive waste through the groundwater. A series of instrument readings may be used to construct a three-dimensional map to track the transport and fate of a mercury spill.

For large mercury spills a terrain conductivity meter may be appropriate for delineating the extent of gross contamination. However, its effectiveness will be dependent on other metals and interference in the area.

Solid and semisolid wastes should be analyzed for mercury using SW846-7471, *Mercury in Solid or Semisolid Wastes (Manual Cold Vapor Technique)*.[20] Alternately, U.S. EPA 200 series CVAA methods including Methods 245.1, 245.2, and 245.5 may be employed when applicable.

11.3 Water

Water samples (drinking water, groundwater) should be analyzed for mercury using SW846-7471, *Mercury in Solid, or Semisolid Wastes (Manual Cold Vapor Technique)*.[24] The American Society for Testing and Materials (ASTM) method (D3223-80, *Standard Test Method for Total Mercury in Water*) may also be used. When applicable, U.S. EPA 200 series CVAA methods including Methods 245.1 and 245.2 may also be employed.

12.0 Prevention

Education is perhaps the most effective measure for the prevention of mercury spills and the resulting hazards to health and safety. Persons who deal with mercury-containing products and instruments in the workplace should be trained in safe handling procedures and how to respond in the event of a spill. Emergency procedures placards or signs should be posted in the workplace, including factories, school laboratories, and medical facilities. ATSDR has published an informational document on mercury hazards, intended for the general public.[6] A short video (approximately two minutes run time) suitable for school children is available at no charge from the ERTC.[27] It can be ordered directly from the ERTC Web site.

When it is necessary to work in the vicinity of mercury, adherence to safety precautions will minimize the chances of accidental exposure. Eating, drinking and smoking should be prohibited in areas that might be contaminated. Install eye wash equipment and emergency showers in the workplace near potential spill areas if necessary. Wear safety goggles or face shields when working with mercury.[3] Keep work surfaces free of cracks, crevices, and indentations where mercury could accumulate. Workplace floors should be constructed of a nonporous material. Mercury should be stored in sealed containers inside locked cabinets.[15]

Small children are at risk from spilled mercury in the home because their breathing zones are closer to the floor, where mercury is likely to accumulate.[6] Children are especially susceptible to permanent damage from mercury exposure because their central nervous systems are not fully developed. Children should not be allowed to handle mercury, and should be immediately evacuated from the area of a spill or suspected spill.

13.0 Contact information[3,13]

U.S. EPA/ERTC

2890 Woodbridge Avenue, Building 18,
Edison NJ 08837

Emergency Response during business hours:	(732) 321-6740
24-hour Emergency Response:	(732) 321-6660

Other Agencies

ATSDR Emergency Response Hotline:	(404) 498-0120
ATSDR Division of Toxicology 1600 Clifton Road NE, Mailstop E-29 Atlanta GA 30333	(404) 498-0160 (888) 422-8737
U. S. Coast Guard (USCG) National Response Center & Terrorist Hotline: (Washington DC metropolitan area):	(800) 424-8802 (202) 426-2675
New Jersey Department of Health and Senior Services:	(609) 984-1863
New Jersey Department of Environmental Protection Hotline:	(877) 927-6337
CHEMTREC:	(800) 424-9300

For Long-Term Response Efforts

The Association of American Railroads, Bureau of Explosives:	(719) 584-0610
U. S. Department of Transportation (DOT) Hotline:	(202) 267-5190
CHEMTREC:	(800) 424-9300

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15.0 Acronyms and Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
BMS	Bristol-Myers Squibb
CAS	Chemical Abstract Society
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cm	centimeter
CVAA	Cold Vapor Atomic Absorption
DOE	Department of Energy
DOT	Department of Transportation
ELSI	End of Service Life Indicator
EM	electromagnetic
ERTC	Emergency Response Team Center
F	Fahrenheit
FDA	Food and Drug Administration
g	gram
g/cc	grams per cubic centimeter
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
GPR	Ground-Penetrating Radar
HAZDAT	ATSDR's Hazardous Substance Release and Health Effects Database
HCl	Hydrochloric acid
Hg	Metallic Mercury
Hg^{+2}	Mercuric ion
HgS	Cinnabar
HNO_3	Nitric acid
H_2SO_4	Sulfuric acid
IDLH	Immediately Dangerous to Life and Health
IP	Ionization Potential
kg	kilogram
km	kilometer
lb	pound
L/min	Liters per minute
m	meter
mL	milliliter
mm	millimeter
mg/day	milligrams per day
mg/kg	milligrams per kilogram
mg/m^3	milligrams per cubic meter
µg /L	micrograms per liter
µg	micrograms

µg/m^3	micrograms per cubic meter
MRL	Minimal Risk Level
NIOSH	National Institute for Occupational Health
ng	nanogram
ng/m^3	nanograms per cubic meter
ng/g	nanograms per gram
ng/L	nanograms per liter
nm	nanometers
NOES	National Occupational Exposure Survey
NPL	National Priorities List
OSC	On-Scene Coordinator
OSHA	Occupational Safety and Health Administration
ppm	parts per million
ppb	parts per billion
PTFE	polytetrafluroethylene
RCRA	Response Conservation and Recovery Act
REL	Recommended Exposure Limit
RfC	Reference Concentration
TLV	Threshold Limit Value
TMR/IMAC™	Trace Mercury Removal Immobilized Metal Affinity Chromatography
TWA	Time-Weighted Average
USCG	United States Coast Guard
U. S. EPA	United States Environmental Protection Agency
UV	ultraviolet
V	volt

APPENDIX A

Specifications for Respirators and Protective Gear

Respirator Specifications:[3,5]

Potential Exposure to Mercury (mg/m^3)	Assigned Protection Factor	Respirator Specifications
0.05 - 0.5	10	8-hour average, airborne exposure, use NIOSH/MSHA-approved half-mask respirator with cartridges providing protection against mercury (ELSI required), or any supplied-air respirator
1.25	25	Any supplied-air respirator operated in continuous-flow mode. Any powered, air-purifying respirator with cartridges providing protection against mercury, ELSI required
2.5	50	Any chemical cartridge respirator with a full facepiece, with cartridges providing protection against mercury, ELSI required. Any air-purifying, full facepiece respirator (gas mask) with a chin-style, front- or back-mounted canister providing protection against mercury, ELSI required. Any supplied-air respirator that has a tight-fitting facepiece and cartridges providing protection against mercury. Any self-contained breathing apparatus with a full facepiece. Any supplied-air respirator with a full facepiece
Escape	50	Any air purifying, facepiece respirator (gas mask) with a chin-style, front- or back-mounted canister providing protection against mercury appropriate self-contained breathing apparatus
10	2000	Any supplied-air respirator operated in a pressure-demand or other positive-pressure mode. NIOSH defines this level as immediately dangerous to life and health (IDLH)
High Exposure		MSHA/NIOSH-approved supplied-air respirator with a full facepiece operated in positive pressure mode or with a full facepiece, hood, or helmet in continuous flow mode. Or use an MSHA/NIOSH-approved self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode
28 mg/m^3 or entry and escape from unknown or IDLH conditions	10,000	Immediately dangerous to life and health (IDLH). If the possibility of this level of exposure exists, use a MSHA/NIOSH-approved self-contained breathing apparatus with a full facepiece, operated in pressure-demand or other positive-pressure mode, or a combination respirator that includes type-C supplied-air respirator with a full facepiece, operated in pressure-demand or other positive-pressure or continuous flow mode, in combination with an auxiliary self-contained breathing apparatus, operated in pressure-demand or other positive-pressure mode

Be sure to consider all potential sources of exposure. You may need a combination of prefilters, cartridges, or canisters to protect against different forms of mercury (e.g., vapor and mist) or against mercury mixed with other chemicals.

ELSI = End of service life indicator

Materials for Protective Clothing:[4,8]

Butyl Rubber (IIR, Butyl)	compatible, recommended
Butyl Rubber/Neoprene (butyl rubber laminated with neoprene)	good resistance, based on a small amount of qualitative data or inconsistent data
Chlorinated Polyethylene (CPE)	recommended
Fluorocarbon Rubber (Viton®, FPM, VIT)	recommended
Viton/Neoprene (Viton laminated with neoprene)	good resistance, based on a small amount of qualitative or inconsistent data
Neoprene (chloroprene rubber, CR, NEO)	limited to good resistance, based on a small amount of qualitative data or inconsistent data; recommended, no effect to garment
Nitrile Rubber (NBR, Nitrile)	recommended
Polycarbonate (PC)	compatible
Polyvinyl Chloride (PVC)	good resistant recommended
Small spills:	nitrile rubber gloves, laboratory coat, eye protection
Spill No Fire / Rescue:	Sealed chemical suit (structural protective suit is inadequate), self-contained (polycarbonate, butyl rubber, viton, nitrile, PVC, chlorinated polyethylene, neoprene)
DuPont Barricade™ Suits (Level A/hooded/totally-encapsulating)	Greater than 480 minutes breakthrough time under conditions of continuous contact, 0 mg/m^3/min permeation rate, Performance Index Number 0 (scale of 0 to 5, with 0 being highest resistance), this material is designated as toxic, and is believed to present significant risk of skin absorption
Saranex ™	Greater than 4 hours breakthrough time, this material is designated as toxic, and is believed to present a significant risk of skin absorption
DuPont Tyvek™ suits (Sarane –23)-	Greater than 210 minutes breakthrough time, less than 0.01 mg/m^3 /min permeation rate, Performance Index Number 1 (scale of 0 to 5, with 0 being highest resistance)
DuPont Tyvek suits (Sarane –23, 2-ply)-	Greater than 480 minutes breakthrough time, less than 0 mg/m^3/min permeation rate, Performance Index Number 0 (scale of 0 to 5, with 0 being highest resistance)

For more information:

OSHA 1910.134 necessary for proper respirator use	workplace conditions, worker training, respirator fit testing, medical exams

OSHA Pub. 3077
OSHA Safety and Health Standards
NIOSH Pocket Guide[5]

Personal Protective Equipment
29 CFR 1910.134

APPENDIX B

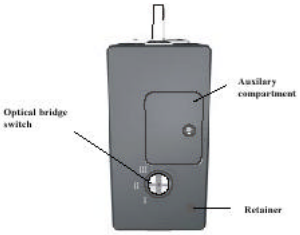
INSTRUCTIONS FOR THE USE OF LUMEX RA-915^{+}

PRE-OPERATIONAL PROCEDURES

Instrument can be used in two modes:

- Self Contained Operation, no preparation required.
- Operation with a stand alone PC, connect the PC to the instrument with the necessary RS-232 cable. Make sure that the instrument and the PC are turned off before making the RS-232 connection

FRONT PANEL



BACK PANEL

LEFT PANEL

Instrument can be run either with the built-in battery or with the use of a low voltage power adaptor.

1. Set the handle of the test cell on the left panel in the **OFF** position and the optical bridge handle on the back panel to position **III**.
2. Switch on the analyzer on with the power button located in the front panel.
3. Press the **Ent** button on the display monitor to go from the Lumex logo to the **MAIN MENU**. An asterisk sign * will appear in the upper left corner of the main menu.

4. Press and hold for several seconds the **LAMP IGNITION** button (front panel). When the spectral lamp turns on, the * sign will go out. (If * `is showing then the lamp is not on or is too weak for use)
5. Warm up the instrument for at least 20 minutes before use.
6. Set the operational parameters by using the SETTINGS command from the main menu by using the cursor control buttons and **Ent** button.
7. Select Language and press **Ent** button.
8. Select the **PARAMETERS** command and change the measurement parameters as necessary. In most cases the default values are used.

PARAMETER	RANGE	DEFAULT
Bas. Corr. Time, sec.	10-255	10
Frame time, sec.	1-255	10
Integr. Time, sec.	1-255	150
Low limit, ng/m^3	1-255	20
High limit, ng/m^3	1-10,0000	100

INSTRUMENT CALIBRATION

1. **TEST** handle in the **OFF** position (left panel).
2. Select **TEST** command from the MAIN MENU.
3. Set the **OPTICAL BRIDGE** to position III (Back Panel) as instructed on the screen and press **Ent** button. Instrument being zeroed.
4. Set the **TEST** handle (left panel) to the **TEST CELL** position (after rotating it back and forth several times) as instructed on the screen. Press **Ent** button.
5. If the **TEST** screen shows Deviation (**R, %**) of equal to or less than 25% then the instrument is functional.
6. Press the **ESC** button.
7. **TEST CELL** handle back to the **OFF** position and press **Ent** button. Main menu will appear.

ON STREAM ANALYSIS (Measurement of Mercury Vapor Concentrations in Air)

1. **TEST** handle in the **OFF** position.
2. Set default parameters using the **PARAMETERS** command.
3. Select **ON STREAM** from the **MAIN MENU** screen and press **Ent** button.
4. **SET OPTICAL BRIDGE TO POSITION III** as instructed on the display screen and press the **Ent** button.
5. The ON STREAM mode screen will appear on the display.

Mercury vapor concentration is measured in terms of ng/m^3.

$1\ ng/m^3 = 0.001\ mg/m^3 = 0.000001\ mg/m^3$

$1\ mg/m^3 = 1000\ mg/m^3 = 1{,}000{,}000\ ng/m^3$

INSTRUCTIONS FOR THE USE OF MERCURY TRACKER 3000

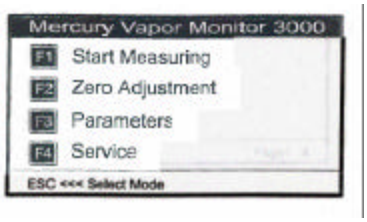
1. Turning on the instrument ignites the mercury lamp and the instrument is stabilized within 15 to 25 minutes.
2. The LCD monitor will indicate that the lamp is ignited and is stabilizing.
3. After stabilization an Auto Zero is performed. The Auto Zero Mode screen reads:

   Absorbance: 0.0001
   Concentration: 0 µg/m^3
   Time left: 17

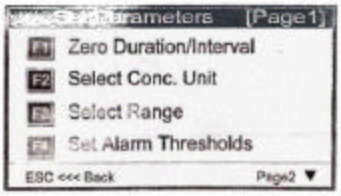
4. After auto-zeroing the instrument automatically goes into the measuring mode. The screen displays:

   Absorbance: 0.0000
   Next Auto-Zero in 15 min
   Concentration: 0 µg/m^3

5. Press the ESC key twice to return to the main menu.



6. Pressing the F2 key manually performs the zero point adjustment.
7. Press F3 to set the parameters, typical values are:



   Zero Duration: 30 seconds
   Zero Interval: 30 minute
   Concentration Unit: µg/m^3
   Range: 0.100

8. Data logger can be used for logging in data and up to 15000 measurements can be stored.