

## NRT Quick Reference Guide: Mustard-Lewisite Mixture (HL)



GHS: Acute Toxicity, Category 1  
 H310 – Fatal in contact with skin  
 H330 – Fatal if inhaled



GHS: Eye Damage/Irritation, Category 1  
 H318 – Causes serious eye damage

### 1. Agent Characteristics

#### Agent Characteristics

**Agent Classification (HL):** Schedule 1 Chemical Warfare Blister (Vesicant) Agent. HL is mixture of Sulfur Mustard (HD; CAS: 505-60-2) and Lewisite (L-1; CAS: 541-25-3) and has some properties of both. Its properties are related to the exact composition, and the composition will vary with manufacturing process and changes after dispersion.

**HL CAS:** Not available (NA). Given that the composition of HL in an actual incident may be unknown, the user should refer to QRGs for L-1 and HD. Decontamination verification must include both L-1 and HD.

**Description:** HL is a dark, oily liquid. HL may have a geranium, garlic, onion, horseradish, or mustard-like odor, depending on the amounts of L-1 and HD present. However, odor should not be depended on to detect HL (see Caution under Section 7.3 below).

This QRG is based on munitions-grade HL, which has a composition of 63/37% by bulk weight of L-1/HD respectively. This HL mixture requires lower ambient temperatures before it will freeze; this property allows for improved ground dispersal and aerial spraying.

HL is both a blister agent (vesicant) and an alkylating agent (causes damage to the DNA of rapidly dividing cells). Exposure to large amounts of HL may be fatal. HL as a blister (vesicant) agent has both immediate effects and delayed health effects on the order of hours, and contains a reported, known human carcinogen. It can be manufactured at different concentrations; with impurities, additives, or thickening materials that will all affect physical properties, appearance, persistence, and analytical detection limits.

Environmental breakdown (hydrolysis) products of HL are easily formed and include both relatively non-toxic compounds, such as thiodiglycol (TDG) [CAS 111-48-8] and hydrochloric acid (HCl), and highly toxic arsenic (III) compounds, such as 2-chlorovinyl arsenous acid (CVAA), 2-chlorovinylarsenious oxide (lewisite oxide), and arsenites; some of which cause blistering similar to L-1. Due to its low freezing point, HL remains a liquid in cold weather and at high altitudes. Decontamination byproducts of HL include toxic mustard sulfone/sulfoxide, as well as arsenic (V) compounds that are generally less toxic than arsenic (III) compounds, but may be considered hazardous.

**Persistence:** HL may be considered a "semi-persistent" chemical warfare agent with liquid deposition on surfaces lasting for hours to days, with the liquid composition changing over time. Persistence will depend upon amount and purity of the agent, method of release, environmental conditions, and the types of surfaces and materials impacted. HL remains a liquid at low temperatures and is persistent in colder climates. **Many vesicant and toxic environmental breakdown products and decontamination byproducts are persistent.** Under certain environmental conditions, when protected from environmental degradation processes, HL breakdown products may persist in soils for decades. Porous, permeable, organic, or polymeric materials such as carpets, vinyl tiles, and painted surfaces can accumulate HL vapors and liquids, acting as "sinks," thereby prolonging persistence.

**Note:** Under certain environmental conditions, Sulfur Mustard (HD) liquid may go through a partial hydrolysis that results in an outer protective coating around "globules" that are resistant to further hydrolysis and can persist for decades if not physically disturbed (see HD QRG). It is unknown if this occurs for HL.

### 2. Physical Properties

#### Physical Properties

<p><b>Molecular Weight:</b> 186.4 g/mol based on eutectic mixture of 63/37% weight L-1 and HD</p> <ul style="list-style-type: none"> <li>• Lewisite (L-1): 207.32 g/mol</li> <li>• Sulfur Mustard (HD): 159.08 g/mol</li> </ul>	<p><b>Formula:</b> NA (mixture of L-1 and HD)</p> <ul style="list-style-type: none"> <li>• L-1: C<sub>2</sub>H<sub>2</sub>AsCl<sub>3</sub></li> <li>• HD: C<sub>4</sub>H<sub>8</sub>Cl<sub>2</sub>S</li> </ul>
<p><b>Vapor Density:</b> 6.5 (air = 1)</p>	<p><b>Flash Point:</b> Not established; assume 219-221°F/104-105°C (HD)</p>
<p><b>Vapor Pressure:</b> 0.248 mm Hg (68°F/20°C)</p>	<p><b>Liquid Density:</b> 1.66 g/mL at (68°F/20°C)</p>
<p><b>Volatility:</b> 2,730 mg/m<sup>3</sup> (68°F/20°C)</p>	<p><b>Melting/Freezing Point:</b>                      Purified mix: 13°F (-25.4°C)                      Typical production batch: -43.6°F (-42°C)</p>
<p><b>Boiling Point:</b> Indefinite, but below 374-378°F/190-192°C</p>	<p><b>Non-aqueous Solubility:</b> Common organic solvents, alcohols, gasoline, oils, fats</p>

<p><b>Hydrolysis (t<sub>1/2</sub>):</b>  <b>L-1:</b> Rapid for vapors or dissolved L-1 but limited by low aqueous solubility  <b>HD:</b> The rate of HD hydrolysis is controlled by the speed of dissolution of the HD into water. Once HD is dissolved in bulk water, hydrolysis proceeds rapidly. (See HD QRG)</p>	<p><b>Aqueous Solubility:</b> Slightly soluble based on solubilities of L-1 and HD individually (See L-1 and HD QRGs)</p>
<p><b>Note:</b> physical properties are listed at/near STP unless otherwise indicated. Properties are for the munitions-grade HL mixture (63/37% L-1/HD, w/w). Other HL mixtures will have different properties.  <b>Conversion Factors for HL:</b> ppm = mg/m<sup>3</sup> x 0.122; mg/m<sup>3</sup> = ppm x 8.21 (assuming MW = 186.4). Also see L-1 and HD QRGs.</p>	

### 3. Release Scenarios

Release Scenarios
<p><b>AIR RELEASE SCENARIOS ARE ASSUMED MOST PROBABLE; HOWEVER, OTHER RELEASE SCENARIOS AND EXPOSURE ROUTES SHOULD BE CONSIDERED.</b></p> <p><b>Open Areas:</b> HL has moderate volatility, and could be dispersed as a vapor or a liquid spray (aerosol), depending upon the percentages of L-1 and HD within the HL mixture. The primary release/attack scenarios are cold weather operations and airborne releases. HL is expected to degrade in the environment fairly rapidly; however, liquid HL on surfaces could persist for days. Environmental conditions will affect the degradation and evaporation rates of HL with cooler and drier conditions enhancing persistence. <b>HL has a melting/freezing point at -25.4°C (-13°F), so the reaerosolization of liquids and solids, as ambient temperatures rise, may present an inhalation hazard.</b> HL vapors are heavier than air, so vapors can accumulate in lower terrains.</p> <p><b>Water/Water Systems:</b> HL released into water will likely hydrolyze within a few hours into vesicant and toxic compounds, which may persist for days to weeks. In sufficient amounts (relative to water volume). HD may form HD “globules” surrounded by an outer protective coating resistant to further hydrolysis. These HD globules may settle out or be entrapped, and can persist for considerable periods of time (years, decades), while retaining vesicant properties, posing a contact hazard to anyone disturbing them. Areas in which the globules may persist include stagnant volumes of water as small as puddles formed by precipitation events. It is unknown if this occurs for HL. If released into water systems such as reservoirs, treatment plants, distribution systems, public fountains or pools, their treatment processes may result in further reaction with HL. Water systems, plumbing, surfaces and equipment that have contacted contaminated water, including potential HD globules, must be evaluated for decontamination along with the bulk water.</p> <p><b>Indoor Facility:</b> HL may be considered as a semi-persistent agent with moderate volatility, and could potentially be distributed inside a building or facility; HVAC systems could potentially be impacted. Liquid HL may result in localized areas of surface contamination. HVAC system intakes near to liquid HL should be investigated for contamination from HL vapors and aerosols. HL vapors are heavier than air so vapors can accumulate in lower levels, basements, floor drains, or utility corridors inside the buildings.</p> <p><b>Other:</b> HL is combustible; agent may burn but does not ignite readily. Fire may produce irritating, corrosive, and/or toxic gases. When heated, vapors may form explosive mixtures with air, presenting an explosion hazard indoors, outdoors, and in sewers. Containers may explode when heated. If HL is released into the air as a liquid spray (aerosol), it has the potential to contaminate agricultural products. If HL is released as a vapor, it is highly unlikely to contaminate agricultural products.</p>

### 4. Health Effects

Health Effects
<p><b>4.1. Onset:</b> Following exposure to HL, onset of symptoms from L-1 is rapid (within seconds to minutes); the effects of HD are more delayed. Severity of effects depends on dose, duration, and route of exposure (not all signs/symptoms may develop). The effects caused by L-1 or HD are not typically fatal immediately, but can require substantial supportive medical care, and secondary infections from blisters/tissue damage may also be fatal.</p> <ul style="list-style-type: none"> <li>• L-1 can cause immediate eye pain and eye/skin/respiratory tract irritation. L-1 can cause skin redness within 15-30 minutes. Blister formation and deep skin burns are approximately 12 hours post-exposure. Eye lesions are very serious resulting in blindness unless decontamination is very prompt</li> <li>• Following HD exposure, actual signs/symptoms (eye irritation, coughing, reddening and burning of skin) are <b>delayed 1-48 hours after exposure</b>, so those exposed may not be aware.</li> </ul>
<p><b>4.2. Signs/Symptoms:</b> Symptoms will vary depending on dose and exposure route (see EXPOSURE ROUTES section below). The following is a general list of possible symptoms. The severity of effects depends upon the dosage.  <b>Mild to Moderate:</b> Immediate stinging and burning pain and strong irritation of eyes, tear production, spasmodic blinking, swelling and fluid accumulation in the eye membranes and eyelids, and inflammation of the cornea. Irritation of mucous membranes in the nose and lower airways, immediate burning nasal pain, violent sneezing, nosebleed, sinus</p>

pain, inflammation of the voice box, cough, and difficulty breathing or shortness of breath. Immediate stinging and burning pain or irritation of skin, redness, delayed blistering with pain, and itching.  
**Severe:** Blistering and scarring of the cornea, rupture of the eye, and blindness. Inflammation of the lungs, accumulation of fluid in the lungs, respiratory failure, and death. Severe blistering and severe burns on skin.  
**Cumulative:** HL has properties of both L-1 and HD. It causes blisters (is a vesicant) and binds to DNA and damages rapidly dividing cells (is an alkylating agent). The alkylating properties of HL make it particularly toxic to the blood-forming tissues (e.g., the bone marrow). Whole-body (systemic) absorption of HL may result in bone marrow suppression and an increased risk for fatal complicating infections. The rate of detoxification of HL in the body is very slow, and repeated exposure is likely to cause a build-up of the agent in the body.

**4.3. Exposure Routes:**  
**Inhalation:** Vapor is absorbed through mucous membranes (mouth, nose, throat, lungs). Respiratory exposure to vapor produces immediate irritation of the upper, then the lower, respiratory tract; with increasing doses, inflammation is more severe and progresses deeper into the respiratory tract.  
**Skin:** Direct contact with liquid or vapor from the HL mixture can cause stinging and burning pain and redness immediately. Blistering can be delayed for hours, but it appears earlier than with exposure to pure HD. Warm and sweaty skin areas (underarms, groin) are most susceptible to exposure.  
**Eyes:** Eyes are the most sensitive to L-1 and HD vapors. Vapors are absorbed through mucous membranes. Symptoms occur immediately; irritation, burning, gritty feeling, itching, weeping, reddening, lid swelling, light sensitivity, pain, and corneal injury. High concentration effects are extremely painful and generally require extended medical treatment. Rapid decontamination (within minutes of exposure) using copious amounts of water is the only way to limit eye injury.  
**Ingestion:** Consumption of contaminated food or drink could cause burning, nausea, and vomiting.

## 5. Effect Levels

Effect Levels					
<b>Air (inhalation vapor hazard): Acute Exposure Guideline Levels (AEGLs) for general population one-time exposure emergency scenarios are not available for HL. However, AEGLs are available for L-1 and HD</b> (complete definitions are available at: <a href="https://www.epa.gov/ae-gl">https://www.epa.gov/ae-gl</a> ). Because AEGLs are not available for HL, use the lower of L-1 or HD values from tables below. NA = Not available.					
AEGL Level in mg/m <sup>3</sup> , at various exposure durations for L-1	10 min.	30 min.	1 hr.	4 hr.	8 hr.
AEGL 1: Threshold mild effects	NA	NA	NA	NA	NA
AEGL 2: Potentially irreversible effects or impaired ability to escape	1.3	0.47	0.25	0.070	0.037
AEGL 3: Threshold for severe effects/medical needs/increasing potential for lethality	3.9	1.4	0.74	0.21	0.11
AEGL Level in mg/m <sup>3</sup> , at various exposure durations for HD	10 min.	30 min.	1 hr.	4 hr.	8 hr.
AEGL 1: Threshold mild effects	0.40	0.13	0.067	0.017	0.008
AEGL 2: Potentially irreversible effects or impaired ability to escape	0.60	0.20	0.10	0.025	0.013
AEGL 3: Threshold for severe effects/medical needs/increasing potential for lethality	3.9	2.7	2.1	0.53	0.27
American Industrial Hygiene Association (AIHA) Emergency Response Planning Guidelines (ERPG™) are not established/determined for L-1 or HD.					

## 6. Exposure Guidelines

Exposure Guidelines	
<b>6.1. Airborne Exposure Limits (AELs): Exposure Guidelines are not available for HL directly. See below for L-1 and HD values.</b>	
CDC has issued recommendations for protecting human health from potential adverse effects of exposure to L-1 and HD. (refer to: NIOSH ERSB-DB, for L-1: <a href="https://www.cdc.gov/niosh/ersbdb/emergencyresponsecard_29750006.html">https://www.cdc.gov/niosh/ersbdb/emergencyresponsecard_29750006.html</a> , and for HD: <a href="https://www.cdc.gov/NIOSH/ersbdb/EmergencyResponseCard_29750008.html">https://www.cdc.gov/NIOSH/ersbdb/EmergencyResponseCard_29750008.html</a> ) (NA = not available)	
<b>Lewisite (L-1) Exposure Guidelines:</b>	
CDC/National Center for Environmental Health (NCEH) IDLH = NA DOD/Army IDLH Equivalent = 0.36 mg/m <sup>3</sup> ; proposed value for Pine Bluff but considered a safe estimate for other IDLH applications. Workers should remove themselves immediately from exposure if the concentration is reached at any point in time. [original source: Army OTSG memorandum, New Immediately Dangerous to Life and Health (IDLH) Concentration Level for Lewisite (August 24, 2009)]	

<b>CDC/NCEH STEL = NA</b>
<b>CDC/NCEH Worker Population Limit (WPL) = 0.003 mg/m<sup>3</sup> **</b>
<b>CDC/NCEH General Population Limit (GPL) = 0.003 mg/m<sup>3</sup> **</b>
** the value 0.003 mg/m <sup>3</sup> is a detection value that can be used as safe level for all civilian worker and general population exposures including long term. These L-1 values for WPL and GPL are based on detection limit and are not health-based. [original source: NCEH, Final Recommendations for Protecting Human Health and Safety against Potential Adverse Effects of Long-term Exposure to Low Doses of Agents: GA, GB, VX, Mustard Agent (H, HD, T), and Lewisite (L-1); 53 FR 8504-8507 (March 15, 1988); (corrected in 53 FR 11002 (April 4, 1988))]
<b>Sulfur Mustard (HD) Exposure Guidelines:</b>
<b>CDC/NCEH IDLH = 0.7 mg/m<sup>3</sup></b> ; workers should remove themselves immediately from exposure if the concentration is reached at any point in time
<b>CDC/NCEH STEL = 0.003 mg/m<sup>3</sup> (3 × 10<sup>-3</sup>)</b> ; exposure at the STEL should be as short as practical (but no longer than 15 minutes) and should not occur more than once per day
<b>CDC/NCEH Worker Population Limit (WPL) = 0.0004 mg/m<sup>3</sup> (4 × 10<sup>-4</sup>)</b>
<b>CDC/NCEH General Population Limit (GPL) = 0.00002 mg/m<sup>3</sup> (2 × 10<sup>-5</sup>)</b>
[original source: CDC, National Center for Environmental Health (NCEH), Interim Recommendations for Airborne Exposure Limits for Chemical Warfare Agents H and HD (Sulfur Mustard), 69 FR 24164-24168 (May 3, 2004).]

**6.2. Occupational:** (NA = not available)

**Lewisite (L-1):**

<b>NIOSH IDLH = NA</b>	<b>OSHA PEL = NA</b>
<b>NIOSH REL-TWA = NA</b>	<b>ACGIH TLV-TWA = NA</b>
<b>NIOSH REL-STEL = NA</b>	<b>ACGIH TLV-STEL = NA</b>

**Sulfur Mustard (HD):**

<b>NIOSH IDLH = NA</b>	<b>OSHA PEL = NA</b>
<b>NIOSH REL-TWA = NA</b>	<b>ACGIH TLV-TWA = NA</b>
<b>NIOSH REL-STEL = NA</b>	<b>ACGIH TLV-STEL = NA</b>

**Arsenic:** Refer to site-specific HASP for any occupational exposure guidelines for Arsenic relevant to response activities. (for more information on arsenic, see NIOSH Pocket Guide to Chemical Hazards: Arsenic, inorganic compounds (as As), <https://www.cdc.gov/niosh/npg/npgd0038.html>).

**6.3. Population:**

**Soil: USAPHC Health Based Environmental Screening Levels (HBESL) =**

- **L-1:** 3.7 mg/kg over work life for Industrial Soil; 0.3 mg/kg over lifetime for Residential Soil.
- **HD:** TBD. The US Department of Defense (DOD) will be issuing new HBESL values for both industrial and residential soil after DOD completes a reevaluation of toxicological information related to liquid mustard skin exposure and vesication (blistering). Until DOD releases these new HBESL values to the public, DO NOT use current values available from websites and other resources.

**Drinking Water:** EPA Provisional Advisory Levels (PALs): see below for more information.

**EPA Provisional Advisory Level (PAL):** PALs represent chemical concentrations in air or drinking water above which varying health effects (PAL1, PAL2, PAL3) are expected. They are developed for 24-hour, 30-day, and 90-day exposure durations. In the event of a nationally significant or large-scale chemical release, EPA can provide PALs, if available, to appropriate end-users and stakeholders as needed (PALs are not currently available to the public) to assist in response decision-making. Contact: [PALs@epa.gov](mailto:PALs@epa.gov), for information on and access to the PALs. (Note: PALs are not intended to define cleanup levels.)

## 7. Personnel Safety

### Personnel Safety

**Note:** Personal Protective Equipment (PPE) selection (Levels A-D), medical surveillance requirements, First Aid options, and personnel decontamination may vary depending upon the amount and purity of agent, site conditions, and the release scenario. Additional information on personnel safety and PPE selection criteria can be found at: [www.cdc.gov/niosh/ershdb](http://www.cdc.gov/niosh/ershdb). We also recommend that responders check their own internal procedures (i.e., SOPs), if applicable.

**7.1. Medical:**

**Pre-incident:** Must have current medical and respiratory clearances as part of an Occupational Medical Surveillance Program according to OSHA HAZWOPER and Respiratory Protection Program, as per 29 CFR 1910.

**During Incident:** Conduct periodic on-site medical monitoring, observe for any signs and symptoms as per HEALTH EFFECTS section above and treat accordingly as per First Aid section below.

**Post-incident:** Perform post-incident medical surveillance, as per 29 CFR 1910. Because health effects may not occur until several hours after exposure, patients/victims should be under medical surveillance for at least 24-48 hours.

**7.2. First Aid:** Immediately remove person from affected area and remove contaminated clothing and articles. Wash bare skin immediately with water, or warm, soapy water if available, at normal household pressures (~50-60 psi) for three minutes, ensure thorough soaking. Rinse eyes exposed to agent (liquid or vapor; eyes are especially sensitive to L-1 and HD) with potable water for at least 15 minutes. If irritation or pain is severe or persists, prolonged eye washing is advised. Do not cover eyes with bandages. Seek immediate medical attention.

**Antidote: Dimercaprol (a.k.a. British Anti-Lewisite (BAL)).** Dimercaprol is currently used in hospital settings for arsenic poisoning. Antidote should only be administered in a hospital setting. Dimercaprol is given by intramuscular injection as an antidote for whole body (systemic) health effects of arsenic/L-1 poisoning but has no effect on local blisters or lesions of the skin, eyes, or airways. **NO ANTIDOTE AVAILABLE FOR HD; be aware effects of HD are delayed 1-48 hours.**

**Other:** RSDL (Reactive Skin Decontamination Lotion), an FDA-cleared kit with a sponge impregnated with a lotion to remove or neutralize chemical warfare agents from contaminated skin. Apply RSDL immediately to area of skin with suspected exposure to a chemical warfare agent (do not wait for symptoms) and wipe affected area using a scrubbing action, rinse with water when time permits. **NOTE: no citations were currently found for the efficacy of RSDL specifically for HL or L-1, but the application methods and decontamination materials present in RSDL may be useful to neutralize HL or L-1 exposure on skin.**

After administering first aid, send person for follow-up medical attention and evaluation. If cleared to resume work, continue to monitor for signs/symptoms and treat accordingly.

### **7.3. Personal Protective Equipment (PPE):**

**GENERAL INFORMATION:** NIOSH Approved<sup>®</sup> Chemical, Biological, Radiological, Nuclear (CBRN) Self Contained Breathing Apparatus (SCBA), NIOSH Approved Air Purifying Respirators (APR) or Powered Air Purifying Respirators (PAPR), full-face masks, and protective clothing should be used. Level A protection should be used until monitoring results confirm identity and concentration of contaminant. Pre-incident training and exercises on the proper use of PPE are recommended.

**Currently no inhalation exposure guidelines exist for the HL mixture. Use L-1 and HD exposure guidelines.**

**Caution: The L-1 component of HL mixture does NOT provide sufficient warning properties (see AGENT CHARACTERISTICS section above) that would allow appropriate use of APR/PAPR in most contamination scenarios (see Level C).**

Per NIOSH guidance –

**LEVEL A:** Recommended for the initial response to an HL incident. NIOSH Approved CBRN full-face-piece SCBA operated in pressure-demand mode with Level A suit that provides protection against CBRN agents. Level A provides the greatest level of skin (totally encapsulating chemical protective suit and chemical-resistant inner and outer gloves, along with chemical-resistant boots with steel toe and shank), respiratory (SCBA), and eye protection when the contaminant identity or concentration is unknown. Select Level A when the HL concentration is unknown or above the IDLH or AEGL-2 for either L-1 or HD, and when there is a potential of ocular or dermal exposure.

**LEVEL B:** Pressure-demand SCBA (NIOSH Approved CBRN full-face-piece SCBA) with Level B protective suit that provides protection against CBRN agents. Level B provides the highest level of respiratory protection (SCBA) when a lesser level of skin protection is required. Select Level B when the HL concentration is unknown or above the IDLH or AEGL-2 for either L-1 or HD, and when dermal exposure is less of a risk. Level B differs from Level A in that it typically incorporates a non-encapsulating, splash-protective, chemical-resistant outer suit that provides protection against most liquids but is not vapor tight (hooded chemical-resistant outer suit and chemical-resistant inner and outer gloves, along with chemical-resistant boots with steel toe and shank). **The Level B PPE dress-out for HL should be modified to ensure there is no exposed skin or potential for ocular exposure.**

**LEVEL C:** May be selected when the contaminant identity and concentration are known and the respiratory protection criteria factors for the use of APR or PAPR (i.e., < IDLH, warning properties) are met. Level C may be appropriate when decontaminating personnel or equipment. Level C still incorporates hooded chemical-resistant outer suit that provides protection against CBRN agents, chemical-resistant inner and outer gloves, and chemical-resistant boots with steel toe and shank.

- For air levels greater than AEGL-2: NIOSH Approved CBRN tight-fitting PAPR with a filter or a combination organic vapor, acid gas, and particulate cartridge/filter combination or a continuous flow respirator. Since no such values exist for the HL mixture, AEGL-2 values for both L-1 and HD may have to be used.
- For air levels greater than AEGL-1: NIOSH Approved CBRN tight-fitting APR with a canister-type gas mask or CBRN PAPR. Since no such values exist for the HL mixture, AEGL-1 values for both L-1 and HD may have to be used.

**LEVEL D:** Select Level D when the contaminant is known, and the concentration is below the appropriate occupational exposure limits or less than AEGL-1 for the stated duration times. Since no such values exist for the HL mixture, AEGL-1 values for both L-1 and HD may have to be used. PPE includes coveralls or other work clothes, boots, and gloves.

**Downgrading PPE levels can be considered only by the site Health and Safety Officer when the identity and concentration of the contaminant and the risks of dermal exposure are known and must be accompanied by on-site monitoring. Monitoring for L-1 and HD is required during an HL response to ensure that exposure guidelines for**

either have not been exceeded. The on-site availability of any applicable medical countermeasures should also be considered when deciding to downgrade PPE during a CBRN response.

## 8. Personnel Decontamination

### Personnel Decontamination

#### 8.1. Personnel Decontamination Procedure:

Tents, berms, and collection vessels should be able to maintain copious amounts of wastewater in a contained and safe manner. Procedures should be in place to treat and replace contaminated materials used during the decontamination process as well as replace necessary chemicals and decontamination solutions.

Prior to entering the hot zone, all personnel are required to familiarize themselves with the site-specific personnel decontamination procedures.

Personnel decontamination should take place in a decontamination area comprised of two decontamination corridors (one for entering and one for exiting). Position corridors upwind and uphill of release area; exit should be upwind and uphill of entrance. Detergent and water solution (pH>8, but <10.5), soft brushes, and durable 6-mil polyethylene bags should be provided.

Personnel decontamination area workers need to wear appropriate PPE as indicated below. Be aware that absorbed agent can be released from clothing and skin as a vapor. Decontamination wash water (effluent) will contain toxic arsenic. Do not release the wash water (effluent) to the environment. See Section 15.2 below for additional guidance on waste management. Arsenic may be toxic to wastewater treatment plant (WWTP) microorganisms. Only discharge non-RCRA hazardous effluent to a WWTP after approval by the WWTP owner/manager.

Conduct personnel decontamination per NIOSH ERSB-DB:

[https://www.cdc.gov/niosh/ersbdb/emergencyresponsecard\\_29750007.html](https://www.cdc.gov/niosh/ersbdb/emergencyresponsecard_29750007.html)

- **Emergency Responders:** Use soft brush to wash PPE with soap and detergent solution in a downward motion, getting into all folds. Repeat washing and rinsing until thoroughly clean. Remove PPE by rolling downward from head; avoid pulling PPE over the head. Remove SCBA last and place all PPE in polyethylene bags.
- **Patient/victim:** Remove all clothing down to at least undergarments, and place in polyethylene bags. Thoroughly wash and rinse skin with soap and water solution, taking care not to break the skin and covering all open wounds. Cover patient/victim (e.g., blanket, towels, Tyvek) and move to treatment area. If available in decontamination kit, apply RSDL immediately to area of skin with suspected exposure to a chemical warfare agent (do not wait for symptoms) and wipe affected area using a scrubbing action, rinse with water when time permits.

#### 8.2. Personnel Decontamination Procedures by Zone/Step: (attendants will verbally direct personnel through each step)

##### Conducted in Hot Zone (exclusion zone)

1	Equipment Drop	Place equipment taken into the Hot Zone on a plastic covered table or container provided prior to entering the contamination reduction corridor. Equipment will either be reused if more than one entry is planned or will be decontaminated later.
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##### Conducted in Warm Zone (contamination reduction zone)

2	Sample Drop	Place samples in a container provided for sample decontamination. Care needs to be taken to ensure that workers maintain chain-of-custody of samples. It is recommended that samples are decontaminated in a separate decontamination line.
3	Outer Boot and Glove Wash	The purpose of this step is to enable physical removal of gross contamination if contamination is visible. If gross contamination is not visible, this step may be skipped. Wash outer boots and then outer gloves using designated decontaminating agents as specified in HASP (e.g., soap and water, trisodium phosphate substitute, or diluted bleach).
4	Glove, Boot, and Suit Wash	Wash all outer surfaces in a contained area (e.g., kiddie pool) using a pressurized spray with designated decontamination solution. Start with decontaminating boots and gloves, then work on suit from the top down, including SCBA/PAPR casing. Decontamination personnel should conduct this step. Care should be taken to ensure that all areas are decontaminated, including around zipper, arms, front torso, and any other area that could have come in contact with contamination. The solution used for decontamination should be contained, collected, and disposed of properly from the decontamination line.
5	Outer Glove, Boot, and Suit Removal	While sitting on a stool, remove outer boots and outer gloves. Undo the SCBA/PAPR belt and hold in hand. While touching only the inside of suit, carefully roll suit in an outward motion from shoulders down to feet. Dispose of boots, gloves, and suit in a designated container. This step may require decontamination personnel to assist either by holding SCBA/PAPR unit or assisting in suit removal.
6	Mask Removal	With inner gloves, remove the mask. Remove cartridge filters and place into designated container. Put mask into mask wash. Decontamination personnel will clean each mask and SCBA/PAPR assembly prior to return to service.
7	Inner Glove Removal	Remove inner gloves by only touching outside of first glove and then only inside of second glove. Place gloves into designated container.

##### Conducted in Cold Zone (support zone)

8	Quadrant Monitoring	Using appropriate HL, L-1, and HD air monitoring equipment, screen personnel for residual contamination by dividing body into 4 sections: upper right and left sides of the body, and lower left and right sides. If positive, perform spot decontamination immediately and direct person to showers.
9	Personal Shower	Personnel should shower using copious quantities of soap and water for a minimum of 5 minutes and change into clean clothes. If a personal shower is not immediately available then, at the minimum, hands and face should be washed thoroughly.
10	Medical Monitoring	Report to medical monitoring station for post-entry monitoring and report to appropriate personnel for debriefing. Observe for any obvious sign of HL exposure. Using criteria listed above in PERSONNEL SAFETY section of this QRG, administer RSDL and notify site Health and Safety officer.

**Emergency Egress Corridor:** Establish an emergency egress line to use for quickly decontaminating personnel who have medical emergencies while in the hot zone. Personnel must be decontaminated prior to receiving treatment from emergency medical technicians or transported to a hospital.

**Hand-Wash Station:** A hand-wash station with soap and water should be available for personnel to clean up or physically remove any residual decontaminant following entry. If a hand-wash station is not initially available or weather conditions prohibit its use, personnel should wash their hands and face as soon as possible.

**Caution:** Avoid waterless hand cleaners, which contain solvents (alcohols) that could increase risk of dermal exposure to HL.

## 9. Field Detection

### Field Detection

**Real-time field screening tools (results not confirmatory or quantitative): Caution should be given to equipment that has not been properly evaluated. False positive and false negatives may occur in the presence of interferents common in the environment.** The following is a summary of minimum screening concentration ranges or levels for equipment procured by many EPA and HAZMAT response teams. Other screening tools may be used by these teams and other agencies and responders, some with similar capabilities and limitations.

**Currently no instruments measure HL directly; see below for separate tables for field detection of L-1 and HD:**

#### 9.1. Minimum Screening Ranges/Levels for Air/(Vapor):

Field Equipment (L-1):	ppm (L-1)	mg/m <sup>3</sup> (L-1)
JCAD M4A1, at 10 secs [30 mins/pre-concentrator]	0.23-5.9	2-50
AP2C / AP4C (AP2C does not detect As or L-1)	ND / 0.15-1.5 (as Arsenic)	ND / 0.5-13 (as Arsenic)
MX-908 Vapor Mode	NA	NA
Dräger (CDS Kit) / CDS I as Arsine or organic Arsenic	0.1 Arsine / 0.35 organic Arsenic	0.35 Arsine / 3.0 organic Arsenic
MINICAMS™ (Near real-time; at 5 minutes)	0.00035	0.003

Note: ND = not detectable; NA = not available

Field Equipment (HD):	ppm (HD)	mg/m <sup>3</sup> (HD)
JCAD M4A1, at 10 secs [30 mins/pre-concentrator]	8 [0.003]	50 [0.02]
AP2C / AP4C	0.08	0.5
MX-908 Vapor Mode	1.2	7.8
Dräger (CDS Kit)	0.15	1.0
MINICAMS™ (Near real-time; at 5 minutes)	0.0005	0.003

#### 9.2. Minimum Screening Ranges/Levels for Vapor/Liquid:

Field Equipment (L-1):	ppm (vapor) (L-1)	mg/m <sup>3</sup> (vapor) (L-1)	mL (liquid) (L-1)
M256 / M256A1 (as blister only, up to 6 mins below 50° F)	1.1	9-14	0.020 (via M8 paper)
M8 (as blister only)	NA	NA	0.020

Note: M256 is combined 2 kits with 12 disposable sampler/detectors for vapors and a booklet of M8 paper for liquids.  
 NA = not applicable

Field Equipment (HD):	ppm (vapor) (HD)	mg/m <sup>3</sup> (vapor) (HD)	mL (liquid) (HD)
M256 / M256A1 (13 mins)	0.46	3.0	0.02 (via M8 paper)
M8	NA	NA	0.02

Note: M256 is combined 2 kits with 12 disposable sampler/detectors for vapors and a booklet of M8 paper for liquids.  
 NA = not applicable

#### 9.3. Minimum Screening Ranges/Levels for Water:

Field Equipment (L-1):	mg/L (L-1)
M272	0.1-2

Field Equipment (HD):	mg/L (HD)
M272	0.02

## 10. Environmental Sampling

### Environmental Sampling

*Note: This section on sampling contains general guidelines and does not replace the need for a site-specific sampling plan*

**10.1. Sampling Concerns:** Detection, sampling equipment and procedures, and analytical techniques will be site-specific and depend on: 1) physical state of the agent; 2) type of surfaces contaminated (e.g., porous vs. non-porous); 3) the purpose of sampling (e.g., characterization, decontamination efficacy, and clearance); and 4) specific laboratory requirements. The U.S. Environmental Protection Agency (EPA) has set up mobile and fixed labs and analytical assets for chemical agent analysis of environmental samples under their Environmental Response Laboratory Network (ERLN), see ANALYSIS section below, (<https://www.epa.gov/emergency-response/environmental-response-laboratory-network>). For questions on environmental sampling for HL call EPA/HQ-EOC at 202-564-3850.

**10.2. Sample Locations and Planning:** Initially consider air monitoring to ensure worker safety and to determine if there is a vapor plume that could impact other areas. Characterization sampling is initiated by targeted or judgmental sampling to identify “hot spots,” potential agent flow paths, and media or objects potentially acting as sinks. Additional biased or random sampling can be used to determine the extent of potential contamination or to verify the efficacy of decontamination. More thorough probabilistic sampling (e.g., grid, statistical approach) may be required for the clearance phase or if there are large uncertainties about the area impacted or the amount released. Because HL may be considered a semi-persistent liquid, sample priorities should include surfaces that are potentially contaminated with liquid (e.g., release site, low lying areas, HVAC, utility corridors) and areas that people are likely to contact or where food or agricultural products are present.

**Note: There are no sampling and analytical methods specific for HL. Samples should be analyzed for presence of both L-1 and HD agent and their breakdown products.** See ANALYSIS section below to ensure sampling procedures are compatible with all analytes. Some preparation techniques for both L-1 and HD and their breakdown products are available in EPA’s Sample Information Collection Documents (<https://www.epa.gov/esam/sample-collection-information-documents-scids>). These provide general information regarding sampling procedures for different media, sampling supplies, sample size, container, holding time, preservation, packaging, and shipping, supporting collection of samples.

[**Additional note specifically for L-1:** L-1 breaks down in most environmental and decontamination conditions to numerous persistent toxic products, such as arsenites, lewisite oxide, and CVAA; some cause blistering similar to L-1. Because of low capacity for analysis that is specific for L-1 and L-1-related compounds, total arsenic (As) may be used as a marker to determine the extent of contamination of the parent L-1. Arsenic is prevalent in many environments; therefore, determining background As levels is recommended.]

[**Additional note specifically for HD:** HD breaks down in most environmental conditions to numerous breakdown products, especially TDG, which may be used as a marker to determine the extent of contamination of the parent HD.]

#### 10.3. Types of Samples:

**Air** (Vapors are heavier than air): Samples are collected using appropriate solid phase absorbent media (tubes) or air sampler (e.g., SUMMA canister) at breathing zone level (~5 ft.) to assess inhalation exposure. To assess off gassing from surfaces and at ground levels, collect air samples at ~6 in. above the ground. Concurrent air sampling and monitoring of air and air particulates during response activities is recommended for both total As and L-1, using high-volume samplers or other appropriate equipment. Concurrent air monitoring for HD is also recommended.

**Water:** Water should be collected in appropriate containers with addition of appropriate de-chlorinating agents and preservatives to minimize HL degradation and hydrolysis prior to analysis. Concurrent air monitoring for L-1, total As, and HD is recommended.

**Soil:** For localized “hot spot” areas where soil deposition may occur (i.e., neat liquid, aerosol or liquid droplets), surface soil samples should be taken from a non-vegetated area to a depth of less than one inch. Sub-surface soil samples are typically not necessary unless a large amount of liquid was poured on the ground, or if an underlying aquifer is endangered. Concurrent air monitoring for L-1, total As, and HD is recommended.

**Surface Wipes:** Wipe samples are often desired to indicate absence of HL (as L-1, total As, and HD) on non-porous surfaces. Concurrent air monitoring for L-1, total As, and HD is recommended.

**Bulk:** For hot spot areas where liquid HL deposition may occur on porous surfaces (e.g., concrete, asphalt), actual pieces (chips) or cores of contaminated surface may be obtained using appropriate tools (scabbling, coring, or drills) for subsequent laboratory extraction analysis for L-1, total As, and HD. Bulk samples of suspected sink materials may be recommended to rule out secondary vapor phase disposition or absorption of L-1, total As, and HD into these materials. Concurrent air monitoring for L-1, total As, and HD is recommended.

**Other Sample Matrices:** Contact EPA/HQ-EOC at 202-564-3850 for sampling instructions.

## 11. Packaging/Shipping: CWA Environmental Samples for Site Characterization

### Packaging and Shipping: CWA Environmental Samples For Site Characterization

The packaging and shipping of environmental samples potentially contaminated with a chemical warfare agent (CWA) would be subject to complex and restrictive regulations established primarily by DOT for ground transportation (49 CFR Parts 171-180), and by DOT, ICAO, and IATA for air transportation (in addition to other regulations by CDC, USPS,



OSHA). Transportation of HL-contaminated waste for treatment and disposal is covered under the WASTE MANAGEMENT section below.

Samples can be collected from environmental media that include surface and subsurface soil, groundwater, surface water, drinking water, dust, air, and solids other than soil (e.g., building materials). Given the wide range of potential environmental media and complex regulatory requirements, the approach would likely be situationally dependent.

**CAUTION:** Environmental samples potentially contaminated with CWA should not be introduced into commercial transportation as an undeclared hazardous material. Hazard classification, packaging, and hazard communication are the shipper's responsibility under DOT's Hazardous Materials Regulations (49 CFR Parts 171-180).

A summary of key packaging and shipping considerations for environmental samples with unknown concentrations of a potential unknown CWA is:

- Transport of pure HL, L-1, or HD is forbidden other than via military (Technical Escort Unit) transport in accordance with 49 CFR §173.7.
- If the collected sample contains or is suspected to contain hazardous materials, as defined in 49 CFR §171.8, the shipper must determine the appropriate UN ID Number, the Proper Shipping Name (PSN), and the Packing Group (PG) from the Hazardous Materials Table in 49 CFR §107.101. The table will then direct the shipper to the type of hazard and handling labels needed, the appropriate packaging (inner and outer packaging), and any special provisions.
- The designated shipper (EPA personnel or contractors) must be trained and certified according to the requirements found in 49 CFR §172.704 (a)(2) and/or by IATA Dangerous Goods (DG) 1.5 requirements for shipments by air.
- Contact the sample-receiving laboratory to determine if they have additional packaging, shipping, or labeling requirements.

Note that there is no UN ID for HL, L-1, or HD listed in the Hazardous Materials Table (49 CFR §172.101). Therefore, the most likely classification would be UN3381, Toxic by inhalation liquid, n.o.s. with an LC50 lower than or equal to 200 mL/m<sup>3</sup> and saturated vapor concentration greater than or equal to 500 LC50, PG I. In the US, non-bulk packaging would then be in accordance with 49 CFR §173.226.

**Use of Mobile labs:** Another consideration would be use of an on-site mobile laboratory for CWA analysis. This could eliminate the shipper's responsibility for transporting the collected samples containing a substance that might be considered forbidden for transport by air or a hazardous material or DG by ground or air transport to an off-site laboratory. In addition, there may be public concern about shipping samples off-site, or reluctance of commercial shipping companies to accept and transport samples from a known CWA-contaminated site. EPA maintains mobile laboratory assets (PHILIS mobile laboratories: <https://www.epa.gov/emergency-response/philis-portable-high-throughput-integrated-laboratory-identification-system>) in NJ and CO that are capable of analyzing CWAs, including HL, L-1, or HD, in environmental matrices, down to health-based risk clearance levels. Access to the PHILIS mobile labs for a CWA incident can be obtained from EPA HQ/EOC at 202-564-3850. EPA also has access to the US Army CBRNE assets, including shipping and analysis, through inter-agency agreements as described in the COORDINATION WITH OTHER AGENCIES section below.

## 12. Analysis

### Analysis

**CAUTION: Many labs may not be able to perform analysis on all matrices (e.g., wipes and soil).** Few laboratories currently have the capability to determine HL, L-1, or HD, particularly for large numbers of samples and for the various types of environmental media. EPA's ERLN labs (<https://www.epa.gov/emergency-response/environmental-response-laboratory-network>) that are specially trained and equipped for the analysis of HL, L-1, or HD, will use sample prep and analytical methods from EPA's Environmental Sampling and Analytical Methods (ESAM) Programs (<https://www.epa.gov/esam>). For access to the nearest ERLN laboratory specially trained and equipped for HL, L-1, or HD analysis, and methods provided in EPA's ESAM, contact EPA/HQ-EOC at 202-564-3850. The ERLN also maintains EPA's Compendium of Environmental Testing Laboratories (CETL), a database of commercial, federal, state, and academic laboratories, which can be queried for specific analyses and matrices. Analysis on environmental matrices for toxic organics, metals, biological and radiological agents, as well as several of the CWAs, including HL, L-1, or HD and their breakdown products, can be obtained by querying the database of laboratories listed in EPA's CETL (<https://cfext.epa.gov/cetl/lblogin.cfm?action=None>); prior registration for access to CETL website is necessary.

## 13. Coordination with Other Agencies: CWA Field Activities

### Coordination With Other Agencies: CWA Field Activities

Numerous agencies other than EPA may be involved in a chemical agent response incident. Every attempt should be made to integrate assets and design a uniform approach to sampling procedures, quality assurance, and data sharing. Every attempt should be made to coordinate activities, share data, and maintain chain-of-custody integrity throughout all phases of the response, amongst all agencies involved.

**Civilian:** The National Guard Civil Support Team (CST) and the U.S. Coast Guard "Strike Teams" deploy survey teams, response vehicles, and mobile labs to hazardous chemical incidents throughout the United States. Many CSTs and Strike Teams have the capabilities to sample, prepare, and analyze certain types of environmental samples for CWA analysis. CSTs have analytical equipment that can provide screening or presumptive data results for CWAs. The OSC should

discuss site-specific types of samples, data quality, and chain-of-custody requirements with Strike Teams and CSTs before integrating their capabilities into the overall CWA response. Other agencies, such as the FBI, may be present on-site performing tasks, such as evidence retrieval, which are specific for their agency.

**Military:** EPA's Special Teams (ERT and CMAD) have access to Department of Defense (DOD) assets through Inter-Agency Agreements (IAA) with the US Army's Combat Capabilities Development Command, Chemical Biological Center (CBC) at Aberdeen Proving Ground, MD. The CBC has expertise and deployable assets for CWA air monitoring (i.e., MINICAMS™), sampling, analysis, decontamination, and waste transport and disposal through their ongoing demilitarization activities at former chemical agent munitions facilities in the US and abroad.

Access to EPA's IAA for support to Federal OSCs at a CBRN response or incident can be arranged through EPA/HQ-EOC at 202-564-3850. Consultation or training for EPA personnel and partners that do not need to go through EPA/HQ-EOC can be arranged via the IAA with EPA's ERT-Special Team at 732-321-6660. Additional CBRNE support can be obtained via the IAA with EPA's CMAD-Special Team, including support for chemical, biological, and radiological agent response through EPA/HQ-EOC at 202-564-3850.

## 14. Environmental Decontamination/Cleanup

### Environmental Decontamination/Cleanup

#### 14.1. Decontamination/Cleanup Planning:

Once site controls are in place, develop a site-specific decontamination/cleanup plan. Environmental decontamination may require a "tiered approach" using a variety of techniques and products. Call EPA/HQ-EOC at 202-564-3850 for more information.

**General Considerations:** A cost vs. benefit evaluation should be undertaken for each decontamination strategy and approach that considers public safety, total cost, impact on the area, wastes generated, time the area or item will be inaccessible and/or out of service, as well as any socio-economic, public health, and/or security impacts that may result. Large volumes of decontamination wastes may be generated that will need to be collected, treated, and disposed of properly. Waste handling and disposal must be addressed as early in the decontamination and cleanup process as possible (see WASTE MANAGEMENT section below).

**Disposal Option:** The urgency to restore an area or item as quickly as possible may result in the outright and timely removal and disposal of contaminated materials. Certain materials may be impacted by the decontamination products, and/or may be cheaper to discard and replace than to decontaminate and restore.

**Monitored Natural Attenuation:** HL degrades via natural processes. Environmental monitoring must be maintained during decontamination and recovery phases. Monitored natural attenuation may require institutional controls (e.g., access restriction and contaminant containment measures). The time to achieve clearance must be considered in the overall cost/benefit evaluation. This option is more passive than other options but is non-destructive to materials. Porous or permeable materials can absorb HL thereby prolonging persistence.

**Fix-in-Place Option:** The contaminated area may be resistant to decontamination products or may be unable or impractical to be treated. Physical barriers can be used to immobilize the contamination and prevent it from coming into contact with the environment or the public. This can be a temporary or permanent solution.

#### 14.2. Decontamination Strategy:

A decontamination strategy can be developed by designating contaminated areas into five broad categories: 1) surfaces or hot spots, 2) large volumetric spaces, 3) sensitive equipment or items, 4) aqueous solutions, and 5) water systems. Areas in each category may be treated using one or more unique decontamination processes in a tiered approach to the overall site-specific decontamination strategy.

Decontamination of HL as a mixture faces the same challenges as the individual components, HD and L-1. The decontamination of HL as a mixture has been studied and has been reported as efficacy against HD on surfaces in the presence of residual L-1 and efficacy against L-1 on surfaces in the presence of residual HD. Hence, strategies presented below are based on the individual components, HD and L-1.

#### Cautions:

Presence of Lewisite in HL:

- Hydrolysis of L-1 is rapid and produces compounds containing As (III), the more toxic oxidation state of arsenic, such as lewisite oxide and most significantly CVAA, which has similar vesicant properties as L-1. In basic solutions, acutely toxic inorganic arsenite ( $\text{AsO}_3$ ) may also be formed. HCl may also be produced, so situation-specific tolerance to potentially altered pH and corrosiveness should be evaluated when developing a decontamination strategy.
- Under oxidizing conditions (e.g., for household chlorine bleach or other hypochlorite-containing solutions), the hydrolysis products of L-1 mentioned above are converted to compounds containing As (V), which are generally less toxic but still can be of concern. The conversion is rapid even under mild conditions, but complete conversion should not be assumed because of the toxicity of CVAA. Decontamination formulations and conditions should be chosen to minimize or eliminate the formation of these toxic breakdown products.

Presence of HD in HL:

- Under oxidizing conditions (particularly for household chlorine bleach or other hypochlorite-containing solutions), HD can break down into several toxic byproducts, such as mustard and vinyl sulfones. Decontamination formulations and conditions should be chosen as to minimize or eliminate the formation of these toxic breakdown products.
- Hydrolysis of HD produces HCl. Situation-specific tolerance to potentially altered pH and corrosiveness should be evaluated when developing a decontamination strategy.

Decontamination:

- Decontamination products may have unique safety/PPE requirements due to their own toxicity or that of breakdown products during use (e.g., use of bleach results in release of chlorine vapors). Strong oxidizers, such as hypochlorite, may react violently with organics.
- Dirt, grime, and other coatings (organic load) can reduce the efficacy of decontamination; pre-cleaning surfaces with soap and water may be needed before the application of decontamination formulations. However, the resulting pre-cleaning rinsates require containment to avoid spread of HL including the L-1 degradation products CVAA which will be formed as a result of pre-cleaning with aqueous solutions.
- Even under ideal decontamination conditions using oxidizers, residual arsenic compounds including arsenate will be present and should be considered in site-specific goals.

For additional information, contact the EPA/HQ-EOC at 202-564-3850.

**Surfaces/Hot Spots:** This category is for areas smaller in size but with higher levels of agent contamination. They may require more rigorous decontamination products and methods. Excess HL liquid should be absorbed using, e.g., vermiculite or dry sand, and transferred into a sealed container and disposed of according to WASTE MANAGEMENT section below. In contrast to the rapid hydrolysis when HD and L-1 are dissolved in water, the hydrolysis of both HD and L-1 on surfaces is generally slower since it is limited by the amount of available moisture. Regardless of hydrolysis rate, hydrolysis products such as CVAA should be avoided. Thus, application of the following oxidative decontamination solutions and formulations may be efficacious by following applicable manufacturers' directions.

- 1) Hypochlorite-containing solutions: Hypochlorite can be corrosive to certain surfaces and materials and should be rinsed thoroughly afterwards.
  - Household bleach solutions ( $\geq 5\%$  sodium hypochlorite) are effective for decontamination of surfaces contaminated with HL with high efficacy expected to be achieved with contact time of 30-60 minutes depending on surface material. Diluted bleach ( $< 0.5\%$  sodium hypochlorite) has been shown to be less effective for these contact times. Note that lowering the pH of hypochlorite solutions is not required and may be counterproductive. If inadequate amount of oxidant is used, highly toxic byproducts will likely accumulate calcium hypochlorite, present in commercial products, such as HTH (10% hypochlorite solution), is better for surfaces with high concentrations of liquids in localized areas.
  - The decontamination technology EasyDecon DF-200® (or equivalent Decon7 (D7)), which is expected to be less corrosive than hypochlorite-containing solutions, is generally effective against surfaces contaminated with HL with a contact time of at least 30 minutes although residual HD may remain and would require additional decontamination. Other proprietary decontamination technologies such as Dahlgren Decon®, CASCAD®, Decon Green®, or L-Gel® have not been tested for decontamination of surfaces with HL. More specifically, all of these technologies have been shown to be effective against HD alone on the order of minutes to hours, but not all have been thoroughly tested against L-1. Availability, cost, and the need for specialized equipment to apply the decontaminant may limit their use early in the response.

**Large Volumetric Spaces:** This category is for areas larger in size but with lower levels of agent contamination. These areas may require less aggressive, but more broadly applied, decontamination products and methods. The described approaches are based on studies of HD or L-1; there are no testing data available for HL mixture.

- 1) Monitored Natural Attenuation is more passive than other decontamination options and is non-destructive to materials. This option may be preferable depending on the scope and severity of contamination.
- 2) Forced or Hot Air ventilation methods are recommended for vapor plume contamination or low surface concentration of HD and L-1 in large volumetric spaces, including HVAC systems, or open areas; efficacy may be typically achieved in hours to days with less waste and adverse impacts to materials. L-1 hydrolysis and vesicant byproduct CVAA may be formed and would stay on surfaces longer than L-1. Capture technologies, such as activated carbon-containing air filters, would be required to prevent transfer of the HD and L-1 vapors to the outside environment or prevent recirculation into other surrounding spaces.
- 3) Fumigations with modified vaporous hydrogen peroxide (mVHP®; a combination of ammonia and hydrogen peroxide vapor) or chlorine dioxide ( $\text{ClO}_2$ ) have been reported to be effective against HD. mVHP® and  $\text{ClO}_2$  have not been tested for decontamination of surfaces with L-1. These oxidants may be theoretically effective and advantageous based on expected formation of less toxic arsenic-containing byproducts.
- 4) Steam application has been reported to effectively degrade HD on surfaces with no HD found in the condensate. Steam has not been tested for L-1 and may lead to L-1 hydrolysis and formation of vesicant byproduct CVAA.

**Sensitive Equipment or Items:** Forced or Hot Air ventilation may be used for HL and can be used either in-situ or ex-situ to decontaminate these items. Capture technologies using activated carbon air filters would be required to prevent transfer of the L-1 and HD vapor to the outside environment or prevent recirculation into other surrounding spaces. Although testing has not been performed, fumigation with mVHP® is another option that could be efficacious aside from formation of less toxic arsenic-containing byproducts, with no or minimal impact on materials.

### Aqueous Solutions:

L-1 component of HL degrades rapidly via hydrolysis but forms other toxic compounds and vesicants, such as CVAA and arsenite, as well as HCl. Decontamination operations involving bleach or other oxidants may yield aqueous solutions containing arsenic compounds that may have been converted to less toxic forms. Some toxicity will still be retained (see toxic byproducts statement under Cautions above). The HD component of HL degrades via hydrolysis but may persist in aqueous solutions, depending on initial concentration and environmental conditions. Also contributing to persistence is that hydrolysis products of HD may accumulate at the interface between the HD liquid and the water, forming a protective coating around HD “globules” that are resistant to further hydrolysis and can persist for decades if not physically disturbed. It is unknown if this occurs for HL. The amount of disturbance required is unknown, so simple mixing of containerized HL solution may not suffice. Hydrolysis of HD produces HCl. If the aqueous solutions result from decontamination operations involving bleach or other high pH conditions, significant HD degradation into toxic byproducts may occur (see toxic byproducts statement under Cautions above). Avoid any additional release and/or inappropriate disposal to water systems, drains, or sewers. Contain or transfer liquid to appropriate containers and dispose of according to WASTE MANAGEMENT section below.

**Water Systems:** Hydrolysis and removal of contaminated water will lessen HD, L-1 and its breakdown products (e.g., CVAA) contamination in water systems, but they may persist in hydraulic dead ends and via sorption to system components (e.g., plastics) that act as sinks. It may be necessary to isolate potentially affected portions of the system to evaluate them and implement decontamination. A contaminated water system may transfer HD, L-1 and its breakdown products (e.g., CVAA) to building and premise plumbing, which then may also require decontamination. As HL mixture is denser than water, it may sink and accumulate in low lying areas, such as the bottom of pipes and tanks. Hydrolysis of HD in water produces HCl.

**Verification of Decontamination:** Site and situation specific. Please contact EPA/HQ-EOC at 202-564-3850 for further assistance.

## 15. Waste Management

### Waste Management

#### 15.1. Transportation:

Federal requirements for the commercial transport of hazardous materials and procedures for exemptions are specified in How to Comply with Federal Hazardous Materials Regulations, available at:

<https://www.fmcsa.dot.gov/regulations/hazardous-materials/how-comply-federal-hazardous-materials-regulations>.

Mustard-Lewisite Mixture (HL), Lewisite (L-1), or Sulfur Mustard (HD) should not be offered for commercial transportation without being rendered safe by neutralization. Contact the PHMSA Hazardous Materials Information Center at 1-800-467-4922 or [infocntr@dot.gov](mailto:infocntr@dot.gov) to discuss specific cases.

Additional resources on packaging, labeling, and shipping are available at: <https://www.phmsa.dot.gov/standards-rulemaking/hazmat/hazardous-materials-regulations>. Detailed state regulations can be found at [www.envcap.org/](http://www.envcap.org/).

This QRG is intended to apply to Federal OSCs in the first 24-48 hours of a response. Once determined, the concentrations of HL, L-1, or HD in individual waste streams should be used to determine which transportation requirements apply. For instance, certain requirements may apply to waste streams with concentrated agent but may not apply to waste streams such as soil containing dilute concentrations of agent.

#### 15.2. Waste Management:

Under the Resource Conservation and Recovery Act (RCRA), waste is classified as hazardous waste (subtitle C) or solid waste (subtitle D). The RCRA regulations generally define a waste to be hazardous if it is: (1) a listed waste (40 CFR §261.31-§261.32); (2) exhibits specific characteristics (40 CFR §261.21-§261.24); or (3) is a discarded commercial chemical product, off specification species, container residue, or spill residue listed in 40 CFR §261.33.

- Lewisite (L-1) is not listed under 40 CFR §261.31-33, but L-1-contaminated waste may be considered toxic hazardous waste, chemical code D004, if it contains arsenic (As) above the regulatory level of 5.0 mg/L when tested according to the specifications in 40 CFR §261.24.
- Sulfur Mustard (HD) is not listed under 40 CFR §261.31-33, but HD-contaminated waste may be considered reactive hazardous waste, D003, if, when mixed with water, it generates toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or the environment (40 CFR §261.23(a)(4)) or if it is a sulfide bearing waste which, when exposed to pH conditions between 2 and 12.5, can generate toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or the environment (40 CFR §261.23(a)(5)).

It is the responsibility of the waste generator to make a hazardous waste determination (40 CFR §262.11).

The states (except for Alaska and Iowa) have the primary responsibility to implement the hazardous waste regulations and can impose more stringent requirements or requirements broader in scope than the federal program. Because L-1 contains As, the state may have specific regulations regarding disposal of As-contaminated wastes. Several states, including CO, IN, KY, MD, OR, and UT, have their own waste designations for chemical agents, which may be applicable for the cleanup of HL-, HD-, or L-1-contaminated residues, decomposition products, soils, and debris. It is critical to open a dialogue with state regulators as early as possible.

Management of toxic decomposition products, associated residual decontamination solutions, local waste acceptance criteria, and transportation and handling requirements should be considered. High pH aqueous decontamination solution waste may be considered corrosive hazardous waste, chemical code D002, if it has a pH greater than or equal to 12.5 (40 CFR §261.22).

EPA/CMAD can provide Federal OSCs with information and support to address knowledge gaps for dealing with wastes contaminated with dilute concentrations of CWA; contact EPA/HQ-EOC at 202-564-3850.

EPA also recommends the creation of pre-incident waste management plans as a preparedness measure for chemical agent releases, and has created an **All-Hazards Waste Management Planning Tool** to help state, local, territorial, and tribal waste management officials coordinate and prepare these plans. Access to the All-Hazards Waste Management Planning Tool requires pre-registration (<https://wasteplan.epa.gov/>).

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