

## NRT Quick Reference Guide: Lewisite (L-1)



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:** Schedule 1 Chemical Warfare Blister (Vesicant) Agent; Lewisite (L); **CAS:** 541-25-3

**Description:** Lewisite (L) is referred to as L-1 and is an oily, colorless, and odorless liquid. When impure, it is a yellow brown through violet-black liquid with a strong penetrating geranium odor. The manufacturing process affects physical properties, appearance, persistence, and analytical detection limits. Lewisite is often referred to as L-1, and with common impurities includes two related compounds, lewisite 2 (L-2) and lewisite 3 (L-3). This QRG is based on L-1 but includes aspects of L-2 and L-3 and will use “L-1” as the collective abbreviation.

L-1 is a blister (vesicant) agent that produces immediate burning pain with blistering starting within a few hours. L-1 is less volatile than Sarin (GB); it is much more volatile than persistent agents VX or HD. Environmental breakdown of L-1 is primarily due to hydrolysis, which is pH dependent, with hydrolysis products of L-1 easily formed. These include hydrochloric acid (HCl) and highly toxic arsenic (III) compounds, such as 2-chlorovinyl arsenous acid (CVAA), 2-chlorovinylarsenous oxide (lewisite oxide), and arsenites; some of which cause blistering similar to L-1. Oxidative decontamination byproducts of L-1 include arsenic (V) compounds, which are generally less toxic than arsenic (III) compounds but may still be considered hazardous.

**Persistence:** L-1 is considered a “low to moderate persistent” chemical warfare agent. Vapor: minutes to hours; liquid: hours to days. Persistence will depend upon the amount and purity of the agent, method of release, environmental conditions, and the types of surfaces and materials impacted. L-1 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, L-1 breakdown products may persist in soils for decades. Porous, permeable, organic, or polymeric materials such as carpets, vinyl tiles, and painted surfaces can accumulate L-1 vapors and liquids, acting as “sinks,” thereby prolonging persistence.

### 2. Physical Properties

#### Physical Properties

<b>Molecular Weight:</b> 207.32 g/mol	<b>Formula:</b> C <sub>2</sub> H <sub>2</sub> AsCl <sub>3</sub>
<b>Vapor Density:</b> 7.1 (air = 1)	<b>Flash Point:</b> Not established
<b>Vapor Pressure:</b> 0.58 mm Hg (77°F/25°C)	<b>Liquid Density:</b> 1.89 g/mL (77°F/25°C)
<b>Volatility:</b> 4,480 mg/m <sup>3</sup> (68°F/20°C)	<b>Melting/Freezing Point:</b> 32.2°F/0.1°C
<b>Boiling Point:</b> 374-378°F/190-192°C	<b>Non-aqueous Solubility:</b> Common organic solvents, alcohols, gasoline, oils, fats
<b>Hydrolysis (t<sub>1/2</sub>):</b> Rapid for vapors or dissolved L-1 but limited by low aqueous solubility	<b>Aqueous Solubility:</b> 0.5 g/L (temperature not reported), to slightly soluble

**Note:** physical properties are listed at/near STP unless otherwise indicated.

**Conversion Factors for L-1:** ppm = mg/m<sup>3</sup> x 0.1179; mg/m<sup>3</sup> = ppm x 8.481

### 3. Release Scenarios

#### Release Scenarios

**AIR RELEASE SCENARIOS ARE ASSUMED MOST PROBABLE; HOWEVER, OTHER RELEASE SCENARIOS AND EXPOSURE ROUTES SHOULD BE CONSIDERED.**

**Open Areas:** Due to its volatility, L-1 could be dispersed as a vapor or liquid spray (aerosol), and the primary release/attack scenario is an airborne release. L-1 is expected to degrade in the environment fairly rapidly; however, liquid L-1 on surfaces generally persists for hours to days. Environmental conditions will affect the degradation and evaporation rates of L-1 with cooler and drier conditions enhancing persistence. **L-1 has a melting/freezing point at 0.1°C (32.2°F), so the reaerosolization of liquids and solids, as ambient temperatures rise, may present an inhalation hazard.** L-1 vapors are heavier than air, so vapors can accumulate in lower terrains.

**Water/Water Systems:** L-1 released into water will likely hydrolyze within a few hours into vesicant and toxic compounds, which may persist for days to weeks. 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 L-1. Water systems, plumbing, surfaces, and equipment that have contacted contaminated water must be evaluated for decontamination along with the bulk water.

**Indoor Facility:** Due to its volatility, L-1 could potentially be dispersed as a vapor or liquid spray (aerosol), inside a building or facility; HVAC systems could be impacted. L-1 vapors are heavier than air so vapors can accumulate in lower levels, basements, floor drains, or utility corridors inside the buildings.

**Other:** L-1 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 L-1 is released into the air as a liquid spray (aerosol), it has the potential to contaminate agricultural products. If L-1 is released as a vapor, it is highly unlikely to contaminate agricultural products.

## 4. Health Effects

### Health Effects

**4.1. Onset:** Onset of symptoms is rapid. Severity of effects depends on dose, duration, and route of exposure (not all signs/symptoms may develop). The effects caused by L-1 are immediate but are not typically fatal; however, secondary infections from blisters/tissue damage may be fatal and can require substantial supportive medical care. 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.

**4.2. Signs/Symptoms:** Initial 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.

**Mild to Moderate:** 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 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.

### 4.3. Exposure Routes:

**Inhalation:** Vapor is absorbed through mucous membranes (mouth, nose, throat, lungs).

**Skin:** Direct contact with liquid or vapor causes immediate effects.

**Eyes:** Eyes are the most sensitive to L-1 vapors. Vapors are absorbed through mucous membranes. Symptoms occur immediately. 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

**Air (inhalation vapor hazard):** Acute Exposure Guideline Levels (AEGLs) for general population one-time exposure emergency scenarios for L-1 (complete definitions are available at: <https://www.epa.gov/aegl>). 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

American Industrial Hygiene Association (AIHA) Emergency Response Planning Guidelines (ERPG<sup>TM</sup>) are not established/determined for L-1.

## 6. Exposure Guidelines

### Exposure Guidelines

**6.1. Airborne Exposure Limits (AELs):** CDC has issued recommendations for protecting human health from potential adverse effects of exposure to this agent. (NA = not available)

(refer to: NIOSH ERSB-DB, [https://www.cdc.gov/niosh/ersbdb/emergencyresponsecard\\_29750006.html](https://www.cdc.gov/niosh/ersbdb/emergencyresponsecard_29750006.html))

**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)]

**CDC/NCEH STEL = NA**

**CDC/NCEH Worker Population Limit (WPL) = 0.003 mg/m<sup>3</sup> \*\***

<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>6.2. Occupational:</b> (NA = not available)	
<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>
<b>Arsenic:</b> 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), <a href="https://www.cdc.gov/niosh/npg/npgd0038.html">https://www.cdc.gov/niosh/npg/npgd0038.html</a> ).	
<b>6.3. Population:</b>	
<b>Soil: USAPHC Health Based Environmental Screening Levels (HBESL) = 3.7 mg/kg over work life for Industrial Soil; 0.3 mg/kg over lifetime for Residential Soil.</b>	
<b>Drinking Water:</b> EPA Provisional Advisory Levels (PALs): see below for more information.	
<b>EPA Provisional Advisory Level (PAL):</b> 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: <a href="mailto:PALs@epa.gov">PALs@epa.gov</a> , for information on and access to the PALs. (Note: PALs are not intended to define cleanup levels.)	

## 7. Personnel Safety

Personnel Safety	
<b>Note:</b> 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: <a href="http://www.cdc.gov/niosh/ershdb">www.cdc.gov/niosh/ershdb</a> . We also recommend that responders check their own internal procedures (i.e., SOPs), if applicable.	
<b>7.1. Medical:</b>	
<b>Pre-incident:</b> 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.	
<b>During Incident:</b> 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.	
<b>Post-incident:</b> 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.	
<b>7.2. First Aid:</b> 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) 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.	
<b>Antidote: Dimercaprol (a.k.a. British Anti-Lewisite (BAL)).</b> 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.	
<b>Other:</b> 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. <b>NOTE: no citations were currently found for the efficacy of RSDL specifically for L-1, but the application methods and decontamination materials present in RSDL may be useful to neutralize L-1 exposure on skin.</b>	
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.	
<b>7.3. Personal Protective Equipment (PPE):</b>	
<b>GENERAL INFORMATION:</b> 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.

Per NIOSH guidance –

**LEVEL A:** Recommended for the initial response to an L-1 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 L-1 concentration is unknown or above the IDLH or AEGL-2, 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 L-1 concentration is unknown or above the IDLH or AEGL-2, 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 L-1 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 PAPER (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 PAPER with a filter or a combination organic vapor, acid gas, and particulate cartridge/filter combination or a continuous flow respirator.
- For air levels greater than AEGL-1: NIOSH Approved CBRN tight-fitting APR with a canister-type gas mask or CBRN PAPER.

**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. 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. 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 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\\_29750006.html](https://www.cdc.gov/niosh/ersbdb/emergencyresponsecard_29750006.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 L-1 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 L-1 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 L-1.

**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.

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

Field Equipment:	ppm	mg/m <sup>3</sup>
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

MINICAMST™ (Near real-time; at 5 minutes)	0.00035	0.003	
Note: ND = not detectable; NA = not available			
<b>9.2. Minimum Screening Ranges/Levels for Vapor/Liquid:</b>			
<b>Field Equipment:</b>	<b>ppm (vapor)</b>	<b>mg/m<sup>3</sup> (vapor)</b>	<b>mL (liquid)</b>
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			
<b>9.3. Minimum Screening Ranges/Levels for Water:</b>			
<b>Field Equipment:</b>	<b>mg/L</b>		
M272	0.1-2		

## 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 L-1 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 L-1 has low to moderate persistence on surfaces, ambient air sampling to help to “clear areas” should be included in the sampling plan.

**Note:** 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. See ANALYSIS section below to ensure sampling procedures are compatible with all analytes. Some preparation techniques for both L-1 and its 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.

#### 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.

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

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

**Bulk:** For hot spot areas where liquid L-1 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 and total As. Bulk samples of suspected sink materials may be recommended to rule out secondary vapor phase disposition or absorption of L-1 and total As into these materials. Concurrent air monitoring for L-1 and total As 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 L-1-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 L-1 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 L-1 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 L-1, 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 L-1, 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 L-1, 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 L-1 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 L-1 and its 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:** L-1 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 L-1 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.

#### Cautions:

- 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.



- 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 the L-1 degradation products including 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 L-1 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 L-1 is dissolved in water, the hydrolysis of L-1 on surfaces 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 with L-1 with efficacy expected to be achieved with contact time of 30-60 minutes depending on surface material. Calcium hypochlorite, present in commercial products, such as HTH (10% hypochlorite solution), is better for surfaces with high concentrations of liquids in localized areas. 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.
- 2) The decontamination technology EasyDecon DF-200® (or equivalent Decon7 (D7)), which is expected to be less corrosive than hypochlorite-containing solution, is effective against surfaces contaminated with L-1 and CVAA with a contact time of at least 30 minutes. Other proprietary decontamination technologies such as Dahlgren Decon®, CASCAD®, Decon Green®, or L-Gel® have not been tested for decontamination of surfaces with 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.

- 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 L-1 in large volumetric spaces, including HVAC systems, or open areas; efficacy may be typically achieved in hours to days based on the low to moderate persistence of L-1 with less waste and adverse impacts to materials. Hydrolysis and vesicant byproduct CVAA may be formed and stay on surfaces longer than L-1. Capture technologies, such as activated carbon-containing air filters, would be required to prevent transfer of the L-1 vapor to the outside environment or prevent recirculation into other surrounding spaces.
- 3) Other approaches such as modified vaporous hydrogen peroxide (mVHP®; a combination of ammonia and hydrogen peroxide vapor), or chlorine dioxide 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. 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 L-1 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 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 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). 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:** Removal of contaminated water will lessen L-1 and its breakdown products' 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 L-1 and its breakdown products to building and premise plumbing, which then may also require decontamination. As L-1 is denser than water, it may sink and accumulate in low lying areas, such as the bottom of pipes and tanks.

**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>.

Lewisite (L-1) 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 L-1 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. 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 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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