

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

For References, Please See: Key References Cited/Used in National Response Team (NRT) Quick Reference Guides (QRGs) for Chemical Warfare Agents. QRGs are intended for Federal OSC/RPMs*

Agent Characteristics	<p>Agent Classification: HL is mixture of sulfur mustard (H) & lewisite (L) & shares properties of both. Its properties are related to the exact composition, & the composition will vary with manufacturing process & changes after dispersion. HL is a Schedule 1 Chemical Warfare Blister (Vesicant) Agent. This QRG is based on munitions grade HL which has a composition of 63/37 weight % L & H. Given that the composition of HL in an actual incident may be unknown, the user should read the QRGs for Sulfur Mustard & Lewisite. Decontamination verification must include both H & L. CAS: NA Formula: NA, Molecular Weight: 186.4 g/mol per 63/37 weight % L & H.</p> <p>Description: HL may have a garlic-like odor, if there is sufficient H present, but may be odorless otherwise. HL is a blister (vesicant) agent that has both immediate effects & also delayed health effects on the order of hours. It can be manufactured at different concentrations; with impurities, additives, or thickening materials which will all affect physical properties, appearance, persistence, & analytical detection limits. Environmental breakdown products of HL, including thiodiglycol (TDG), are relatively nontoxic, but some decon by-products can be toxic (sulfones, arsenic (III) compounds, such as arsenites, lewisite oxide, & 2-chlorovinyl arsenous acid (CVAA)). Some cause similar blistering as HL. Decon by-products include arsenic (V) compounds, which are generally less toxic than arsenic (III) compounds, but may be considered hazardous.</p> <p>Persistence: HL may be considered a "semi-persistent" agent with liquid deposition on surfaces lasting for hours to days. Persistence will depend upon the amount & purity of the agent, method of release, environmental conditions, & the types of surfaces & materials impacted. Porous, organic & polymeric materials such as carpets & vinyl tiles can act as sinks for absorbing vapors & liquids, prolonging the persistence of HL. Many toxic environmental & decon byproducts are persistent. Under certain conditions, when protected from environmental degradation processes, H, L, &/or lewisite oxide could persist in soil & water for decades. HL, H, & L may be present as globules.</p>	
	<p>Physical properties are listed at/near STP & assume ideal gas behavior unless otherwise indicated & refer to 63/37 (L/H weight %) mixture, which has the lowest freezing point of any mixture. Other mixtures will have different physical properties. Conversion Factors: ppm = mg/m³ x 0.122; mg/m³ = ppm x 8.21 (assuming MW = 186.4 for mixture. See H & L QRGs for respective MWs & conversion factors)</p> <p>Liquid Density: 1.66 g/cm³ Freezing Point: -14°F/-25°C Vapor Pressure: 0.25 mm Hg (68°F/20°C) Vapor Density: 6.5 (air = 1) Aqueous Solubility: > 0.5 g/L & < 0.9 g/L Flash Point: N/A. Assume 223°F/106°C (H) Volatility: 2,730 mg/m³ (68°F/20°C) Boiling Point: est. 200°C Soluble: organic solvents, oils, fats, alcohols</p>	
Release Scenarios	<p>COLD WEATHER, AIR RELEASE SCENARIOS ARE ASSUMED MOST PROBABLE; HOWEVER OTHER RELEASE SCENARIOS & EXPOSURE ROUTES SHOULD BE CONSIDERED. An HL mixture of 63% L, 37% H (w/w) will yield the lowest freezing point temperature (eutectic) mixture for cold weather, high altitude use.</p> <p>Open Areas: HL has moderate volatility, & could be dispersed as a vapor or a liquid, depending upon the percentages of the H & L within the mixture. The primary release/attack scenarios are cold weather operations & airborne releases. HL is expected to degrade in the environment fairly rapidly; however, liquid on surfaces could persist for days. Environmental conditions will affect the degradation & evaporation rates of HL with cooler & drier conditions enhancing persistence. HL vapors are heavier than air, so vapors can accumulate in lower terrains. HL has a freezing point at -14°F (-25°C), so the reaerosolization of liquids & solids, as ambient temperatures rise, may present a real hazard. Water/Water Systems: HL released into water will likely degrade within a few days; however toxic L breakdown products may persist from days to weeks. If released into water systems such as reservoirs, treatment plants, distribution systems, public fountains or pools, treatment processes can further break down agent. Water systems, plumbing, surfaces, & equipment that have contacted contaminated water must be evaluated for decon along with the bulk water. When released into water, HL may dissolve & hydrolyze, but in sufficient amounts (relative to water volume) may also form globules surrounded by a protective outer layer resistant to hydrolysis. These globules may settle out or be entrapped, persisting for years & 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. Indoor Facility: HL may be considered as a semi-persistent agent with moderate volatility, & could potentially be distribute throughout a building or facility from a point source. 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 & aerosols. HL vapors are heavier than air so vapors can accumulate in lower levels or utility corridors inside the buildings.</p>	
Health Effects	Onset	Onset & severity of effects depend on dose, duration, & route of exposure (not all signs/symptoms may develop). The effects caused by H or L are not typically fatal immediately, but can require substantial supportive medical care, & secondary infections from blisters/tissue damage may be fatal. L can cause immediate eye pain & eye/skin/respiratory tract irritation & skin redness within 15-30 min. Blister formation & deep skin burns are approximately 12 hours post exposure. Actual signs/symptoms of H exposure (eye irritation, coughing, reddening & burning of skin) are DELAYED 1-48 HOURS AFTER EXPOSURE.
	Signs/Symptoms	Information below is exposure route specific. Regardless of route the following range of effects may occur depending on dose. Mild: Mild effects are due to H & delayed 1-48 hours (severity depends on dose): Eye irritation (tearing, grittiness); runny nose, sneezing, nosebleed, hoarseness, hacking cough. Moderate: Effects of H delayed 1-24 hours: Above plus reddening, swelling of eyelids, severe cough, shortness of breath, reddening of skin. Effects for L immediate & include those for H plus stinging, burning pain & itching, spasmodic blinking, nosebleed, difficulty breathing or shortness of breath. Severe: Effects of H delayed 1-24 hours: Upper respiratory/lung damage may occur at high concentrations & longer exposure durations. Effects of L include corneal blistering & scarring, blindness. Inflammation of lungs, lung edema, respiratory failure & death.
	Exposure Routes	Inhalation: Vapor exposure is absorbed in mucous membranes (mouth, throat, & lungs). Skin: Direct contact with H & L mixtures can cause redness or blisters immediately. Warm & sweaty skin areas (underarms, groin) are most susceptible. Eyes: Eyes are the most sensitive to H & L injury; effects noted immediately; irritation, burning, gritty feeling, itching, weeping, reddening, lid swelling, light-sensitivity, pain, & corneal injury. High concentration effects extremely painful & generally require extended medical treatment. Ingestion: Consumption of contaminated food or drink could cause burning, nausea, & vomiting.
Effect Levels	<p>Air: Acute Exposure Guideline Levels (AEGs) for general population one-time exposure emergency scenarios for HL (complete definitions are available in Key References Cited/Used in NRT Quick Reference Guides for Chemical Warfare Agents). AEGs are not available for HL, reader is directed to the QRGs for Sulfur Mustard & Lewisite.</p> <p>Exposure Guidelines: IDLH = NA; STEL = NA; Worker Population Limit (WPL) [an 8-hour time-weighted average occupational value] = 4.0 x 10⁻⁴ mg/m³ (H); none for L except detection limit = 0.003 mg/m³; General Population Limit (GPL): [a 24-hour time-weighted average] = 2.0 x 10⁻⁵ mg/m³ (H); none for L except detection limit = 0.003 mg/m³. Soil: Industrial Exposure Scenario = NA; Residential Exposure Scenario = NA; Drinking Water: NA. See QRGs for Sulfur Mustard & Lewisite</p>	
Personnel Safety	Note	Personal Protective Equipment (PPE) selection (levels A-D), medical surveillance requirements, First Aid options & personnel decon may vary depending upon the agent, site & the release scenario. Additional information on personnel safety & PPE selection criteria can be found at: www.cdc.gov/niosh/ershdb
	Medical	Pre-incident: Annual physical & respiratory function exams. During Incident: Conduct periodic on-site medical monitoring, observe for any signs & symptoms as per Health Effects section above & treat accordingly as per First Aid section below.
	First Aid	Immediately remove person from affected area, remove contaminated articles. Wash bare skin with warm soapy water, & rinse eyes with plain water for 10-15 minutes if exposed to liquid agent. Antidote: British Anti-Lewisite (BAL) AVAILABLE FOR L, NONE AVAILABLE FOR H. Send person for follow up medical attention & evaluation; be aware effects are delayed 1-48 hours. If cleared to resume work, continue to monitor for signs/symptoms & treat accordingly.
	PPE	GENERAL INFORMATION: NIOSH-certified Chemical, Biological, Radiological, Nuclear (CBRN) Self Contained Breathing Apparatus (SCBA), Air Purifying Respirators (APR) or Powered Air Purifying Respirators (PAPR), full-face masks, & protective clothing should be used. Pre-incident training & exercises on the proper use of PPE is recommended. Few inhalation exposure guidelines have been developed for the HL mixture. The L component of HL does NOT provide sufficient warning properties that would allow the appropriate use of an APR/PAPR in most HL contamination scenarios (see Level C). Per NIOSH guidance - LEVEL A: Recommended for the initial response to a HL incident. Level A provides the greatest level of skin (fully encapsulating suit), respiratory (SCBA), & eye protection when the contaminant identity or concentration is unknown. Select Level A when either the HL concentration is unknown & when there is a potential of ocular or dermal exposure. LEVEL B (modified): Provides the highest level of respiratory protection (SCBA) when a lesser level of skin protection is required. Select Level B when either the HL concentration is unknown & dermal exposure is less of a risk. Level B differs from Level A in that it incorporates a non-encapsulating, splash-protective, chemical-resistant outer suit that provides protection against most liquids but is not airtight. 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: Level C may not be appropriate for an HL response since there are insufficient warning properties for HL inhalation exposures to permit the appropriate use an APR/PAPR. LEVEL D: Select Level D when the HL contaminant is known & the concentration is below the appropriate occupational exposure limit for the stated duration times. Check with the H&S section to determine the appropriate occupational exposure limit (i.e.: WPL) for the stated exposure duration. Downgrading PPE levels can be considered only when the identity & concentration of the contaminant & the risks of dermal exposure are known, & must be accompanied by on-site monitoring. Monitoring for H & L is required during an HL response to ensure that the exposure guidelines for either have not been exceeded (see Sulfur Mustard & Lewisite QRGs).

Detect	<p>Real-time field screening tools (results not confirmatory or quantitative). Caution should be given to equipment that has not been properly evaluated. False positive & false negatives may occur in the presence of interferents common in the environment. Few instruments measure HL directly, see the Sulfur Mustard & Lewisite QRGs for the field detection of H & L - Minimum Screening Levels 0.15 ppm HL as Arsenic* (AP2C) / 0.5 mg/m3 HL as Arsenic* (AP4C)</p>
Sampling	<p>Note: This section on sampling contains general guidelines & does not replace the need for a site-specific sampling plan (See reference list for specific guidance) Sampling Concerns: Detection, sampling equipment & procedures, & analytical techniques will be highly site-specific & depend on: 1) physical state of the agent; 2) type of surfaces contaminated (e.g., porous vs. nonporous); 3) the purpose of sampling (e.g. characterization, decon efficacy & clearance); & 4) specific laboratory requirements. Few laboratories currently have capability to determine HL, particularly for large numbers of samples & in all types of media. The EPA is in the process setting up analytical assets for chemical agent analysis of environmental samples, see ANALYSIS below. For sampling questions, call the EPA/HQ-EOC at 202-564-3850.</p>
	<p>Sample Locations & Planning: Initially consider atmospheric sampling to ensure worker safety & to determine if there is a vapor plume. Characterization sampling is initiated by targeted sampling & analysis to identify "hot spots", potential agent flow paths, & 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 efficacy of decon. More thorough sampling (e.g., grid, statistical approach) will 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 aerosol/liquid (e.g., release site, low lying areas) & which humans are likely to contact or where vegetation used as food.</p>
	<p>Note: There are no sampling & analytical methods specific for HL. Samples should be analyzed for the presence of both H & L agent & their breakdown products. The reader is directed to the QRGs for Sulfur Mustard & Lewisite for appropriate sampling methods. See ANALYSIS section below to ensure sampling procedures are compatible with all analytes. Types of Samples: Air: Samples are collected using appropriate solid phase absorbent (tubes) at breathing zone level (5 ft.) to assess inhalation exposure & at ground levels (~ 6 in.) to assess off gassing at surfaces. Water: Water should be collected in appropriate containers with addition of appropriate de-chlorinating agents & preservatives. Soil: For localized "hot spot" areas where soil deposition may occur (i.e., aerosol or liquid droplets), surface soil samples should be taken from a non-vegetated area to a depth of less than one inch. Subsurface soil samples are typically not necessary unless large amounts of liquid HL were poured on ground or if an underlying aquifer is endangered. Surface Wipes: Wipe samples are often desired to indicate absence of HL (as H & L) on non-porous surfaces. Concurrent air monitoring is recommended. Bulk: For hot spot areas where liquid HL deposition may occur on porous surfaces (e.g., concrete, asphalt), actual pieces or cores of contaminated surface may be obtained using appropriate tools (scabbling, coring or drills) for subsequent laboratory extraction & analysis for both H & L. Other Sample Matrices: Contact EPA/HQ-EOC at 202-564-3850 for sampling instructions.</p>
	<p>Sample Packaging & Shipping: The packaging & shipping of samples are subject to strict regulations established by DOT, CDC, USPS, OSHA, & IATA. Contact the sample-receiving laboratory to determine if they have additional packaging, shipping or labeling requirements.</p>
Anal- ysis	<p>CAUTION: Many labs may not be able to perform analysis on all matrices (e.g., wipes & soil). The Environmental Response Laboratory Network (ERLN) will use uniform, compatible sample prep & analytical methods. (See http://www.epa.gov/sam). For access to the nearest ERLN lab specially trained & equipped for in HL analysis, contact the EPA/HQ-EOC at 202-564-3850.</p>
Decontamination/Cleanup	<p>Decon/Cleanup Planning: Once site controls are in place, develop a site specific decon/cleanup plan. Decontamination may require a "tiered approach" using a variety of techniques & products. Call the EPA/HQ-EOC at 202-564-3850 for more information, including disposal of arsenic contaminated waste. CAUTION: SEE NOTE IN AGENT CHARACTERISTICS CONCERNING TOXIC BYPRODUCTS. ASSUMPTION: Decon cleanup strategy is based on the presence of H or L; no data is available for HL mixture. General Considerations: A cost vs. benefit evaluation should be undertaken for each decon strategy & approach which considers: public safety, total cost, impact on the facility, wastes generated, as well as the time the facility or item will be out of service & any socio-economic, psychological, &/or security impacts that may result. Large volumes of decon wastes may be generated which will need to be collected, treated & disposed of properly. Waste handling & disposal must be addressed as early in the decon & cleanup process as possible, see WASTE DISPOSAL section. Disposal Option: The urgency to restore a facility as quickly as possible may result in the outright & timely removal & disposal of contaminated materials. Certain materials may be resistant to decon formulations, or may be cheaper to discard & replace then to decon & restore. Monitored Natural Attenuation: HL is degraded via natural processes. Environmental monitoring must be maintained during decon & recovery phases. Monitored natural attenuation may require institutional controls (e.g. access restriction & 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 nondestructive to materials. 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 separate & immobilize the agent contamination from coming into contact with the environment or the public. This can be a temporary or permanent solution. Decon Strategy: A decon strategy can be developed by designating contaminated areas into 3 broad categories: 1) surfaces or hot-spots, 2) large volumetric spaces, & 3) sensitive equipment or items. Areas in each category may be treated using one or more unique decon processes in a tiered approach to overall site specific decon strategy. 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 & methods. Hydrolysis of H on surfaces is slow – decontaminants that rely on hydrolysis will not destroy this agent on surfaces. Hypochlorite solutions: Hypochlorite can be very damaging (corrosive) to certain surfaces & materials & should be rinsed thoroughly afterwards. Household bleach solutions (5.0% sodium hypochlorite) are very effective for H & are expected to be effective for L with efficacy achieved with contact time of 15-60 minutes depending on surface material. Calcium hypochlorite, present in commercial products, such as HTH (10% hypochlorite solution), is better for surfaces with high amounts of localized, liquid contaminant. Large Volumetric Spaces: This category is for areas larger in size but with lower levels of agent contamination. They may require less aggressive but more broadly applied decon products & methods. 1) Monitored Natural Attenuation is more passive than other decon options & is non-destructive to materials. This option may be preferable given the scope & severity of contamination; 2) Forced or hot air ventilation methods are recommended for vapor plume contamination or when low concentrations are present in large volumetric spaces or open areas; efficacy typically can be achieved in hours to days with less waste & adverse impacts to materials. 3) Fumigation with modified vaporous hydrogen peroxide (mVHP®) has been reported to be effective against H. HVAC systems in large indoor spaces may require a separate decon strategy which could include the use of hot air ventilation or fumigation. Sensitive Equipment & Items: 1) Forced or hot air ventilation can be used for HL either in-situ or ex-situ to decon these items, although H may be removed preferentially. 2) mVHP® fumigation can be used on these items for removal of H with less corrosion to electronics than dilute hypochlorite solutions. CAUTION: Decon products may have unique safety/PPE requirements due to their own toxicity or that of breakdown products during use (e.g., bleach results in chlorine vapors). Strong oxidizers such as hypochlorite may react violently with organics. Proprietary decon foams & gels such as DF-200®, CASCAD®, Decon Green®, or L-Gel® have been reported to be effective against H on the order of minutes to hours, but have not been thoroughly tested. L has not been tested against these products. Under oxidizing conditions, (i.e.; bleach) H can break down into several toxic by-products, such as mustard & vinyl sulfones. Hydrolysis of H releases HCl which can affect the pH of solutions. Formulations should be chosen that do not allow the formation of these toxic by-products. Availability, cost & the need for specialized equipment may limit their use early in the response. Dirt, grime, & other coatings can reduce the efficacy of decon; pre-cleaning surfaces with soap & water may be needed before the application of decon formulations but resulting pre-cleaning rinsates may contain & spread agent & therefore must be contained & treated prior to disposal. Verification of Decon: Site & situation specific. Please contact NRC for initial notification (1-800-424-8802) & EPA/HQ-EOC (202-564-3850) post notification.</p>
	Waste Disposal
<p>Waste Disposal Planning: Waste disposal for agent-contaminated wastes generated from the decontamination & disposal activities will be problematic. Landfills willing to take these wastes may be limited & incineration may be prohibitively expensive or impractical. All waste disposal options should be investigated as early into the response process as possible. Transportation of the agent contaminated wastes from the site to the landfill or incinerator may be problematic as well. First, agreements must be reached between the waste sender & acceptor BEFORE transport, followed by timely public notification of the transport & disposal phases. Transportation of hazardous waste may cross several states & localities, which may exceed federal regulations. Requirements for transporting hazardous materials, & procedure for exemption, are specified in http://www.fmcsa.dot.gov/safety-security/hazmat/complyhmpregs.htm#hmp. HL, H & L are classified as a Division 6.1 material & is shipped as Hazard Zone A. The L component of the HL mixture contains Arsenic (As), state & local authorities may have specific regulations regarding the disposal of As containing wastes. The U.S. EPA has developed a web-based Incident Waste Management Planning & Response Tool which contains links to guidance related to waste transportation, contact information for potential treatment, disposal facilities, & state regulatory offices, packaging guidance to minimize risk to workers, & guidance to minimize the potential for contaminating the treatment or disposal facility. Access to the EPA's web based disposal tool requires pre-registration (http://www2.ergweb.com/bdrtool/login.asp).</p>	