

NRT Quick Reference Guide: Sulfur Mustard (HD)

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: Schedule 1 Chemical Warfare Blister (Vesicant) Agent CAS: 505-60-2 Formula: C₄H₈Cl₂S, Molecular Weight: 159.08 g/mol</p> <p>Description: Sulfur mustard is sometimes called "mustard gas" but is actually a yellow to brown oily liquid with a garlic, onion, horseradish or mustard-like odor. It is a blister (vesicant) agent that will have delayed health effects on the order of hours. It can be manufactured at different concentrations; with impurities, additives, or thickening materials which will all effect physical properties, appearance, persistence, & analytical detection limits. Distilled mustard (HD), is considered the most potent form and is the basis of this QRG. Environmental breakdown products of HD, including thiodiglycol (TDG), are relatively nontoxic, but some decon by-products can be toxic (sulfones).</p> <p>Persistence: HD is considered a "semi-persistent" agent with liquid deposition on surfaces lasting for 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. Under certain environmental conditions, 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. Porous, permeable, organic or polymeric materials such as carpets & vinyl tiles can act as sinks for absorbing HD vapors & liquids, prolonging persistence.</p>																														
	<p>Physical properties are listed at/near STP unless otherwise indicated. Conversion Factors: ppm = mg/m³ x 0.1538; mg/m³ = ppm x 6.503</p> <p>Vapor Pressure: 0.072 mm Hg (68°F/20°C) Vapor Density: 5.4 (air = 1) Aqueous Solubility: 0.92 g/L</p> <p>Volatility: 920 mg/m³ (86°F/30°C) Boiling Point: ~422°F/217°C Soluble: (all) organic solvents, oils, fats</p> <p>Freezing Point: 58.1°F/14.5°C Flash Point: 223°F/106°C Liquid Density: 1.27g/cm³</p>																														
Release Scenarios	<p>AIR RELEASE SCENARIOS ARE ASSUMED MOST PROBABLE; HOWEVER OTHER RELEASE SCENARIOS & EXPOSURE ROUTES SHOULD BE CONSIDERED.</p> <p>Open Areas: HD is difficult to disperse in air due to low volatility; however, it may be possible to disperse HD as a vapor/aerosol plume if an appropriate heat/explosive device is employed. The low volatility of HD would limit the size & extent of plume dissipation, posing localized hazards. HD has a freezing point at 15°C (58°F), so the reaerosolization of liquids & solids, as ambient temperatures rise, may present a real hazard. HD vapors are heavier than air and can accumulate in lower terrains.</p> <p>Water/Water Systems: HD released into water may dissolve & hydrolyze, but in sufficient amounts (relative to water volume) HD 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. Water systems, plumbing, surfaces, & equipment that have contacted HD globules, must be evaluated for decontamination.</p> <p>Indoor Facility: HD is a semi-persistent agent with low to moderate volatility, & would be difficult to distribute effectively throughout a building or facility from a point source. Liquid HD will result in localized areas of surface contamination. HVAC system intakes near to liquid HD should be investigated for contamination from HD vapors & aerosols. HD 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 HD are not typically fatal immediately, but can require substantial supportive medical care as there is no antidote, & secondary infections from blisters/tissue damage may be fatal. HD produces effects by entering cells & causing DNA damage/cell death in seconds (this is not like an acid burn). Despite the immediate DNA damage, actual signs/symptoms are DELAYED 1-48 HOURS AFTER EXPOSURE—so those exposed may not be aware.																													
	Signs/Symptoms	<p>Information below is exposure route specific. Regardless of route the following range of effects may occur depending on dose.</p> <p>Mild: Effects delayed 1-48 hours (severity depends on dose): Eye irritation (tearing, grittiness); runny nose, sneezing, nosebleed, hoarseness, hacking cough.</p> <p>Moderate: Effects delayed 1-24 hours: Above plus reddening, swelling of eyelids, severe cough, shortness of breath, reddening of skin.</p> <p>Severe: Effects delayed 1-24 hours: Upper respiratory/lung damage may occur at high concentrations & longer exposure durations.</p>																													
	Exposure Routes	<p>Inhalation: Injury develops slowly, intensifies over several days. Vapor exposure is absorbed in mucous membranes (mouth, throat, & lungs).</p> <p>Skin: Direct contact with HD liquid can cause redness or blisters in 2 to 24 hours. Warm & sweaty skin areas (underarms, groin) are most susceptible.</p> <p>Eyes: Eyes are the most sensitive to HD injury; effects noted 1-12 hours; irritation, burning, gritty feeling, itching, weeping, reddening, lid swelling, light-sensitivity, pain, & corneal injury. High concentration effects extremely painful & generally require extended medical treatment.</p> <p>Ingestion: Consumption of contaminated food or drink could cause burning, nausea, & vomiting.</p>																													
Effect Levels	<p>Air: Acute Exposure Guideline Levels (AEGs) for general population one-time exposure emergency scenarios for HD (complete definitions are available in Key References Cited/Used* in NRT Quick Reference Guides for Chemical Warfare Agents):</p> <table border="1"> <thead> <tr> <th>AEGL Level in mg/m³, at exposure duration →</th> <th>10 min.</th> <th>30 min.</th> <th>1 hr.</th> <th>4 hr.</th> <th>8 hr.</th> </tr> </thead> <tbody> <tr> <td>AEGL 1: threshold mild effects</td> <td>0.40</td> <td>0.13</td> <td>0.067</td> <td>0.017</td> <td>0.0083</td> </tr> <tr> <td>AEGL 2: potentially irreversible effects or impaired ability to escape</td> <td>0.60</td> <td>0.20</td> <td>0.10</td> <td>0.025</td> <td>0.013</td> </tr> <tr> <td>AEGL 3: threshold for severe effects/medical needs/increasing potential for lethality</td> <td>3.9</td> <td>2.7</td> <td>2.1</td> <td>0.53</td> <td>0.27</td> </tr> </tbody> </table> <p>Exposure Guidelines: IDLH = 0.7 mg/m³; STEL = 3.0 x 10⁻³ mg/m³; Worker Population Limit (WPL) [an 8-hour time-weighted average occupational value] = 4.0 x 10⁻⁴ mg/m³; General Population Limit (GPL): [a 24-hour time-weighted average] = 2.0 x 10⁻⁵ mg/m³. Soil: Industrial Exposure Scenario = 0.3 mg/kg (10⁻⁴ cancer risk); Residential Exposure Scenario = 0.01 mg/kg (10⁻⁵ cancer risk); Drinking Water: Army field standard at 15L/day, for 7 days = 47 µg/L; Provisional Advisory Levels (PAL-1) for dissolved HD are not available due to rapid hydrolysis of HD to TDG.</p>							AEGL Level in mg/m ³ , at exposure duration →	10 min.	30 min.	1 hr.	4 hr.	8 hr.	AEGL 1: threshold mild effects	0.40	0.13	0.067	0.017	0.0083	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
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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 . We also recommend that responders check their own internal procedures (SOPs) if they have them.																														
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: NO ANTIDOTE AVAILABLE. 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	<p>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. Per NIOSH guidance - LEVEL A: Recommended for the initial response to a HD 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 the HD concentration is unknown or above the IDLH or AEGL-2, & when there is a potential of ocular or dermal exposure. LEVEL B: Provides the highest level of respiratory protection (SCBA) when a lesser level of skin protection is required. Select Level B when the HD concentration is unknown or above the IDLH or AEGL-2 & 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. LEVEL C: Select Level C when the contaminant identity & concentration are known & 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 D: Select Level D when the contaminant is known & the concentration is below the appropriate occupational exposure limit or less than AEGL-1 for the stated duration times. 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.</p>																														
Field Detection	<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 interferences common in the environment.</p> <p>NOTE: Detection equipment does not measure contaminant levels. Rather detect the presence of HD at levels as low as listed below.</p> <table border="1"> <thead> <tr> <th>Minimum Screening Levels</th> <th>CAM/ICAM</th> <th>AP2C/AP4C</th> <th>APD-2000</th> <th>Dräger</th> <th>M256</th> <th>M272 (water)</th> </tr> </thead> <tbody> <tr> <td>ppm</td> <td>0.03</td> <td>0.06</td> <td>0.03</td> <td>0.15</td> <td>0.08</td> <td>2.0 mg/L</td> </tr> </tbody> </table>							Minimum Screening Levels	CAM/ICAM	AP2C/AP4C	APD-2000	Dräger	M256	M272 (water)	ppm	0.03	0.06	0.03	0.15	0.08	2.0 mg/L										
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	mg/m ³	0.2	0.42	0.22	1	2	NA
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)</p> <p>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 HD, 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 HD is 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 is used as food.</p>						
	<p>Note: HD breaks down in most environmental conditions to numerous breakdown products, especially TDG, which is relatively nontoxic and may be used as a marker to determine the extent of contamination of the parent HD. Under certain decon conditions HD can break down into several toxic by-products, such as mustard and vinyl sulfones. Samples should be analyzed for the presence of HD agent & its breakdown products (TDG, etc.), see ANALYSIS section below to ensure sampling procedures are compatible with all analytes.</p> <p>Types of Samples: Air (Vapors are heavier than 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.</p> <p>Water: Water should be collected in appropriate containers with addition of appropriate de-chlorinating agents & preservatives.</p> <p>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 amount of liquid was poured on ground or if an underlying aquifer is endangered.</p> <p>Surface Wipes: Wipe samples are often desired to indicate absence of HD on non-porous surfaces. Concurrent air monitoring is recommended.</p> <p>Bulk: For hot spot areas where liquid HD 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.</p> <p>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>						
	<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 HD analysis, contact the EPA/HQ-EOC at 202-564-3850.</p>						
Anal- ysis							
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 and products. Call the EPA/HQ-EOC at 202-564-3850 for more information.</p> <p>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.</p> <p>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.</p> <p>Monitored Natural Attenuation: HD 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.</p> <p>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.</p> <p>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.</p> <p>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. In contrast to the rapid hydrolysis when HD is dissolved in water, the hydrolysis of HD on surfaces is slow – decontaminants that rely on hydrolysis will not destroy the agent on surfaces. 1) Hypochlorite solutions are effective but can be very corrosive to metals & may require thorough rinse or neutralization after decon. Household bleach solutions (5.0% sodium hypochlorite) are very effective for HD 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.</p> <p>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 of HD are 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 (VHP®) has been reported to be effective against HD. HVAC systems in large indoor spaces may require a separate decon strategy which could include the use of hot air ventilation or fumigation.</p> <p>Sensitive Equipment & Items: 1) Forced or hot air ventilation can be used for HD either in-situ or ex-situ to decon these items. 2) mVHP fumigation can be used on these items with less corrosion to electronics than dilute hypochlorite solutions.</p> <p>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 HD on the order of minutes to hours, but have not been thoroughly tested. Under oxidizing conditions, (i.e.; bleach) HD can break down into several toxic by-products, such as mustard and vinyl sulfones. Hydrolysis of HD releases HCl ions 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, and other coatings can reduce the efficacy of decon; pre-cleaning surfaces with soap and water may be needed before the application of decon formulations but resulting pre-cleaning rinsates may contain and spread agent.</p> <p>Verification of Decon: Site & situation specific. Please contact NRC for initial notification (1-800-424-8802) and EPA/HQ-EOC (202-564-3850) post notification.</p>						
Waste Disposal	<p>CAUTION: Hazardous waste transportation & disposal are regulated federally; however more stringent regulations may exist under state authority. These regulations differ from state-to-state. Detailed state regulations can be found at www.envcap.org.</p>						
	<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 federal, 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/complyhmrregs.htm#hmp. HD is classified as a Division 6.1 material & is shipped as Hazard Zone A. 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>						