

Agent Characteristics	<p><b>Agent Classification:</b> Schedule 1 Chemical Warfare Nerve Agent; <b>CAS:</b> 50782-69-9; <b>Formula:</b> C<sub>11</sub>H<sub>26</sub>NO<sub>2</sub>PS; <b>Molecular Weight:</b> 267.38 g/mol.</p> <p><b>Description:</b> Odorless, oily, yellow/amber colored liquid when pure. VX is a lethal cholinesterase inhibitor having a similar mechanism of toxicity as organophosphate insecticides, though it is much more potent. VX is more potent than the G-agents. However, VX has a very low vapor pressure and is difficult to maintain or disperse as vapor in air. Environmental breakdown products of VX, including methylphosphonic acid (MPA) and ethyl methylphosphonic acid (EMPA), may be present. VX breakdown can result in the formation of compound EA-2192, which is considered almost as toxic as VX by ingestion exposure route. EA-2192 formation is maximized between pH 7-10, but can be formed in potentially significant amounts outside this range.</p> <p><b>Persistence:</b> VX is considered a "persistent" chemical warfare agent. Vapor: hours to days; liquid: hours to months. Persistence will depend upon amount and purity of the agent, method of release, environmental conditions, and the types of surfaces and materials impacted. Porous, permeable, organic or polymeric materials such as carpets and vinyl tiles can act as "sinks" for absorbing VX vapors and liquids, prolonging persistence.</p>																														
	<p>Physical properties are listed at/near STP unless otherwise indicated. Conversion Factors: ppm = mg/m<sup>3</sup> x 0.09144; mg/m<sup>3</sup> = ppm x 10.936</p> <table border="1"> <thead> <tr> <th>Vapor Density</th> <th>Vapor Pressure</th> <th>Volatility</th> <th>Boiling Point</th> <th>Freezing Point</th> <th>Flash Point</th> <th>Liquid Density</th> <th>Aqueous Solubility</th> <th>Non-aqueous Solubility</th> </tr> </thead> <tbody> <tr> <td>9.2 (air = 1)</td> <td>0.0007 mm Hg (68°F/20°C)</td> <td>10.5 mg/m<sup>3</sup> (77°F/25°C)</td> <td>568°F/298°C</td> <td>&lt;-38°F/-39°C</td> <td>318°F/159°C</td> <td>1.008 g/mL (77°F/25°C)</td> <td>30 g/L (temp not reported)</td> <td>Common solvents, alcohols, gasoline, oils, fats</td> </tr> </tbody> </table>							Vapor Density	Vapor Pressure	Volatility	Boiling Point	Freezing Point	Flash Point	Liquid Density	Aqueous Solubility	Non-aqueous Solubility	9.2 (air = 1)	0.0007 mm Hg (68°F/20°C)	10.5 mg/m <sup>3</sup> (77°F/25°C)	568°F/298°C	<-38°F/-39°C	318°F/159°C	1.008 g/mL (77°F/25°C)	30 g/L (temp not reported)	Common solvents, alcohols, gasoline, oils, fats						
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Release Scenarios	<p><b>AIR RELEASE SCENARIOS ARE ASSUMED MOST PROBABLE; HOWEVER, OTHER RELEASE SCENARIOS AND EXPOSURE ROUTES SHOULD BE CONSIDERED.</b></p> <p><b>Open Areas:</b> VX is difficult to disperse in air as a gas due to low volatility, but even small quantities can be lethal. It may be possible to disperse VX as a vapor/aerosol plume if an appropriate heat/explosive device is employed; however, the low volatility of VX would limit the size and extent of plume dissipation, posing localized hazards. VX vapors when present are heavier than air, so vapors can accumulate in lower terrains.</p> <p><b>Water/Water Systems:</b> VX released into water will likely hydrolyze with a half-life of about 1,000 hours at pH 7, with persistence depending on released amount and environmental conditions; however, it could potentially persist for weeks depending on overall dilution and breakdown processes. The hydrolysis breakdown product of VX, EA-2192, may be a greater ingestion concern. If released into water systems such as reservoirs, treatment plants, distribution systems, public fountains or pools, treatment processes can further break down agent. For water systems, plumbing, surfaces and equipment that have contacted contaminated water must be evaluated for decontamination along with the bulk water.</p> <p><b>Indoor Facility:</b> Due to its low volatility, VX would be difficult to distribute effectively throughout a building or facility from a point source. Liquid VX will result in localized areas of surface contamination. VX vapors are heavier than air so vapors can accumulate in lower levels or utility corridors inside the buildings.</p>																														
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Effect Levels	<p><b>Air: Acute Exposure Guideline Levels (AEGs)</b> for general population one-time exposure emergency scenarios for VX (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>AEG Level in mg/m<sup>3</sup>, at various exposure durations</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>AEG 1: Threshold mild effects</td> <td>0.00057</td> <td>0.00033</td> <td>0.00017</td> <td>0.00010</td> <td>0.000071</td> </tr> <tr> <td>AEG 2: Potentially irreversible effects or impaired ability to escape</td> <td>0.0072</td> <td>0.0042</td> <td>0.0029</td> <td>0.0015</td> <td>0.0010</td> </tr> <tr> <td>AEG 3: Threshold for severe effects/medical needs/increasing potential for lethality</td> <td>0.029</td> <td>0.015</td> <td>0.010</td> <td>0.0052</td> <td>0.0038</td> </tr> </tbody> </table> <p>Exposure Guidelines: IDLH = 0.003 mg/m<sup>3</sup>; STEL = 1.0 x 10<sup>-5</sup> mg/m<sup>3</sup>; <b>Worker Population Limit (WPL)</b> [an 8-hr time-weighted average occupational value] = 1.0 x 10<sup>-6</sup> mg/m<sup>3</sup>; <b>General Population Limit (GPL)</b> [a 24-hr time-weighted average lifetime chronic value] = 6.0 x 10<sup>-7</sup> mg/m<sup>3</sup>. <b>Soil: Industrial Exposure Scenario</b> = 1.1 mg/kg; <b>Residential Exposure Scenario</b> = 0.043 mg/kg. <b>Drinking Water:</b> Provisional Advisory Levels (PAL-1) for general public at 2 L/day, for 1, 30, and 90 days = 2.7, 0.21, and 0.21 µg/L, respectively.</p>							AEG Level in mg/m <sup>3</sup> , at various exposure durations	10 min.	30 min.	1 hr.	4 hr.	8 hr.	AEG 1: Threshold mild effects	0.00057	0.00033	0.00017	0.00010	0.000071	AEG 2: Potentially irreversible effects or impaired ability to escape	0.0072	0.0042	0.0029	0.0015	0.0010	AEG 3: Threshold for severe effects/medical needs/increasing potential for lethality	0.029	0.015	0.010	0.0052	0.0038
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Rinse eyes exposed to liquid agent with potable water for 15 minutes. <b>Antidote:</b> Atropine, 2-PAM Chloride injections (Duo Dote/Mark II kits). <b>Antidote kit should only be administered as per pre-incident training.</b> Send person for follow-up medical attention and evaluation. If cleared to resume work, continue to monitor for signs/symptoms and treat accordingly.</td> </tr> <tr> <td>PPE</td> <td><b>GENERAL INFORMATION:</b> 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, and protective clothing should be used. Pre-incident training and exercises on the proper use of PPE are recommended. Per NIOSH guidance - <b>LEVEL A:</b> Recommended for the initial response to a VX incident. Level A provides the greatest level of skin (fully encapsulating suit), respiratory (SCBA), and eye protection when the contaminant identity or concentration is unknown. Select Level A when the VX concentration is unknown or above the IDLH or AEG-2, and when there is a potential of ocular or dermal exposure. <b>LEVEL B:</b> Provides the highest level of respiratory protection (SCBA) when a lesser level of skin protection is required. Select Level B when the VX concentration is unknown or above the IDLH or AEG-2 and 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. <b>LEVEL C:</b> Select Level C when the contaminant identity and concentration are known and the respiratory protection criteria factors for the use of APR or PAPR (i.e., &lt; IDLH, warning properties) are met. Level C may be appropriate when decontaminating personnel or equipment. <b>LEVEL D:</b> Select Level D when the contaminant is known and the concentration is below the appropriate occupational exposure limit or less than AEG-1 for the stated duration times. <b>Downgrading PPE levels can be considered only when the identity and concentration of the contaminant and the risks of dermal exposure are known, and must be accompanied by on-site monitoring.</b></td> </tr> </table>							Note	Personal Protective Equipment (PPE) selection (levels A-D), medical surveillance requirements, First Aid options and personnel decontamination may vary depending upon the amount and purity of agent, site conditions and the release scenario. Additional information on personnel safety and PPE selection criteria can be found at: <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 they have them.	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Field Detection	<p>Real-time field screening tools (results not confirmatory or quantitative) AND may not specify type of nerve agent. 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 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. NA = not available.</p>																														
	<p><b>NOTE: Detection equipment does not measure contaminant levels. Rather, they detect the presence of a nerve agent at levels as listed below.</b></p> <table border="1"> <thead> <tr> <th>Minimum Screening Ranges</th> <th>CAM/ICAM</th> <th>AP2C/AP4C</th> <th>APD-2000</th> <th>Dräger (CDS Kit)</th> <th>M256/M256A1</th> <th>M272 (water)</th> </tr> </thead> <tbody> <tr> <td>ppm</td> <td>0.0037-0.02</td> <td>0.0009-0.0015</td> <td>0.0037-0.004</td> <td>0.025</td> <td>0.002-0.009</td> <td>0.02 mg/L</td> </tr> <tr> <td>mg/m<sup>3</sup></td> <td>0.03-0.1</td> <td>0.01-0.03</td> <td>0.25-0.04</td> <td>0.27</td> <td>0.005-0.1</td> <td>NA</td> </tr> </tbody> </table>							Minimum Screening Ranges	CAM/ICAM	AP2C/AP4C	APD-2000	Dräger (CDS Kit)	M256/M256A1	M272 (water)	ppm	0.0037-0.02	0.0009-0.0015	0.0037-0.004	0.025	0.002-0.009	0.02 mg/L	mg/m <sup>3</sup>	0.03-0.1	0.01-0.03	0.25-0.04	0.27	0.005-0.1	NA			
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Sampling	<p><b>Note:</b> This section on sampling contains general guidelines and does not replace the need for a site-specific sampling plan (See Key References Cited/Used)</p> <p><b>Sampling Concerns:</b> 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. Few laboratories currently have capability to determine VX (or its breakdown product EA-2192), in all types of media. 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 (<a href="http://www2.epa.gov/emergency-response/environmental-response-laboratory-network">www2.epa.gov/emergency-response/environmental-response-laboratory-network</a>). For sampling questions, call the EPA/HQ-EOC at 202-564-3850.</p>
	<p><b>Sample Locations and Planning:</b> 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 VX is a persistent liquid, sample priorities should include surfaces that are potentially contaminated with aerosol/liquid (e.g., release site, low lying areas) and that humans are likely to contact or where vegetation is used as food.</p>
	<p><b>Note:</b> VX breaks down in most environmental conditions to numerous breakdown products, especially EA-2192, MPA and EMPA, which may be used as markers to determine the extent of contamination of the parent VX. See ANALYSIS section below to ensure sampling procedures are compatible with all analytes.</p> <p><b>Types of Samples:</b></p> <p><b>Air (Vapors are heavier than air):</b> Samples are collected using appropriate solid phase absorbent (tubes) or air sampler (e.g., SUMMA canister) at breathing zone level (~5 ft.) to assess inhalation exposure and at ground levels (~6 in.) to assess off gassing at surfaces.</p> <p><b>Water:</b> Water should be collected in appropriate containers with addition of appropriate de-chlorinating agents and preservatives. In large volumes of water, VX is expected to dissipate via breakdown, hydrolysis and dilution. To rule out contamination concerns, particularly in small bodies of water, analyses should include EA-2192.</p> <p><b>Soil:</b> 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. 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.</p> <p><b>Surface Wipes:</b> Wipe samples are often desired to indicate absence of VX on non-porous surfaces. Concurrent air monitoring is recommended.</p> <p><b>Bulk:</b> For hot spot areas where liquid VX 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. Bulk samples of suspected sink materials may be recommended to rule out secondary vapor phase disposition or absorption of VX into these materials.</p> <p><b>Other Sample Matrices:</b> Contact EPA/HQ-EOC at 202-564-3850 for sampling instructions.</p>
	<p><b>Sample Packaging and Shipping:</b> The packaging and shipping of samples are subject to strict regulations established by DOT, CDC, USPS, OSHA and IATA. Contact the sample-receiving laboratory to determine if they have additional packaging, shipping or labeling requirements.</p>
Anal ysis	<p><b>CAUTION:</b> Many labs may not be able to perform analysis on all matrices (e.g., wipes and soil). The ERLN will use uniform, compatible sample prep and analytical methods. (See <a href="http://www2.epa.gov/emergency-response/environmental-response-laboratory-network">www2.epa.gov/emergency-response/environmental-response-laboratory-network</a>). For access to the nearest ERLN laboratory specially trained and equipped for VX analysis, contact the EPA/HQ-EOC at 202-564-3850.</p>
Decontamination/Cleanup	<p><b>Decontamination/Cleanup Planning:</b> Once site controls are in place, develop a site-specific decontamination/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><b>General Considerations:</b> A cost vs. benefit evaluation should be undertaken for each decontamination strategy and approach that 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 and any socio-economic, psychological, 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).</p> <p><b>Disposal Option:</b> The urgency to restore a facility as quickly as possible may result in the outright and timely removal and disposal of contaminated materials. Certain materials may be resistant to decontamination formulations, or may be cheaper to discard and replace than to decontaminate and restore.</p> <p><b>Monitored Natural Attenuation:</b> VX 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. Potential formation of EA-2192 must be considered and addressed.</p> <p><b>Fix-in-Place Option:</b> 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 and immobilize the agent contamination from coming into contact with the environment or the public. This can be a temporary or permanent solution.</p> <p><b>Decontamination Strategy:</b> A decon strategy can be developed by designating contaminated areas into three broad categories: 1) surfaces or hot spots, 2) large volumetric spaces, and 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><b>CAUTION:</b> VX hydrolyzes and forms the toxic breakdown product EA-2192, with greatest yields between pH levels 7 and 10. For decontamination and EA-2192 information, contact the EPA/HQ-EOC at 202-564-3850. It is advisable to choose a decontamination solution containing a strong oxidant, such as chlorine or peroxide, which will help limit EA-2192 formation regardless of pH. Presence of EA-2192 may present significant challenges in waste disposal.</p> <p><b>Surfaces/Hot Spots:</b> This category is for areas smaller in size but with higher levels of agent contamination. They may require more rigorous decontamination products and methods.</p> <p>1) Hypochlorite Solutions: Hypochlorite can be very corrosive to certain surfaces and materials and should be rinsed thoroughly afterwards. Household bleach solutions (≥5% sodium hypochlorite) are very effective for VX 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 concentrations of liquids in localized areas.</p> <p>2) Aqueous peroxide solutions may be effective in breaking down VX without the formation of the EA-2192 species. Proprietary decontamination foams and gels such as DF-200®, CASCAD®, Decon Green®, or L-Gel® have been shown to be effective against VX on the order of minutes to hours, but not all have been thoroughly tested. Availability, cost and the need for specialized equipment may limit their use early in the response.</p> <p><b>Large Volumetric Spaces:</b> This category is for areas larger in size but with lower levels of agent contamination.</p> <p>1) Monitored Natural Attenuation is more passive than other decontamination options and is non-destructive to materials. This option may be preferable given the scope and severity of contamination.</p> <p>2) Forced or Hot Air ventilation methods are recommended for vapor plume contamination or low concentration of VX in large volumetric spaces or open areas; efficacy typically can be achieved in days to weeks with less waste and adverse impacts to materials.</p> <p>3) Fumigation with modified vaporous hydrogen peroxide (VHP®) has been reported to be effective against VX. HVAC systems in large indoor spaces may require a separate decontamination strategy that could include the use of Hot Air ventilation or fumigation.</p> <p><b>Sensitive Equipment and Items:</b> 1) Forced or Hot Air ventilation may be used for VX and can be used either in-situ or ex-situ to decontaminate these items. The low volatility of VX may necessitate high operating temperatures.</p> <p>2) modified VHP® fumigation can be used on these items with less corrosion to electronics than dilute hypochlorite solutions.</p> <p><b>CAUTION:</b> Decontamination 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. Formulations should be chosen that do not allow the formation of toxic breakdown products such as EA-2192. Dirt, grime and other coatings can reduce the efficacy of decontamination; pre-cleaning surfaces with soap and water may be needed before the application of decontamination formulations but resulting pre-cleaning rinsates may contain and spread agent and toxic breakdown products.</p> <p><b>Verification of Decontamination:</b> Site and situation specific. Please contact EPA/HQ-EOC at 202-564-3850 for further assistance.</p>
Waste Management	<p><b>CAUTION:</b> Federal requirements for transporting hazardous materials and procedures for exemptions are specified in <a href="http://www.fmcsa.dot.gov/safety-security/hazmat/complyhregs.htm#hmp">www.fmcsa.dot.gov/safety-security/hazmat/complyhregs.htm#hmp</a>. These regulations differ from state-to-state. Detailed state regulations can be found at: <a href="http://www.envcap.org">www.envcap.org</a>. Current resources on packaging, labeling and shipping are available at: <a href="http://www.phmsa.dot.gov/hazmat">www.phmsa.dot.gov/hazmat</a>.</p> <p><b>Waste Management:</b> Under the Resource Conservation and Recovery Act (RCRA), waste generally is classified as hazardous waste (subtitle C) or solid waste (subtitle D). Under RCRA's statutory authority, a waste is considered hazardous if it: (A) causes or significantly contributes to an increase in mortality or an increase in serious, irreversible or incapacitating reversible illness or (B) poses a substantial, present or potential hazard to human health or the environment when improperly treated, stored, transported or disposed of or otherwise managed. The RCRA regulations generally define a waste as hazardous if it is: (1) a listed waste (40 CFR§261.21, §261.32), (2) exhibits specific characteristics (§261.21-261.24) or (3) is a spilled or discarded commercial chemical product (§261.33). The States (except for Alaska and Iowa) have the primary responsibility to implement the hazardous waste regulations and can impose more stringent requirements than the Federal program, so it is critical to open a dialogue with regulators as early as possible. Several states (CO, IN, KY, MD, OR, UT) have their own waste designations for CWA, which may be applicable for the cleanup of contaminated residues. VX is not a hazardous waste under the Federal regulations, but state codes may apply for VX-contaminated residues, soils and debris. Management of toxic decomposition products, associated residual decontamination solutions, local waste acceptance criteria, and transportation and handling requirements should be considered. The EPA has developed I-WASTE, a web-based tool that contains links to waste transportation guidance, treatment and disposal facilities, state regulatory offices, packaging guidance, and guidance to minimize the potential for contaminating the treatment or disposal facility. Access to this decision support tool requires pre-registration (<a href="http://www2.ergweb.com/bdrtool/login.asp">www2.ergweb.com/bdrtool/login.asp</a>).</p>