Health Effects

Agent Characteristics

Description: 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 may be formed in potentially significant amounts outside this range.

Persistence: 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.

Release Scenarios

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

Open Areas: 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.

Water/Water Systems: 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 water equipment that have contacted contaminated water must be evaluated for decontamination along with the bulk water.

Indoor Facility: Due to its low volatility, VX would be difficult to disperse effectively throughout a building or facility from a point source. Liquid VX will result in localized areas of surface contamination. VX compounds heavier than air may collect inside buildings. If VX is used in low quantities, concerns inside the building may be more limited. If VX is released at low quantities in an indoor environment, lower floors where the vapor may dissipate away from vents can accumulate higher levels of VX vapors and liquids, prolonging persistence.

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/m³ (77°F/25°C) 568°F/298°C <~38°F/39°C 318°F/159°C 1.08 g/ml (77°F/25°C) 30 g/l (temp not reported) Common solvents, alcohols, gasoline, oils, fats

Vapor Properties are listed at/near STP unless otherwise indicated. Conversion Factors: ppm = mg/m³ x 0.00144; mg/m³ = ppm x 10.936

Health Effects

Onset: Onset of symptoms is dose and route dependent. After exposure, symptoms may occur within seconds if VX is present in vapor form or within minutes to hours if in liquid form. Even extremely low dose exposure to VX can be fatal and immediate administration of an antidote is critical (see First Aid below).

Signs/Symptoms: Symptoms will vary depending on exposure route; however, the following is a general list of all possible symptoms. The severity of effects depends upon the dosage.

- Mild: Runny nose, reduction in pupil size (miosis), diminution of vision, tightness of chest, difficulty in breathing.
- Moderate: Increased miosis (to level of pinpointing of pupils), headaches, confusion, drowsiness, nasal congestion, tightness of chest, nausea, vomiting, diarrhea, cramps, generalized weakness, twitching of large muscle groups.
- Severe: Involuntary defecation and urination, drooling, twitching, staggering, convulsions, cessation of breathing, loss of consciousness, coma, death.

Exposure Routes: Inhalation: Inhalation of very small concentrations can produce health effects. Skin: Direct contact with liquid agent is especially toxic. Moderate to severe signs/symptoms occur at, but are not limited to, the site of contact. Exposure can also result from absorption of vapors via skin.

- Eyes: Eyes are the most sensitive target organs of nerve agent exposure. Miosis (reduction in pupil size) will typically be the first sign of exposure.
- Ingestion: Contaminated drinking water and foods are the most likely route for ingestion of agent. Target organ from ingestion is the GI tract.
- Other: Females appear to be more susceptible to nerve agent effects. Certain genetic traits may increase susceptibility.

Effect Levels

Vapor Exposure Durations

<table>
<thead>
<tr>
<th>AEGL Level in mg/m³ 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>AEGL 1: Threshold mild effects</td>
<td>0.00067</td>
<td>0.00033</td>
<td>0.00017</td>
<td>0.00010</td>
<td>0.000071</td>
</tr>
<tr>
<td>AEGL 2: Potentially reversible 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>AEGL 3: Threshold for severe effects/medical/necrotoxic potential for lethality</td>
<td>0.029</td>
<td>0.015</td>
<td>0.010</td>
<td>0.0062</td>
<td>0.0038</td>
</tr>
</tbody>
</table>

Exposure Guidelines: IDLH = 0.003 mg/m³; STEL = 1.0 x 10⁴ mg/m³; Worker Population Limit (WPL) (8-hr time-weighted average occupational value) = 1.0 x 10⁴ mg/m³; General Population Limit (GPL) (24-hr time-weighted average lifetime chronic value) = 6.0 x 10⁻⁴ mg/m³; Soil: Industrial Exposure Scenario = 1.1 mg/kg; Residential Exposure Scenario = 0.043 mg/kg

Drinking Water: Provisional Advisory Levels (PAL-1) for public water at 2/day, for 1, 30, and 90 days are 2.7, 0.21, and 0.21 µg/L, respectively.

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

First Aid

Personal Safety

Pre-incident: Annual physical, respiratory function exams and a baseline cholinesterase activity determination. During Incident: Conduct periodic on-site medical monitoring, observe for any signs and symptoms as per Health Effects section above and treat accordingly as per First Aid section below.

First Aid: Immediately remove person from affected area and remove contaminated clothing and articles. Wash bare skin immediately with water, or warm, soapy water if available, at normal high pressure water (50-60 psi) for three minutes, ensure thorough soaping. Rinse eyes exposed to liquid agent with potable water for 15 minutes. Antidote: Atropine, 2-PAM Chloride injections (Duo Dote/Mark II kits). Antidote kit should only be administered as per pre-incident training. Send person for follow-up medical attention and evaluation. If cleared to resume work, continue to monitor for signs/symptoms and 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, and protective clothing should be used. Pre-incident and exercises on the proper use of PPE should be conducted. Per NIOSH guidance - LEVEL A: 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 AEGL-2, and 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 VX concentration is unknown or above the IDLH or AEGL-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. LEVEL C: 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., <= 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 and 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 and concentration of the contaminant and the risks of dermal exposure are known, and must be accompanied by on-site monitoring.

Personnel Safety

Field Detection

Real-time field screening test results (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.

NOTE: Detection equipment does not measure contaminant levels. Rather, they detect the presence of a nerve agent at levels as listed below.

Minimum Screening Ranges: CAMICAM (2 ppm), AP2CA (4 ppm), APD-2000 (2 ppm), Drager (CDS Kit) (0.0037 ppm), M256 (2 ppm), 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/m³

0.03-0.1

0.01-0.03

0.25-0.04

0.27

0.005-0.1

NA

Updated January 2015 (replaced previous version dated 2011)
Decontamination/Cleanup

Anal Sampling

Note: This section on sampling contains general guidelines and does not replace the need for a site-specific sampling plan (See Key References Cited/Used)

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 contacting agent; 3) persistence of the agent; and 4) type and degree of sampling required. 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 (www2.epa.gov/emergency-response/environmental-response-laboratory-network). For sampling questions, call the EPA/HQ-EOC at 202-564-3850.

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 used to provide the clearance data or uncertain release areas. 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.

Sample Note: 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.

Types of Samples:

Air (Vapors are heavier than air): 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.

Water: Water should be collected in appropriate containers with additional of appropriate chlorinating agents and preservatives. In large volumes of water, VX is expected to dissipate via biodegradation and evaporation. To avoid altering small bodies of water, analyses should include EA-2192.

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. 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.

Surface Wipes: Wipe samples are often indicated to indicate absence of VX on non-porous surfaces. Concurrent air monitoring is recommended.

Bulk: 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 contamination of VX into these materials.

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

Sample Package and Shipping:
The package 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 shipping, packaging or labeling requirements.

CAUTION: Many labs may not be able to determine on all matrices (e.g., wipes and soil). The ERLN will use uniform, compatible sample prep and analytical methods. (See www2.epa.gov/emergency-response/environmental-response-laboratory-network). For access to the nearest ERLN laboratory specially trained and equipped for VX analysis, contact the EPA/HQ-EOC at 202-564-3850.

Decontamination/Cleanup

Decontamination/Cleanup Planning: 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.

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 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).

Disposal Option: 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.

Monitored Natural Attenuation: VX degrades via natural processes. Environmental monitoring must be maintained during decontamination and recovery phases. Monitored natural attenuation should be considered for resources that are contaminated or if there are proven natural attenuation concentrations (e.g., aquifers for 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.

Fix-in-Place Option: The contaminated area may remain to resistant 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.

Decontamination Strategy: 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.

CAUTION: 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.

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. 1) Hypochlorite Solutions: Hypochlorite can be very corrosive to certain surfaces and materials and should be rinsed thoroughly afterwards. Household bleach solutions (such as HTH (10% hypochlorite solution), is better for surfaces with high concentrations of liquids in localized areas. 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 for VX, and do not form EA-2192.

Large Volumetric Spaces: This category is for areas larger in size but with lower levels of agent contamination. 1) Monitor 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. 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. 3) Fumigation with modified vaporized 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.

Sensitive Equipment and Items:

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 makes it suitable for forced air decontamination. Exposure to VHP® is not as destructive as direct contact with unheated VHP®. 2) Acidic solutions containing peracetic acid with less corrosion to electronics than dilute hypochlorite solutions.

CAUTION: Decontamination products may have unique safety/PPPE 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 surfaces 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.

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


Waste Management

Waste Management: 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 CFR261.21, §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 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 summed their regulations into one regulatory program. VX is not considered to be a hazardous waste under the RCRA, but state regulations 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 management to minimize the potential for contaminating the treatment or disposal facility. Access to this decision support tool requires pre-registration (www2.epa.gov/idtool/login.asp).

Updated January 2015 (previous version dated 2011)