NRT Quick Reference Guide:
Cyclosarin (GF)
[January 2015 Update]

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

Agent Classification: Schedule 1 Chemical Warfare Nerve Agent; CAS: 329-99-7; Formula: $C_7H_{14}FO_2P$; Molecular Weight: 180.2 g/mol.
Description: Colorless liquid, generally odorless. GF is a lethal cholinesterase inhibitor with a mechanism of toxicity similar to organophosphate insecticides, though it is much more potent. Environmental breakdown products of GF, including methylphosphonic acid (MPA), are relatively non-toxic. Other breakdown products include fluoride ion, which may exist as hydrofluoric acid (HF) depending on the pH. GF can react violently with strong oxidizers and may decompose when in contact with metals, evolving flammable hydrogen gas. GF is combustible but not easily ignited when heated; GF vapors can form explosive mixtures with air.
Persistence: GF is considered a "moderately low persistent" chemical warfare agent. Vapor: minutes to hours; liquid: hours to days. 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 accumulate agent by sorbing GF vapors and liquids, acting as "sinks," thereby prolonging persistence.

Physical properties are listed at/near STP unless otherwise indicated. Conversion Factors: ppm = mg/m³ x 0.1357; mg/m³ = ppm x 7.370

Vapor Density	Vapor Pressure	Volatility	Boiling Point	Freezing Point	Flash Point	Liquid Density	Aqueous Solubility	Non-aqueous Solubility
6.2 (air = 1)	0.044 mm Hg (77°F/25°C)	580 mg/m³ (77°F/25°C)	462°F/239°C	-22°F/-30°C	201°F/94°C	1.13 g/mL (68°F/20°C)	Insoluble in H_2O	Common solvents, alcohols, gasoline, oils, fats

Release Scenarios

AIR RELEASE SCENARIOS ARE ASSUMED MOST PROBABLE; HOWEVER, OTHER RELEASE SCENARIOS AND EXPOSURE ROUTES SHOULD BE CONSIDERED.
Open Areas: GF has low volatility but may still be present as a vapor or aerosol, and the primary release/attack scenario is an airborne release. GF is expected to degrade in the environment fairly rapidly; however, liquid GF on surfaces generally persists for hours to days. Environmental conditions will affect the degradation and evaporation rates of GF with cooler and drier conditions enhancing persistence. GF vapors are heavier than air, so vapors can accumulate in lower terrains.
Water/Water Systems: GF is not typically considered a water release hazard. If released into natural waters or water systems, GF will likely hydrolyze with a half-life estimated at 19 hours at pH 7, with persistence depending on released amount and environmental conditions.
Indoor Facility: GF could potentially be dispersed as a vapor or aerosol inside a building or facility; HVAC systems could be impacted. GF vapors are heavier than air so vapors can accumulate in lower levels or utility corridors inside the buildings.

Health Effects

Onset	Onset of symptoms is dose and route dependent. After exposure, symptoms may occur within seconds if GF is present in vapor form or within minutes to hours if in liquid form. Even a relatively low dose exposure to GF 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), dimness 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: A primary exposure route; 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

Air: Acute Exposure Guideline Levels (AEGLs) for general population one-time exposure emergency scenarios for GF (complete definitions are available in Key References Cited/Used in NRT Quick Reference Guides for Chemical Warfare Agents):

AEGL Level in mg/m³, at various exposure durations	10 min.	30 min.	1 hr.	4 hr.	8 hr.
AEGL 1: Threshold mild effects	0.0035	0.0020	0.0014	0.00070	0.00050
AEGL 2: Potentially irreversible effects or impaired ability to escape	0.044	0.025	0.018	0.0085	0.0065
AEGL 3: Threshold for severe effects/medical needs/increasing potential for lethality	0.38	0.19	0.013	0.070	0.051

Exposure Guidelines: IDLH = 0.05 mg/m³; STEL = 5.0 x 10^{-5} mg/m³; Worker Population Limit (WPL) [an 8-hr time-weighted average occupational value] = 3.0 x 10^{-5} mg/m³; General Population Limit (GPL) [a 24-hr time-weighted average] = 1.0 x 10^{-6} mg/m³. Soil: Industrial Exposure Scenario = 5.2 mg/kg; Residential Exposure Scenario = 0.22 mg/kg.
Drinking Water: Provisional Advisory Levels (PAL-1) for general public at 2 L/day, for 1, 30, and 90 days = 7.4, 1.6, and 0.44 µg/L, respectively.

Personnel Safety

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/ershdb. We also recommend that responders check their own internal procedures (i.e., SOPs), if they have them.
Medical	Pre-incident: A baseline cholinesterase activity determination and an annual physical and respiratory function exam. 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 household pressures (~50-60 psi) for three minutes, ensure thorough soaking. 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 training and exercises on the proper use of PPE are recommended. Per NIOSH guidance - LEVEL A: Recommended for the initial response to a GF 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 GF 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 GF 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.

Field Detection

Real-time field screening tools (results not confirmatory or quantitative): Caution should be given to equipment that has not been properly evaluated. False positive and false negatives may occur in the presence of interferents common in the environment. The following is a summary of minimum screening concentration ranges 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	CAM/ICAM	AP2C/AP4C	APD-2000	Dräger (CDS Kit)	M256/M256A1	M272 (water)
ppm	0.014-0.02	0.0015-0.0017	0.015	0.025	0.002-0.009	0.02 mg/L
mg/m³	0.03-0.1	0.01-0.03	0.1-0.11	0.18	0.005-0.007	NA

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 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 GF, particularly for large numbers of samples and 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 required for the clearance phase or if there are large uncertainties about the area impacted or the amount released. Because GF is generally not persistent, air sampling to help to "clear areas" should be included in the sampling plan.
	Note: GF breaks down in most environmental conditions to numerous breakdown products, especially fluoride ion and MPA, which may be used as markers to determine the extent of contamination of the parent GF. 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 addition of appropriate de-chlorinating agents and preservatives; G-agents are unlikely to persist in water. Soil: For localized hot spot areas where soil deposition may occur, surface soil samples should be taken from a non-vegetated area to a depth of less than one inch. Sub-surface soil samples may not be 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 desired to indicate absence of GF on non-porous surfaces. Concurrent air monitoring is recommended. Bulk: For hot spot areas where liquid GF 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 GF into these materials. Other Sample Matrices: Contact EPA/HQ-EOC at 202-564-3850 for sampling instructions.
	Sample Packaging and Shipping: 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.
Analysis	CAUTION: 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 www2.epa.gov/emergency-response/environmental-response-laboratory-network). For access to the nearest ERLN laboratory specially trained and equipped for GF 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: GF 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. 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 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 decontamination 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 decontamination processes in a tiered approach to the overall site-specific decontamination strategy. All statements about decontamination efficacy are based upon GB and have not been verified for GF. However, because hydrolysis has been identified as a major degradation pathway for both GF and GB and because reports of hydrolysis rates for GF are similar to GB, the limited data available suggest similar efficacy for GF as GB. 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. Decontamination of GF occurs mainly through hydrolysis, which may be catalyzed (sped up), by hypochlorites. 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) may be very effective for GF with efficacy expected to be 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. 2) Hydroxide (e.g., sodium, potassium – 10% solution) is expected to react rapidly with GF, but solutions are very damaging to many surfaces and should be rinsed thoroughly after use. 3) Other high pH solutions, such as sodium carbonate (10% solution), are expected to decontaminate but slower than decontamination with sodium or potassium hydroxide. Proprietary decontamination foams and gels such as DF-200®, CASCAD®, Decon Green®, or L-Gel® may be effective against GF, but not all have been thoroughly tested. Availability, cost and the need for specialized equipment may limit their use early in the response. Large Volumetric Spaces: This category is for areas larger in size but with lower levels of agent contamination. They may require less aggressive but more broadly applied decontamination products and methods. 1) Monitored Natural Attenuation is more passive than other decontamination options and is non-destructive to materials. This option may be preferable given the scope and severity of contamination. 2) Forced or Hot Air ventilation methods are recommended for vapor plume contamination or low concentration of GF in large volumetric spaces or open areas; efficacy may be typically achieved in hours to days with less waste and adverse impacts to materials. Sensitive Equipment and Items: Forced or Hot Air ventilation may be used for GF and can be used either in-situ or ex-situ to decontaminate these items. CAUTION: 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). 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. Verification of Decontamination: Site and situation specific. Please contact EPA/HQ-EOC at 202-564-3850 for further assistance.
Waste Management	CAUTION: Federal requirements for transporting hazardous materials and procedures for exemptions are specified in www.fmcsa.dot.gov/safety-security/hazmat/complyhmregs.htm#hmp. These regulations differ from state-to-state. Detailed state regulations can be found at www.envcap.org/. Current resources on packaging, labeling and shipping are available at www.phmsa.dot.gov/hazmat.
	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 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. GF is not a hazardous waste under the Federal regulations, but state codes may apply for GF-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 (www2.ergweb.com/bdrtool/login.asp).