UK Health Security Agency

Nerve agents

Incident management

This document provides information needed for response to a chemical incident, such as physicochemical properties, health effects and decontamination advice.

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Contents

Main points

General

Nerve agents are a group of highly toxic organophosphorus compounds.

Nerve agents are split into two groups based on physiochemical and structural properties:

G agents, which includes sarin (GB), soman (GD), tabun (GA) and cyclosarin (GF). These are volatile liquids that are non-persistent, evaporating rapidly after release.

V agents, which includes VX and VG. These are oily liquids that are less volatile and more persistent than G agents.

Antidotes

The use of atropine and pralidoxime is recommended for patients with excessive secretions, clinically significant hypoxia, bradycardia, or hypotension. For detailed clinical management advice on these antidotes and other antidotes for nerve agent poisoning see TOXBASE.

Health

G agents are major inhalation hazards; ocular exposure is likely and dermal absorption can occur.

V agents have lower volatility and are primarily hazardous via skin absorption.

Miosis (excessive constriction of the pupil), which may be painful and last for several days, occurs rapidly following ocular exposure to a nerve agent.

Increased salivation, chest tightness, rhinorrhoea, bronchorrhoea and/or bronchospasm can occur within seconds or minutes of substantial inhalation of a nerve agent.

Systemic features include abdominal pain, nausea and vomiting, involuntary micturition and defecation, muscle weakness and fasciculation, tremor, restlessness, ataxia, coma and convulsions.

If exposure is substantial, death will occur from respiratory failure within minutes unless antidotes and ventilatory support are provided. Individuals with lesser exposure may still become sick after several hours.

Casualty decontamination at the scene

Following disrobe, improvised dry decontamination should be considered for an incident involving nerve agents, unless casualties are demonstrating signs or symptoms of exposure to caustic or corrosive substances.

Environment

Avoid release to the environment; inform the Environment Agency of any incidents.

Hazard identification

Nerve agents are not subject to GB classification and labelling requirements as they are schedule 1 chemical warfare agents subject to international prohibition under the Chemical Weapons Convention. For more information visit: http://www.opcw.org/chemical-weapons-convention/.

Physicochemical properties

Nerve agents share similar physiological properties with other agents in their class. As such one example from each class is given below.

Table 1a. Physicochemical properties of sarin (G agent)

CAS number	107-44-8
Molecular weight	140
Empirical formula	$C_4H_{10}FO_2P$
Common synonyms	GB, Agent GB, o-Isopropylmethyl phosphonofluoridate, ortho-Isopropylmethyl phosphonofluoridate Methylphosphonoflouridic acid 1-methylethyl ester; Isopropoxymethylphosphoryl fluoride
State at room temperature	Colourless, transparent, odourless liquid
Volatility	Vapour pressure: 2.86 mmHg at 25°C
Specific gravity **Vapour density**	1.09 at 25°C (water = 1) 4.86 (Air = 1)
Flammability	Combustible but doesn't ignite readily
Lower explosive limit	-
Upper explosive limit	-
Water solubility	Miscible with water
Reactivity	Non-flammable. When heated, vapours may form explosive mixtures with air, presenting an explosion hazard indoors, outdoors, and in sewers. Containers may explode when heated. When heated to decomposition or reacted with steam, it emits very toxic fumes of fluorides and oxides of phosphorus. Slightly corrosive to steel. Hydrolyzed by water.
Reaction or degradation products	Acidic conditions produce hydrogen fluoride; alkaline conditions produce isopropyl alcohol and polymers.
Odour	Practically odourless

References

Centre for Disease Control and Prevention. NIOSH. Sarin (GB): Nerve agent (viewed September 2024).

National Library of Medicine US and National Center for Biotechnology Information. 'PubChem Compound Summary for CID 7871, Sarin'. PubChem 2004 (viewed September 2024)

Table 1b. Physicochemical properties of VX (V agent)

CAS number	50782-69-9
Molecular weight	267
Formula	$C_{11}H_{26}NO_2PS$
Common synonyms	Methylphosphonothioic acid S-[2-[bis(methylethyl)amino]ethyl] O-ethyl ester; O-ethyl S-[2-(diisopropylamino)ethyl]methylphosphonothiote; Tx 60
State at room temperature	Odourless, colourless to straw colored liquid, similar in appearance to motor oil
Volatility	Vapour pressure 0.0007mm Hg at 25°C
Specific gravity **Vapour density**	1.01 at 25°C (water = 1) 9.2 (air = 1)
Flammability	Combustible - may burn but does not ignite readily
Lower explosive limit	-
Upper explosive limit	-
Water solubility	Solubility in water, 30 g/L at 25°C. Dissolves well in organic solvents
Reactivity	Sulphur oxides and nitrogen oxides are released when VX is heated to decomposition. Contact with metals may evolve flammable hydrogen gas.
Reaction or degradation products	When heated, vapours may form explosive mixtures with air, presenting an explosion hazard indoors, outdoors, and in sewers. Containers may explode when heated.
Odour	Practically odourless

References

National Library of Medicine US and National Center for Biotechnology Information. 'PubChem Compound Summary for CID 39793'. PubChem 2004 (viewed September 2024)

Reported effect levels from authoritative sources

The tables below provide an estimate of toxicity to humans from the stated nerve agents and should not be used as exposure guidelines.

Table 2a. Modern human lethality (LD_{50} or LCt_{50}) toxicity estimates for nerve agents

Agent	Liquid (mg/70 kg individual)	Inhalation (mg-min/m^3)	Percutaneous vapour (mg-min/m^3)
GA	1500	70	15,000
GB	1700	35	12,000
GD	350	35	3000
VX	5	15	150

Abbreviations

LD_{50} - The dose at which 50% of the exposed population will show a particular effect (death or severe intoxication - prostration, convulsions or vomiting)

LCt_{50} - the dose expressed as a product of the concentration (c) and the exposure duration (t) required to produce the effect in the 50% of the exposed population.

Reference

Worek, F, Jenner, J, & Thiermann, H (eds). 'Chemical Warfare Toxicology : Volume 1: Fundamental Aspects'. Royal Society of Chemistry 2016, Cambridge. Available from ProQuest Ebook Central.

Table 2b. Modern human severe Effects (ED_{50} or ECt_{50}) toxicity estimates for nerve agents

Agent	Liquid (mg/70 kg individual)	Inhalation (mg-min/m^3)	Percutaneous vapour (mg-min/m^3)
GA (tabun)	900	50	12,000
GB (sarin)	1000	25	8000
GD (soman)	200	25	2000
VX	2	10	25

Abbreviations

ED_{50} – the dose at which 50% of the exposed population will show a particular effect (death or severe intoxication – prostration, convulsions or vomiting)

ECt_{50} – the dose expressed as a product of the concentration (c) and the exposure duration (t) required to produce the effect in 50% of the exposed population.

Reference

Worek, F, Jenner, J, & Thiermann, H (eds). 'Chemical Warfare Toxicology : Volume 1: Fundamental Aspects'. Royal Society of Chemistry 2016, Cambridge. Available from ProQuest Ebook Central.

Published emergency response guidelines

Table 3a. Acute exposure guideline levels (AEGLs) for cyclosarin (GF)

	Concentration (mg/m^3)				
	10 min	**30 min**	**60 min**	**4 hours**	**8 hours**
AEGL-1 [note 1]	$3.5x10^{-3}$	$2x10^{-3}$	$1.4x10^{-3}$	$7x10^{-4}$	$5 x10^{-4}$
AEGL-2 [note 2]	0.044	0.025	0.018	$8.5x10^{-3}$	$6.5x10^{-3}$
AEGL-3 [note 3]	0.38	0.19	0.13	0.070	0.051

Table 3b. Acute exposure guideline levels (AEGLs) for sarin (GB)

	Concentration (mg/m^3)				
	10 min	**30 min**	**60 min**	**4 hours**	**8 hours**
AEGL-1 [note 1]	$6.9 x10^{-3}$	$4x10^{-3}$	$2.8x10^{-3}$	$1.4x10^{-3}$	$1x10^{-3}$
AEGL-2 [note 2]	0.087	0.05	0.035	0.017	0.013
AEGL-3 [note 3]	0.38	0.19	0.13	0.07	0.051

Table 3c. Acute exposure guideline levels (AEGLs) for soman (GD)

	Concentration (mg/m^3)				
	10 min	**30 min**	**60 min**	**4 hours**	**8 hours**
AEGL-1 [note 1]	$3.5x10^{-3}$	$2x10^{-3}$	$1.4x10^{-3}$	$7x10^{-4}$	$5x10^{-4}$
AEGL-2 [note 2]	0.044	0.025	0.018	$8.5x10^{-3}$	$6.5x10^{-3}$
AEGL-3 [note 3]	0.38	0.19	0.13	0.07	0.051

Table 3d. Acute exposure guideline levels (AEGLs) for tabun (GA)

	Concentration (mg/m^3)				
	10 min	**30 min**	**60 min**	**4 hours**	**8 hours**
AEGL-1 [note 1]	$6.9x10^{-3}$	$4x10^{-3}$	$2.8x10^{-3}$	$1.4x10^{-3}$	$1x10^{-3}$
AEGL-2 [note 2]	0.087	0.05	0.035	0.017	0.013
AEGL-3 [note 3]	0.76	0.38	0.26	0.14	0.1

Table 3e. Acute exposure guideline levels (AEGLs) for VX

	Concentration (mg/m^3)				
	10 min	**30 min**	**60 min**	**4 hours**	**8 hours**
AEGL-1 [note 1]	$5.7x10^{-4}$	$3.3x10^{-4}$	$1.7x10^{-4}$	$1x10^{-4}$	$7.1x10^{-5}$
AEGL-2 [note 2]	$7.2x10^{-3}$	$4.2x10^{-3}$	$2.9x10^{-3}$	$1.5x10^{-3}$	$1x10^{-3}$
AEGL-3 [note 3]	0.029	0.015	0.01	$5.2x10^{-3}$	$3.8x10^{-3}$

Notes to Tables 3a to 3e

Note 1: Level of the chemical in air at or above which the general population could experience notable discomfort.

Note 2: Level of the chemical in air at or above which there may be irreversible or other serious long-lasting effects or impaired ability to escape.

Note 3: Level of the chemical in air at or above which the general population could experience life-threatening health effects or death.

Reference

US Environmental Protection Agency. ‘Acute Exposure Guideline Levels’ (viewed September 2024)

Exposure standards, guidelines or regulations

There are no occupational standards or guidelines for nerve agents as they are schedule 1 chemical warfare agents subject to international prohibition under the Chemical Weapons Convention. For more information visit: http://www.opcw.org/chemical-weapons-convention/.

Health effects

G agents

G agents (Tabun, Soman, Sarin and Cyclosarin) are volatile and therefore major inhalation hazards; ocular exposure is likely and dermal absorption can also occur.

The onset of features occurs very rapidly after inhalation (within seconds or minutes) and more slowly after skin exposure.

Table 4. Signs or symptoms of acute exposure to G agents

Route	Signs and symptoms
Inhalation	Increased salivation, chest tightness, rhinorrhoea, bronchorrhoea and/or bronchospasm can occur within seconds or minutes of substantial inhalation. Systemic absorption will rapidly produce systemic features.
Ingestion	Ingestion of food or water contaminated with nerve agents may cause abdominal pain, nausea, vomiting, diarrhoea, involuntary defecation and systemic features.
Dermal	Contact with a nerve agent may produce localised sweating and fasciculation, which may spread to involve whole muscle groups. Skin absorption will produce delayed systemic features. In the absence of respiratory protection, dermal exposure is likely to be accompanied by respiratory exposure.
Ocular	Miosis, which may be painful and last for several days, occurs rapidly following ocular exposure to a nerve agent. It is a sensitive marker of exposure but not of severity. Ciliary muscle spasm will impair accommodation. Conjunctival injection and eye pain may occur, with reduced visual acuity for several days in severe cases.
Systemic features	Miosis is common. Systemic features include abdominal pain, nausea and vomiting, involuntary micturition and defecation, muscle weakness and fasciculation, tremor, restlessness, ataxia, coma and convulsions. Bradycardia and hypotension, or tachycardia and hypertension, may occur, depending on whether muscarinic or nicotinic effects predominate. Dysrhythmias may occur. If exposure is substantial, death will occur from respiratory failure within minutes unless antidotes and ventilatory support are provided. Individuals with mild or moderate exposure usually recover completely.

Route	Signs and symptoms
	Late complications of poisoning may result from aspiration or hypoxic brain injury from early loss of consciousness and respiratory failure. The intermediate syndrome (delayed respiratory failure after apparent resolution of cholinergic symptoms) has not been recorded after nerve agent poisoning.

Reference

TOXBASE Sarin. April 2022 (viewed September 2024).

V agents

Dermal exposure is the main route of exposure because V agents have lower volatility compared with the other nerve agents. A very small exposure may be sufficient to cause severe poisoning several hours later; systemic features may be delayed for many hours because VX forms a reservoir in the skin.

Inhalation and eye exposure will only occur if the ambient temperature is high or if exposure occurs in an enclosed space.

Table 5. Signs or symptoms of acute exposure to V agents

Route	Signs and symptoms
Inhalation	Increased salivation, chest tightness, rhinorrhoea, bronchorrhoea and/or bronchospasm can occur within seconds or minutes of substantial inhalation of a nerve agent. Systemic absorption will rapidly produce systemic clinical features.
Ingestion	Ingestion of food or water contaminated with nerve agents may cause abdominal pain, nausea, vomiting, diarrhoea, involuntary defecation and systemic features.
Dermal	Contact with VX or VG may produce localised sweating and fasciculation, which may spread to involve whole muscle groups. Skin absorption will produce delayed systemic effects. In the absence of respiratory protection, dermal exposure may be accompanied by respiratory exposure.
Ocular	Miosis, which may be painful and last for several days, occurs rapidly following ocular exposure to a nerve agent Conjunctival injection and eye pain may occur, with reduced visual acuity for several days in severe cases.

Systemic features	These features may be delayed for many hours after exposure. Miosis is common. Features include abdominal pain, nausea and vomiting, involuntary micturition and defecation, muscle weakness and fasciculation, tremor, restlessness, ataxia, coma, and convulsions. Bradycardia and hypotension, or tachycardia and hypertension, may occur, depending on whether muscarinic or nicotinic effects predominate, together with dysrhythmias. If exposure is substantial, death will occur from respiratory failure within minutes or hours unless antidotes and ventilatory support are provided. Individuals with lesser exposure may still become sick after several hours. Late complications of poisoning may result from aspiration or hypoxic brain injury from early loss of consciousness and respiratory failure. The intermediate syndrome (delayed respiratory failure after apparent resolution of cholinergic symptoms) has not been recorded after nerve agent poisoning.

Reference

TOXBASE VX. April 2022 (viewed September 2024).

Decontamination at the scene

Chemical specific advice

The approach used for decontamination at the scene will depend upon the incident, location of the casualties and the chemicals involved. Therefore, a risk assessment should be conducted to decide on the most appropriate method of decontamination.

Following disrobe, improvised dry decontamination should be considered for an incident involving nerve agents, unless casualties are demonstrating signs or symptoms of exposure to caustic or corrosive substances.

People who are processed through improvised decontamination should subsequently be moved to a safe location, triaged and subject to health and scientific advice. Based on the outcome of the assessment, they may require further decontamination.

Emergency services and public health professionals can obtain further advice from the UK Health Security Agency (UKHSA) Radiation, Chemicals and Environment Directorate using the 24- hour chemical hotline number: 0344 892 0555.

Disrobe

The disrobe process is highly effective at reducing exposure to HAZMAT/CBRN material when performed within 15 minutes of exposure.

Therefore, disrobe must be considered the primary action following evacuation from a contaminated area.

Where possible, disrobing should be conducted at the scene and by the casualty themselves. Disrobing should be systematic to prevent transfer of contaminant from clothing to skin. Clothing should not be pulled over the head if possible.

Clothing stuck to the casualty by the contaminant should not be forcefully removed, as this risks causing further harm.

Consideration should be given to ensuring the welfare and dignity of casualties as far as possible. Immediately after decontamination the opportunity should be provided to dry and dress in clean robes or clothes.

Improvised decontamination

Improvised decontamination is an immediate method of decontamination prior to the use of specialised resources. This should be performed on all contaminated casualties unless medical advice is received to the contrary. Improvised dry decontamination should be considered for an incident involving chemicals unless the agent appears to be corrosive or caustic.

Unprotected first responders and members of the public should not approach casualties incapacitated by exposure to administer improvised decontamination, as they may be exposed to contaminants and become a casualty themselves.

Important note: Improvised decontamination should continue until more structured interventions such as Interim or Specialist Operational Response are present.

Improvised dry decontamination

Improvised dry decontamination should be considered for an incident involving nerve agents unless casualties are demonstrating obvious signs of chemical burns or skin irritation.

Any available dry absorbent material can be used such as kitchen towel, paper tissues (for example blue roll) and clean cloth.

Exposed skin surfaces should be blotted first and then rubbed, starting with the face, head, and neck, and moving down and away from the body.

Blotting and rubbing should not be too aggressive, as it could drive contamination further into the skin.

Casualties should also blow their nose to remove contaminants from the nasal cavities.

All waste material arising from decontamination should be left in situ, and ideally bagged, for disposal at a later stage.

Improvised wet decontamination

Wet decontamination should be used if contamination with a caustic chemical substance is suspected.

Water should only be used for decontamination where casualty signs and symptoms are consistent with exposure to caustic or corrosive substances such as acids or alkalis.

Wet decontamination may be performed using copious amounts of water from any available source such as taps, showers, water bottles, fixed installation hose-reels and sprinklers to gently rinse the affected skin. Other natural sources of water may be considered unless this creates greater risks to the individuals affected. Wet wipes or baby wipes may be used as an effective alternative.

Improvised decontamination should not involve overly aggressive methods to remove contamination as this could further damage affected tissues and drive the contamination further into the skin.

Where appropriate, seek professional advice on how to dispose of contaminated water and prevent run-off going into the water system.

Additional notes

Following improvised decontamination, remain cautious and observe for signs and symptoms in the decontaminated person and in unprotected staff.

If water is used to decontaminate casualties this may be contaminated, and therefore hazardous, and a potential source of further contamination spread.

All materials (paper tissues and so on) used in this process may also be contaminated and, where possible, should not be used on new casualties.

The risk from hypothermia should be considered when disrobe and any form of wet decontamination is carried out.

People who are contaminated should not eat, drink or smoke before or during the decontamination process and should avoid touching their face.

When vulnerable people are affected by a hazardous substance, they may need additional support to remove themselves, their clothing or the substance.

Casualties should remain in the area and should not leave to seek care at a hospital, as this presents a contamination risk. Further care will be administered on site by the appropriate emergency services.

Interim wet decontamination

Interim decontamination is the use of standard Fire and Rescue Service equipment to provide a planned and structured decontamination process prior to the availability of purpose-designed decontamination equipment.

Decontamination at the scene references

Home Office. 'Initial operational response to a CBRN incident.' Version 2.0 July 2015

NHS England. 'Emergency Preparedness, Resilience and Response (EPRR): Guidance for the initial management of self-presenters from incidents involving hazardous materials.' February 2019

JESIP. 'Initial Operational Response IOR to Incidents Suspected to Involve Hazardous Substances or CBRN Materials' June 2024

Clinical decontamination and first aid

Clinical decontamination is the process where trained healthcare professionals, using purpose-designed decontamination equipment, treat contaminated persons individually.

Detailed information on clinical management can be found on TOXBASE.

Important notes

The use of atropine and pralidoxime is recommended for patients with excessive secretions, and/or clinically significant hypoxia, and/or bradycardia, and/or hypotension. For detailed clinical management advice on these antidotes and other antidotes for nerve agent poisoning see TOXBASE.

Once body surface contaminants have been removed or if your patient was exposed by ingestion or inhalation, the risk that secondary care givers may become contaminated is very low. Secondary carers should wear standard hospital PPE as a precaution against secondary contamination from vomit and body fluids.

If the patient has not been decontaminated following surface contamination, secondary carers must wear appropriate NHS PPE for chemical exposure to avoid contaminating themselves.

The area should be well ventilated.

For comprehensive clinical advice consult TOXBASE directly.

Clinical decontamination following surface contamination

Avoid contaminating yourself. Consider staff members/first responders. If any contamination occurs or they develop symptoms then decontaminate and treat as appropriate.

Carry out decontamination in a well-ventilated area, preferably with its own ventilation system.

The patient should remove soiled clothing themselves if possible and try to avoid any cross-contamination from clothing to unexposed skin. Patients should avoid touching their face as much as possible.

Contaminated clothing should be removed, double-bagged, sealed and stored safely.

Dry decontamination should be attempted in the first instance unless it is thought that

a corrosive substance is also involved (if so see below for advice on wet decontamination).

Blotting the skin should be gentle rather than aggressive in order to prevent further contamination into the skin.

All waste material from dry decontamination should be left in situ and bagged for appropriate later disposal.

If the patient has signs and symptoms indicating exposure to a corrosive substance such as burns or skin irritation then wet decontamination rather than dry should be attempted.

Wet decontamination - gently wash the skin for 45 to 90 seconds initially ideally using a cloth or sponge. This should not be too aggressive in order to prevent further contamination into the skin.

If appropriate seek specialist advice regarding disposal of contaminated water or run-off going into the water system.

Dermal exposure, inhalation, and ingestion

Maintain a clear airway and ensure adequate ventilation.

Give oxygen.

Continuous suctioning of the airway may be required because of excessive secretions.

Patients with excessive secretions, and/or clinically significant hypoxia, and/or bradycardia, and/or hypotension require immediate oxygen, atropine and pralidoxime.

For detailed clinical management advice including information on antidotes for nerve agent poisoning see TOXBASE.

Monitor BP and pulse, oxygen saturation, cardiac rhythm and arterial blood gases. Check and record pupil size.

Perform a 12-lead ECG in all patients who require assessment.

Other supportive measures as indicated by the patient’s clinical condition.

Ocular exposure

Remove contact lenses if present.
Anaesthetise the eye with a topical local anaesthetic (oxybuprocaine, amethocaine or similar). However, do not delay irrigation if local anaesthetic is not immediately available.

Immediately irrigate the affected eye thoroughly with 1000 mL 0.9% saline or equivalent crystalloid (for example via an infusion bag with a giving set) for a minimum of 10 to 15 minutes. A Morgan Lens may be used if anaesthetic has been given. Amphoteric, hypertonic, chelating solutions may be used if available.

Any particles lodged in the conjunctival recesses should be removed.

Patients with corneal damage or those whose symptoms do not resolve rapidly should be discussed urgently with an ophthalmologist.

If the patient develops features of systemic toxicity manage as per dermal/inhalation/ingestion.

Other supportive measures as indicated by the patient's clinical condition.

Clinical decontamination and first aid references

TOXBASE (viewed September 2024).

TOXBASE VX (2022)

TOXBASE G series nerve agents – features and management (2022)

TOXBASE Skin decontamination – nerve agents (2022)

About the UK Health Security Agency

UKHSA is responsible for protecting every member of every community from the impact of infectious diseases, chemical, biological, radiological and nuclear incidents and other health threats. We provide intellectual, scientific and operational leadership at national and local level, as well as on the global stage, to make the nation health secure.

UKHSA is an executive agency, sponsored by the Department of Health and Social Care.

This document from the UKHSA Radiation, Chemicals and Environment Directorate reflects understanding and evaluation of the current scientific evidence as presented and referenced here.

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For queries relating to this document, please contact chemcompendium@ukhsa.gov.uk or enquiries@ukhsa.gov.uk

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