Public Health England

Protecting and improving the nation's health

Nerve Agents

Incident Management

Key Points

Fire

- Sarin is not combustible while VX may burn but does not ignite easily

Health

- G agents are volatile and major inhalation hazards; though ocular exposure is likely and dermal can occur
- V agents have lower volatility and are primarily hazardous via skin absorption
- miosis, 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
- 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

Environment

- avoid release to the environment; inform the Environment Agency of substantial incidents

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Hazard Identification

Nerve agents are not subject to EU or UK 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.

Sarin (G agent)

CAS number	107-44-8
Molecular weight	140
Formula	$C_4H_{10}FO_2P$
Common synonyms	GB: Agent GB; Methylphosphonoflouridic acid 1-methylethyl ester; Isopropoxymethylphosphoryl fluoride
State at room temperature	Colourless liquid
Volatility	Vapour pressure: 2.86mm Hg at 25°C
Specific gravity **Vapour density**	1.09 at 25°C (water = 1) 4.86 (air = 1)
Flammability	Not combustible
Lower explosive limit	-
Upper explosive limit	-
Water solubility	Miscible in water
Reactivity	Reacts with tin, magnesium, some aluminium and cadmium plated steel. It will slightly attack brass, copper and lead.
Reaction or degradation products	Releases fumes of fluorides and oxides of phosphorus when heated to decomposition. May release hydrogen fluoride when in contact with acids or possible acid vapours. Basic solutions can cause sarin to hydrolyse and form isopropyl alcohol and polymers.
Odour	Practically odourless

References

Hazardous Substances Data Bank. Sarin HSDB No. 6382 (last revision date 31/12/2013). US National Library of Medicine: Bethesda MD. http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB (accessed 08/2017)

Sarin (HAZARDTEXT™ Hazard Management). In Klasco RK (Ed): TOMES® System, Truven Healthcare Analytics Inc, Greenwood Village CO, US. RightAnswer.com Inc, Midland MI, US. http://www.rightanswerknowledge.com (accessed 08/2017).

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	Clear to straw-coloured liquid that looks like motor oil
Volatility	Vapour pressure 0.007mm 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, 3% w/v at 25°C
Reaction or degradation products	Sulphur oxides and nitrogen oxides are released when VX is heated to decomposition. Contact with metals may evolve flammable hydrogen gas.
Odour	Practically odourless

References

Hazardous Substances Data Bank. VX HSDB No 6459. (last revision date 31/12/2013). US National Library of Medicine: Bethesda MD. http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB (accessed 08/2017)

VX (HAZARDTEXT™ Hazard Management). In Klasco RK (Ed): TOMES® System, Truven Healthcare Analytics Inc, Greenwood Village CO, US. RightAnswer.com Inc, Midland MI, US. http://www.rightanswerknowledge.com (accessed 08/2017).

Published Emergency Response Guidelines

Emergency response planning guideline (ERPG) values

	Listed value (ppm)	Calculated value (mg/m^3)
ERPG-1*	Data not available	
ERPG-2†		
ERPG-3‡		

* Maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined, objectionable odour

† Maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action

‡ Maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects

Acute exposure guideline levels (AEGLs)

Cyclosarin (GF)	mg/m^3				
	10 min	30 min	60 min	4 hours	8 hours
AEGL-1*	3.5x10^{-3}	2x10^{-3}	1.4x10^{-3}	7x10^{-4}	5 x10^{-4}
AEGL-2†	0.044	0.025	0.018	8.5x10^{-3}	6.5x10^{-3}
AEGL-3‡	0.38	0.19	0.13	0.070	0.051
Sarin (GB)	mg/m^3				
	10 min	30 min	60 min	4 hours	8 hours
AEGL-1*	6.9 x10^{-3}	4x10^{-3}	2.8x10^{-3}	1.4x10^{-3}	1x10^{-3}
AEGL-2†	0.087	0.05	0.035	0.017	0.013
AEGL-3‡	0.38	0.19	0.13	0.07	0.051
Soman (GD)	mg/m^3				
	10 min	30 min	60 min	4 hours	8 hours
AEGL-1*	3.5x10^{-3}	2x10^{-3}	1.4x10^{-3}	7x10^{-4}	5x10^{-4}
AEGL-2†	0.044	0.025	0.018	8.5x10^{-3}	6.5x10^{-3}
AEGL-3‡	0.38	0.19	0.13	0.07	0.051
Tabun (GA)	mg/m^3				
	10 min	30 min	60 min	4 hours	8 hours
AEGL-1*	6.9x10^{-3}	4x10^{-3}	2.8x10^{-3}	1.4x10^{-3}	1x10^{-3}
AEGL-2†	0.087	0.05	0.035	0.017	0.013
AEGL-3‡	0.76	0.38	0.26	0.14	0.1
VX	mg/m^3				
	10 min	30 min	60 min	4 hours	8 hours
AEGL-1*	5.7x10^{-4}	3.3x10^{-4}	1.7x10^{-4}	1x10^{-4}	7.1x10^{-5}
AEGL-2†	7.2x10^{-3}	4.2x10^{-3}	2.9x10^{-3}	1.5x10^{-3}	1x10^{-3}
AEGL-3‡	0.029	0.015	0.01	5.2x10^{-3}	3.8x10^{-3}

* Level of the chemical in air at or above which the general population could experience notable discomfort

† 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

‡ 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. http://www.epa.gov/oppt/aegl/pubs/chemlist.htm (accessed 08/2017).

Exposure Standards, Guidelines or Regulations

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

Health Effects of G nerve agents

Major route of exposure

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

Important note

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

Immediate signs or symptoms of acute exposure

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 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 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 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 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

References

TOXBASE. Nerve agents 06/2015. http://www.toxbase.org (accessed 08/2017).

TOXBASE. G series nerve agents – features and management 06/2017. http://www.toxbase.org (accessed 08/2017).

Health Effects of V nerve agents

Major route of exposure

- dermal exposure is the main route of exposure because V agents have lower volatility compared with the other nerve agents
- inhalation and eye exposure will only occur if the ambient temperature is high or exposure occurs in an enclosed space

Important note

- systemic features may be delayed for many hours

Immediate signs or symptoms of acute exposure

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

References

TOXBASE. Nerve agents 06/2015. http://www.toxbase.org (accessed 08/2017).

TOXBASE. VX and VG nerve agents – features and management 02/2016. http://www.toxbase.org (accessed 08/2017).

Decontamination at the Scene

Summary

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 Public Health England (Centre for Radiation, Chemical and Environmental Hazards) 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, disrobe at the scene should be conducted by the casualty themselves and should be systematic to avoid transferring any contamination from clothing to the skin. Consideration should be given to ensuring the welfare and dignity of casualties as far as possible.

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**.

Improvised dry decontamination

- any available dry absorbent material can be used such as kitchen towel, paper tissues (eg blue roll) and clean cloth
- exposed skin surfaces should be blotted and rubbed, starting with the face, head and neck and moving down and away from the body

- rubbing and blotting should not be too aggressive, or it could drive contamination further into the skin
- all waste material arising from decontamination should be left in situ, and ideally bagged, for disposal at a later stage

Improvised wet decontamination

- 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 any available source of water such as taps, showers, fixed installation hose-reels and sprinklers
- when using water, it is important to try and limit the duration of decontamination to between 45 and 90 seconds and, ideally, to use a washing aid such as cloth or sponge
- improvised decontamination should not involve overly aggressive methods to remove contamination as this could 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 etc) 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
- 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/clothes

Interim wet decontamination

Interim decontamination is the use of standard fire and rescue service (FRS) equipment to provide a planned and structured decontamination process prior to the availability of purpose-designed decontamination equipment.

Decontamination at the scene references

National Ambulance Resilience Unit. Joint Emergency Services Interoperability Programme (JESIP). Initial operational response to a CBRN incident. Version 1.0, September 2013.

NHS England. Emergency Preparedness, Resilience and Response (EPRR). Chemical incidents: planning for the management of self-presenting patients in healthcare settings. April 2015.

Clinical Decontamination and First Aid

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

Detailed information on clinical management can be found on TOXBASE - www.toxbase.org.

Important note

- 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
- **patients with clinically significant hypoxia, bradycardia, and or hypotension require oxygen and atropine, with airway stabilisation as necessary, before decontamination**
- **decontamination is very important after exposure to VX or VG, as it should reduce the risk of late severe poisoning**

Clinical decontamination following surface contamination

- carry out decontamination after resuscitation
- this should be performed in a well-ventilated area, preferably with its own ventilation system
- contaminated clothing should be removed, double-bagged, sealed and stored safely
- decontaminate open wounds first and avoid contamination of unexposed skin
- any particulate matter adherent to skin should be removed and the patient washed with copious amounts of water under low pressure for at least 10-15 minutes
- the earlier irrigation begins, the greater the benefit
- pay particular attention to mucous membranes, moist areas such as skin folds, fingernails and ears

Dermal/ inhalation/ ingestion

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

- maintain a clear airway and ensure adequate ventilation
- give oxygen
- continuous suctioning of the airway may be required because of excessive secretions
- monitor BP and pulse, oxygen saturation, cardiac rhythm and arterial blood gases
- 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 (eg oxybuprocaine, amethocaine or similar); however, **do not delay irrigation if local anaesthetic is not immediately available**
- immediately irrigate the affected eye thoroughly with 1,000 mL 0.9% saline or equivalent crystalloid (eg by an infusion bag with a giving set) for a minimum of 10-15 minutes. Amphoteric solutions are available and may be used. A Morgan lens may be used if anaesthetic has been given
- 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 inhalation/dermal exposure/ingestion
- other supportive measures as indicated by the patient's clinical condition

Health effects and decontamination references

TOXBASE http://www.toxbase.org (accessed 08/2017)

TOXBASE VX and VG nerve agents - features and management, 02/2016

TOXBASE G series nerve agents - features and management, 06/2017

This document from the PHE Centre for Radiation, Chemical and Environmental Hazards reflects understanding and evaluation of the current scientific evidence as presented and referenced here.

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