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Chapter 2: Chemical Hazards

Chapter Objectives

Upon completing this chapter, the reader should be able to:

1. Discuss and explain some of the key historical events using chemical agents.
2. Be able to list and describe several chemical weapons types.
3. Explain the mode of action of nerve agents and blister agents.

End-of Chapter Questions

3. What is the most common method of chemical weapon destruction in the United States? What are the products of this destruction technology? Are there any hazards with use of this technology? Be specific.

   The most common methods for CW destruction in the United States are controlled incineration and chemical neutralization.

   If incineration is working optimally, the end-products include carbon dioxide, water, various phosphorus oxides, and possibly HCl or HF. Hazards include flameout (which

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would release CWs directly out the stack) or releases from containers during transport and processing.

For chemical neutralization, concentrated sodium hydroxide reacts with the CW producing a mixture of compounds of relatively low hazard, termed a hydrolysate. This waste mixture is shipped to a commercial treatment and disposal facility for post-treatment. Hazards include releases from containers during transport and processing.

See: http://www.cdc.gov/nceh/demil/methods.htm

http://www.cma.army.mil/fndocumentviewer.aspx?docid=003672521

4. By what routes can chemical agents enter the body? Which route is most effective for VX? For sarin?

- *Inhalation*
- *Ingestion*
- *Absorption through skin*
- *Puncture (injection)*

Most effective route of entry for VX: Inhalation is highly effective; however, given that VX has a low vapor pressure, inhalation may not be likely. Entry via ingestion, puncture and absorption through the skin are also extremely effective.

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Most effective route of entry for sarin: Inhalation

5. Define the following terms: LD_{50}; edema; miosis; lachrymation; emesis, cytotoxic; vesicant.

LD_{50}: Standard measurement of acute toxicity that is stated in milligrams (mg) of compund per kilogram (kg) of body weight. An LD50 represents the individual dose required to kill 50 percent of a population of test animals (e.g., laboratory rats).

Edema: Swelling caused by fluid accumulation in tissue

Miosis: Constriction of the pupil of the eye

Lachrymation: Excessive tearing of the eyes

Emesis: Vomiting

Cytotoxic: Can cause death of cells

Vesicant: An agent that causes blistering of tissue

6. The G-series nerve agents are based on the chemical properties of what common chemical(s)? Discuss the mode of action of the nerve agents in general.

Pesticides, specifically the organophosphates. This class of compounds disrupts the nervous system via binding and phosphorylation of the enzyme acetylcholinesterase. This results in the accumulation of acetylcholine, a neurotransmitter, to continually stimulate receptors throughout the central and peripheral nervous systems.

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7. Does the dose rate of a nerve agent affect the body's response? Explain. What is the effect of daily exposure to small doses of a nerve agent over several days?

Dose rate is critical to the body's response. If a very large dose of nerve agent has been acquired quickly, death can occur rapidly.

Daily exposure to minute doses can be cumulative, resulting in symptoms after several days.

8. Explain 'persistence' of a chemical weapons agent, in terms of its reactions with air, microorganisms, sunlight, and so on. Which chemical agents are persistent? Is there a practical advantage to an army or terrorist organization using a persistent weapon? Explain.

A chemical agent that does not decompose readily in the presence of oxygen, sunlight and/or microbial populations is termed persistent.

VX is considered persistent due to its low vapor pressure. It is oily and will not decompose except over relatively long periods. Hence it may be used as an area denial weapon (See question 9).

9. Define and explain an 'area denial weapon.' How could it be employed in modern warfare? By a terrorist group?

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Such a weapon may be sprayed on to a site to render it toxic to the opposing side in a conflict. Simple skin contact could result in severe effects, including death.

10. Response to chlorine or phosgene exposure involves rapid administration of an antitoxin such as atropine. True or false? Explain.

False. Atropine is effective against nerve agents, not choking agents.

Examination Test Bank

1. The very first chemical weapons ever used in modern times were developed by the French during the Franco-Prussian War of 1870. (*False*)

2. Certain chemical agents such as chlorine gas have had a history of use during wartime, particularly during World War I. (*True*)

3. Chemical weapons were extensively studied after World War I for potential future military use. (*True*)

4. Over the past century chemical warfare agents have been used on civilian populations in order to quell civilian uprisings, for example in Egypt and Italy. (*True*)

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5. Chemical weapons stockpiles in the US had existed in most states; however, all these stockpiles have been destroyed since 1999 using both incineration and chemical neutralization technologies. (*False*)

6. A loss of kidney function with an ultimate failure to urinate is defined as:

a. edema b. eshcar c. anuria d. amnesia e. mediastinitis

7. If no treatment is available for a blood agent (e.g., cyanide) victim, the person could die of a diminished amount of O_2 in blood and tissues resulting from:

a. airway obstruction due to edema
b. weakness of respiration muscles
c. depression of cellular respiration
d. anuria
e. toxicoplasmolysis

8. Chemical agents can enter the body by all of the following routes EXCEPT:

a. consumed through food
b. inhaled
c. absorbed through skin/wounds/abrasions
d. absorbed through eyes
e. all these routes are possible

9. Sulfur mustards have been linked with:

a. decreased libido b. chronic depression c. miosis
d. emesis e. a and b only

10. Sulfur mustard is a known:

a. mutagen b. carcinogen c. allergen

d. cholinesterase inhibitor e. all of the above

11. Indicators of a chemical weapons release:

a. oily film on bodies of water

b. large numbers of dead insects and dead birds

c. blisters or rashes on skin

d. large areas where vegetation appears burned or discolored

e. all of the above

Refer to the table:

	LD_{50}	Vapor Density (Air = 1)	K_{ow}	Specific Gravity (Water = 1)
Sarin	0.0048	1.10	0.8	1.09
VX	0.00063	1.01	3.1	1.01
Cyanogen chloride	0.002	N/A	1.0	1.19
Potassium cyanide	0.004	0.94	0.004	1.20
Mustard gas	0.01	5.4	18.4	1.27

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12. In the event of a release, which of the chemical weapons listed is most toxic?

a. sarin b. VX c. cyanogen chloride

d. potassium cyanide e. mustard gas

13. Which of the agents in the table would be most readily absorbed in human fatty tissue?

a. sarin b. VX c. cyanogen chloride

d. potassium cyanide e. mustard gas

14. Which of the agents will sink if in contact with a body of water?

a. sarin b. cyanogen chloride c. potassium cyanide

e. mustard gas e. all of the above

15. The G-series chemical warfare agents are based on the chemical properties of common pesticides. (*True*)

16. Nerve agents (cholinesterase inhibitors) interfere with oxygen transfer to red blood cells, thus causing cell asphyxiation. (*False*)

17. A chemical agent that is termed 'persistent' is one that cannot be readily decomposed by sunlight or microorganisms, or via reactions with oxygen. (*True*)

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18. Persistence of a chemical warfare agent increases in hilly, wooded terrain rather than open terrain. (*True*)

19. The V agents are non-persistent, whereas the G agents are persistent. (*False*)

20. Dose rate of a nerve agent is not very critical with regard to the body's response. (*False*)

21. Daily exposure to very small doses of a nerve agent can be cumulative, resulting in symptoms after several days. (*True*)

22. Regular clothing will not allow the penetration of nerve agents, whether they occur in a liquid or vapor form. (*False*)

23. Agent HD was originally H that had been purified through washing and vacuum distillation to reduce sulfur impurities. (*True*)

24. Blister agents dissipate or vaporize rapidly after release, and therefore are a short-duration hazard. (*False*)

25. Both G- and V- agents can be absorbed directly through the skin. (*True*)

26. Young military troops may have better survival rates in a chemical agent attack than older

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civilians. (*True*)

27. Little effective medical care exists for persons with mustard agent exposure and lesions, other than relieving symptoms and preventing infection. (*True*)

28. Response to a chlorine or phosgene exposure involves rapid administration of an anti-toxin such as atropine. (*False*)

29. Hydrogen cyanide prevents transfer of oxygen to cells and tissue. (*True*)

30. Phosgene is a corrosive and highly toxic gas that leads to 'dry land drowning'. (*True*)

31. Several chemical warfare agents possess unique odors, which can be used as an initial identifier. For example, some agents smell like newly-mown hay or garlic. (*True*)

32. Measurement that can be used to compare the relative toxicity of several chemical weapons:

    a. TLV b. IDLH c. LF-100 d. $\underline{LD_{50}}$ e. MSM test

33. The dose rate of a nerve agent is highly critical with regard to the body's response. (*True*)

34. Hydrogen cyanide prevents transfer of oxygen to living tissue. (*True*)

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Match

35. tabun [d]	a. venomous
36. sarin [g]	b. sulfur impurities removed
37. HD [b]	c. blood agent
38. VX [a]	d. first of the chemical warfare agents developed by the Germans
39. L [f]	e. IDLH
	f. blister agent
	g. Aum Shinrikyo cult, Japan

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40. miosis [c]	a. excessive tearing of the eyes
41. emesis [e]	b. methamphetamine
42. paranoia [b]	c. constriction of pupil
43. lacrimation [a]	d. shattering effect
44. wheal [f]	e. vomiting
45. atropine [h]	f. evanescent area of edema of the skin
	g. excessive bleeding
	h. antidote for nerve agent exposure

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Short Answer

1. List three ‘advantages’ to terrorists in using chemical weapons on a populated area.

a. Chemical weapons tend to have a long ‘shelf life’

b. Responders may not be able to immediately identify the chemical; this will allow time for the perpetrator to escape the area

c. Psychological effects may occur, i.e., panic among the affected population

d. Many chemical agents are persistent after release (e.g., VX)

e. May result in mass casualties

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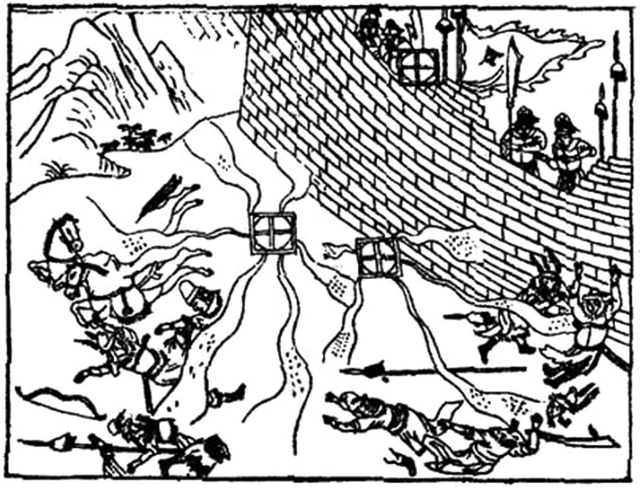


Figure 2.1 Illustration from thirteenth century China showing soft case grenades thrown from battlements to explode and release noxious fumes. (Reproduced with kind permission from Leong Kit Meng.)

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Figure 2.2 Trench warfare, World War I. (Courtesy of Wikipedia, https://en.wikipedia.org/wiki/Trench_warfare#/media/File:Cheshire_Regiment_trench_Somme_1916.jpg.)

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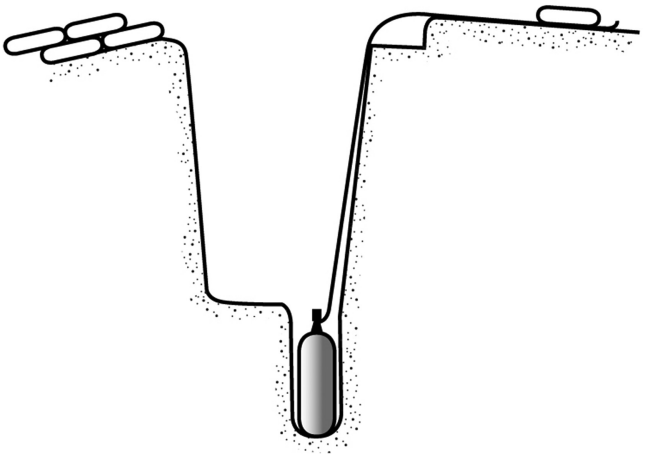


Figure 2.3 Typical German chemical cylinder setup ready for discharge. Thousands of cylinders were opened simultaneously, creating the gas cloud. (Courtesy of Army War College, *German Methods of Offense*, Volume 1, in: *Gas Warfare*, War Department, Washington, D.C., p. 14, 1918. With permission.)

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Figure 2.4 Chlorine being released from canisters, World War I. (Courtesy of U.S. Army Medical Department Center and School, http://www.bordeninstitute.army.mil/published_volumes/chemBio/Ch2.pdf.)

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Figure 2.5 Canadian soldier suffering from mustard gas burns sustained during World War I. (Courtesy of Wikipedia, http://en.wikipedia.org/wiki/File:Mustard_gas_burns.jpg.)

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Figure 2.6 Fritz Haber is considered by many to be the *Father of Chemical Warfare*. (Courtesy of the Nobel Prize, http://nobelprize.org/nobel_prizes/chemistry/laureates/1918/index.html.)

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Figure 2.7 Victims of Iraqi chemical weapons, early 1980s. (Courtesy of Wikipedia, http://en.wikipedia.org/wiki/File:Chemical_weapon2.jpg.)

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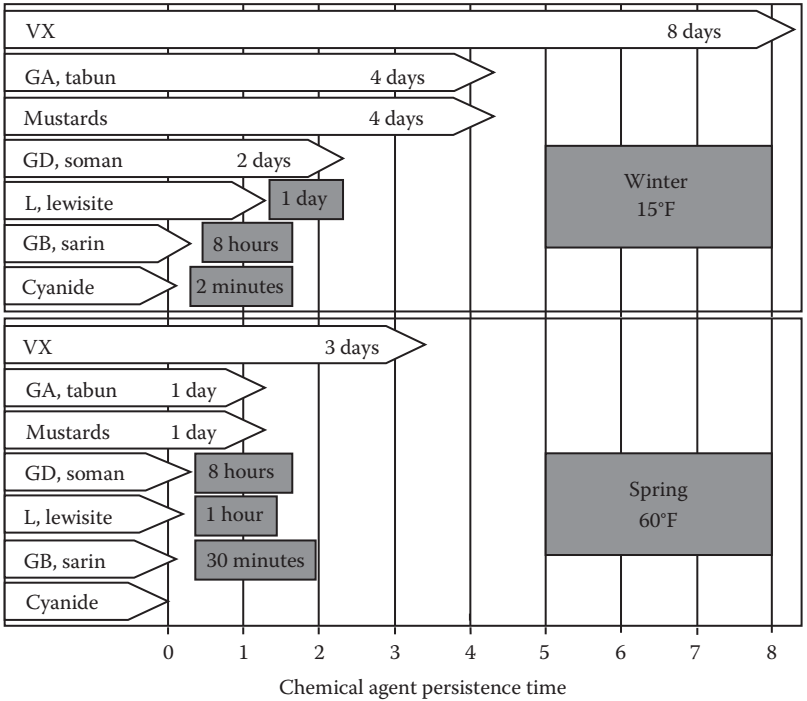


Figure 2.8 Graphical representation of the persistence of various types of chemical weapons agents during two times of year. (Courtesy of Swedish Defence Research Agency. With permission.)

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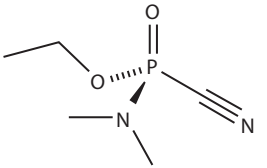


Figure 2.9 Structure of tabun.

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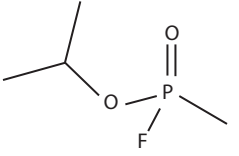


Figure 2.10 Structure of sarin.

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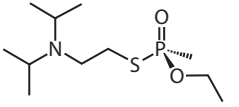


Figure 2.11 Structure of VX.

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Courtesy of CRC Press/Taylor & Francis Group



Figure 2.12 Atropine autoinjectors.

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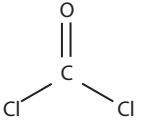


Figure 2.13 Structure of phosgene.

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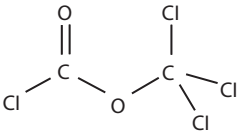


Figure 2.14 Structure of diphosgene.

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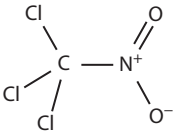


Figure 2.15 Structure of chloropicrin.

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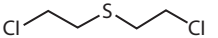


Figure 2.16 Structure of sulfur mustard.

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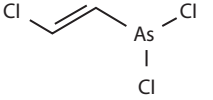


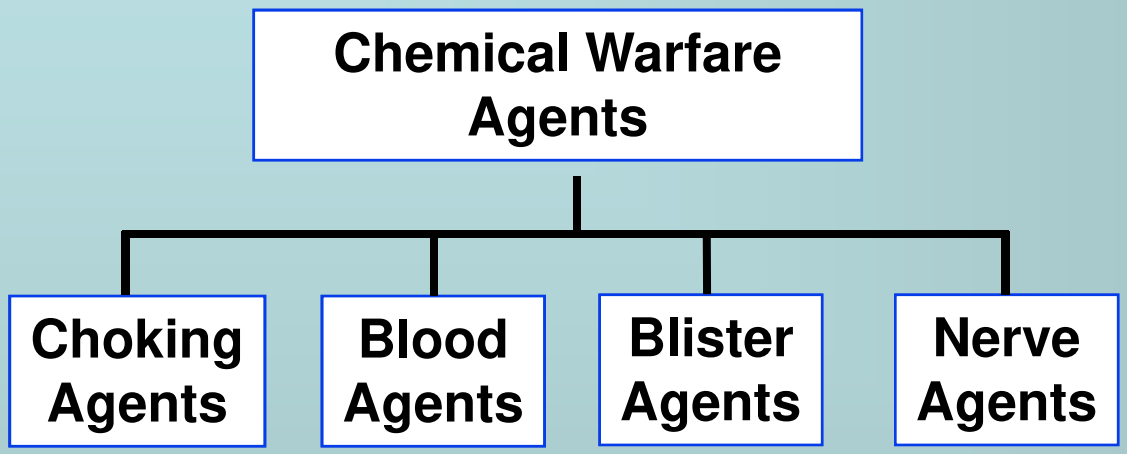
Figure 2.17 Structure of lewisite.

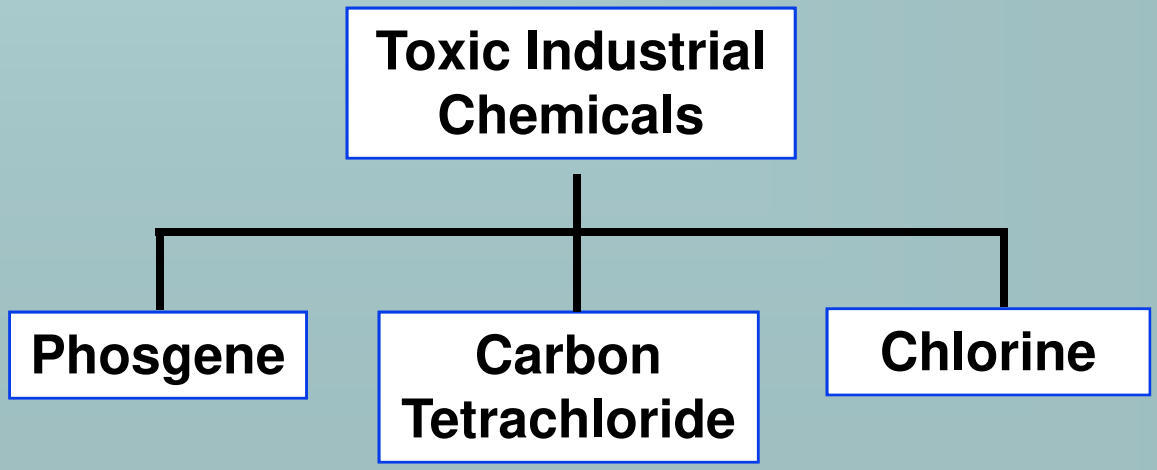
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Chemical Threats

Classification of Chemical Agents





(Only three are listed; however, hundreds of TICs are potentially available)

"We have the ability to make and use chemicals and poisonous gas. And those gases and poisons are made of the simplest ingredients, which are available in the pharmacies and we could, as well, smuggle them from one country to another if needed. And this is for use against vital institutions and residential populations."

- Ramzi Yousef

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Toxic Industrial Chemicals (TICs)

Phosgene

- Dissemination: Liquid when cooled and under pressure
- A gas when released
- Routes of entry: Inhalation, ingestion, or absorption

Phosgene

- Availability: Commercially available
- Odor: Strong, offensive smell at high concentrations; new-mown hay at low concs.
- Signs and symptoms: Burns or blisters on the skin from liquid exposure; burning of the eyes, difficulty breathing, nausea and dizziness, pulmonary edema after 2-6 hours with heavy exposure

Carbon tetrachloride
Key ingredient in Freons (Freon 10, Freon R-11, R-12)

- Dissemination: Liquid
- Routes of entry: Inhalation, ingestion, or absorption
- Signs and symptoms: Adverse effects on central nervous system and brain, headaches, dizziness, nausea, liver and kidney damage, blurred vision, coma, death.

- Availability: Freon 10, R-11 and R12 now banned, though carbon tetrachloride still commercially available
- Odor: Ether or chloroform
- Highly carcinogenic in animals; causes mutations in animals

Chlorine

- Commercially available
- Odor: Strong, corrosive smell
- Signs and symptoms: Burns or blisters on the skin from liquid exposure; burning of the eyes, difficulty breathing, nausea and dizziness, pulmonary edema

TICs When Used as a Weapon

- Thousands of chemicals can be used as a terrorist weapon.

  Many common, commercially-available substances can be used successfully in an act of terrorism

- Dissemination: Liquids, solids, gases

  Availability: Commercially available and often a ‘soft’ target

Sources of TICs

- Chemical manufacturing plants
- Food processing and storage facilities
- Gasoline and jet fuel storage tanks
- Industries with cyanide and mercury compounds
- Pesticide_manufacturing and supply distributors
- Educational, medical, and research laboratories
- Hospitals and medical clinics

Chemical Weapons Defined

Any chemical which, through its chemical effect on living processes, may cause death, temporary loss of performance, or permanent injury to people and animals.

-- The Chemical Weapons Convention

The CWC

In 1992, after a decade of negotiations, the Conference on Disarmament agreed to the text of **The Chemical Weapons Convention** (CWC), which was then adopted by the General Assembly at its forty-seventh session, on 30 November 1992, in its resolution entitled Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction.

http://www.un.org/Depts/dda/WMD/cwc/

Signatories included: US, UK, China, Russia, Israel … (184 ‘States-Parties’ total)

Did not sign the CWC: North Korea, Syria, Iraq, Egypt, South Sudan, Angola

History of Chemical Weapons

- WW I
  - Chorine gas released into the wind
  - Mustard gas used during trench warfare

- WW II
  - Japan's admitted use on China
  - German bombing of Bari Harbor, Italy (2,000 100 lb mustard bombs)

- Geneva Protocol in 1975
  - Prevented use of Chemical Weapons
  - Except defoliants and riot control agents
- Several treaties requiring disposal of stored chemical weapons in 1985, 1992, 1993 and 2002.
- Used in Iran/Iraq conflict in 1982-1987

With the Armistice of WWI, the horrors of chemical warfare prompted the banning of chemical weapons in war.

This commitment resulted in the signing, by 16 nations, of the 1925 Geneva Protocol for the Prohibition of the Use of Asphyxiating, Poisonous or Other Gases, and Bacteriological Methods of Warfare.

The United States did not sign the Protocol until 1975.

The Geneva Protocol does not, incidentally, prohibit the development, production, or possession of chemical weapons, only its use on the battlefield.

Many nations signing the Geneva Protocol included the caveat that they had the right to retaliate with chemical weapons should they be attacked in such a way.

Where are / were US Chemical Weapons Stockpiled?

Anniston Army Depot

- Location: Anniston, AL
- Designation: Closed (September 2011)
- Weapons Stored:
  - GB (Sarin)
  - VX (Nerve Gas)
  - Blister Agent
- History:
  - Established as a munitions storage facility in 1941.
  - Began storing approximately 7% of the national chemical warfare agent stockpile in the early 1960's.
  - Disposal of the stockpile began in 2003.
  - GB disposal was completed in 2006, VX in 2008, and blister agent in 2011.

Pine Bluff Arsenal

- Designation: Closed (Transitioned into a Chemical Agent Disposal facility)
- Weapons Stored:
  - GB (Sarin)
  - VX (Nerve Gas)
  - HD (Distilled Mustard)
- History:
  - GB disposal completed in 2007, VX in 2008.
  - Mustard disposal ongoing.
  - The Pine Bluff facility now functions as the preeminent Chemical Agent Disposal facility, collecting and destroying chemical munitions and materiel, and decontaminating and recycling ton containers stored at the facility.
  - The final chemical weapons production facility in the U.S. was destroyed at Pine Bluff in 2006.

Newport Chemical Depot

- Location: Newport, IN
- Designation: Closed (January 2010)
- Weapons Stored:
  - VX (Nerve Gas)
- History:
  - Opened in 1941 as a warfare materials and chemical agent production facility.
  - Housed the sole VX production facility in the U.S.
  - Production of warfare materials stopped in the 1960's.
  - Demolition of the production facility began in 1998.
  - VX disposal completed in 2008.

Edgewood Area of Aberdeen Proving Ground

- Location: Edgewood, MD
- Designation: Closed (June 2007)
- Weapons Stored:
  - Approximately 5% of the nation's original chemical weapons supply.
- History:
  - Opened in 1917 as the Army's primary research and development center for equipment and munitions.
  - Chemical agent storage began in 1941.
  - Disposal of all chemical agents completed February 2006.

Umatilla Chemical Depot

- Location: Umatilla, OR
- Designation: Closed (October 2011)
- Weapons Stored:
  - GB (Sarin)
  - VX (Nerve Gas)
  - HD (Distilled Mustard)
- History:
  - Opened in 1941 as a materiel storage facility for everything from blankets to ammunition.
  - Changed to a chemical storage depot in 1962.
  - In preparation for closure, non-chemical supplies were shipped elsewhere from 1990-1994.
  - Chemical munitions were destroyed from 2004-2011.

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Deseret Chemical Depot

- Location: Tooele, UT
- Designation: Closed (January 2012)
- Weapons Stored:
  - GB (Sarin)
  - GA (Tabun)
  - VX (Nerve Gas)
  - H (Sulfur Mustard)
  - HD (Distilled Mustard)
  - HT (Mustard/T)
  - Lewisite
- History:
  - Approximately 44% of the nation's original chemical weapons stockpile.
  - Chemical disposal began in 1996 and officially ended in January 2012.

Johnston Atoll Chemical Agent Disposal System

- Location: Johnston Atoll, HI
- Designation: Closed (2000)
- Weapons Stored:
  - GB (Sarin)
  - VX (Nerve Gas)
  - HD (Distilled Mustard)
- History:
  - Developed as the first full-scale chemical disposal facility.
  - Over 14 years the facility destroyed over 4 million pounds of chemical warfare agents.
  - The facility was dismantled in 2000, but official closure and decontamination continues.

Bluegrass Army Depot

- Location: Richmond, KY
- Designation: Active (Scheduled for closure)
- Weapons Stored:
  - GB (Sarin)
  - VX (Nerve Gas)
  - Mustard Agents
- History:
  - Holds 532 tons of chemical munitions.

Pueblo Chemical Depot

- Location: Pueblo, CO
- Designation: Active (Scheduled for closure)
- Weapons Stored:
  - 7% of the United States' original chemical stockpile.
- History:
  - Transitioned into a chemical stockpile in 1942.
  - A chemical-agent destruction plant is under construction.

Types of Chemical Weapons

- Nerve agents
- Blood agents
- Blister agents
- Choking agents
- Psychochemical agents
- Riot Control/Training agents

Nerve Agents

- G Series
  - Tabun (GA)
  - Sarin (GB)
  - Soman (GD)
  - *Cyclosarin* (GF)
- V Series
  - VX, VE, VM, others

G Series

- Pesticide-based
- Inhaled or absorbed by skin
- Non-persistent (volatile gas)
  - Requires thickening agent to increase effectiveness

V Series

- V for ‘venomous’
- Persistent liquid
- Oily, odorless, tasteless, looks like motor oil

Nerve Agents
Common Effects and Symptoms

- Miosis (constriction of pupils) and visual effects
- Headaches
- Nasal congestion
- Salivation
- Tightness in the chest
- Vomiting
- Giddiness
- Anxiety

- Difficulty in thinking
- Difficulty sleeping
- Nightmares
- Muscle twitches
- Tremors
- Weakness
- Abdominal cramps
- Diarrhea
- Involuntary urination and defecation

Nerve Agents

- Dissemination: Liquid or vapor
- Not commercially available

Signs/Symptoms:

SLUDGEM

– Salivation

– Lacrimation or tearing

– Urination

– Defecation

– Gastrointestinal disorders

– Emesis or vomiting

– Miosis or pin-pointed pupils

Nerve Agents

- Nerve agents (cholinesterase inhibitors) interfere with CNS
- React with enzyme acetylcholinesterase and creating an excess of acetylcholine which affects the transmission of nerve impulses.

Nerve agents the most toxic of known chemical agents.

The G agents are non-persistent

The V agents are persistent.

However, the G agents can be ‘thickened’ with other materials which will increase their persistence.

Some are volatile and some are non-volatile at room temperature.

GB is a relatively volatile liquid (thus, non-persistent)

- Near-complete volatilization of sarin (GB): mainly a vapor hazard.

- VX is a relatively non-volatile liquid, and persistent. Mainly a liquid contact hazard.

Nerve agents can be absorbed through any of a victim's body surfaces.

Regular clothing is penetrated by nerve agents whether they occur in a liquid or vapor form.

Liquid nerve agent could be absorbed through the skin, eyes, mouth and membranes of the nose and through the gastrointestinal tract when eaten with food or water.

Major route of entry: respiratory tract.

If no treatment available for a nerve agent victim, the person will likely die of a diminished amount of O_2 in blood and tissues resulting from:

- airway obstruction
- weakness of respiration muscles
- depression of respiration

However, a patient may survive, even after several lethal doses of nerve agent:

- assisted ventilation provided
- airways drained
- atropine

If a very large dose of nerve agent has been acquired quickly, death can occur rapidly.

Dose rate is critical.

Daily exposure to small doses can be cumulative resulting in symptoms after several days.

Protective clothing is required, consisting of:

- Respirator or SCBA
- CBRNE suit or full protective clothing (designed to keep gases, vapor, liquids, and solids from any contact with the skin while preventing ingestion or inhalation),
- Gloves
- Overboots

Nerve agent vapor is absorbed slowly through the skin.

Sarin attacks, Tokyo

地下鉄サリン事件 ('subway sarin incident') was an act of domestic terrorism perpetrated by members of Aum Shinrikyo, March 20, 1995.

Five coordinated attacks: conspirators released sarin gas on several lines of the Tokyo Subway.

Killed 12, seriously injured 54, created vision problems for nearly a thousand more.

Attack directed against trains passing through Kasumigaseki and Nagatacho, home to the Japanese government.

The most serious attack in Japan since end of WWII.

Problems with Response?

- Victims not decontaminated
- Responders did not don appropriate PPE; hence, they also became ill.
- ‘Self-admits’ (?)

Disposal of VX

- Early on the US implemented program CHASE (Cut Holes And Sink ‘Em).
  - During this program stockpiles of VX and other agents where put into ships and sunk off of the coast of New Jersey, but due to the dangers this was soon abandoned.
- Now the agent is eliminated through the use of chemical neutralization.
  - Through hydrolization, VX was chemically reduced to a less toxic agent, and was subsequently destroyed.

Blister Agents (Vesicants)

- Distilled mustard (HD)
- Ethyldichloroarsine (ED)
- Lewisite (L)
- Methyldichloroarsine (MD)
- Mustard/lewisite Mix (HL)
- Nitrogen mustard (HN-1)
- Nitrogen mustard (HN-2)
- Nitrogen mustard (HN-3)
- Phenyldichloroarsine (PD)

Blister Agents (Vesicants)

- Dissemination: Liquid or vapor
- Not commercially available

HD (sulfur mustard)

HN (nitrogen mustard)

Military casualties:

- Reduces fighting efficiency due to protective gear worn
- Damage to skin, eyes, lungs

Very persistent

Sulfur Mustard, HD

- Bis (2-chloroethyl) sulfide
- $C_4H_8Cl_2S$
- Density: 1.27 g/ml
- Phase: liquid
- Solubility in water: negligible
- Melting point: 14.4 °C
- Boiling point: 217 °C
- Vapor pressure: 0.11 mm Hg @ 25 °C

Agent HD is H that has been purified through washing and vacuum distillation to reduce sulfur impurities.

US supply of sulfur mustard:

- one-ton containers
- artillery shells
- other munitions

Blister Agents --

- mustard (H)
- distilled mustard (HD)
- nitrogen mustard (HN)
- lewisite (L)

Used in large amounts during World War I, intended to contaminate troops, force enemy troops to wear full protective equipment, reduce combat efficiency.

- World War I, many troops out of service for hours, days, weeks, years
- Actual deaths limited even though exposure to blister agents can be fatal.

Persistence

A persistent agent retains casualty-producing effects from minutes to days.

Persistence of chemical agents influenced by:

- type of agent
- type of terrain
- temperature
- wind
- humidity
- precipitation

Non-persistent agents dissipate or vaporize rapidly after release, are a short-duration hazard.

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Persistence increases in wooded, rather than open terrain (why is this?)

Persistence longer in winter than summer.

Threat from vapor increases under hot conditions, decreases with cool temperatures.

Relevant Properties of Chemical Weapons

- LD_{50}
- K_{ow}
- Specific gravity
- Vapor density
- Vapor pressure
- IDLH

	VX	HD
Vapor pressure, mm Hg	1.48	0.11
Vapor density	9.2	5.4
Specific gravity	1.09	1.27
Volatility, mg/m^3	22,000	600

Which is more persistent on a cold day?
A hot day?

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Toxicology

Not all persons respond in the same manner to any chemical agent.

Both lewisite (L) and phosgene oxime (CX) are immediately painful

Mustard agents may cause little or no pain for hours after exposure.

Mustard (H and HD) is used primarily to bring about delayed casualties.

Sulfur mustard exposure attacks the skin/eyes/ respiratory tract, but a victim can remain symptom-free for some time after exposure.

Effects of Blister Agents

- Method of exposure
- Temperature
- Physical condition of victim before exposure

affect length of time before symptoms appear and severity of skin blisters.

Young troops have better survival rates in a chemical agent attack than older civilians.

- When we talk about terrorism, WMDs, etc. must think of casualties as civilians who are likely not going to survive as well as young, fit military troops.

- Age and health of a population are some of the factors to consider in assessing reactions to mustard gases.

- The respiratory tract is subject to mustard attacks on the mucous membranes.
- Mustard gas causes depletion of all elements of bone marrow and temporary blindness.

- Victims may have lengthy psychological problems:
  - chronic depression
  - loss of libido
  - anxiety

- Sulfur mustard is a known carcinogen.
- No effective medical care exists for persons with mustard agent exposure and lesions.

- Carcinogen:
- Mutagen:
- Teratogen:

Response

Care is directed toward relieving symptoms and preventing infections in order to promote healing.

Response

Responders should understand principles of **toxicology**, the scientific discipline of the effects, antidotes, detection, and other studies related to poisons.

Response

Distilled mustard (HD) and nitrogen mustard (HN-3) are serious concerns:

- persistent in the field
- chemically stable
- attack the skin/eyes/respiratory tract
- resistant to drugs that may counter such effects

Responders must rely on PPE and respirator or SCBA.

Treatment and Decon

Victims contaminated with blister agents create a danger to those around them.

Other staff having contact with contaminated persons must wear full PPE (remember sarin response, Tokyo).

Decontamination must be done outdoors to prevent vapor accumulation indoors.

Treatment and Decon

Separate contaminated persons from those uncontaminated.

Decon should be carried out on equipment and vehicles used to treat or transport victims.

Medical Management

Management is supportive.

The skin lesions should be managed in the same way that a necrotic ulcerated lesion from another cause would be managed.

Necrosis:

Blood Agents

- Arsine (SA)
- Cyanogen chloride (CK)
- Hydrogen cyanide (AC)

Blood Agents

- Dissemination: Liquid or gas
- Commercially available
- Signs/Symptoms: Gasping for air, frothing or vomiting, nausea, stupor, coma, and death
- Treatments available, but must be delivered immediately

Hydrogen Cyanide

- Prevents transfer of oxygen to tissue
- Damages gas mask filters
- Non-persistent

- Injures by interfering with cell respiration (exchange of O_2 and CO_2 between blood and tissues).
- Cyanide blocks the use of O_2 in cells, causing asphyxiation in cells.

- Arsine (SA) interferes with blood and damages the liver and kidneys.
- A severe exposure could cause anemia.
- Arsine is a carcinogen.

If vapor used, little need for decontamination; if liquid is present, wash skin promptly to remove contamination.

- U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID)

Cyanide liquid is absorbed through the skin can continue to penetrate the bloodstream.

Pulmonary (Choking) Agents

- Phosgene
- Diphosgene
- Chlorine

Moderately persistent

Choking Agents

- Dissemination: Liquid or gas
- Availability: Commercially available
- Signs/Symptoms: Irritation of airway from nose to lungs, pulmonary edema, coughing, skin lesions (if liquid touches skin), heart failure

- Pulmonary (choking) agents cause physical injury to the lungs through inhalation.
- Membranes may swell and lungs may become filled with liquid, and, in serious cases, lack of O_2 causes death.

- Phosgene (CG) was big killer in World War I (80% of all chemical fatalities).

- Phosgene is a corrosive and highly toxic gas that leads to ‘dry land drowning’ through pulmonary edema which can occur up to 48 hours after exposure.

- A serious skin irritant, produces acute lesions similar to those from frostbite or burns.
- $HCl_{(aq)}$ and CO form through its decomposition
- Thermal decomposition releases toxic and/or hazardous gases.

Psychochemical Agents

- Incapacitating agent
- Administered by food/water or aerosol
- No permanent injury, *lasts for days*
- Very persistent in food/water
- *Non-persistent in vapor*

Riot Control

- Non-lethal
- Temporary incapacitation without permanent harm (<2hrs)
- Strong irritant to mucous membranes
- CS gas (solid form)
- Tear gas or vomit gas

Terrorist Use of Chemical Agents:
Exposure, Dissemination, Characteristics

Chemical weapons work ‘optimally’ when used against untrained people and unprotected targets.

Chemical *warfare* attacks, by their very nature, seriously affect warfare effectiveness:

- combat stress
- poor morale
- general inefficiency

Agent forms:

- vapor
- aerosol
- solid
- liquid

Chemical agents are distributed by:

- spray devices
- bombs
- aircraft
- rockets
- missiles
- mines
- water supplies/reservoirs

Indicators of a Possible Chemical Incident

- Dead animals: numerous animals (wild, domestic, small, large), birds and fish in same area.
- Lack of insect life: If normal insect activity (ground, air, water) missing, check ground, water, shoreline etc. for dead insects.

- Near water: check for dead fish, aquatic birds.

- Blisters/rashes: Individuals experiencing unexplained water-like blisters, wheals, other rashes.

- Mass casualties: Many persons exhibiting unexplained serious health problems (nausea, disorientation, difficulty in breathing, convulsions, death).

- Definite pattern of casualties: Casualties distributed in a pattern that may be associated with agent dissemination methods.

- Illnesses occurring in confined geographic area: Lower rates for people indoors versus outdoors.

- Unusual liquid droplets: Surfaces may have oily droplets/film; water surfaces have oily film.

- Areas with unusual appearance: Large areas of trees, shrubs, food crops, lawns that are dead, discolored, withered (no drought).

Unusual odors:

- fruity, flowery
- sharp/pungent
- garlic/horseradish
- bitter almonds
- peach kernels
- new mown hay

The particular odor must be completely out of character with surroundings.

- Unusual metal debris: Unexploded bomb-like materials, especially if they contain a liquid (no recent rain).

Symptoms

Signs that a toxic chemical agent has been released:

- unexplained runny nose
- obvious attack of spray emitting from an aircraft
- smoke/mist/fumes/ clouds of unknown origin
- laughter or strange behavior in other persons
- slurred speech
- difficulty in breathing
- eyesight problems

Chemical Detection Equipment and Associated Technologies

- M8 paper: detects V-type nerve agents (VX), G-type nerve agents (sarin, soman) and H-type vesicants (sulfur mustard).
- M256 Series Chemical Agent Detector Kit: V-type nerve agents (VX), G-type nerve agents (sarin, soman) and H-type vesicants (sulfur mustard).
- Draeger colorimetric tubes
- Photoionization detector (PID)

Detection:

M256A1, M272 water testing kit, MINICAMS, the ICAD, M18A2, M21 remote sensing alarm, M90, M93A1 Fox, Bubbler, CAM, and DAAMS, M8 paper, or M9 paper.

Factors to Consider when Choosing a Detection Device

- Agents detected
- Sensitivity
- Resistance to interference
- Response time
- Start-up time
- Detection status
- Alarm capability
- Portability
- Power capabilities
- Battery needs
- Operational environment
- Durability
- Procurement costs

‘Advantages’ of Chemical Weapons to Terrorists

- Persistent nature of many types (VX, mustard gas)
- Long-term storage
- Range of casualties (stun or kill)
- Psychological effects
- Range of production costs
  - Some vesicants are byproducts or similar compounds to common material

Disadvantages of Chemical Weapons

- Corrosive
- Expensive equipment to produce/store
  - Corrosion resistant
  - Strict temperature control
- Nondiscriminatory

End