Chemical Weapons: A Summary Report of Characteristics and Effects

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Summary

The potential for terrorist use of chemical agents is a noted concern highlighted by the Tokyo sarin gas attacks of 1995. The events of September 11, 2001, increased congressional attention towards reducing the vulnerability of the United States to such unconventional attacks. The possibility that terrorist groups might obtain insecure chemical weapons led to increased scrutiny of declared Libyan chemical weapon stockpiles following the fall of the Qadhafi regime. Experts have expressed similar concerns regarding the security and use of Syrian chemical weapons, reportedly including stocks of nerve (sarin, VX) and blister (mustard gas) agents. For analysis of chemical weapons in Syria, see CRS Report R42848, *Syria's Chemical Weapons: Issues for Congress*, coordinated by (name redacted).

Military planners generally organize chemical agents, such as chemical weapons and toxic industrial chemicals, into four groups: nerve agents (such as sarin and VX), blister agents (such as mustard gas), choking agents (such as chlorine and phosgene), and blood agents (such as hydrogen cyanide). While the relative military threat posed by the various chemical types has varied over time, terrorist use of these chemicals against civilian targets is viewed as a low probability, high consequence event.

Chemical weapons and toxic industrial chemicals cause a variety of symptoms in their victims. These symptoms depend on the chemical agent used, and a victim of chemical exposure may exhibit a combination of symptoms. Some chemical agents cause death by interfering with the nervous system. Some chemical agents inhibit breathing and lead to asphyxiation. Other chemical agents have caustic effects on contact. As a result, effective chemical attack treatment depends on identifying at least the type of chemical agent used. Additionally, chemical agents trapped on the body or clothes of victims may place first responders and medical professionals at risk.

Civilian protection from and detection of chemical agents is an area of federal concern. Whether terrorist groups are capable of using chemical agents as weapons of mass destruction is unclear. Some experts have asserted that the volumes of chemicals required to cause mass casualties makes that scenario unlikely. They claim that chemical terrorism is more likely to be small in scale. Other experts have suggested that there has been an increase in terrorist interest regarding chemical agents, and that this interest could lead to their use in terrorist attacks. Some experts assert that insecure stockpiles of military-grade chemical agents would lower the barrier to terrorist acquisition of chemical agents and thus increase the possibility that terrorists might use them. The change of regimes in Libya and Egypt and recent events in Syria have increased concern that such military-grade chemical agents might transition into terrorist hands and then be used to attack U.S. sites either domestically or abroad.

Contents

Contacts

Introduction

Experts believe that terrorist use of chemical agents is an event with low probability, but potentially high consequences. While terrorist groups may or may not have an increased interest in chemical agent acquisition and use, the domestic vulnerability of the United States to chemical attack remains an issue. Both the United States and Russia have signed and ratified the Chemical Weapons Convention (CWC), and are reducing, and eventually eliminating, their chemical weapon stockpiles.[1] The possibility that terrorist groups might obtain insecure chemical weapons led to increased scrutiny of declared Libyan chemical weapon stockpiles following the fall of the Qadhafi regime. Experts have expressed similar concerns regarding the security of Syrian chemical weapons, reportedly including stocks of nerve (sarin, VX) and blister (mustard gas) agents, and their potential use. For analysis of chemical weapons possession and use in Syria, see CRS Report R42848, *Syria's Chemical Weapons: Issues for Congress*, coordinated by (name reda cted).

Policy approaches to reducing chemical agent vulnerability have generally treated them as a group, rather than addressing specific agents. Additionally, military and civilian chemical agent detection has developed with little coordination, so that civilian toxic industrial chemical kits and military chemical weapons detectors have varying sensitivities and detection capabilities. Treatments for chemical exposure vary on a chemical by chemical basis. Because comparatively few individuals have been exposed to modern chemical weapons, health care providers have limited practical experience in treatment of chemical casualties, especially among civilians. While national efforts to reduce vulnerability to terrorist chemical agent use continue, it is not clear whether these efforts address the risks from those specific agents that pose the greatest danger. This report describes the different types of chemical weapons and toxic industrial chemicals, their availability, treatment, and detection.

Types of Chemical Agents

Chemical agents are, for the purpose of this report, chemicals posing exceptional lethality and danger to humans.[2] Some chemical agents are toxic industrial chemicals used for commercial purposes, while others are chemicals developed predominantly as weapons.

Different chemical weapons cause different symptoms in and injuries to their victims. Because of this range of potential effects, identifying the chemical agent is a key step to determining the most effective treatment. Also, chemical weapons may produce their effects by multiple different exposure routes, for example by skin contact or by inhalation. As a consequence, depending on the encountered chemical, those affected must employ different protective equipment and approaches; for example, a gas mask alone does not provide sufficient protection against chemicals that can damage through skin contact.

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[1] CRS Report RL31559, *Proliferation Control Regimes: Background and Status*, coordinated by (name redacted).

[2] Experts might disagree about which chemical compounds pose the highest terrorist threats. The discussion in this report does not represent a complete list of all potential threats. For example, it does not address incapacitating agents or riot control agents.

Military planners generally categorize chemical agents into at least four classes: nerve, blister, choking, and blood agents.[3] This method organizes chemical agents by their biological effects. Modern militaries have generally focused on nerve and blister agents as weapons. Several choking and blood agents are chemicals widely used in industrial processes.

Nerve Agents

Chemicals categorized as nerve agents disrupt normal functioning of the nervous system. Nerve agents do not occur naturally. Rather, they are manmade compounds that require manufacture and isolation for high purity and toxicity. Most nerve agents belong to a group of chemicals called organophosphates. Organophosphates have a wide range of toxicity. Some insecticides contain organophosphates, though these are significantly less toxic compounds than those developed as chemical weapons. Nerve agents are mainly liquids.

The first nerve agent, tabun or GA, was made in Germany in the 1930s. Following this discovery, a series of nerve agents similar to tabun were developed. This series, known as the G-series, includes the weapons sarin (GB) and soman (GD). In the late 1940s, another series of nerve agents, the V-series, was invented in England. This series includes the chemical weapon VX. Historically, multiple countries, including the United States and the Soviet Union, manufactured and maintained stockpiles of nerve agents. As signatories to the Chemical Weapons Convention (CWC), both the United States and Russia are reducing, and eventually eliminating, their nerve agent stockpiles.

Military and terrorist use of nerve agents has been rare. Public intelligence assessments issued by the United Kingdom and the United States on August 29 and August 30, 2013, respectively, stated that the Syrian government used a nerve agent on August 21, 2013, against opposition forces outside of Damascus, Syria.[4] During the 1980-1988 Iran-Iraq war, Iraq used nerve agents against Iranian troops and later against members of its Kurdish population in northern Iraq.[5] In 1995, the Japanese apocalyptic cult Aum Shinrikyo used sarin on the Tokyo subway and reportedly carried out an attack in the city of Matsumoto as well.[6]

Production

National chemical weapons programs have produced nerve agents for decades. A terrorist group might overcome technological barriers to synthesize these agents by using commercially available equipment, though the extreme toxicity of these compounds would pose appreciable danger to the manufacturer. Nerve agent production requires the use of toxic chemicals during

[3] A fifth category is incapacitating agents, which this report does not address. Department of the Army, *Multi-Service Doctrine for Chemical, Biological, Radiological, and Nuclear Operations*, FM 3-11, July 2011.

[4] Office of the Press Secretary, The White House, *Government Assessment of the Syrian Government's Use of Chemical Weapons on August 21, 2013*, August 30, 2013; and Chairman of the Joint Intelligence Committee, Joint Intelligence Organisation, *Syria: Reported Chemical Weapons Use*, August 29, 2013.

[5] Organization for the Prohibition of Chemical Weapons, "Brief History of Chemical Weapons Use," http://www.opcw.org/about-chemical-weapons/history-of-cw-use/.

[6] For an overview of the Aum Shinrikyo use of sarin in the Tokyo subway system, see David E. Kaplan, "Aum Shinrikyo (1995)" in *Toxic Terror: Assessing Terrorist Use of Chemical and Biological Weapons*, Jonathan B. Tucker, Ed. (Cambridge, MA: MIT Press) 2000. See also Organization for the Prohibition of Chemical Weapons, "Brief History of Chemical Weapons Use," http://www.opcw.org/about-chemical-weapons/history-of-cw-use/.

synthesis and specialized equipment to contain the nerve agents produced.[7] Of the nerve agents, VX is the most difficult to manufacture.

An alternative to the direct manufacture of nerve agents is to manufacture certain chemicals that, when mixed, react to form the desired nerve agent. These chemical combinations are called *binary* chemical weapons. Binary chemical weapons have certain advantages and disadvantages when compared with the actual nerve agent. The chemicals comprising a binary chemical weapon are much less toxic than the actual nerve agent and thus are less dangerous to manufacture, transport, and handle.[8] The nerve agent obtained through the use of a binary chemical weapon may be less pure or effective than directly manufactured nerve agent, since the conditions under which the nerve agent is manufactured are less controlled.[9]

Effects

Nerve agents are extremely dangerous and can enter the body through the lungs or by skin contact. For the G-series nerve agents, such as sarin, the inhalation toxicity is significantly greater than the dermal toxicity. Of the nerve agents, VX is the most deadly and tabun is the least deadly, though all are exceedingly toxic.

Nerve agents interfere with the nervous system, causing overstimulation of muscles. Victims may suffer nausea and weakness and possibly convulsions and spasms. At higher concentration, loss of muscle control, nervous system irregularities, and death may occur. The action of nerve agents can be irreversible if victims are not quickly treated.

Treatment

Treatment for nerve agent exposure relies on two drugs, atropine and pralidoxime chloride, as antidotes.[10] Atropine prevents muscle spasm and allows the body time to clear the nerve agent. Pralidoxime chloride limits the effects of nerve agents by reversing the agent's action. U.S. troops during the Persian Gulf War received both of these drugs in the form of an antidote kit. Anticonvulsants, such as Diazepam (Valium), may reduce convulsions and seizures brought on by exposure to nerve agents.[11]

The treatment window for nerve agent exposure is agent-dependent. Some agents quickly and irreversibly act within the body, while others require a much longer time. The most effective treatment occurs before or immediately after exposure to the nerve agents has taken place. For example, treatment of soman must begin within minutes to be effective, while tabun treatment can occur up to several hours after exposure. Prophylactic use of some compounds, such as

[7] Note that the toxic chemicals used to manufacture nerve agents are considerably less toxic than the nerve agent itself.

[8] For further discussion of binary chemical weapons, see U.S. Congress, Office of Technology Assessment, *Technologies Underlying Weapons of Mass Destruction*, OTA-BP-ISC-115 (Washington, DC: Government Printing Office) December 1993.

[9] For a discussion of this effect in the context of the former Iraqi chemical weapons program, see Jonathan B. Tucker, *War of Nerves: Chemical Warfare from World War I to al-Qaeda*, (Pantheon) 2006.

[10] Department of the Army, *Multiservice Tactics, Techniques and Procedures for Treatment of Chemical Agent Casualties and Conventional Military Chemical Injuries*, FM 4-02.285, 2007.

[11] Chemical Casualty Care Division, U.S. Army Medical Research Institute of Chemical Defense, *Field Management of Chemical Casualties Handbook*, Third Edition, February, 2007.

pyridostigmine bromide, may allow effective treatments for some nerve agents to occur with longer delay.[12]

Blister Agents

Chemicals categorized as blister agents, also known as vesicants, cause painful blistering of the skin. Such blistering is not generally lethal. Militarily, blister agents produce casualties and reduce the combat effectiveness of opposing troops by requiring them to wear bulky protective equipment.[13] The most common blister agents are called mustard agents, due to their odor. Mustard agents are oily liquids that range in color from very pale yellow to dark brown, depending on the type and purity, and have a faint odor of mustard, onion, or garlic.[14] These liquids evaporate quickly, and their vapors are also injurious.

Blister agents are not naturally occurring compounds. Mustard agents, for example, were first developed in the late 1800s. During World War I, both sides in the conflict used these weapons against their enemies. Mustard-type blister agents produced the greatest number of chemical casualties during World War I, though fewer than 5% of these casualties died. Countries have stockpiled blister agents in their chemical weapon inventories.[15] Mustard agent was also used by both sides in the Iran-Iraq war.[16] As a signatory to the CWC, the United States is in the process of destroying its stockpile of blister agents.

Production

Production of blister agents is less complicated than that of nerve agents. Similar to manufacture of nerve agents, it requires the use of toxic chemicals and specialized equipment to contain the agent produced. The most common blister agents have many different methods for their production published in the open literature.[17]

Effects

Blister agents can enter the body by inhalation or contact with the skin or eyes. Some agents can penetrate through normal clothing material, causing burns even in cloth-covered areas. While blister agents react quickly upon skin contact, their symptoms may be delayed. In the case of mustard agent, damage occurs within one to two minutes of exposure, but symptoms do not

[12] Chemical Casualty Care Division, United States Army Medical Research Institute of Chemical Defense, *Medical Management of Chemical Casualties Handbook*, Fourth Edition, January, 2007.

[13] Department of the Army, *Multiservice Tactics, Techniques and Procedures for Treatment of Chemical Agent Casualties and Conventional Military Chemical Injuries*, FM 4-02.285, 2007.

[14] D. Hank Ellison, *Handbook of Chemical and Biological Warfare Agents* (Boca Raton, FL: CRC Press) 2000.

[15] The Director of National Intelligence testified that Syria maintains a stockpile of sulfur mustard blister agents. James R. Clapper, Director of National Intelligence, *Worldwide Threat Assessment of the US Intelligence Community*, statement for the record before the Senate Select Committee on Intelligence on March 12, 2013.

[16] Robert J. Einhorn, Assistant Secretary of State for Nonproliferation, Department of State, before the Senate Committee on Foreign Relations, Subcommittee on Near Eastern and South Asian Affairs, and Subcommittee on European Affairs, October 5, 2000.

[17] As of 1993, at least nine methods to produce sulfur mustard were publically available. See U.S. Congress, Office of Technology Assessment, *Technologies Underlying Weapons of Mass Destruction*, OTA-BP-ISC-115 (Washington, DC: Government Printing Office) December 1993, p. 151.

manifest for several hours.[18] As even low concentrations of vaporized blister agents quickly cause damage, it is unlikely that exposed individuals can remove these agents from the skin prior to injury.

The initial symptoms of blister agent exposure are a reddening of the skin, resembling sunburn, combined with pain in the affected area. Swollen skin, blisters, and lesions may then develop, depending on the degree of exposure. Systemic symptoms, such as malaise, vomiting, and fever, may also develop in extreme cases. Exposure to large amounts of liquid mustard agent may prove fatal.[19]

The eyes are also very sensitive to blister agents. Following exposure to high concentration vapor, great pain, corneal damage, and scarring may occur. Liquid agent often causes the most severe eye damage. This may come from contact with airborne droplets or by self-contamination of the eyes from contaminated clothing or body parts.[20]

Victims inhaling blister agents may suffer damage to their lungs. While a single, low-level exposure may produce only temporary impairment, high concentrations or repeated exposures may cause permanent damage. Inhalation victims may have symptoms ranging from mild bronchitis to blistering of the lungs.[21]

Treatment

Damage from blister agent exposure, lesions and other skin irritations, is symptomatically treated. Hospitalization may be required for respiratory tract injuries. Victims who suffer severe lung damage may require mechanical ventilation. Exposure to large amounts of mustard agent may weaken the whole immune system, requiring special precautions to avoid opportunistic infections during recovery.[22]

Choking Agents

Chemicals categorized as choking agents act on the lungs, causing difficulty in breathing and, potentially, permanent lung damage. Examples of choking agents include chlorine, ammonia, and phosgene. Choking agents are generally gases, have marked odors, and may color the surrounding air.

Choking agents were manufactured for wartime use, and were extensively used during World War I. The first major, successful, chemical attack of the war used chlorine gas at Ypres in 1915.[23]

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[18] Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services, *Toxicological Profile for Sulfur Mustard*, September 2003.

[19] Department of the Army, *Multiservice Tactics, Techniques and Procedures for Treatment of Chemical Agent Casualties and Conventional Military Chemical Injuries*, FM 4-02.285, 2007.

[20] Department of the Army, *Multiservice Tactics, Techniques and Procedures for Treatment of Chemical Agent Casualties and Conventional Military Chemical Injuries*, FM 4-02.285, 2007.

[21] Department of the Army, *Multiservice Tactics, Techniques and Procedures for Treatment of Chemical Agent Casualties and Conventional Military Chemical Injuries*, FM 4-02.285, 2007.

[22] Chemical Casualty Care Division, U.S. Army Medical Research Institute of Chemical Defense, *Field Management of Chemical Casualties Handbook*, Third Edition, February, 2007.

[23] A. Boserup, *The Problem of Chemical and Biological Warfare—Volume I—The Rise of CB Weapons* (Stockholm: (continued...)

Chlorine gas was later supplemented by phosgene use, which caused greater casualties. More recently, Iraqi insurgents attempted to use chlorine gas as part of improvised explosive devices in 2006 and 2007.[24] Choking agents are encountered during industrial accidents.[25]

Production

Many choking agents no longer have a military purpose, and instead industrial users predominantly employ them. Commercial applications use chlorine and ammonia in large quantities for water disinfection and food refrigeration. Methods for producing choking agents are well-known, but may be technically challenging. Choking agents require specialized equipment to produce, compress, and contain them.

Effects

Choking agents injure their victims through inhalation and have a comparatively mild effect on the skin. Exposure to low chemical concentrations causes chest discomfort or shortness of breath, irritation of nose and throat, and tearing eyes. High agent concentrations may quickly cause swelling of the lungs, respiratory failure, and possibly death. Symptoms of lung damage can occur up to 48 hours after inhalation of moderate concentrations, and may not manifest themselves until physical effort aggravates the lungs.[26]

Treatment

Victims of choking agents are generally treated symptomatically. Because exercise may exacerbate lung damage, victims are kept at rest until the danger of fluid in the lungs is past. Symptoms such as tightness of the chest and coughing are treated with immediate rest and comfort. Shallow breathing and insufficient oxygen may require supplemental oxygen.[27]

Swelling and accumulation of fluids in the lungs are likely after exposure to a high dose of choking agent. Administration of corticosteroids has been recommended in cases of fluid accumulation, but their beneficial effects have not been proven.[28] Rest, warmth, sedation, and oxygen are still the primary treatments, even in the case of marked edema.

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Almqvist & Wiskell), 1973.

[24] See, for example, Damien Cave and Ahmad Fadam, "Iraq Insurgents Employ Chlorine in Bomb Attacks," *The New York Times*, February 22, 2007, and Jim Garamone, "Terrorists Using Chlorine Car Bombs to Intimidate Iraqis," *American Forces Press Service*, June 6, 2007.

[25] For examples of industrial accidents involving chlorine, see Robert Jones, Brandon Wills, and Christopher Kang, "Chlorine Gas: An Evolving Hazardous Material Threat and Unconventional Weapon," *Western Journal of Emergency Medicine*, 11(2), May 2010, pp. 151-156.

[26] Chemical Casualty Care Division, United States Army Medical Research Institute of Chemical Defense, *Medical Management of Chemical Casualties Handbook*, Fourth Edition, January 2007.

[27] Chemical Casualty Care Division, U.S. Army Medical Research Institute of Chemical Defense, *Field Management of Chemical Casualties Handbook*, Third Edition, February 2007.

[28] Department of the Army, *Multiservice Tactics, Techniques and Procedures for Treatment of Chemical Agent Casualties and Conventional Military Chemical Injuries*, FM 4-02.285, 2007.

Blood Agents

Chemicals categorized as blood agents interfere with oxygen utilization at the cellular level. This category includes hydrogen cyanide and cyanide salts. Hydrogen cyanide is a very volatile gas, smelling of almonds, while cyanide salts are odorless solids.

Militaries have considered hydrogen cyanide for use as a chemical warfare agent, but it has rare use in military situations because it quickly disperses. France manufactured hydrogen cyanide as a military agent during World War I.[29] Hydrogen cyanide was used in other situations though; the principle agent used to kill individuals in German World War II concentration camps, Zyklon B, used hydrogen cyanide as its active agent.[30] Hydrogen cyanide use was attributed to both sides during the Iran-Iraq war.[31]

Production

Hydrogen cyanide and cyanide salts have industrial applications in the chemical, electroplating, and mining industries. As with choking agents, methods for producing blood agents are relatively well-known. However, the gaseous nature of hydrogen cyanide complicates production and storage.

Effects

Blood agents act through inhalation or ingestion and impair cellular oxygen use.[32] The central nervous system is especially susceptible to this effect. The symptoms of blood agent exposure depend upon the agent concentration and duration of exposure. In mild cases, headache, dizziness, and nausea may occur for several hours, followed by complete spontaneous recovery. Higher concentration or longer exposure may cause convulsions and coma. Very high concentrations may lead to powerful gasping for breath, violent convulsions, and cardiac failure within a few minutes.[33]

Treatment

Treatment with specific antidotes, amyl or sodium nitrite combined with sodium thiosulfate, may reverse the effects of blood agents. The combination of these two chemicals removes cyanide, the active compound in blood agents, from the body. When convulsion or depressed breathing are present, treatment includes ventilation with oxygen and administration of anticonvulsant. Cyanide

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[29] Chemical Casualty Care Division, United States Army Medical Research Institute of Chemical Defense, *Medical Management of Chemical Casualties Handbook*, Fourth Edition, January 2007.

[30] J. H. Barrington, Ed., *The Zyklon B Trial: Trial of Bruno Tesch and Two Others* (London) 1948.

[31] Testimony of Robert J. Einhorn, Assistant Secretary of State for Nonproliferation, Department of State, before the Senate Committee on Foreign Relations, Subcommittee on Near Eastern and South Asian Affairs, and Subcommittee on European Affairs, October 5, 2000.

[32] Agency for Toxic Substances and Disease Registry, Public Health Service, U.S. Department of Health and Human Services, *Toxicological Profile for Cyanide*, July 2006.

[33] Department of the Army, *Multiservice Tactics, Techniques and Procedures for Treatment of Chemical Agent Casualties and Conventional Military Chemical Injuries*, FM 4-02.285, 2007.

is metabolized more readily than most chemical weapons; with prompt treatment, victims may recover from otherwise-fatal doses.[34]

Protection Against Chemical Agents

Protection against chemical agents is predominantly physical, rather than medicinal, in nature. Physical protections limit exposure by protecting the eyes, lungs, and/or skin from chemical contact.

Physical

Physical protection against chemical agents includes gas masks and special protective clothing.[35] Gas mask filters equipped with chemical filters are effective against inhaled chemical agents but may not provide sufficient protection against chemical agents active on skin contact, such as VX or mustard agents, or high concentrations of other nerve agents.

Gas mask filters contain layers of activated charcoal and fine porous material to remove particles and chemicals from the airstream. The activated charcoal binds chemicals, preventing them from being inhaled. Each gas mask filter has a finite capacity, proportional to the amount of unbound activated charcoal remaining, and so has a limited lifetime once put into operation.

A protective garment protects against those chemical weapons that cause effect upon skin contact. These garments range in complexity and protective ability. Hazardous materials suits are typically suits made of layered rubber containing activated charcoal. In comparison, military battle dress over-garments designed to protect against chemical weapons in the battlefield are generally cloth, sometimes treated to resist absorbing liquids, containing a layer of charcoal-impregnated foam. The rubber in protective equipment is impermeable to most chemical agents, while the activated charcoal acts in a manner similar to a gas mask filter. The combination of properly fitted and worn mask and suit should provide full protection against most chemical exposures.

Medical

Few examples of medical prophylaxis against chemical weapons exist. Unlike against biological weapons, vaccines do not provide immunity from the effects of chemical weapons. However, pre-exposure use of pyridostigmine bromide provides some protection against the nerve agent soman.[36] Pyridostigmine bromide acts to supplement post-exposure administration of the nerve agent antidotes atropine and pralidoxime chloride. Use of pyridostigmine bromide prevents

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[34] Chemical Casualty Care Division, United States Army Medical Research Institute of Chemical Defense, *Medical Management of Chemical Casualties Handbook*, Fourth Edition, January 2007.

[35] For an overview, see Michael R. Jones, "Personal Protective Equipment: Practical and Theoretical Considerations," in *Chemical Warfare Agents: Chemistry, Pharmacology, Toxicology, and Therapeutics, Second Edition*, James A. Romano, Jr., Brian J. Lukey, and Harry Salem, Eds. (Boca Raton, FL: CRC Press) 2008.

[36] The Food and Drug Administration has approved this compound for military treatment of soman exposure. Pyridostigmine bromide has limited treatment effectiveness against other nerve agents. U.S. Food and Drug Administration, U.S. Department of Health and Human Services, "FDA Approves Pyridostigmine Bromide as Pretreatment Against Nerve Gas," February 5, 2003.

permanent binding of nerve agents within the nervous system. Pyridostigmine bromide use is recommended only when there is a high imminent threat of chemical weapon use, as it has noticeable side effects.

The U.S. Army Medical Research Institute of Chemical Defense developed as an added protection against skin contact, a chemical resistant topical skin cream. The Skin Exposure Reduction Paste Against Chemical Warfare Agents, also known as SERPACWA, aims to complement chemical protective equipment provided to soldiers in the field.[37]

Decontamination

Decontamination, where chemicals are removed from the victims, usually through washing the eyes and skin with water and (against some chemical agents) a dilute bleach solution, is an essential protection against secondary chemical exposure. In addition to stopping the victim's exposure to the chemical agent, this procedure prevents those treating the victim from becoming victims themselves, and avoids contamination of treatment facilities.[38] Decontamination is especially important in those cases where victims have encountered liquid chemical agents, and may have significant amounts of chemical agent trapped in their garments. In events with gaseous agents, decontamination may be less critical. Treatment of the victims with general care or agent-specific antidotes occurs following decontamination.

Detection of Chemical Agents

Chemical weapons detection has been predominantly an area of concern for military planners, although the manufacture of some of these agents for commercial use requires detection capabilities at manufacturing plants and by first responders trained to handle hazardous materials. While some military units have equipment for chemical weapon detection, civilian first responders use a variety of commercial equipment to detect and identify a wide range of chemicals, generally in a hazardous material context.

Because of the wide spectrum of potential chemical agents, the development of a portable, integrated instrument that quickly detects all chemical agents remains an area of research and development. The Department of Defense employs a series of technologies to detect and identify chemical agents, including personal sensors, automated atmospheric sampling, and laboratory methods adapted for battlefield use.[39]

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[37] For more information regarding SERPACWA, see Brian J. Lukey, Harry F. Slife Jr., Edward D. Clarkson, et al., "Chemical Warfare Agent Decontamination from Skin," in *Chemical Warfare Agents: Chemistry, Pharmacology, Toxicology, and Therapeutics, Second Edition*, James A. Romano, Jr., Brian J. Lukey, and Harry Salem, Eds. (Boca Raton, FL: CRC Press) 2008.

[38] Following the 1995 sarin attack in the Tokyo subway, it was determined that 10% of the emergency medical technicians who transported victims to the hospital and 23% of the hospital staff workers who treated those victims developed symptoms of sarin exposure. Tetsu Okumura, Kouichiro Suzuki, Atsuhiro Fukuda, et al., "The Tokyo Subway Sarin Attack: Disaster Management, Part 1: Community Emergency Response," *Academic Emergency Medicine*, 5(6), 1998, pp. 613-617; and Tetsu Okumura, Kouichiro Suzuki, Atsuhiro Fukuda, et al., "The Tokyo Subway Sarin Attack: Disaster Management, Part 2: Hospital Response," *Academic Emergency Medicine*, 5(6), 1998, pp. 618-624.

[39] For a summary overview of chemical detectors, see Department of the Army, *Toxic Chemical Agent Safety* (continued...)

Detection of chemical agents can serve multiple purposes. One is to provide warning of a chemical attack, allowing additional time to react to potential exposure. Another is to identify the chemical agent used in an attack. This might provide for better treatment and more effective response. Finally, determining when an area is clear of chemical agents after an attack requires sensitive post-event detection.

Some techniques for detecting chemical agents, such as detection paper, tickets, and tubes, rely on sampling the local environment. Detection paper is absorbent paper impregnated with special dyes. When the paper absorbs a drop of chemical agent, one of the pigments dissolves, causing the paper to change color. Detection tickets are similar to detection paper. The ticket is waved in the air or used with a hand pump to determine if chemical agents are present. Detection tubes use a similar technology, but rely on a hand pump to draw air samples through the tube, which discolors in the presence of an agent. A disadvantage to these techniques is that other substances can also dissolve these pigments, causing false positives. The pigments involved can be specific to a type of agent, so an array of papers, tickets, or tubes may be required to identify the exact agent encountered.

Handheld detectors, such as the Chemical Agent Monitor (CAM), are able to detect some chemical agents, namely mustard agents and nerve agents. Automatic sampling devices, such as the Automatic Chemical Agent Detector/Alarm (ACADA), are also employed to provide automated, constant atmospheric sampling. These devices sometimes use a technique called ion mobility spectroscopy to detect the presence of chemical agents.

Much of the above equipment is commercially available, and hazardous material response teams could use it to assess a chemical release. Typically, hazardous material response teams possess detection paper, tickets, or tubes, but these teams may not have standardized equipment across jurisdictions. To aid first responders in choosing the best or most appropriate system for their use, the Department of Homeland Security has provided guidelines to assess various types of detectors.[40]

Another way of detecting a chemical terrorism event would be through the public health system. The sudden arrival of chemical casualties in local hospitals will quickly alert health care professionals. Since September 11, 2001, increases in public health networking have improved information sharing between localities.[41]

This may increase the likelihood of identifying, for example, a covert release of blister agents through identification of symptoms. Public health monitoring also may aid in forensic investigations following a covert event, especially if symptoms are delayed. Such public health monitoring may also provide opportunities to identify terrorists who may have self-inflicted chemical weapon injuries. Additionally, the Laboratory Response Network has been established,

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Standards, Pamphlet 385-61, pp. 7-11.

[40] Office of Grants and Training, Preparedness Directorate, Department of Homeland Security, *Guide for the Selection of Chemical Detection Equipment for Emergency First Responders*, Guide 100-06. Third Edition, January 2007.

[41] For example, the Centers for Disease Control and Prevention have established the National Electronic Disease Surveillance System to more quickly identify and respond to public health threats. For more information on the National Electronic Disease Surveillance System, see http://wwwn.cdc.gov/nndss/script/nedss.aspx.

which links together diagnostic laboratories for the identification of chemical agents, as well as disease outbreaks.[42]

Chemical Agents as Weapons of Terror Rather Than as Weapons of Mass Destruction

In February 2012, the Director of the Defense Intelligence Agency identified that "terrorist organizations are working to acquire and employ chemical, biological, and radiological materials."[43] Many experts believe that it would be difficult for terrorist groups to use chemical agents as weapons of mass destruction. In 1993, the Office of Technology Assessment estimated that VX, the most lethal of nerve agents, spread uniformly and efficiently would require tons of material to kill 50% of the people in a 100 km^2 area.[44] On the other hand, chemical agents might be effectively used as weapons of terror in situations where limited or enclosed space might decrease the required amounts of chemical. That is, the use of the weapon itself, even if casualties are few, could cause fear that would magnify the attack's effect beyond what would be expected based solely on the number of casualties.

Few examples exist of successful chemical terror attacks. In 1995, Aum Shinrikyo, a Japanese apocalyptic cult, used sarin on the Tokyo subway. The attack killed 12 people and sent more than 5,000 to the hospital with some degree of injury.[45] This same cult reportedly carried out an attack in Matsumoto as well, where 7 people were killed and over 200 injured. Both of these attacks used G-series nerve agents, which are more toxic through inhalation than by contact. V-series agents employed in a similar manner might have caused greater fatalities.

In comparison, blister agents would likely be less lethal, but more injurious, if used in a similar manner. Blister agents are dermally active, so contact with the agent would cause injury. Additionally, since mustard agent vapor penetrates most fabrics, victims near the point of release might suffer grievously. Blister agents, while not likely to cause mass destruction, might cause mass terror and injury.

Military planners no longer consider choking agents as useful military weapons, since chemical suits and masks provide high protection. However, according the Director of National Intelligence, the 2006-2007 attacks in Iraq using conventional explosives combined with chlorine gas "highlighted terrorist interest in using commercial and easily available toxic industrial chemicals as weapons."[46] As a weapon of mass destruction used against civilians, the

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[42] Centers for Disease Control and Prevention, Department of Health and Human Services, "Facts About the Laboratory Response Network," http://www.bt.cdc.gov/lrn/factsheet.asp.

[43] Testimony of Lieutenant General Ronald L. Burgess, Jr., Director, Defense Intelligence Agency, before the Senate Armed Services Committee on February 16, 2012.

[44] U.S. Congress, Office of Technology Assessment, *Technologies Underlying Weapons of Mass Destruction*, OTA-BP-ISC-115 (Washington, DC: Government Printing Office) December 1993.

[45] For an overview of the Aum Shinrikyo use of sarin in the Tokyo subway system, see David E. Kaplan, "Aum Shinrikyo (1995)" in *Toxic Terror: Assessing Terrorist Use of Chemical and Biological Weapons*, Jonathan B. Tucker, Ed. (Cambridge, MA: MIT Press) 2000. See also Organization for the Prohibition of Chemical Weapons, "Brief History of Chemical Weapons Use," http://www.opcw.org/about-chemical-weapons/history-of-cw-use/.

[46] Dennis C. Blair, Director of National Intelligence, *Annual Threat Assessment of the Intelligence Community for the Senate Armed Services Committee*, March 10, 2009.

comparatively low lethality of choking agents complicates their use as a weapon of mass destruction, since very large volumes would be needed.[47] On the other hand, the industrial availability of some choking agents provides opportunities for acquisition and subsequent use of potentially very large volumes of such agents. For example, the United States produces approximately 1 billion pounds of chlorine a year for use in water treatment facilities. Experts have noted the potential vulnerabilities of chlorine-filled rail tank cars, its primary transport method.[48]

Terrorist attack on industrial stores at chemical or water treatment facilities or during shipment is another potential source of concern. In order to address the concern of security at chemical facilities with large amounts of hazardous chemicals, Congress provided DHS with statutory authority to regulate these facilities for security purposes. In 2007, DHS issued regulations, called chemical facility anti-terrorism standards (CFATS), but compliance with these regulations is incomplete. The 113th Congress has held oversight hearings on CFATS and considered its reauthorization.[49]

Terrorists may find blood agents difficult to employ as weapons of mass destruction for many of the same reasons that apply to choking agents. The quick dispersal of blood agents, combined with the large amounts necessary to cause mass casualties, make such agents difficult to use on a mass scale. Some industrially manufactured blood agents are used on-site without being shipped. However, terrorist groups continue their interest in these agents, perhaps because of a belief that they may cause mass casualties.

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[47] The first use of chlorine, at Ypres in 1915, was a release of 168 tons of chlorine gas. It is estimated to have killed 5,000 unprotected Allied troops. For a comparison of this amount to that used in current industrial processes and transportation, see G. Ackerman, J. Bale, K. Moran, *Assessing Terrorist Motivations for Attacking Critical "Chemical" Infrastructure*, UCRL-SR-20871, December 20, 2004.

[48] For example, the Metropolitan Washington Council of Governments uses the deliberate explosion of a rail-car of liquefied chlorine as an example scenario in its Regional Emergency Coordination Plan. See http://www.mwcog.org/security/security/download/recp_evacuation_902.pdf.

[49] For more information on chemical facility security, see CRS Report R42918, *Chemical Facility Security: Issues and Options for the 113th Congress*, by (name redacted).