14

Emergency Response to a Chemical Warfare Agent Incident: Domestic Preparedness, First Response, and Public Health Considerations

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CONTENTS

I. INTRODUCTION

The past 20 years have evidenced a steady, upward trend in the number of nations having chemical warfare (CW) capability. The proliferation and use of CW agents within unstable sectors of the world is an additional cause for grave concern regarding the possible future use of such agents, both in open conflict and in the hands of terrorists. The televised images shown of the reactions to potential CW missile attacks by Iraq against targets in Saudi Arabia and Israel during the Gulf War are still vivid in our minds. The bombings of the World Trade Center in New York in 1993 and the Alfred P. Murrah Federal Building in Oklahoma City in 1995 brought the face of terrorism into every American home with startling clarity. Terrorism is no longer something that happens overseas, occurs at an American embassy, or is encountered only by travelers. In fact, the face of the terrorist can be that of someone's neighbor or one-time classmate. Terrorism can derive from clandestine, state-directed initiatives or from small splinter groups with special interests or agendas. The Aum Shinrikyo cult in Japan successfully manufactured the CW agent sarin and combined psychological manipulation and religious zeal to support the terrorist actions of its organization. Access to chemical manufacturing facilities and suppliers around the globe provides terrorists the availability of precursors and chemical reagents, while faltering economic conditions can pave the way for theft or sale of the chemical agents themselves. A particularly troubling phenomenon is the availability of accurate information about the chemical properties, uses, and effects of CW agents on the Internet. This medium makes once highly sensitive information available to virtually every person on earth.

On a more optimistic note, the increased worldwide awareness of the need to control the production, storage, and use of CW agents has led to the formulation and signing of a treaty, outlined in the Chemical Weapons Convention, calling for the prohibition and elimination of CW agent production. The Russian Federation's chemical weapons arsenal includes 40,000 metric tons of toxic agents at seven storage sites. The United States had about 31,000 metric agent tons prior to the start of its Stockpile Disposal Program and over 25,000 tons of these toxic agents still remain.[1] While such prohibition is a noble endeavor, implementation of aggressive projects to destroy these enormous stockpiles of CW agents poses significant public health problems for civilian populations living near storage sites, destruction facilities, or transportation routes. Additionally, the manufacture of large quantities of toxic industrial chemicals that is prevalent in most industrialized countries can present an accident threat to civilian communities surrounding such an area. Facilities of this nature are also not immune to sabotage or terrorist attack. The targeting of an industrial complex producing or utilizing toxic industrial chemicals as a means of waging war was the topic of a recent international conference.[2]

Over the past 5 years, subsequent to the publication of the last edition of this text, enormous emphasis has been placed on domestic preparedness for possible use of weapons of mass destruction (WMD). Chemical warfare agents, along with nuclear weapons and biological warfare agents, are included in this category. The reader is referred to the previous edition where much of the information on medical and public health considerations of CW agents remains accurate.[3] This chapter is designed to expand on the previous work and to put this information into a more current context.

A. EXECUTIVE INITIATIVES

In 1986, National Security Decision Directive 207 was released, which highlighted the need for a coordinated, centrally managed approach to combat terrorism. It also reaffirmed federal agencies' roles and responsibilities under the auspices of the National Security Council. The Department of State was responsible for coordinating the national response to international terrorism while the Federal Bureau of Investigation (FBI) through the Department of Justice was responsible for domestic terrorism.[4]

In June 1995, following the bombing of the Oklahoma City Federal building, Presidential Decision Directive 39 was issued. This directive detailed federal agency roles and responsibilities and defined three anti-terrorism strategies as follows: (1) to proactively reduce vulnerabilities to attack and deter such attacks before they occur, (2) to conduct crisis management of terrorist attacks in responding to such acts and conduct activities to apprehend and punish terrorists, and (3) to manage the consequences of these attacks.[5] Furthermore, the highest priority was given to developing effective capabilities to respond to the threat posed by weapons of mass destruction in the hands of terrorists. The FBI was charged with taking the lead in crisis management, while the Federal Emergency Management Agency (FEMA) was tasked with ensuring national preparedness for a terrorist attack. Additionally, the Attorney General was directed to study the threat terrorism posed to critical U.S. infrastructure, including the water supply. The President's Commission on Critical Infrastructure Protection published a report in October 1997 recognizing several shortcomings in the capabilities of first responders—firefighters, paramedics, and police—to effectively deal with the challenges of a WMD attack.[4] The Commission recommended responders receive additional assets, to include adequate equipment and training.

Presidential decision directive 62, signed in May 1998, created a more systematic approach to the problem by reinforcing and clarifying the current counter-Terrorism mission of the more than 40 federal agencies involved.[6] The Directive also established the Office of the National Coordinator for Security, Infrastructure Protection and Counter-Terrorism. The Coordinator oversees and reports to the President on the policies and programs relevant to preparedness and consequence management for WMD. Presidential Decision Directive 63, signed on the same day, required more effective interaction between government agencies and the private sector.[7] As a result, the National Infrastructure Protection Center at the FBI was tasked to increase the capabilities of federal agencies by increasing information sharing. The Center also serves as the principal facilitator of a coordinated federal response to a WMD incident.

B. LEGISLATIVE INITIATIVES

The U.S. Congress has acknowledged the threat of terrorism and has enacted legislation to address the issue. Certain acts of terrorism are now federal crimes, regardless of where they are committed.[4,8] The Foreign Crisis Act of 1961 prohibits U.S. assistance to foreign countries whose governments supported terrorism. The Act to Combat International Terrorism (PL 98–533), enacted in 1984, offers a bounty to persons providing information leading to the arrest of a terrorist in any country if the target was a U.S. citizen or property. Furthermore, Congress has delineated agency roles and responsibilities and appropriated funds to enhance federal, state, and local response capabilities to terrorism, including those involving chemicals. The National Defense Authorization Act of 1994 (PL 103–160) by Congress was designed to strengthen federal response planning for potential terrorist use of chemical or biological (CB) weapons. The Anti-Terrorism and Effective Death Penalty Act of 1996 (PL 104–132) prohibits terrorist fund-raising, financial transactions, and other assistance to terrorists. It prescribes procedures for removing alien terrorists from the U.S. and expands and strengthens criminal prohibitions and penalties pertaining to terrorism.

Title XIV of the Defense Authorization Act of 1997 (PL 104–201), championed by Senators Nunn, Lugar, and Domenici, directed the Defense Department to assist federal, state, and local officials with training, technical advice, equipment, and other actions necessary to increase the local response capabilities to respond to and manage the consequences of a WMD terrorist incident. Specifically, the Defense Department was directed to assist civilian officials in developing chemical and biological defensive programs, and to help the Public Health Service to organize Metropolitan Medical Strike Teams.

Public Law 105–119, the Departments of Commerce, Justice, and State, the Judiciary and Related Agencies Appropriations Act of 1998 directed the federal government to provide grants to state and local governments to procure detection, decontamination, personal protective, and communications equipment. The Act also directed the Attorney General to fund the operation of large training facilities at Fort McClellan, Alabama and The New Mexico Institute of Mining and Technology.

House Report 105–825, the Conference Report Accompanying Department of Justice (DOJ) Fiscal Year 1999 Appropriations Act, provided more than $100 million to the Office of Justice Programs. This money is to be used to buy equipment, conduct training, provide technical assistance, and fund research and development. This appropriation provides for the equipment and training required by first responders, fire and emergency services and law enforcement, for a WMD incident.

C. THE FEDERAL RESPONSE PLAN

The Federal Response Plan establishes the process and implementing structure for federal agencies to lend assistance in any declared disaster or emergency, including terrorists' use of chemical agents.[9] The plan organizes the federal response under 12 Emergency Support Functions, with a designated agency assigned primary responsibility for each, and others given responsibility in support roles.

Crisis management is primarily a law enforcement function. It refers to activities undertaken to pre-empt terrorist attack. The Department of Justice has assigned responsibility for these duties to the FBI. The Bureau acts as the on-scene manager for the federal government and controls access to the incident.[10] Once an attack has occurred, consequence management responsibilities predominate. State and local officials have primary authority for this. The Federal Emergency Management Agency, as the lead federal agency for consequence management, coordinates and structures the federal response to supplement state and local assets.[11] During an event, there would be both crisis and consequence management activities occurring simultaneously.

The Department of Health and Human Services directs and resources the federal response under Emergency Support Function #8, Health and Medical Services. Response actions under this function are grouped into four general categories: prevention, medical services, mental health services, and environmental health. The Centers for Disease Control and Prevention serve as the lead in this mission to assess the health and medical effects of exposure, conduct field investigations, collect samples, provide advice on protection from the hazard, and lend technical assistance for treatment and decontamination of victims.

Special teams from within the federal government can rapidly respond to assess an incident and help locate and examine an unknown WMD device. More than two dozen Weapons of Mass Destruction Civil Support Detachments, formerly called Rapid Assessment and Initial Detection (RAID) Teams have been formed.[12] An early assessment will determine the type of agent used and the location of downwind hazard. This information is critical for making appropriate decisions regarding areas currently contaminated and allowing for evacuation of those potentially in danger. The Department of Defense has established the Chemical and Biological Incident Response Force to respond rapidly in the event of a chemical or biological incident. This dedicated force under the control of the U.S. Marine Corps is equipped with the most current detection equipment and trained for mass casualty decontamination and consequence management.

The Office of Emergency Preparedness provides other emergency response teams, such as Disaster Mortuary Teams. Additionally, it has established special National Medical Response Teams to provide treatment, decontamination, and special pharmaceuticals to treat up to 1,000 patients. The Metropolitan Medical Strike Teams, also established under this office, ensure the continued viability of a jurisdiction's existing health system given the added burden of a WMD incident. The Metropolitan Medical Response System consists of parts of existing local systems that can be called in to provide triage, treatment, and patient decontamination. This system transports patients who have been decontaminated at the scene to other facilities as appropriate for continued care. The System also assists medical facilities in developing procedures that ensure patients are decontaminated before they enter a facility.[13]

II. CHEMICAL WARFARE (CW) AGENTS

Medical professionals and emergency response personnel seldom see mass casualties that resemble CW agent casualties. With the increased threat of terrorism world-wide, a focus on the management of CW agent casualties is timely and appropriate. A goal of any WMD response plan should be to train teams of professionals to understand chemical agent threats and how to respond to them efficiently. A more complete description of the agents, their effects, and the medical management of casualties are presented in other texts and are only summarized in this section for general information.

Chemical warfare agents are either lethal in their effects or incapacitating, depending upon the class of agent, the concentration, and the period of exposure. The lethal agents, nerve, blood and pulmonary, or choking agents and the incapacitating vesicant agents will be covered below. Excluded from this discussion are other incapacitants and riot-control agents.

Chemical warfare agents are also classified as "persistent" and "non-persistent." The former includes the vesicants such as sulfur mustard (HD) and Lewisite (L) and the nerve agent VX. Non-persistent agents are more volatile and do not remain in an open environment for more than a few hours. Among these are phosgene, cyanide, and the nerve agents, tabun (GA), sarin (GB), soman (GD), and cyclosarin (GF). Toxicity follows exposure to chemical agents dispersed as solids, liquids, aerosols, or vapor (see Table 14.1). Chemical warfare agents have characteristics that make them uniquely suited to warfare. In addition to their extreme toxicity, their chemical structures are simple, and the manufacturing processes for most are relatively uncomplicated and inexpensive. Cyanide and phosgene represent particularly significant hazards because they are manufactured in large quantities for use in industry and are shipped in bulk by truck or train.

A. MEANS OF INTOXICATION

Most CW agents were designed to be volatile and non-persistent and are encountered as vapor or gas. These agents can also be dispersed as an aerosol following a

TABLE 14.1
Comparison of Potencies of Chemical Warfare Agents

CW Agent	**ECt_{50}**	**LCt_{50}**
Nerve agents	3–5	10–200
Mustard	50–100	1500
Cyanide	>1000	2500–5000
Phosgene	>1000	3000

Note: Ct is concentration of vapor (mg/m^3) × time (minutes of exposure); ECt_{50} is the Ct producing clinical symptoms in 50% of the exposed population; LCt_{50} is the Ct that is lethal for 50% of the exposed population.

detonation. The persistence of the agent is dependent on factors such as temperature, pressure, and wind speed. Thus, for some of the nerve agents such as GA, GB, and GD, as well as phosgene and chlorine, the primary route of intoxication is through the respiratory tract. The nerve agents VX and thickened GD and the vesicant agent sulfur mustard are three of the most persistent CW agents and pose a threat from dermal absorption as liquids or droplets. These agents can pose vapor hazards as well.

Contamination of foodstuffs by chemical agents may occur from contact with vapor, aerosol, or droplets. The effects of the chemical agents on food depend on the nature of the agent, as well as the nature of the food. For example, foods having a low water content and a high fat content such as butter, oils, fatty meats, and fish absorb vesicant and nerve agents so readily that removal of the agents is virtually impossible. Chemical agents can cause the food to become highly toxic without changing the appearance of the food. Unprotected foodstuffs may be so contaminated that their consumption will produce gastrointestinal irritation or systemic poisoning. Protected foodstuffs in cans and bottles or food wrapped in heavy plastic are not affected by agent vapor and can be salvaged following decontamination.[14]

Few environmental factors impact community and individual well being more than the ready availability of adequate and safe, potable water. Surface water sources in the area of a chemical release could become contaminated. The contamination of water, whether intentional or inadvertent, may reach concentrations that could produce casualties. Deep ground water reservoirs and protected water storage tanks are regarded as safe sources of drinking water following a vapor release of chemical agents. While avoiding any possibly contaminated water source should be a goal, methods such as reverse osmosis are available to treat large volumes of potentially contaminated water for emergency drinking. However, these techniques may not eliminate low-dose exposure to the contaminating agent. The fate and distribution of CW agents in the environment have been recently reviewed.[15]

B. CLINICAL EFFECTS

1. Nerve Agents

Nerve agents exert their effects by inhibition of the enzyme acetylcholinesterase (AChE), leading to accumulation of excess levels of the neurotransmitter acetylcholine (ACh) at cholinergic synapses. Enzyme inhibition is both rapid and irreversible, thus making organophosphorus (OP) nerve agents highly toxic and extremely dangerous chemicals (see Table 1). These agents were designed to kill or incapacitate enemy forces, disrupt military operations, and deny terrain to the adversary. However, in unscrupulous hands, they have been shown to be effective weapons of terror.

Nerve agents gain entry by absorption through the lungs or skin and impair the activity of cholinergic synapses, including those of smooth and skeletal muscle, autonomic ganglia, and the central nervous system. Acute toxic effects of nerve agents can be elicited at very low concentrations, while lethal effects are observed at somewhat higher concentrations. Threshold symptoms for vapor exposure are commonly stated to be miosis, rhinorrhea, and airway constriction,[16] generally appearing at a Ct (vapor concentration × exposure time) of 2–3 $mg \cdot min/m^3$. Low-to-moderate exposure of skin to liquid nerve agent causes localized sweating, nausea, vomiting, and a feeling of weakness.[17] Lethal amounts of vapor or liquid cause a rapid cascade of events, culminating within a minute or two in convulsion, loss of consciousness, apnea, paralysis, and death.[18] Toxicity is thus concentration-dependent, requiring a defined minimal concentration of agent; recovery generally occurs by synthesis of new AChE.

Additionally, after both vapor and liquid agent exposure, there are CNS effects that vary in intensity and duration. After mild to moderate exposure to nerve agent, there may be forgetfulness, an inability to concentrate, insomnia, impaired judgment, nightmares, irritability, and depression. These effects may be present for 4 to 6 weeks. They may also occur upon recovery from acute, severe effects of exposure. Long-term and low-dose effects of the nerve agents are the topic of Chapter 1 of this text.

2. Vesicants

Sulfur mustard (H, HD) has been a major military threat agent since World War I. Lewisite (L) also falls into this class. Sulfur mustard constitutes both a vapor and a liquid threat to all exposed skin and mucous membranes. The effects are delayed, appearing 2–24 h after exposure. Mustard reacts with tissues within minutes of absorption. In extracellular water, it rapidly forms a highly reactive cyclic compound that binds to enzymes, proteins, and other substances. Mustard is a strong alkylating agent that causes cross-linking in DNA strands leading to cell death.[19,20] Blood, tissue, and blister fluid do not contain mustard and cannot cause further toxicity. Typical effects occur in the eye, ranging from mild to severe conjunctivitis, blepharitis, and damage to the cornea. Airways react with initial irritation, progressing to severe damage of lower airways with higher concentrations; respiratory failure and pneumonia, in addition to bone marrow suppression, may lead to death in sulfur mustard poisoning. Skin injury initially shows erythema, followed by formation of vesicles that later coalesce to form bullae.[19]

3. Blood Agents

Chemical warfare blood agents are hydrogen cyanide (hydrocyanic acid, AC) and cyanogen chloride (CK). Cyanide is a rapidly acting lethal agent that causes death within 6 to 8 min after inhalation of a high concentration (Table 1). However, few toxic effects are seen below a lethal concentration. Once absorbed, the cyanide ion rapidly combines with the active site of the enzyme cytochrome oxidase interfering with aerobic metabolism, creating excess lactic acid and metabolic acidosis.[21] Cell death is the final outcome. The organs most susceptible to cyanide are the CNS and the heart. The onset and progression of signs and symptoms are slower after ingestion of cyanide or after inhalation of a low concentration of vapor. There may be an asymptomatic period of several minutes, followed by the initial transient hyperpnea. This may be followed by feelings of anxiety, agitation, vertigo, weakness, nausea, vomiting, and trembling. Later, there is a loss of consciousness, decrease in respiration, convulsions, apnea, and cardiac arrest.

4. Pulmonary Agents

Phosgene is a simple, highly volatile molecule ($COCl_2$) known as carbonyl chloride (CG). The odor of phosgene has been described as an odor of newly mown hay. Upon inhalation, CG chemically induces acute lung injury because of a reaction of its carbonyl group with groups affecting cell membrane stability.[22] This allows plasma to leak into the alveoli and produces pulmonary edema. There is a symptom-free period (10 min to 24 h) that varies with the amount of CG inhaled. Substantial toxicity can occur from levels of 1.5–2 ppm. Its aroma is detectable at 2–3 ppm, hence toxicity may occur without subject awareness.[17] In cases where individuals are exposed to high concentrations of phosgene, there may be initial symptoms of mucous membrane irritation followed by pulmonary edema, hypoxia, hypotension, bronchospasm, right heart failure, and death.

C. EMERGENCY MEDICAL TREATMENT

1. Nerve Agents

The principles of care for a casualty with nerve agent intoxication include termination of exposure, maintenance of ventilation, administration of antidotes, and supportive therapy. For successful medical management, early and intense therapy after severe exposure to nerve agents is necessary to prevent death. The condition of the patient will dictate the need for specific treatment procedures and the order of administration. It is of utmost importance that medical care providers are protected from contamination by use of appropriate protective clothing, otherwise they may become additional casualties.[16]

Decontamination of the casualty is not necessary if exposure is due only to vapor. However, clothing that may trap vapor needs to be removed. The patient should be removed from the source of the vapor, if possible, or fitted with a protective mask if this is a practical alternative. Removal of affected clothing and decontamination of the underlying skin will help terminate liquid agent exposure. Visible droplets of agent can be wiped or blotted off, followed by flushing or rinsing with copious amounts of water. The agents can be neutralized with soap and water or by 0.5% hypochlorite solution, followed by rinsing with water. It should be noted that neutralization of the agent is not immediate and can take minutes to hours to complete. Agent absorbed into the skin cannot be removed, so the casualty from liquid exposure may continue to worsen because of continued absorption of the agent from the dermis and subcutaneous tissues. As a rule, the longer the asymptomatic period after exposure, the milder will be the eventual symptoms.[17,23]

Endotracheal intubation and assisted ventilation with oxygen is essential for apneic casualties. This is necessary for survival and may be needed for an extended period. Airway resistance is initially high because of bronchoconstriction as well as copious secretions. If respiratory impairment is only mild to moderate, it can be reversed by antidote treatment without the need for ventilation.[16]

Antidotal therapy includes the use of atropine to block the effects of excess ACh primarily at peripheral muscarinic receptor sites. Following atropine use, secretions are reduced and constriction of smooth muscle is reversed. Since it has little effect at nicotinic sites, skeletal muscle fasciculation will continue. Similarly, miosis will not be reversed. Pralidoxime chloride (2-PAM Cl) is the oxime of choice in the U.S. for reactivation of nerve agent inhibited ChE. By breaking the OP-enzyme bond, oximes restore normal activity of the enzyme. Clinically, this is noticeable in those organs with nicotinic receptors. Abnormal activity in skeletal muscle decreases and normal strength returns. Diazepam is an anticonvulsant drug used to reduce brain damage caused by prolonged seizure activity, as seen in severe poisoning from nerve agents. Diazepam therapy is indicated with other therapy at the onset of severe effects from a nerve agent whether convulsions are present or not. The use of atropine, 2-PAM, and diazepam therapy affords considerable benefit for most cases of nerve agent exposure. For a more complete discussion of medical management of nerve agent casualties, see references.[16,17]

2. Vesicants

Sulfur mustard causes tissue damage within several minutes after contact without showing corresponding clinical signs. Decontamination must be performed immediately after contact to prevent injury. However, even slightly delayed decontamination can reduce the severity of lesions. Irrigation with water, use of soap and water with no scrubbing, or 0.5% hypochlorite are all effective measures.[17] Medical management of a patient exposed to mustard can range from symptomatic care for erythema to total management for a severely ill patient with burns, immunosuppression, and multi-system involvement.[18,19] Following decontamination to include the flushing of eyes, medical management of the casualty should be administered at a fixed medical facility as symptoms are delayed. Erythema is treated with soothing lotions and topical steroids, while large blisters can be drained. Denuded areas need irrigation with saline or sodium hypochlorite, topical antibiotics, and observation for infection. Eye injuries need initial saline irrigation, followed by use of atropine eyedrops, antibiotic ointments, and sterile petrolatum to prevent lid adhesions. Early pulmonary symptoms in the upper airway respond to steam inhalation and cough suppressants, but later infection needs specific antibiotic therapy. Mechanical ventilation and bronchodilators can help. Death can occur because of pulmonary insufficiency and infection complicated by a comprised immune response caused by mustard-induced bone marrow suppression. Some general precautions for care of casualties include maintenance of fluid balance and adequate nutritional support. Additionally, close monitoring of white blood cell counts and liberal use of analgesics and antipruritics aid in treatment.[19] Historical reports indicate that most casualties from mustard will require therapy for their skin and eye injuries, and a few additional ones will need attention for pulmonary lesions. Only a very few will require intensive care.[18]

3. Blood Agents

Exposure is terminated by evacuation to fresh air or by masking. Skin decontamination is not necessary because of the highly volatile nature of the agents. However, wet, contaminated clothing should be removed and the underlying skin decontaminated with water. Detoxification of cyanide is preceded by its removal from the cytochrome oxidase complex by intravenous injection of sodium nitrite. This treatment forms methemoglobin to which cyanide preferentially binds.[21] Intravenous injection of sodium thiosulfate follows. This sulfate combines with cyanide to produce thiocyanate, which is excreted by the kidneys. Supportive care consists of providing oxygen and correcting any metabolic acidosis. Full recovery is relatively rapid following cyanide intoxication if the antidotes are given before cessation of cardiac activity.

4. Pulmonary Agents

Termination of exposure by physical removal of the casualty or use of a mask is a vital first measure. Rest is important as any physical exertion shortens the latent period and increases the severity of symptoms.[17,22] The airways need to be kept clear and the circulation checked for hypotension. Bronchospasm is treated with bronchodilators. Positive airway pressure may be required. Oxygen therapy is indicated to treat hypoxia and intubation may also be required. In the absence of a bacterial infection, the toxic effects of low to moderate exposures to phosgene will be relatively short-lived with proper respiratory monitoring in place.[22] Exposure to moderate to high concentrations of phosgene may result in acute respiratory distress and death.

III. PROGRAMS TO PROTECT CIVILIAN POPULATIONS

A. Civilian vs. Military Response Considerations

Prior to plans for the destruction of the CW stockpiles of most countries, and preceding the sarin attacks in Matsumoto and Tokyo, the development and implementation of defensive measures against CW agents was primarily centered on the military use of these chemicals. However, military and civil defense planners face very different situations when planning for a potential chemical threat, mainly with respect to prior knowledge about the identity of the enemy and the time, place, and means of attack. The value of deployment of a chemical detection system and the use of highly specific antidotes, therapeutics, or pretreatment drugs diminishes considerably in the most probable civilian terrorism situation, in which the enemy, the agent, the time, and the place of attack are unknown. For civil defense purposes, it is therefore, more appropriate to emphasize prior planning, medical treatment, and consequence management over prevention. The responsibility for prevention in this case is left to intelligence and law enforcement agencies. However, it would be advisable to include the medical community in the distribution of pre-incident intelligence in order to maximize the medical response in dealing with chemical incidents. One significant difference between military and civilian response planning for a CW incident is that the populations to be protected are fundamentally different. In military chemical defense planning, the population of interest is primarily healthy young males between the ages of 18 to 26 years, while the civilian community at risk includes this prior population, as a minority, as well as both genders, the very young, the very old, and the sick. Furthermore, acceptable levels of exposure for military personnel operating in a CW environment differ significantly from those of first responders and medical personnel who might find themselves involved in a civilian emergency situation. In the first case, military standards prevail while NIOSH exposure criteria should be considered when CW responses are planned or when appropriate protective equipment is designed for utilization in civilian emergencies.

B. THE ISRAELI MODEL

While the Japanese have actually experienced the consequences of a CW agent incident, there is no population more aware of the present day threat of CW than that of the nation of Israel. Early in this country's history, and well ahead of the invasion of Kuwait by Iraq in 1990, Israel had implemented an aggressive program of domestic preparedness. Their program of "Homeland Defense" includes extensive preparations for the widespread use of CW agents against the population. Doctrine was established for the protection of the civilian population by the Ministry of Defense and is based on the concept of "protected space." Protected space is a readily accessible space capable of providing occupants with protection against both conventional and non-conventional weapons for several hours. Since 1992, all new buildings, as well as additions to existing buildings, have been required to be equipped with a protective space that meets specific engineering specifications. Expedient measures to provide a protective space within a home or office are taught in civil defense training classes. Examples of such measures include the use of wet towels at the bottom of a doorway or the use of tape around door and window openings. Furthermore, every Israeli citizen is issued a protective mask and atropine injectors to be used in the event of a chemical attack. As mentioned earlier, a civilian population is not homogeneous and the Israelis have adopted measures to meet the needs of most of the citizenry. The government has provided standard protective masks of various sizes including a protective mask with a blower unit for those who cannot use the standard mask, a protective hood-kit designed for children ages 3 to 8 years old, an infant protective suit with a blower designed for infants 0 to 3 years old, and a medical hood-kit designed for people with impaired respiratory systems. Distribution of protective kits is administered by the Israeli Defense Force's Home Front Command through a system of 21 exchange centers located throughout the country.[24] Hospitals and medical centers prepare for the use of chemical agents by stockpiling needed medications and by routinely conducting realistic mass chemical casualty exercises. Their experience during the Gulf War demonstrated the need for mass decontamination facilities and efficient triage. Following missile attacks on Israel during the Gulf War, there were large numbers of panicked "worried well." The presence of large numbers of patients, who think they have been exposed to a chemical agent, or who are presenting with psychosomatic symptoms, could severely limit a medical facility's ability to respond rapidly and effectively to the needs of critical casualties. Planning, as well as training and education of the populace, should minimize these effects in a future incident.

C. CHEMICAL STOCKPILE EMERGENCY PREPAREDNESS PROGRAM

In the U.S., the Chemical Stockpile Emergency Preparedness Program, or CSEPP, is a partnership among state, local, and federal governments. It was created as a result of a directive from Congress that chemical weapons stockpiled at eight U.S. Army installations in the U.S. be destroyed over the course of several years. A total of 39 counties in 10 states participate in CSEPP. The slight but real threat of an emergency involving chemical agents at these sites necessitates that local officials and responders remain ready for such an emergency and involve the community in their efforts. The U.S. Army is custodian of the stockpiles, while the Federal Emergency Management Agency is the source of long-standing experience in planning for contingencies in civilian areas. Partnering with the U.S. Environmental Protection Agency and the U.S. Department of Health and Human Services, the combined effort of CSEPP allows for the funding, guidance, resources, and training needed to effectively provide protection to communities surrounding stockpile sites. Protective measures are determined for each community based on its unique needs and considerations. The plans and procedures are appropriate for the specific agents stored at the nearby Army installation. The most common emergency protective measures are evacuation and shelter-in-place and are based on two planning zones, the Immediate Response Zone and the Protective Action Zone.[25] The distance from the stockpile for each zone varies and is based on risk analyses. In the case of a stockpile accident, the community is informed and instructed through radio and television Emergency Broadcast/Alert Systems and/or over loudspeakers. Sirens and tone alert radios serve to alert and warn residents in Immediate Response Zones. Evacuation routes are designated and fully equipped shelters are identified. This provide the right atmosphere for people to stay calm and follow the recommendations of local officials and emergency managers. Public information facilities in neighbor-hoods serve to disseminate information and function as response command centers for questions from the media and concerned citizens.

IV. ELEMENTS OF THE RESPONSE

A. CLUES TO THE PRESENCE OF CHEMICAL WARFARE AGENTS

If CW agents were employed in a civilian situation, real-time detection and monitoring are not currently widely available for many of the agents. With the exception of a public announcement by a terrorist group of the employment of a toxic chemical agent or a public announcement of an accidental release, signs and symptoms of persons exposed to the toxicant will most likely be the first indication of the presence of the agent. For this reason, it is essential that first responders and medical personnel be familiar with the clinical aspects of CW agent intoxication. This is not only critical for treating the casualties, but just as important to protect the responders themselves and to limit the spread of contamination. In a previous section, we examined the clinical signs of CW agent intoxication and how CW agents could be dispersed in the environment. Because of their chemical characteristics, CW agent use in a domestic terrorist incident may not be associated with a high explosive event, and these agents are likely to be dispersed in such a manner that would primarily involve a vapor hazard. In the immediate vicinity of the incident, where there may be a continuing source of agent vapor, the probability of detecting the CW agent is greatest. However, due to the chemical properties (persistent vs. non-persistent) of many of the agents, detection may not be possible at the time emergency medical personnel arrive at an incident. Once casualties of a CW agent incident are removed from the area of the attack and become accessible to medical personnel, the signs and symptoms of the patients may be the only detection method available to guide incident commanders and law enforcement personnel. Thus, improved detection and improved diagnostic technologies are two sides of the improved response coin. More will be said about efforts to enhance the ability to rapidly and specifically diagnose exposure to chemical agents.

Effective and efficient incident response depends on the rapid and accurate identification of the chemical agents involved. The protection of first responders and emergency medical personnel at local medical facilities, as well as the effective treatment of casualties, hinges on this critical capability. Various devices capable of detecting chemical agents in the environment are available to civilian communities. Many devices were designed for military applications but have now been adapted for civilian use.

B. HAZMAT RESPONSE

An emergency response to an incident that involves the accidental or intentional release of toxic chemicals or materials will typically be categorized as a hazardous materials (HAZMAT) incident. With the greater emphasis placed on this type of response, HAZMAT incident response plans have become increasingly standardized across the country. Specialized HAZMAT teams are routinely activated to respond in such situations. HAZMAT teams are typically part of the fire services and will possess chemical detection equipment. The first responders, typically the police or fire department, must be capable of determining that a HAZMAT incident has occurred. Unfortunately, most emergency response vehicles do not have any chemical detection equipment, and the first responder must make a quick judgement call whether or not to call in HAZMAT units.

The equipment needs of early responders to a domestic incident in which CW agents may be involved are significantly different than those for military personnel. The military has the advantage of intelligence information that enables the users of the equipment to predict a probable threat agent and the likely area of impact from the chemical agent. In the case of first responders to a domestic terrorist incident, there are currently no such benefits of intelligence. The medical personnel on site will require equipment capable of detecting the widest range of chemical agents. HAZMAT teams are routinely equipped with chemical detection devices and detection kits, but these are usually chemical-specific tests indicating only the presence or absence of a single suspected toxic industrial chemical or class of chemicals. Chemical detection equipment currently used by HAZMAT teams varies considerably by locality, with many large metropolitan areas having significant technology available. Today, most local response units in the U.S. have limited capability for CW agent detection. A critical review of the abilities of emergency responders to detect chemical agents has recently been made available.[26]

C. CURRENTLY AVAILABLE DETECTION TECHNOLOGY

A wide variety of commercial equipment is available for detection of hazardous chemicals, including a number of CW agents. A listing of the technologies and the manufacturers of the technology have been compiled by various organizations.[27–29] The following is a list of the principal technologies employed in currently available detection equipment that can be employed by HAZMAT teams and medical units. The Metropolitan Medical Strike Teams organized and equipped by the U.S. Public Health Service, for example, have purchased detection paper, three different detection kits, and portable chemical agent detectors and monitors.

Ion Mobility Spectrometry (IMS) technology is used to detect nerve, vesicant, and blood agents. The Chemical Agent Monitor (CAM) uses ion mobility spectrometry to provide a portable, hand-held point detection instrument for monitoring nerve or vesicant agent vapors. Minimum levels detectable are about 100 times the acceptable exposure limit (AEL) for the nerve agents and about 50 times the AEL for vesicants. This insensitivity to low concentrations limits the utility of this instrument to check the efficacy of decontamination efforts or in occupational exposure measurements.

Acoustic wave sensors are also used to detect nerve and vesicant agents. The Surface Acoustic Wave Chemical Agent Detector (SAW Mini-CAD) is a commercially available, pocket-sized instrument that can automatically monitor for trace levels of toxic vapors of both sulfur mustard and the G nerve agents with a high degree of specificity.

Color change chemistry detectors can detect nerve, vesicant, and blood agents. Colorimetric tubes are the most common detection technology used by HAZMAT teams. There are several hundred different types of colorimetric tubes available that can detect a variety of chemicals. A HAZMAT team's analytical capabilities usually include tests for chlorine, cyanide, phosgene gas, and organophosphate pesticides. Direct reading detector tubes can be used for both short-term and long-term measurements. Recently, one manufacturer of detection tubes has developed a kit specifically for OP nerve agents. Routine HAZMAT tests rarely include a capability to detect vesicant agents. This is particularly unfortunate, as the clinical signs of exposure to sulfur mustard can be delayed, and a continued exposure of personnel can result until signs appear or until the agent is detected.

The M18 detection kit and the M256A1 kit are military items. The M18 is a colorimetric device for measuring the concentration of selected airborne chemicals. The M18 comes with detector tubes for cyanide, phosgene, Lewisite, sulfur mustard, and nerve agents GA, GB, GD, and VX.

The M256A1 kit includes detector tickets that detect low concentrations of cyanide, vesicant, and nerve agents in vapor form. The tests take approximately 15 min. Sensitivity of this kit is such that the tests may provide a negative reading at concentrations below that immediately dangerous to life and health (IDLH). Occupational Safety and Health Administration (OSHA) rules call for the use of maximum personal protection until concentrations can be shown to be less than 50 times the AEL. The IDLH is the maximum concentration of a contaminant to which a person could be exposed for 30 min without experiencing any escape-impairing or irreversible health effects. The AEL is a general term indicating a level of exposure that is unlikely to result in adverse health effects.

M8 and M9 detection papers provide a rapid, inexpensive test for the presence of liquid mustard or nerve agents. Use of the paper should be as a screening test only because of the paper's propensity to show false positive results. False positive results for the presence of a CW agent in a civilian community could produce hysteria and panic.

Additional detectors currently available use other technology such as electrochemical detectors for vesicant, nerve, blood, and choking agents, infrared spectroscopy detectors for vesicant and nerve agents, and photo ionization detectors for the detection of nerve and blister agents.

Mass spectrometry (MS), gas chromatography (GC), and Fourier transform infrared (FTIR) spectrometry technologies are the basis for fixed facility CW agent detection and can provide definitive identification of the agent. Furthermore, they possess the sensitivity to detect low levels of the agents in the range of occupational exposure levels. Where these new technologies can be of benefit to the medical community is in fixed medical facilities for monitoring air samples for low levels of agents that may cause an occupational hazard or in predicting the medical impact of a chemical event. However, few local governments, organizations, or medical facilities have invested in such equipment to date.

D. LABORATORY ANALYSIS

As mentioned earlier, clinical signs and symptoms displayed by casualties will be the earliest and often an accurate method for determining the presence of a specific class of chemical agent. This rapid diagnosis is essential in saving lives and preventing further exposure. Furthermore, the signs and symptoms of the patient will provide the most important information on which to base emergency treatment. In emergency situations, medical personnel should have available analytical methods and tools for monitoring patients and confirming their diagnosis. Additionally, forensic scientists must have techniques to retrospectively piece together the clinical course of a patient or to examine aspects of the incident. The following is a brief discussion of some of the techniques available for laboratory analysis.

1. Nerve Agents

The requirement for direct measurements of nerve agents and/or their metabolites in clinical samples has given rise to the development of sensitive techniques utilizing gas chromatography-mass spectrometry (GC-MS),[30] gas chromatography-tandem mass spectrometry (GC-MS-MS), and capillary gas chromatography.[31] Extremely sensitive retrospective detection of organophosphorus nerve agents has been recently described by Polhuijs et al.[32] The research group at TNO Prins Maurits Laboratory in the Netherlands has applied this method in analyzing blood samples obtained from victims of the Tokyo sarin incident. The technique reactivates sarin-inhibited enzyme by treating the inhibited enzyme with fluoride ions, thus converting the OP leaving group into the corresponding phosphofluoridate. The U.S. Army Medical Research Institute of Chemical Defense at Aberdeen Proving Ground, Maryland proposes several GC-MS methods for measuring nerve agent metabolites in urine in their Technical Bulletin, TB MED 296.[33] These techniques are based on extensive animal studies.[34–36] In these studies, almost total recoveries of the given doses for GB and GF, in metabolite form, were obtained from the exposed animal's urine. Sensitive methods like those just described can be used in following the course of medical treatment, in health surveillance programs, and as forensic tools.

Since normal serum cholinesterase activity ranges from 182 to 804 IU/L, the determination of a single cholinesterase (ChE) inhibition level can only be an indirect indication of toxicity resulting from exposure to nerve agents. The following information exemplifies this rather well. In a report of Japanese victims of the Tokyo sarin attack, patients who exhibited moderate symptoms of intoxication had serum ChE values ranging from 300–750 IU/L.[37] Additionally, these patients had red blood cell (RBC) ChE activity ranging between 0.3 and 2.0 IU vs. 1.2–2.0 IU for asymptomatic patients.

The basis for the standard method for determining blood (ChE) inhibition is the measurement of the enzymatic products derived when either acetylcholine or acetylthiocholine are used as substrates. The rate of formation of acetate is measured by changes in pH, while the formation of thiocholine is determined colorimetrically.[38] A portable device utilizing this method, the Test-Mate OP Kit (EQM Research Incorporated, 2585 Montana Avenue, Cincinnati, OH 45211), provides a rapid, reasonably sensitive assay for ChE inhibition following OP exposure. The kit should be appropriate for emergency contingencies, and only very small blood samples are required. Military forces are viewing such a portable kit as a means to screen and monitor chemical casualties and have adopted it for Theater Army Medical Laboratories. Such a rapid detection device could also be useful in a triage or hospital setting.

2. Vesicants

The last documented use of sulfur mustard against military forces was during the Iran-Iraq conflict. Several sensitive GC-MS and GC-MS-MS were developed and have been used to demonstrate exposure to sulfur mustard in samples from casualties of this conflict.[39–44] In cases of suspected exposure to sulfur mustard, U.S. Army laboratories utilize methods described in TB MED 296.[33] In this method, thiodiglycol (2,2-thiodiethanol), one of the *in vivo* degradation products of sulfur mustard, is used to confirm an exposure.[45–47]

3. Cyanide

Several assays for detecting the presence of cyanide in blood samples have been used in the past.[48,49] However, a more efficient gas chromatography and mass spectrometry method for determining cyanide and its major metabolite, thiocyanate, in blood has been described.[50] Another gas chromatographic procedure in which cyanide is converted to cyanogen chloride has also proved to be specific, sensitive, and rapid, thus permitting measurements in emergency situations.[51] Alternatively, there is an automated fluorometric measurement described in TB MED 296.[33,52] With this method, tests for both plasma free CN- and total blood CN- are accomplished directly by a completely automated method requiring less than 30 min.

V. PROTECTION OF FIRST RESPONDERS AND VICTIMS

A. PROGRAMS TO IMPROVE THE RESPONSE

1. Training

The U.S. has placed strong emphasis on effective training for civilian response to a chemical incident within the city response structure. Under federal law, training assistance is to be provided to 120 U.S. cities. Recent legislation has directed that this assistance be extended to 37 additional metropolitan areas.

Accordingly, a federal interagency team coordinates the training and exercise programs with the target cities. Courses are offered in six subjects: Awareness, Operations, Technician-HAZMAT, Technician-Emergency Medical Services, Hospital Provider, and Incident Command. City officials determine which training best fits their needs, and teams consisting of CB experts from the Department of Defense (DoD), as well as professional civilian first responders, present the training. Those receiving the training later promulgate it on a sustaining basis in their own communities. The effectiveness of the training is assessed in subsequent “tabletop” and functional exercises that provide direct feedback to the city for future activities and programs the city may pursue in order to enhance the response to chemical terrorism.

2. The Chemical and Biological Hotline

Congressional legislation has specifically directed the establishment of a designated telephonic link to a designated source of relevant data and expert advice for the use of state or local officials responding to emergencies involving a weapon of mass destruction. This link, the Chemical and Biological Hotline, (1-800-424-8802) is operated 7 days a week, 24 h a day.[53] It provides emergency technical assistance from a variety of federal agencies, or, if warranted, an actual federal response to assist first responders during incidents. The hotline is intended for use by first responders as well as state emergency operations centers and medical facilities. Assistance is provided on a wide array of subjects, which include personal protective equipment, decontamination systems and methods, toxicology information, and medical symptoms and treatment for exposure to CB agents.

3. Chemical Weapons Improved Response Program

To address the issue of identifying response capability shortfalls, the DoD established the Chemical Weapons Improved Response Program. The program has formed an alliance between federal, state, and local government offices as well as various industry organizations. Through an iterative process of workshops, conferences, exercises, and technical studies, the program has structured its work around four functional working groups: Health and Safety; Emergency Management; Emergency Response; and Law Enforcement. The responsibility of each group is to identify, prioritize, and arrive at solutions pertinent to first responders.

A major focus of this program is on issues that impact the well being of the community at large and the challenges associated with maximizing the impact of local and regional public health and medical services. In examining the impact of a chemical terrorist attack, three priorities were identified:[54] timely and accurate communication between responder groups, a system to identify and distribute available resources including pharmaceuticals, and operating procedures for all responsible agencies.

To address the myriad of issues a chemical attack would present to a community, a response template plan with national applicability, referred to as the Off-Site Triage, Treatment and Transport Center, was formulated.[55] The concept was designed to address the non-critical and non-exposed patients who can be expected to seek medical help. This concept requires the set-up of an ancillary medical facility to handle the large number of walking wounded and "worried well" casualties that are expected from a terrorist attack. The facility would be a temporary site that supplements existing assets, since many of these centers can be set-up as are deemed necessary. The care envisioned to be provided in such a center includes decontamination, initial entry into the medical care system for patients not processed at the scene, care for non-critical patients, transportation to medical facilities for patients in need, and mental health care.

4. Applied Research

This DoD program has initiated a number of research studies that are of interest to first responders. Examples include studies on the protection afforded by standard firefighting turnout gear from CW agents, methods for mass casualty decontamination, and the effect of positive or negative pressure ventilation on vapor concentrations inside structures.

Firefighters respond to incidents wearing what is referred to as turnout gear and self-contained breathing apparatus (SCBA). The protection afforded by these ensembles was assessed in test chambers using a chemical simulant. The equipment was found to provide the wearer sufficient protection against nerve and blister agents to allow for the reconnaissance and rescue of victims. Furthermore, the protective efficacy of the gear can be increased simply by using common, heavy-duty duct tape.[56] Guidelines established from these studies are meant to assist Incident Commanders in making decisions to enter chemical agent vapor environments to perform rescue, reconnaissance, mitigation, or detection operations and to establish minimum criteria for entry for first responders. In a parallel study addressing law enforcement and emergency medical services issues, six commercial, level C chemical protective suits and the standard police duty uniforms were assessed to determine what protection they afforded the wearer.[57] Testing revealed protective factors ranging from 2 for the standard duty uniform to 42 for commercial suits. The commercial ensembles consisting of the respirator, gloves, and over-garment were felt to provide adequate protection to responders in areas of low concentration as might be found at the perimeter of the incident, but not for activities in areas where the threat is expected to be much greater.

Another tool fire fighters bring to an incident are fans used to blow smoke out of the building in order to facilitate evacuation and rescue. These fans were assessed for use in reducing chemical vapor hazards.[58] Using simulants, it was determined that dramatic reductions in vapor concentrations can be attained with these fans by creating positive pressure ventilation in structures. Fans can reduce the vapor concentration 50–70% within the first 10 min of use. This reduction significantly increases the first responders' protection above and beyond the adequate protection provided by standard turnout gear with SCBA.

5. Mass Casualty Decontamination

Following a chemical terrorist attack, it can be assumed that many of the civilians that are present are not contaminated, but during the crucial minutes immediately following the event, there is currently no way of determining with certainty those who are contaminated. HAZMAT teams that respond to accidents or spills of industrial chemicals are well prepared to decontaminate themselves but have limited capability to care for mass casualties. However, a terrorist attack could well involve hundreds, if not thousands of victims, so the scale of the response must be expanded. An underlying assumption has been that decontamination should occur as soon as possible after exposure, so a recent study considered methods using equipment fire fighters already bring to every incident. Fire fighters have access to large amounts of water, so three water-based decontamination methods were assessed: water alone, soap and water, and bleach and water.[59] Water alone was found to be a very effective method via physical removal. The shear forces and dilution achieved by using high-volume, low-pressure (60 pounds per square inch) showering was found to be the most practical method of mass casualty decontamination. Various shower applications were examined. Some included the use of tarps and establishing decontamination corridors for privacy concerns. The use of soap provides a slight improvement via ionic degradation of the chemical agent, however a supply of it has to be on hand. This requires that fire fighters either bring it on their trucks, creating a logistical burden, or otherwise procure it on scene, which would take time. The use of bleach (sodium hypochlorite) and water was not recommended. Although these solutions react with most chemical agents, the preparation and application of the solution would take time, a distinct disadvantage where speed is critical.

Based on their findings, investigators proposed the following principles to guide the decontamination of large numbers of civilians at chemical incidents:

- Expect a 5:1 ratio of unaffected/affected casualties.
- Decontaminate as soon as possible.
- Disrobing is decontamination; top to bottom, the more the better.
- Water flushing generally is the best mass decontamination method.
- After known exposure to liquid agent, first responders must self-decontaminate as soon as possible to avoid serious effects.

Triaging casualties at an incident site may exceed emergency responders' capabilities. There may be too many people to rescue, decontaminate, and treat, regardless of exposure to the chemical agent. Victims must be prioritized into ambulatory and non-ambulatory groups, and further grouped based on agent signs and symptoms, or the likelihood of exposure. Emergency care providers will have to decide when, for example, to perform only hasty decontamination, if at all, on a severely injured casualty who is not clearly a chemical casualty. Conversely, casualties displaying symptoms of severe chemical exposure may require antidotes and other aid before decontamination is possible. Toxic exposure issues emergency personnel could encounter on the perimeter of an incident have recently been addressed.[57] The threat to responders who perform activities on the perimeter, be they police or emergency medical service, should be minimal. As a routine matter, no significant vapor, aerosol, or liquid danger is expected. The most likely threat will come as a result of a wind shift or off-gassing from people exiting the incident scene.

Recent advances made by scientists working in the U.S. Army Medical Chemical Defense Research Program include two potential products that may aid in casualty decontamination. A skin exposure reduction paste (formerly known as Topical Skin Protectant, TSP) was just approved for a New Drug Application by the FDA. The formulation consists of a mixture of a perfluorinated polyether base oil to which is added fine polytetrafluoroethylene particulate as thickener. Animal studies have shown that this formulation is effective for at least 4 h of continuous contact with CW agents. An enzymatic sponge for medical decontamination of CW agents has recently been tested. These polyurethane sponges will have cholinesterase and organophosphate hydrolase enzymes immobilized to the polymer. The enzymes retain their activity for long periods of time and under harsh environmental conditions. The sponge itself is wetted with a solution that absorbs the agent from the skin. Once removed from the skin, the sponge could be reactivated with an oxime.

VI. ISSUES RELATED TO LOW-DOSE EXPOSURE TO CHEMICAL AGENTS

The health effects of exposure to low doses of CW agents have been of considerable interest for several decades. During the period of large-scale production of CW agents in the U.S., this subject was a particularly important occupational health issue for workers in production plants. New attention to this issue was raised when the results of human testing involving chemical agents, conducted by the U.S. Army, was the topic of National Research Council reports.[60,61] Interest in this issue peaked again when risk assessment and public health programs were initiated in response to the chemical demilitarization of the stockpiles of these same weapons. It was at this time that the U.S. Department of Health and Human Services published their conclusions in the Federal Register regarding the risk of adverse health effects to exposure to low doses of nerve agent. The most recent interest in this subject has been generated as a result of "Gulf War Syndrome." One of the suggested causes of this malady is that soldiers were exposed to low levels of CW agents during their period of service in the Gulf. Several panels of experts have reviewed these suggestions extensively.[62,63] Current knowledge of the health effects of exposure to low doses of nerve agents has been reviewed and is the subject of a chapter in this text.[64–66] However, this issue remains critical and is of significant importance to civilian responders to a CW agent incident. The issues are basic. To respond rapidly and effectively to a chemical incident and to respond in such a way as to save lives, first responders must subject themselves to levels of the agents that may exceed current occupational exposure limits (Table 2). Currently available detection technology for use at the scene of an incident cannot measure chemical agents at these occupational exposure levels. Additionally,

TABLE 14.2
Human Exposure Values for Sarin

Agent GB
LCt_{50} = 100 mg min/m^3
No death dose = 10 mg min/m^3
NNM effect dose = 4 mg min/m^3
ECt_{50} (miosis) = 2–4 mg min/m^3
NOAEL = 0.5 mg min/m^3
MSC (1 h) = 0.001 mg/m^3
MSC (8 h) = 0.0003 mg/m^3
Safety factor of 0.1 for general population
0.0001 mg/m^3 (1 h)
0.00003 mg/m^3 (8 h)
0.000003 mg/m^3 (72 h)
IDLH 0.2 mg/m^3 (air-supplied respirator required)
Hand held detector threshold 0.01 mg/m^3

Note: NNM = no neuromuscular effect level; MSC = maximum safe concentration; and IDLH = immediately dangerous to life and health.

many of the protective ensembles that will be used by first responders will not protect down to these levels or have not been definitively tested for their protective efficacy. While the data appears to point to no adverse health effects from an acute, low dose of nerve agent, studies are continuing that may provide additional support to these conclusions or may find effects that have previously gone undetected.

VII. SUMMARY

The accidental or intentional release of chemical agents is similar to the hazardous materials incidents that metropolitan public safety personnel contend with routinely. The emergency response to a release of CW agent can use the existing framework of response to toxic chemical incidents and can be modified and enhanced for maximum effectiveness. Additionally, poison control centers located throughout the country deal with chemical poisonings on a daily basis and can serve as the initial focus of efforts to improve the response of the medical community to dangerous CW agents. Information in this chapter has described the adverse health effects of CW agents and the threat they pose from the standpoint of protecting civilian communities in the event of their use. Future advances should include improved methods of detection or laboratory analysis and better knowledge of the potential health consequence of such exposures in a general population.

Information in other chapters in this text describes areas of ongoing work that will expand our knowledge base, thus allowing for greater ability to deal with chemical agent exposure in mass casualty situations.

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