ADVANCES IN
BIOLOGICAL AND CHEMICAL TERRORISM COUNTERMEASURES

EDITED BY
RONALD J. KENDALL
STEVEN M. PRESLEY
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Preface

This textbook, *Advances in Biological and Chemical Terrorism Countermeasures*, is offered as a contribution to establish the state-of-the-science of research on countermeasures to biological and chemical threat agents. Although the context of this book is heavily focused on the United States, its application should be considered global in nature. Biological and chemical terrorism are continuing threats to the United States and other nations; ironically, as we began writing this book in July 2007, the National Intelligence Council of the United States had just issued a report in which it is stated, "As a result, we judged that the United States currently is in a heightened threat environment." The July 2007 National Intelligence Report went on to state that "we assessed that al-Qa'ida will continue to try to acquire and employ chemical, biological, radiological or nuclear material attacks and will not hesitate to use them if it develops what it deems is sufficient capability." Therefore, we believe that this textbook is timely and will continue to offer strategies and perspectives to assist the United States and other nations to defend themselves from terroristic threats.

Research was begun in 1998 at Texas Tech University to develop countermeasures against biological and chemical threat agents. Subsequently, through The Institute of Environmental and Human Health (TIEHH) at Texas Tech University, the Admiral Elmo R. Zumwalt, Jr. National Program for Countermeasures to Biological and Chemical Threats (Zumwalt Program) was commissioned to further advance the university's and its collaborators' research and development of countermeasures to biological and chemical threats. Support for this research program has primarily occurred through the U.S. Army and, particularly, through the Research Development and Engineering Command, which has challenged our program to develop a multidisciplinary toxicology research program to address countermeasures to biological and chemical threat agents. Indeed, *Advances in Biological and Chemical Terrorism Countermeasures* draws heavily from the funding received through the U.S. Army and incorporates other leading scientists' research and their involvement with countermeasures against biological and chemical threats over the past few years.

Drawing upon the research data developed on countermeasures to biological and chemical threats as well as literature review, this book involved many months of planning and coordination by its authors as well as a meeting in July 2007 in Beaver Creek, Colorado, to bring all the chapters together for the book. Following months of planning, the authors met and discussed these issues for several days to coordinate this book as it relates to advances in countermeasures to both types of threats. Although the book does not attempt to completely implement all aspects of countermeasures to biological and chemical threats, it particularly addresses the research and development that has occurred through the Zumwalt Program at Texas Tech University.

The main authors of *Advances in Biological and Chemical Terrorism Countermeasures* participated fully in a collegial and multidisciplinary perspective at the

Beaver Creek meeting. Additional persons who offered input into individual chapters are noted as contributing authors to an individual chapter, even if they did not participate in the Beaver Creek meeting. The authors did participate in the Beaver Creek meeting and fully support the conclusions reached by the group, particularly those related to the conclusions and research recommendations chapter.

Countermeasures to biological and chemical threats continue to evolve as a national priority issue and we envision this issue will be before us for many years to come. We offer this book as a science-based text to improve our ability to implement countermeasures to biological and chemical terrorism. The authors believe that this book will contribute to developing the science of addressing countermeasures to biological and chemical terrorism that oftentimes challenge environmental toxicologists by virtue of the potential threats that are continuing to emerge with biological and chemical threat agents and that may require more complex experimental designs to evaluate.

We appreciated the opportunity to work together as a team in the publication of *Advances in Biological and Chemical Terrorism Countermeasures*, and we appreciate the Research Development and Engineering Command of the U.S. Army in supporting our research and the ultimate development of this textbook.

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About the Editors

Galen P. Austin is a senior research associate at The Institute of Environmental and Human Health, Texas Tech University. He earned his doctoral degree in animal science with an emphasis on beef cattle production from Texas Tech University in December 2003. As an animal scientist, Dr. Austin's research interests are varied regarding livestock production and the environment. He has utilized GPS/GIS technology to monitor beef cattle movement and behavior and is interested in livestock disease epidemiology, in particular, zoonotic diseases. Additionally, Dr. Austin is concerned with and has research interests in the protection from and detection of agricultural terrorism directed at both on-farm/ranch livestock and confined animal feeding operations.

Ronald J. Kendall serves as the founding director of The Institute of Environmental and Human Health (TIEHH), a joint venture between Texas Tech University and Texas Tech University Health Sciences Center at Lubbock, Texas. He is professor and chairman of the Department of Environmental Toxicology at Texas Tech University. He graduated from the University of South Carolina and received his MS degree from Clemson University and his PhD from Virginia Polytechnic Institute and State University. He received a U.S. Environmental Protection Agency (EPA) postdoctoral traineeship at the Massachusetts Institute of Technology. Dr. Kendall served on the EPA's Science Advisory Panel from June 1995 to December 2002, and was appointed chairman from January 1999 to December 2002. He has served on many other boards, including past president of the Society of Environmental Toxicology and Chemistry, Board of Directors of the SETAC Foundation for Environmental Education, the Endocrine Disrupters Screening and Testing Advisory Committee of the U.S. Environmental Protection Agency, and multiple panels of the National Research Council. He currently serves as editor of terrestrial toxicology for the journal *Environmental Toxicology and Chemistry.* In addition, he has authored more than 200 refereed journal and technical articles and has published or edited many books. He has made more than 170 public and scientific presentations in the field of wildlife and environmental toxicology and has successfully won 136 research grants from federal, state, and foreign governments, industries, and foundations. He has served as advisor for 31 students at the graduate levels, including MS and PhD degrees, and has authored 10 courses in environmental toxicology and wildlife toxicology. He has received numerous awards, addressed the U.N. Committee on Sustainable Development, and has consulted with many foreign countries on environmental issues. Dr. Kendall was awarded a Fulbright Fellowship in 1991.

Steven M. Presley is an associate professor of environmental toxicology in The Institute of Environmental and Human Health, and serves as research coordinator for the Admiral Elmo R. Zumwalt, Jr. National Program for Countermeasures to Biological and Chemical Threats at Texas Tech University. Professionally trained

as a medical entomologist, Dr. Presley also served as a U.S. Navy officer and is a graduate of the U.S. Marine Corps Command and Staff College, earning a master's of military studies degree focused on domestic terrorism, and has extensive training and practical experience in various aspects of biological, chemical, and radiological incident detection, response, and mitigation. His operational and research experience has focused upon the surveillance, prevention, and control of biological threats in the environment, and specifically vector-borne infectious diseases in tropical and semi-tropical environments. He has led malaria control operations and research efforts in Africa, Asia, and South America, as well as Rift Valley fever, Crimean Congo hemorrhagic fever, and cutaneous leishmaniasis studies in Africa and Asia. He has published more than 35 scientific and technical manuscripts, and was awarded the Rear Admiral Charles S. Stephenson Award for Excellence in Preventive Medicine for the year 2000–2001.

Philip N. Smith received his doctoral degree in environmental toxicology from Texas Tech University in May 2000, and has since advanced from senior research associate to assistant professor. Dr. Smith is an ecotoxicologist with wide-ranging interests in contaminant exposure and responses among ecological receptors. His research is focused on pathways of contaminant exposure among mammals, birds, aquatic organisms, and trophic transfer of environmental contaminants. Additionally, physiological and population-level responses to contaminant exposure are of particular interest to Dr. Smith. Dr. Smith's research is grounded in ecological relevance and is strategically aligned with his academic emphasis, which is ecological risk assessment. He is a reviewer for ten national and international journals and serves as editorial board member for two international journals, *Environmental Pollution*, and *Environmental Toxicology and Chemistry.*

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1 State of the Science
Background, History, and Current Threats

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Alas America's future enemies may not fight according to these Marquis of Queensberry rules. They might use nuclear, biological, or chemical weapons, not only on the "regional" battlefield that the Pentagon planners assign to them, but also in that unanticipated region of warfare—the United States itself.

—Former Under-Secretary of Defense for Policy Fred C. Iklé (1997)

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1.1 INTRODUCTION

1.1.1 Summary of World Situation and Perspective on Likely Future Situation

Western civilization is at war—a multifaceted, asymmetric, global war being fought in a nondelineated, undefined battle space, waged against a faceless enemy that operates from the shadows, utilizing both conventional and unconventional weapons and tactics to achieve its objectives. These 21st-century terrorists do not officially represent nation-states, but often they represent a religious ideology expressed through violence and death. They are driven by hatred and religious fanaticism, with many striving for the destruction of Western society and culture, and ultimately for the establishment of a global theocracy. The employment of unconventional weapons and weapons of mass destruction against civilian noncombatants is not novel or unique to present times. Mankind has exploited diseases, toxins, and poisons since the earliest

days of recorded history to wage warfare, commit crimes, and influence or coerce others. However, accessibility to biological and chemical weapon agents, and their enhanced capacity to cause morbidity and mortality, as well as improvement of tactics for their employment, have significantly increased the need for the development of more effective means of detecting and countering such weapons. Additionally, Western society has become considerably more vulnerable to terrorism.

Many advanced sovereign nations have experienced an increase in terrorist activities due to an erosion of the restraints that once limited the terrorist's abilities to engage modern military, law enforcement, and intelligence agencies. Previously effective restraints included political and ideological isolation, prohibitive technical and fiscal requirements for the production of adequate qualities and quantities of terror-based weapons, and complex logistical and organizational obstacles that precluded delivery of such weapons (Stern 1999). Terrorist groups and individuals that Western societies now face, both militarily and in civil society, are not restrained in their actions. They have proven to be innovative and resilient, with a willingness to murder civilians and to martyr themselves without guilt or hesitation. Terrorists capitalize on the critical vulnerability fundamental to most advanced Western societies—openness and freedom. The avowed willingness of terrorists to use any means, including covert biological and chemical weapons against noncombatants, has dramatically impacted the psyche, social norms, and economies of many Western societies, and has instilled a chronic state of awareness of the ever-present threat of terrorism into every aspect of daily life in those societies (e.g., air travel, food and water supplies, public gatherings, etc.). "Noncombatant" is a misnomer in this context; the reality of the "global war on terrorism" is that civilians and civil society are the actual tactical targets for terrorism and are forced into a role as primary combatants.

The citizenry and governmental infrastructures of the West continue to regain their footing following the horrific terrorist attacks upon the United States on September 11, 2001. As a direct result of the September 11 attacks, there was a dramatic realization of the unrestrained, ruthless violence that could be targeted at and perpetrated upon Western civilization by relatively low-tech terrorists. This changed the collective mind-set of Western governments and militaries with regard to terrorists and their threats, and caused reassessment of vulnerabilities and protective capabilities. Western governments and peoples have increasingly recognized the vulnerabilities inherent to a free and open democratic society. Such vulnerabilities are not limited to those overt and covert threats associated with expansive coastlines and borders, or industrial and transportation systems, but include the day-to-day necessities of life such as food production, water supply, and a safe environment within which to work and recreate. The ability to reduce or eliminate these vulnerabilities and respond to terrorism, particularly biological and chemical terrorism, is highly dependent upon innovative and unprecedented mergers and collaborations among academia, engineering, industry, medical arts, and research sciences.

The primary focus and intent of this book is to improve the reader's understanding of the current status of scientific research on countermeasures to biological and chemical threat agents through an enhanced knowledge of the history of their usage,

the types and extent of the threats to humans and society at large that they pose, and an awareness of the vulnerabilities within Western societies that exist due to lifestyle and demographics.

Scientific research efforts to develop and employ capabilities to counter biological and chemical threat agents and weapons must address the basic tenets of environmental toxicology and focus upon all environmental compartments, including the air, biological organisms, land, and water. The relevance of the relationship between exposure, dose, and effect, and how toxicants may move through or be retained in the environment is critical to identifying and characterizing the hazards associated with both biological and chemical threat agents.

1.1.2 Critical Terminology Used in This Book

Throughout the chapters of this book there are critical terms and phrases that are used, many of which may have different specific meanings to scientists from different disciplines. Because of the highly multidisciplinary composition of the authors of the present text, every effort has been made to standardize usage and meaning of such terms and phrases, and a glossary of terminology and phrases is provided following the final chapter. A few critical concepts essential to the understanding of this topic are explained in this chapter.

The terms *chemical weapon* and *biological weapon* are often used collectively in reference to a chemical compound or substance, or a pathogenic organism or toxin derived from a living organism that has been enhanced or modified for use as a weapon to cause morbidity or mortality in a population; whether this agent is specific to humans, animals, or plants is dependent upon the objectives of the user. The enhancement or "weaponization" of the biological pathogen, toxin, or chemical substance may be by means to improve its ease of delivery, longevity in the environment in which it is delivered, toxicological or disease-causing effects upon the intended target population, or speed of action once within the intended target population. Biological weapons may be either living organisms that infect the victim and cause disease (such as bacteria and viruses) or specific toxins derived from bacteria, viruses, and other naturally occurring organisms.

Biological or *chemical terrorism* can be defined as the threat of, or intentional release or delivery of such agents for the purpose of influencing the conduct of a government, or intimidating or coercing a civilian population, which is an expansion on the definition used by the U.S. General Accounting Office (GAO 2001). The term *"international terrorism*" means activities that involve violent acts or acts dangerous to human life that are a violation of the criminal laws of the United States or of any state, or that would be a criminal violation if committed within the jurisdiction of the United States or of any state. The term *"domestic terrorism*" means activities that involve acts dangerous to human life that are a violation of the criminal laws of the United States or of any state and appear to be intended (1) to intimidate or coerce a civilian population; (2) to influence the policy of a government by intimidation or coercion; or (3) to affect the conduct of a government by mass destruction, assassination, or kidnapping; and (4) occur primarily within the territorial jurisdiction of the United States (U.S. Code 18).

The actual use of biological or chemical agents by terrorists to cause disease or debilitate a population can be either overt or covert. The overt use of a biological or chemical weapon, particularly a chemical agent, is an immediately recognizable incident, either through the delivery method (e.g., explosion, motor vehicle, etc.) or the near-immediate physiological effects on the targeted population. Most military use of chemical weapons can be characterized as overt, is typically tactical in scope, and is focused on immobilizing, debilitating, or killing victims within a specific building, location, or area of the battle space. An excellent discussion of the comparative and theoretical differences in the delivery and intended impacts of biological and chemical weapons, both covert and overt, is provided in the first two chapters of Falkenrath and others (2001). Covert use of either weapon type, but more especially biological agents, may be intended to accomplish more strategic objectives. Because of the self-perpetuating capabilities and delayed morbidity or mortality following exposure or infection, most disease-causing organisms used as biological weapons, particularly the zoonoses, can be delivered upon a target population without risk of immediate detection. Strategic objectives that may be sought through the covert delivery of a biological weapon might include the disruption of food production, processing, or delivery, and the disruption of industry or the economy through worker absenteeism.

Only moderate technical skills are required to develop or improvise effective delivery equipment for the covert use of either chemical or biological weapons. An assessment of a population's vulnerability to attack with biological or chemical weapons must consider the potential use of any delivery method, not just highly technical and use-specific delivery systems. An example of diverse and simple low-technology means of agent delivery is the use of the U.S. Postal Service to deliver letters and parcels contaminated with anthrax spores (*Bacillus anthracis*) during October 2001. Further discussion of types of biological and chemical weapons, their deployment and potential effects are provided in Chapter 2. Directly compared, there is a greater likelihood of the surreptitious release of a biological agent than for a chemical agent, for unlike chemical agents, which are often more acute or immediate in their effects, biological pathogen agents must invade and replicate within the host animal or plant tissues before pathology and clinical symptoms of infection present themselves (MacIntyre et al. 2000).

Information available in this chapter will provide a brief overview of the history of biological and chemical weapons and their use for terrorism, briefly discuss the technical aspects characteristic of currently recognized biological and chemical threat agents, and relate the importance of ongoing and needed multidisciplinary research programs to address countermeasures to biological and chemical threats to both military and civilian elements of Western society, economic viability, and political stability.

1.2 HISTORY OF BIOLOGICAL AND CHEMICAL AGENTS AS WEAPONS

It is important for the reader to understand that the use of biological and chemical threat agents against humans and their interests, including crops, livestock, and wildlife, is not a new or novel concept. Numerous references to the use of biological

pathogens, toxins, and chemical agents as weapons can be found throughout written history. The modality of these weapons has not significantly changed, but technologies to enhance their effectiveness and capacity to exploit those modalities have improved. The actual delivery and resultant human morbidity or mortality resulting from the use of biological and chemical weapons is only one aspect of their effectiveness. The psychological aspects such as fear and terror produced within a population and society at large that result from the threat of their use can be just as effective, if not more so. References to the use of biological and chemical agents as weapons reach back into the earliest annals of recorded history. Although not an exhaustive or all-inclusive listing of the historic use of biological or chemical weapons, we present an overview of those specific incidents that represent the wide spectrum of technology utilized in the production and delivery or dissemination of such weapons.

Perhaps one of the earliest reported and most simple uses of a biological agent in warfare is from the 6th century BC, when Assyrian armies used a toxin derived from ergot-infected rye to poison the water wells of besieged enemies.* Another unique and innovative use of biological agents is reported from around 400 BC, in which it was the practice of Scythian archers to dip the heads of their arrows into vats of bacteria-rich human excrement and decomposing corpses (Smart 1997). Although not necessarily a distinct and effective biological weapon by modern standards, the bacterial contamination to the wound caused by such an arrow and highly probable secondary infection was most likely very effective in causing increased (however delayed) morbidity and mortality in their enemies. Effective chemical weapons were believed to have been used in warfare as early as 429 BC during the Peloponnesian War. Using hollowed-out wooden beams, Spartan forces and their allies directed smoke from a burning concoction of sulfur and pitch into the Athenians' fort—disabling the defenders with an effective choking agent (Thucydides 431 BC). The tactics used by the Spartans bear a striking resemblance to those of Sadam Hussein's Iraqi military use of chemical agents such as tabun and mustard gas during the Iran-Iraq War and against the Kurds throughout the 1980s nearly 2,500 years later (DOD 1996; Zilinskas 1997).

Warfare and weapon technologies and tactics advanced significantly by the Middle Ages, but the frailty and susceptibility to disease of the warriors had not much improved. During the long siege of Kaffa† by the Tartars, squalid and desperate conditions led to an outbreak of plague (*Yersinia pestis*) among the Tartar forces in 1346 (Deaux 1969; Gottfried 1983; Marks 1971). With death claiming a large portion of the army, the Tartars catapulted corpses of those who succumbed to the disease over the city walls into the Genoese defenders. This caused great terror among the city's defenders who, in an attempt to escape infection, fled by ship back to Genoa and took the plague back to southwestern Europe. Much speculation and discussion on

* Ergot is a fungal (*Claviceps* spp.) disease of cereal grains, including rye, from which various water-soluble toxins can be derived that, when ingested, cause abdominal cramps, spasms, and a form of gangrene.

† Kaffa was a Greek colony built on the site of the ancient city of Theodosia and is currently the Black Sea port city of Feodosiya. Genoese traders assumed control in early 13th century and developed Kaffa into a major Black Sea point of commerce. Tartar forces under Mongol control ultimately conquered the city and drove out the Genoese in 1475.

whether the catapulted, infected corpses were truly an effective means of infecting the defenders has been exhaustive; some argue that the fleas would have detached from the bodies prior to being catapulted and thus infection from the corpses could not have occurred. Perhaps dogs and rats fed upon the corpses, became infected, and thus infected the fleas that fed upon them. Subsequently, those rats and fleas then boarded the ships, where the fleas then fed upon the crowded and fleeing Italians (thus completing the zoonotic disease cycle), who then transported the plague and contributed to the establishment of a second epidemic focal point of the Black Death pandemic in Europe. The original focal point of the Black Death epidemic that decimated Europe is believed to have been Constantinople.

Russians under the leadership of Peter the Great exploited the same "biological pathogen" delivery methods that the Tartars used, catapulting of plague-infected corpses, against the Swedes during the Great Northern War (1700–1721). After a long and severe Russian winter, the plague-devastated and severely weakened Swedish army under the leadership of Charles XII was soundly defeated at Poltava in July of 1709 (Smart 1997).

Smallpox has been used throughout history as a very effective biological weapon agent. It is suspected that Francisco Pizarro (circa 1470–1541), in his conquest of Peru, presented the immuno-naive natives blankets and clothing contaminated with the smallpox virus—thus causing a widespread smallpox epidemic and decimating their defenses. A later and controversial suspected use of smallpox as a biological weapon agent occurred during the French and Indian War (1754–1767). English forces were frustrated and suffering extensive losses to the guerilla tactics of the Indians during Pontiac's Rebellion in New England. After trying numerous unorthodox approaches, English forces reportedly distributed blankets soiled with the exudates, excreta, and vomit from smallpox victims at the English Fort Pitt to Indians loyal to the French. An epidemic of smallpox ensued and Fort Carillon fell to the English soldiers (Smart 1997). Numerous historical documents exist to support these stories, including correspondence between Governor General Jefferey Amherst and his field commander Colonel Henry Bouquet that were discovered as part of the British Manuscript Project, 1941–1945, undertaken by the U.S. Library of Congress during World War II. In a letter from Colonel Bouquet to General Amherst, dated July 13, 1763, he suggests the distribution of blankets to inoculate the Indians with the disease: "I will try to innoculate the Indians by means of blankets that may fall into their hands, taking care [illegible] not to get the disease myself."* In General Amherst's reply dated July 16, 1763, he approves Colonel Bouquet's suggested method and encourages him to do whatever is necessary to gain victory: "You will do well to try to innoculate the Indians by means of blanketts, so well as to try every other method that can serve to extirpate this execrable race. I should be very glad your [illegible] scheme for hunting them down by dogs could take effect."†

* See letter from Colonel Henry Bouquet to General Jefferey Amherst, dated July 13, 1763, at http://www.nativeweb.org/pages/legal/amherst/34_40_305_fn.jpeg.

† See letter from General Amherst to Colonel Bouquet, dated July 16, 1763, at http://www.nativeweb.org/pages/legal/amherst/34_41_114_fn.jpeg. Also see Francis Parkman, The Conspiracy of Pontiac and the Indian War after the Conquest of Canada (Boston: Little, Brown, 1886).

During World War I, German agents (including Captain Erich von Steinmentz), disguised as women, illegally entered the United States to inoculate horses, mules, and cattle with anthrax and glanders prior to their shipment to France to support the war effort (Smart 1997). The arrival of the 20th century not only brought more covert usage of biological pathogens but also welcomed the large-scale production, stockpiling, and overt use of chemical weapons on the battlefield. The first large-scale use of chemical weapons on the modern battlefield occurred on April 15, 1915, near Ypres, Belgium. Approximately 150 tons of chlorine gas was released from 6,000 cylinders upwind of Allied forces, killing 800 and debilitating 15,000. Although very simplistic in the delivery and dissemination technologies used (gas cylinders and wind), the attack was very effective both physically and psychologically. German forces once again tested new chemical weapon technologies on July 12, 1917, again near Ypres, Belgium, when artillery units delivered sulfur mustard via artillery shells onto Allied infantry and caused more than 20,000 casualties (Smart 1997).

Immediately after witnessing and suffering the horrors of an estimated 530,000–1,300,000 casualties resulting from the use of approximately 125,000 tons of chemical weapons during World War I (Legro 1995), the international community moved to outlaw the use of such weapons through the Geneva protocol of 1925.* The protocol was initially signed by only 38 nations but has since been signed by more than 130 nations. Neither the United States nor Japan was an initial signatory, but eventually the United States did conditionally ratify the protocol in 1975.

During World War I, World War II, and throughout the Cold War, vast quantities of chemical weapons were produced and stockpiled by the Soviet Union and the United States; however, very few were actually employed during World War II. It is estimated that as much as 181,000 metric tons of chemical weapons were produced and stockpiled in the Soviet Union during this period, while some 27,000 metric tons were stockpiled in the United States (Falkenrath et al. 2001; U.S. Office of Technology Assessment [OTA] 1993). The most notable use of biological weapons during wartime, at least to any significant scale, occurred in the 1930s and 1940s. The Japanese Imperial Army established Unit 731 in Beiyinhe, Manchuria, in 1932 to research and manufacture biological warfare agents, including anthrax, glanders, and plague. A full account of Unit 731's activities and the overall efforts of the Japanese army to research, build, and employ biological weapons during WWII can be found in books by Harris (1994) and Williams and Wallace (1989). The facility was moved to Ping Fan in 1937 and large-scale biological weapon production and delivery research was conducted. Various pathogens and delivery methods were refined, but one stands out as an excellent example of a simple method for delivering biological agents. In 1937 Japanese military airplanes dropped plague-infected fleas, some contained in porcelain bombs and some loose, as well as *Yersinia pestis*–saturated rice onto Chinese and Soviet villages, which ultimately caused significant plague outbreaks among civilians and military personnel.

* The 1925 Geneva Protocol was actually the League of Nations' *Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare.*

In 1942 the U.S. military began research into the offensive use of biological weapons in response to a perceived German biowarfare threat (U.S. biological weapon efforts were located at Camp Detrick, Maryland). The program was terminated in 1969 by President Richard M. Nixon, and the stockpiles of biological weapons were destroyed in 1971 and 1972. Also in 1972, the Convention on the Prohibition of the Development, Production, and Stockpiling of Bacteriological and Toxin Weapons and Their Destruction (The Biological Weapons Conventions) was signed.* Although the United States used significant amounts of various herbicidal defoliants to gain visual access to enemy actions and supply routes throughout Southeast Asia during the Vietnam War, the use of these defoliants was not targeted at humans. Nevertheless, human exposure to one compound in particular, "Agent Orange" (2,4-D and 2,4,5-T) and dioxin contaminants, has been shown to have devastating long-term health consequences.†

Throughout the second half of the 20th century, particularly after the Biological Weapons Conventions, the use of biological and chemical agents as weapons of war, at least on a large scale, has been limited. However, there have been numerous incidents of biological or chemical agents being used in limited and focused attacks against individuals or small groups. Historical trends related specifically to events involving the use of biological agents ($n = 415$) have been empirically reviewed and were classified according to three general types: terrorist events, criminal events, and state-sponsored assassinations (Tucker 1999). In that article, Tucker concludes that although the historical records may lead to the belief that future incidents of bioterrorism will likely involve hoaxes and relatively small-scale events, the ability to utilize dual-use technologies for the production of bioterrorism agents coupled with the availability of scientists formerly employed by the Soviet Union have actually *increased* the potential for mass casualty terrorism.

One relatively recent incident involving the use of a biological agent on a community scale very clearly fits the definition of bioterrorism and is an excellent demonstration of the difficulty associated with recognizing a covert bioterror attack. In an attempt to sway a countywide election by inhibiting the ability of voters to reach polling stations, members of a cult following of Baghwan Sri Rajneesh contaminated the salad bars of four different restaurants in the Dalles, Oregon, area with *Salmonella typhimurium* in 1984. More than 750 people suffered the ill effects of the exposure, but the knowledge that it was an act of bioterrorism was not revealed until

* There were 140 states that ratified the Biological Weapons Convention as of May 1997 according to the Arms Control and Disarmament Agency (ACDA Fact Sheet, May 3, 1997). See also Convention on the Prohibition of the Development, Production, and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction, April 10, 1972, 26 U.S.T. 583, 1015 U.N.T.S. 163. There are now 160 nations that have signed and 143 nations that have ratified the conventions.

† Numerous references are available regarding the use and health effects of herbicides used in Southeast Asia during the Vietnam War, most notably: *Veterans and Agent Orange: Health Effects of Herbicides Used in Vietnam,* Institute of Medicine, National Academy of Sciences, National Academy Press, Washington, D.C. 1994; *Comparison of Serum Levels of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin with Indirect Estimates of Agent Orange Exposure among Vietnam Veterans, Final Report,* Centers for Disease Control, 1989, Atlanta, GA; *Oversite Review of the CDC's Agent Orange Study,* U.S. Congress, Hearing before the House Committee on Government Operations, July 11, 1989.

almost 2 years later when a cult member being tried on unrelated charges confessed to the 1984 attacks. A full report describing this community-focused, politically driven act of biological terrorism is provided by Torok et al. (1997).

A more elaborate and deadly attack, this time a chemical terrorism attack by members of the Aum Shinrikyo, a Japanese apocalyptic cult, was carried out in the Tokyo subway system in March 1995 (Olson 1999). It was suspected by international intelligence agencies that Aum Shinrikyo was working to develop biological and chemical weapons, but not until they killed 12 and severely injured thousands more by releasing sarin gas were they taken seriously.

There are numerous excellent sources of additional information and details regarding the historical use and impact of both biological and chemical weapon agents, in warfare as well as for terrorism, available to the reader through the Internet, particularly the U.S. Army's Textbooks of Military Medicine entitled *Medical Aspects of Chemical and Biological Warfare* (Sidell et al. 1997).

History can be an excellent source of information for planning strategies and developing methods and technologies to prevent and respond to terrorist threats, but we must not limit our assessment of potential threats and countermeasure strategies and technologies to only addressing a repeat of historical events. The historical record regarding the use of biological or chemical weapons by terrorist groups as weapons of mass destruction, particularly by domestic and non-state-sponsored groups and rogue fanatical religious or apocalyptic groups, suggests that technological, organizational, and logistical restraints limit the threat they pose on a national scale to the United States. However, a statement before the House Subcommittee on National Security, Veterans Affairs, and International Relations by John V. Parachini (senior associate, Center for Nonproliferation Studies, Monterey Institute of International Studies) in October 1999, in response to the U.S. Government Accounting Office's report on the threat posed by terrorists' use of biological and chemical threat agents, very clearly identifies the changing threat scenario posed by international terrorist groups such as Osama bin Laden's al-Qa'ida and others with superior organizational structure, near limitless monetary and technological resources, and worldwide reach. However, information gained during the global war on terror regarding the intricate and complex organization and technologies available to groups such as al-Qa'ida and nation-states that indirectly support and sponsor them suggests that those restraints may no longer exist—at least, not to an extent upon which we can rely.

1.3 GENERAL FOCUS AND INTENDED TOPICS

The following section provides a brief description of the intended knowledge and concepts to be conveyed through the various chapters of this textbook. The research efforts and successes resulting from the Admiral Elmo R. Zumwalt, Jr. National Program for Countermeasures to Biological and Chemical Threats (Zumwalt Program) have focused, since its inception, upon four critical areas: (1) modeling, simulation, and visualization of threats; (2) strategies for environmental protection from chemical and biological threats; (3) personal protection and therapeutics; and (4) mechanistic

and toxic effects of biological and chemical weapons. These topic areas were used in developing the specific chapter topics used in this book.

Chapter 2 provides an extensive discussion of the threats and vulnerabilities associated with the employment and effects of biological and chemical threat agents by terrorists. The chapter strives to educate the reader on the relationships among risk (potential for exposure), vulnerability (weakness or situation predisposing one to exposure) and threat as they relate to effectively responding to and countering such an attack: Vulnerability + Risk = Threat.

Chapter 3 focuses upon the research findings and technical advances in the modeling, simulation, and visualization of how biological and chemical threat agents disperse and move through the environment and structures. Chapter 4 reports on the state-of-the-science related to the strategies and approaches for assessment necessary for environmental protection from biological and chemical threat agents. Chapter 5 discusses the important mechanistic and toxic effects of chemical weapons on humans. Chapter 6 provides an extensive overview of the challenges faced and successes accomplished in the field of sensor development to detect and identify biological and chemical threats in the environment. Chapter 7 reports on recent advances and remaining opportunities for research in the area of phage display and its applications for the detection and therapeutic intervention of biological threat agent exposures, *in vivo*. Chapter 8 summarizes the need for, and research-based advances in, the development of personal protective capabilities against chemical threats. Chapter 9 provides an overview of recognized biological threat agents and their mechanisms of effect, and summarizes advances and accomplishments of related research. And finally, Chapter 10 offers significant conclusions of the scientists involved in the Zumwalt Program, specific areas identified as needing further research, and how their current and future multidisciplinary research findings may contribute to countering biological and chemical threats.

1.4 CONCLUSIONS

Although the challenges Western civilization now faces both at home and abroad as a result of this global war on terrorism are numerous and daunting, as we have discussed here, the concept of biological and chemical warfare is not new. However, the technologies associated with these tactics and the vulnerabilities inherent in modern Western society have changed immensely. As we recognize and assess potential vulnerabilities that are common within Western societies, such as unrestricted movement and travel within continental borders, food production and distribution technologies and methods, communication systems and electronic essentials, as well as medicine and public health services, it is critical that we design and implement scientific research programs to effectively address and counter the threats. Research and development programs specifically designed to address these threats must integrate multidisciplinary expertise and high levels of experience, and maintain research momentum to ensure that there exists the capability to successfully counter future biological and chemical threats. As we have learned from history, strategic advances gained through applied scientific research will ultimately ensure victory in the war against terrorism.

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2 Threats and Vulnerabilities Associated with Biological and Chemical Terrorism

Steven M. Presley, Galen P. Austin, Philip N. Smith, and Ronald J. Kendall

CONTENTS

2.1 INTRODUCTION

To provide a better understanding and appreciation for the complexities and challenges associated with countering the effective use of biological and chemical weapons against human populations and our interests, it is necessary to clearly define what biological and chemical weapon agents are, how they may be used, how to accurately detect them, and how to protect ourselves against them. The terms *biological threat agents* and *chemical threat agents* may be collectively used as *bio-chem threat agents* and refer to biological organisms or compounds and chemical compounds and substances that have been identified as having a significant potential pathogenic or toxic use against humans, agricultural resources, and other elements of infrastructure. It is necessary to define some of the terminology associated with this topic to provide the reader with a clearer understanding of how biological and chemical threat agents may be employed against humans and our interests. *Terrorism* can best be defined, for the purposes of this book, as the calculated unlawful use