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Introduction

The use of chemical and/or biological (CB) agents as weapons dates back many centuries; however, extensive use of these agents as weapons in military conflict began in World War I. Since then, research programs on chemical warfare agents, followed by research on biological agents, have been undertaken by a number of countries, including the United States, Japan, Germany, Italy, and the United Kingdom. Many countries, including the United States, believed that chemical warfare was no more cruel than any other kind of warfare and, thus, should not be banned. During World War II, the United States adopted a "no first use" policy but warned that retaliation against those who did use CB agents would be quick and extensive.

The United States discontinued its offensive biological and chemical military research programs in 1969 and 1989, respectively, but continued to expand its defensive programs. (In fact, the defensive program has been increased substantially since Desert Shield/Desert Storm.) During the Cold War, the perceived CB threat posed by the Soviet Union was based on three factors: (1) the broad range of chemical and biological weapons believed to be possessed by Soviet forces; (2) their ability to deploy and support CB weapons on the battlefield; (3) and the extensive research program apparently being pursued in the Soviet Union. U.S. tactics, training, and requirements were based on responding to this threat.

Since the end of the Cold War, the perceived military threats to the

United States have changed, but the tactics, training, and requirements for CB defense have not changed, although little rationale has been presented for retaining them. Although the threat from the former Soviet Union has significantly lessened, some experts believe that Russia has maintained its arsenal for CB warfare. In addition, more than a dozen other countries (e.g., China, North Korea, India) have been developing technologies and offensive CB capabilities that may pose military threats, but these technologies and capabilities are not as advanced as the technologies and capabilities of the former Soviet Union (Commission to Assess the Organization of the Federal Government to Combat the Proliferation of Weapons of Mass Destruction, 1999).

Because the United States expects to be able to project power globally, the health and preparedness of its military forces, including their ability to detect and protect themselves against CB attack, are central elements of overall U.S. military strength (Payne, 1998). Current doctrine requires that the military be prepared to engage successfully in two simultaneous major regional conflicts while conducting peacekeeping operations and other assignments around the globe. Uncertainty about the future requires that U.S. strategy be adaptable, and the diversity of potential missions, as well as potential threats, have contributed to the complexity of developing a strategy (Secretary of Defense, 1999).

Since Desert Storm, the joint services have mandated that troops receive predeployment and postdeployment health assessments. For the purpose of joint health surveillance, in the December 4, 1998, memorandum the chairman of the Joint Chiefs of Staff (JCS) issued the following official definition of a deployment:

> A troop movement resulting from a JCS/unified command deployment order for 30 continuous days or greater to a land-based location outside the United States that does not have a permanent U.S. military medical treatment facility (i.e., funded by the Defense Health Program). Routine shipboard operations that are not anticipated to involve field operations ashore for over 30 continuous days are exempt from the requirements for pre- and post-deployment health assessments.

Subsequent to Operation Desert Shield/Desert Storm, U.S. forces have been deployed to Haiti, Somalia, Bosnia, Southwest Asia, and, most recently, Kosovo. During these deployments, our forces could have been or may be exposed to CB attacks. This report evaluates our current ability to protect our forces from CB exposures (excluding medical protection, such as vaccines) and assesses improvements in force protection through the development and implementation of doctrine, tactics, techniques, procedures, and training.

BACKGROUND OF THE STUDY

Since Operation Desert Shield/Desert Storm, Gulf War veterans have expressed concerns that their postdeployment medical symptoms could have been caused by hazardous exposures or other deployment-related factors. Potential exposure to a broad range of CB and other harmful agents was not unique to Gulf operations. Hazardous exposures have been a component of all military operations in this century. Nevertheless, the Gulf War deployment focused national attention on the potential, but uncertain, relationship between the presence of CB agents in theater and symptoms reported by military personnel. Particular attention has been given to the potential long-term health effects of low-level exposures to CB agents. As a result, a number of studies have been undertaken addressing the health of veterans and the potential health effects of their service.

At least six different panels (the Defense Science Board Task Force on Persian Gulf War Health Effects; the National Institutes of Health Technology Assessment Workshop; the Institute of Medicine (IOM) Committee on Health Consequences of Service in the Persian Gulf; the Institute of Medicine Committee on the Comprehensive Clinical Evaluation Program; the Presidential Advisory Committee on Gulf War Veterans' Illnesses; and a Veterans Administration Expert Panel) have conducted extensive reviews and published reports on the health of veterans and the possibility that they may have suffered adverse health effects as a result of some exposure during their period of service. The focus of these and other studies has been on assessing the current health of veterans, ensuring that appropriate care is being provided, and evaluating the possible connections between the current health status of veterans and their service in and specific exposures during the Gulf War. These expert panels have recommended improvements in U.S. Department of Defense (DoD) policies, procedures, and technologies for protecting the health of military personnel during deployments.

Deputy Secretary of Defense John White met with the leadership of the National Academies to discuss DoD's continuing efforts to improve its protection of military personnel from adverse health effects related to deployments in hostile environments. Although many of the lessons learned from previous assessments of Operation Desert Shield/Desert Storm have been reported, prospective analyses (1) to identify gaps and shortcomings in policy, doctrine, training, and equipment and (2) to develop a strategy to improve the management of battlefield health risks in future deployments have not been done. The DoD requested that the National Academies perform a prospective evaluation of strategies to protect deployed U.S. forces. This report, which addresses the issues of

physical protection and decontamination, is one of four initial reports that will be submitted in response to that request.

CHARGE TO THE NATIONAL ACADEMIES

The DoD sought an independent, unbiased evaluation of the capabilities of current DoD research and development (R&D) in response to new threats, research priorities for filling important information and technology gaps, and recommendations for improving the effectiveness and responsiveness of R&D. The evaluations are focused on four areas: (1) risk assessments of deployments in hostile environments; (2) technologies and methods for detecting and tracking exposures to chemical agents, biological agents, and other harmful agents; (3) physical protection and decontamination; and (4) medical protection, health consequences and treatment, and medical record keeping. Studies addressing topics 1, 2, and 4 were conducted concurrently with this study by the Commission on Life Sciences, Commission on Engineering and Technical Systems, and the IOM, respectively.

Scope of the Study

The objective of this study, carried out under the auspices of the Commission on Engineering and Technical Systems, is to assess DoD's current and potential approaches and technologies for physical protection—both individual and collective—against CB agents and decontamination of personnel and equipment. The evaluation also examines the implementation of current policies, doctrine, and training as they relate to protection and decontamination of exposures to CB agents during troop deployments and recommends strategies to improve protection against deleterious health effects in future deployments. Specifically, this report includes a review and evaluation of the following areas:

- the adequacy of current protective equipment and protective measures (as well as equipment in development)
- the efficacy of current and proposed methods for decontaminating personnel and equipment after exposures to CB agents
- current policies, doctrine, and training to protect and decontaminate personnel and equipment in future deployments (i.e., major regional conflicts [MRCs], lesser regional conflicts [LRCs], and operations other than war [OOTWs])
- the impact of equipment and procedures on unit effectiveness and other human performance factors
- current and projected military capabilities to provide emergency response

Limitations

This report addresses nonmedical force protection (e.g., individual and collective protective clothing and equipment) in a potential CB environment. Medical aspects of nuclear, biological, and chemical (NBC) defense, including medical preventive measures (e.g., vaccines) and treatments (e.g., antidote kits) and their doctrine and training protocols, are addressed in the medical surveillance, record keeping, and risk reduction report (IOM, 1999a). The trade-offs between NBC medical defense and NBC nonmedical physical protection (e.g., protective clothing and masks) will be addressed in the third year study.

Radioactivity associated with nuclear weapons or other military uses of radioactive materials (i.e., depleted uranium) are not addressed in this report. Although individual and collective protective equipment is designed to protect against radioactive materials, this aspect of protection is beyond the scope of this study.

Since the end of the Cold War, multinational forces have been increasingly used in deployments. Coalition troops and U.S. troops should receive similar training and equipment and doctrine should be applied uniformly. However, this issue could not be evaluated in the present study because the data on doctrine and training are not sufficient. The authors encourage the North Atlantic Treaty Organization (NATO) to establish guidelines in these areas (e.g., NATO, 1996a, 1996b).

In keeping with the definition of deployment issued by the chairman of the JCS, this study does not explicitly consider the contamination of ships and other ocean vessels, even though they may be involved in the transportation of deploying forces and are potential CB targets. However, many aspects of personal protection, collective protection, and decontamination of land-based personnel and equipment may apply to shipboard situations. The contamination of aircraft personnel and equipment, as well as airfields, are included.

This study focuses only on deployed forces and does not explicitly consider nondeployed forces or nonmilitary contract employees who perform work in the host nation. Although these individuals are vital to successful missions and the technical aspects of protecting them may be the same as for deployed troops, the implementation of a protective strategy and the development of doctrine and training for them are beyond the scope of this study.

The shift to a Force Projection strategy and the decrease in the number of active duty personnel have increased U.S. dependence on Reserves and National Guard personnel. DoD has not yet developed a viable plan for preparing reserve forces for deployment in a CB environment. Their training may not be comparable to active-component training and their equipment may not be up to date. Nevertheless, the needs of the reserve

units are the same as for active duty forces. (For a discussion of strategies for improving the integration of reserve components and active deployed forces see *Technology-Based Pilot Programs* [NRC, 1999a].)

APPROACH OF THE STUDY

The study was led by two principal investigators, an inhalation toxicologist with expertise in personal protection and a physical chemist with expertise in CB and military operations. A panel of advisors with expertise in respiratory protection, dermatology, systems engineering, human performance and human factors, and textiles provided additional support and advice.

The principal investigators and National Academies staff, with the participation of the advisory panel, made numerous site visits to DoD agencies and related organizations, hosted a series of public meetings and one public workshop, commissioned papers to address specific issues, attended demonstrations of current simulation and modeling efforts, and toured the facilities at the U.S. Army Chemical School, the Soldier and Biological Chemical Command (SBCCOM) Soldier Systems Center and the SBCCOM Edgewood Chemical Biological Center. In-depth briefings and presentations covered the following topics: the worldwide CB threat; the role and adequacy of threat information in materiel development from the perspectives of intelligence support and program managers; the method by which threat information is provided in response to research, development, test, and evaluation (RDT&E) questions; the way threat information is used to support the development of philosophy and doctrine; the relationship between physical protection and decontamination training protocols and doctrine; the consistency of training among Army components and among services; the way(s) threat information is used to support the development of physical protection and decontamination materiel; the status of current related programs and funding levels; and current and emerging technologies (including how they will address current and potential new threats). Additional sources of information included guidebooks, technical reports, field manuals, issue papers, information papers, journal articles, and information on the World Wide Web.

OVERVIEW OF THE REPORT

The remainder of this report is divided into seven chapters. Chapter 2 is an assessment of the threat and risk, including an historical overview of the development of CB agents and their use; a discussion of the theoretical relationships of policy, doctrine, training, R&D, and perceived threats; and the adequacy of threat information for the development of physical

protection doctrine, training protocols, and materiel. Chapter 3 is a description of CB philosophy, doctrine, and training in light of the changing threat in the post-Cold War environment. In Chapter 4, physical protection, including protection levels; current and emerging technologies in fibers, textiles, and garments; respiratory protection; and training in the use of these technologies, are reviewed and assessed.

Decontamination is addressed in Chapter 5. Given the limitations of detection, monitoring, and providing protection, decontamination systems will always be necessary for personnel and equipment, as well as for nonpersonnel functional areas (e.g., sensitive equipment, facilities, large open areas). Because of their differing vulnerabilities and requirements, and because of the limitations of current decontamination systems, new technologies will have to be developed. Chapter 6 is a summary and assessment of methods of testing the elements of protective strategy and evaluating the effectiveness of training and readiness.

Chapter 7 provides a brief assessment of the military's capabilities to provide emergency response and references other work that specifically addresses this issue. The term "emergency response" in the CB arena refers to incidents of domestic terrorism, which is beyond the scope of this study. Nevertheless, the military plays a role in responding to CB domestic terrorism, CB terrorist attacks against U.S. facilities in other countries (e.g., U.S. embassies), and CB attacks against the military at U.S. points of embarkation.

Chapter 8 reviews and evaluates the relationship among R&D, funding, doctrine, and priorities; and summarizes the key findings and recommendations for continuing or beginning investments in various R&D areas. The discussion includes R&D in a joint service environment, changes brought about by new legislation, and the impact of laws and presidential directives on service programs. The chapter also includes key findings and priority recommendations for improving DoD's protection of deployed forces.