

Threat and Risk Assessment

HISTORICAL PERSPECTIVE OF THE CHEMICAL/BIOLOGICAL BATTLE SPACE

CB agents have been considered effective weapons for combat for more than a millennium, from the tossing of plague victims over castle walls to the poisoning of water supplies and individuals. However, lethal CB weapons were first used extensively by the military in World War I (U.S. Army Office of the Surgeon General, 1997). Trench warfare, in which forces were deployed in fixed positions vulnerable to concentrated pockets of lethal fumes, provided fertile ground for the development of chemical weapons that could be dispersed as fogs, mists, or dense vapors. The first chemicals used during World War I were noxious gases (chlorine [Cl₂], hydrogen sulfide [H₂S], and phosgene [COCl₂]) and were released from upwind storage vessels along enemy lines. Local meteorological patterns were used to predict the movement of the gas clouds. However, this methodology was often ineffective because rapid changes could cause deadly clouds to settle on friendly forces, resulting in self-inflicted casualties. Early chemical agents were primarily inhalation threats, and effective gas masks (or respirators) were quickly developed and refined to protect personnel against toxic gases.

Respirators greatly diminished the tactical advantage of using toxic gases, and new chemical warfare agents had to be developed. Some of the new agents were chemical mustard agents, sulfur and nitrogen mustards, which caused serious injury and incapacitation not only when they were inhaled but also when they came into contact with the skin or mucous

membranes. Because of the percutaneous threat of these agents, gas masks alone could no longer provide adequate protection, and garments to protect skin had to be developed.

In addition to new agents, new delivery systems were also developed. At first, artillery shells were modified to accommodate agents. Later, more sophisticated techniques evolved. Although there was still some risk that changes in local weather and climate could cause chemical agents to drift onto friendly targets, the risk was mitigated significantly as targeting became more accurate.

During the interval between World War I and World War II, new and more lethal families of chemical agents were developed. German scientists working to provide weapons for their military, discovered and refined a series of “nerve” agents—tabun (GA), soman (GD), and sarin (GB)—that attacked the central nervous system, could be absorbed through mucous membranes and the skin as well as inhaled, and were lethal in much smaller doses than the chemicals that had been used during World War I. At the same time, Japanese scientists were experimenting with agents of biological origin, such as plague and typhus. These agents were tested on human prisoners (U.S. Army Office of the Surgeon General, 1997).

Although neither chemical nor biological agents were actually used during World War II to achieve any military objectives, work continued and provided the foundation for the extensive CB research program of the Cold War powers. Led by scientists in the United States and the Soviet Union, the CB weapons programs flourished during the 1950s and 1960s. New nerve agents were developed (the family of V agents) that were not only more lethal in smaller inhaled doses but could also be absorbed directly through the skin. Existing agents were refined and mixed with additives to increase their persistence in the environment and the difficulty of decontamination.

During this time, natural toxins produced by biological organisms were also developed as weapons. The poisons produced, for example, by castor beans (ricin), puffer fish (tetrodotoxin), bacteria (botulinum), and fungi (mycotoxins) are among the most toxic compounds known and are lethal in even smaller quantities than V-agents. Although the production of large quantities of these toxins was difficult because of their high degree of lethality, much smaller amounts were required.

In addition to plague and typhus, other biological pathogens were studied as biological warfare agents, and weaponization techniques were researched and developed. Virtually every type of disease, condition, and means of dissemination was studied. From smallpox to cholera, from anthrax to hemorrhagic fevers, from tularemia to parasites, these agents and others were considered as possible weapons. The exposure of troops

to pathogens or toxins through food supplies, water supplies, aerosols, and insect or animal vectors was also studied.

During the post-1950s era, the means of dissemination of lethal agents became major research objectives. Airborne spray tanks, specialized artillery shells, CB-capable missile warheads, and an assortment of individual weapons were developed. At the same time, the threat of exposure led to the development of defenses. Protection (both individual and collective) and decontamination became high-priority issues and stimulated the development of protective equipment. Thus, gas masks, protective garments, boots, gloves, protective shelters, and decontaminating solutions and systems were produced.

Even as the development of more and more lethal agents continued, societal fears and the conviction that the use of weapons of mass destruction was unethical resulted in treaties and international agreements that limited the proliferation, control, and testing of CB weapons. The Geneva Protocol of 1925 condemned the use in war of asphyxiating, poisonous, or other gases, as well as bacteriological warfare. The United States signed the Geneva Protocol but did not ratify it until 1975. However, the United States reserved the right not to be bound by the protocol if any enemy or state or any of its allies did not respect the protocol.

In 1972, the Biological and Toxins Weapons Convention (BWC) was signed. Under the terms of the convention, the parties agreed not to develop, produce, stockpile, or acquire biological agents, toxins, weapons, or means of delivery. Many years later, the Chemical Weapons Convention (CWC) banned the acquisition, development, production, transfer, and use of chemical weapons throughout the world. The United States signed the CWC in 1993 but did not ratify it until 1997. On June 25, 1999, the President issued an Executive Order implementing the CWC; it went into effect on June 26, 1999.

Since the implementation of these treaties, both the United States and the former Soviet Union have embarked on programs to destroy residual stockpiles (U.S. Army Office of the Surgeon General, 1997). However, CB technologies have been transferred to, and proliferated in, other countries; and modern bioengineering and molecular biological capabilities have given even small nations and groups the capability of developing novel, lethal agents. Documentation of the use of chemical weapons in localized wars and credible warnings from the intelligence community confirm that many potential enemies in regions to which U.S. forces may be deployed have the capability of using CB weapons.

Thus, the United States could find itself confronted with adversaries who have either chosen not to sign and ratify the CWC and/or BWC or have chosen to ignore them. Nevertheless, as a signatory of both the CWC and BWC, the United States has adopted a national policy of not using

biological or chemical weapons in warfare even in retaliation for a CB attack. This asymmetrical threat has led to a national military strategy based on defense and deterrence (Chow et al., 1998; DoD, 1995; Joint Chiefs of Staff, 1995; Secretary of Defense, 1999; U.S. Army and U.S. Marine Corps, 1996). The policy is to deter the use of CB agents by enabling U.S. forces to survive, fight, and win a war under CB conditions. This policy has stimulated a continuing research program for refining military doctrine, for developing protective technologies, and for training U.S. forces against CB attack.

U.S. RESPONSE

The Army Chemical Corps has historically been the military organization primarily responsible for dealing with CB threats. Founded in June 1918 as the Chemical Warfare Service and renamed the Army Chemical Corps in August 1946, the Army Chemical Corps has alternately enjoyed support and been threatened with elimination, depending on political and economic exigencies. Prior to 1920, the development of chemical defenses was not tightly structured. Various chemical warfare schools (called gas schools) existed, but no single department was responsible for coordinating chemical warfare activities. The Army assumed the *de facto* role of executive agent for CB R&D by virtue of its large and long-term investment in the development of chemical equipment and its extensive experience with chemical exposure on the battlefield. The Army controlled the production of chemicals, the development and production of defensive equipment, training, testing, basic research, and a new chemical warfare unit.

Although the Army was more actively involved in this area than other services, in fact each military service was free to develop its own CB defense program and materiel. Each service had a separate budget and administered the budget and its program independently, cooperating with other services as the needs of basic or developmental research dictated. Each service also prioritized its needs for equipment separately, on the basis of service-specific needs. As operations became more and more integrated and cooperative (joint operations), both Congress and the military departments recognized the need for joint R&D programs and integrated procedures to improve joint operations and decrease logistical support burdens. This need has become more compelling as budgets have become more constrained and the cost of duplication of equipment has become unsupportable.

In the early 1990s, Congress began to encourage joint R&D programs. However, encouragement was not enough to overcome decades of independent activities (Nilo, 1999). Therefore, Congress passed Public Law

(PL) 103-160, the National Defense Authorization Act for Fiscal Year 1994 (Title XVII), which included the following stipulations (U.S. Congress, 1994):

- The CB defense program would be coordinated by a single DoD office that would oversee the program through the Defense Acquisition Board process.
- The CB defense program would have a coordinated/integrated budget.
- CB defense funds would be administered from DoD-level accounts.
- The Army would be the executive agent for coordination and integration of the CB defense program.

In order to meet the requirements of PL 103-160, a new structure, the Joint NBC¹ Defense Board, was established to provide oversight and management of DoD's NBC defense program (Figure 2-1). The NBC Defense Board's responsibilities include approval of (1) joint NBC requirements; (2) the Joint NBC Modernization Plan; (3) the consolidated NBC Defense Program Objective Memorandum (POM); (4) the Joint NBC Research, Development, and Acquisition (RDA) Plan; (5) joint training and doctrine initiatives; and (6) the Joint NBC Logistics Support Plan. The Joint NBC Defense Board Secretariat is responsible for management of program and acquisition strategies; planning, programming, budgeting, and execution of the program; and consolidation and integration of CB requirements and programs for all services.

Two subordinate groups support the Joint NBC Defense Board: the Joint Service Integration Group (JSIG) and the Joint Service Materiel Group (JSMG). The JSIG is responsible for joint NBC requirements, priorities, training, and doctrine. Thus, the JSIG develops a prioritized list of needs, requirements, and programs, which are based on commander-in-chief (CINC) priorities, threat projections, and analyses. A list of current, integrated CINC priorities, as well as the NBC Defense Program priorities can be found in Tables 2-1 and 2-2.

The priorities identified by the JSIG are inputs to the JSMG, which is responsible for the coordination, integration, planning, and programming of nonmedical RDA, science and technology, and logistics sustainment. Other responsibilities of the JSMG include preparation of the Joint Service NBC Defense RDA Plan, preparation of the Joint Service NBC Defense Logistics Support Plan, continuous review of the technology base, and reviews of developmental programs for possible NBC defense applications

¹Although the NBC defense program addresses nuclear, as well as chemical and biological threats, the National Academies was only asked to address chemical and biological threats. Thus, this report only includes the chemical and biological aspects of CB defense.

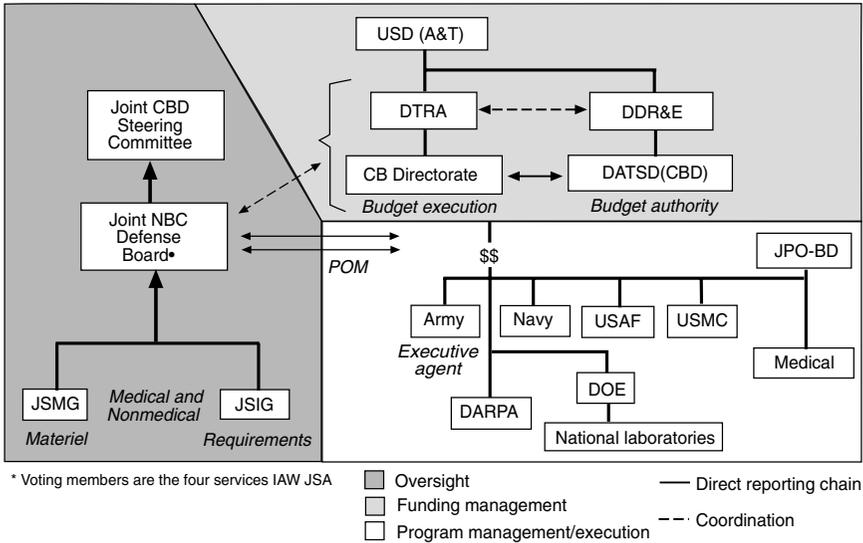


FIGURE 2-1 Management structure of the DoD Chemical and Biological Defense Program

Note: CBD = chemical/biological defense; DARPA = Defense Advanced Research Projects Agency; DATSD (CBD) = Deputy Assistant to the Secretary of Defense for Chemical/Biological Defense; DDR&E = Director, Defense Research and Engineering; DOE = U.S. Department of Energy; DTRA = Defense Threat Reduction Agency; IAW JSA = in accordance with the joint service agreement; JPO-BD = Joint Program Office for Biological Defense; JSIG = Joint Service Integration Group; JSMG = Joint Service Materiel Group; USAF = United States Air Force; USD(A&T) = Undersecretary of Defense (Acquisition and Technology); USMC = U.S. Marine Corps

Source: Nilo, 1999.

and/or impacts. The JSMG and the JSIG jointly prepare the consolidated NBC Defense POM strategy.

The services receive funding for NBC defense programs from the Office of the Secretary of Defense after having their inputs considered by the NBC Defense Board. Programmatic and other decisions are based on a formal voting process in which each member has one vote. The membership of each group (the NBC Defense Board, the JSIG, and the JSMG) consists of representatives of each of the services, the joint staff, the Defense Logistics Agency, the Joint Program Office for Biological Defense (JPO-BD), the Medical Research Materiel Command, and the Special Operations Command.

TABLE 2-1 Integrated CINC Priorities

1.	Intelligence
2.	Precision attack with no collateral damage
3.	Special operations forces counterterrorism
4.	NBC detection and warning
5.	Theater missile defense with no collateral damage
6.	Defeat underground targets
7.	Target planning and battle damage assessment
8.	Individual protection
9.	Proliferation pathway analysis
10.	Cruise missile DEF/ADA with no collateral damage
11.	Collective protection
12.	Defeat mobile target
13.	Offensive information warfare
14.	Logistics consequences capability
15.	Decontamination
16.	NBC medical treatment

Source: Nilo, 1999.

Execution of the RDA program under the JSMG is controlled by a group of five commodity area managers. Each service has been assigned lead responsibility for the commodity area most closely aligned with its expertise: contamination avoidance—Army; individual protection—Marine Corps; collective protection—Navy; decontamination—Air Force; medical protection—Medical Research Materiel Command. These commodity area managers are responsible for developing materiel that is usable in the field.

Discussions with personnel at the U.S. Army Chemical School, Soldier and Biological Chemical Command, JSMG, Deputy Chief of Staff for Operations, and outside contractors revealed general dissatisfaction with the prioritization process because service-specific projects were often given priority over projects based on multiservice needs through a process of political compromise and CINC priorities were largely ignored in the process (Blankenbiller, 1998; Nilo, 1999; U.S. Army SBCCOM, 1998). A comparison of CINC priorities (shown in Table 2-1) and program priorities (shown in Table 2-2) lends some credence to these complaints.

RELATIONSHIPS AMONG POLICY; DOCTRINE; RESEARCH, DEVELOPMENT AND ACQUISITION; AND THREAT

The intelligence community provides data, analysis, and advice on the development of CB capabilities of threat nations. Based on information about the types, quantities, and delivery systems of CB agents, CINCs and the JSIG evaluate the ways these agents could be used against U.S.

TABLE 2-2 Nuclear, Biological, Chemical (NBC) Nonmedical Defense Program Priorities

Priority	Area	Program
1	CA	Joint Biological Point Detection System
2	CA	Joint Biological Remote Early Warning System
3	CA	Joint Service Light NBC Reconnaissance System
4	BM	Joint Warning and Reporting Network
5	CA	Joint Service Lightweight Standoff Chemical Agent Detector
6	CA	Biological Integrated Detection Systems
7	CA	Chemical/Biological Mass Spectrometer
8	CA	Interim Biological Agent Detector
9	IP	Joint Lightweight Integrated Suit Technology (JLIST)
10	CA	Joint Chemical Agent Detector
11	IP	Aircrew Mask Programs
12	CA	NBC Reconnaissance System Product Improvement Program
13	CA	Automatic Chemical Agent Detector and Alarm
14	RES	Joint Service Fixed-Site Decontamination
15	CA	Long-Range Biological Stand-off Detection System
16	IP	Protection Assessment Test System
17	RES	Joint Service Sensitive Equipment Decontamination
18	IP	M40A1 Series Mask
19	CA	Special Operations Modular Chemical/Biological Detector
20	IP	Joint Service Aviation Mask
21	CA	Joint Service Warning and Identification LIDAR Detector
22	IP	Joint Protective Aircrew Chemical Ensemble
23	IP	Chemical Environment Survivability Suit
24	RES	Fixed-Site Decontamination Subitem: Joint Advanced Decontamination System
25	CP	Joint Transportable Collective Protection System
26	BM	Multipurpose Integrated Chemical Agent Alarm
27	CA	Shipboard Automatic Agent Detector
28	CA	Improved Chemical Agent Monitor
29	CP	Shipboard Collective Protective Equipment
30	CA	Improved Point Detection System
31	IP	Joint Service General Purpose Mask
32	CP	Joint Collective Protection Improvement Program
33	RES	Joint Lightweight Portable Decontamination System
34	CA	Joint Chemical/Biological Agent Water Monitor
35	RES	Lightweight Decontamination System
36	RES	Modular Decontamination System
37	RES	Sorbent Decontamination System
38	IP	Joint Canteen Refilling System
39	IP	Chemical Environment Survivability Mask
40	CA	Pocket RADIAC (Radioactivity, Detection, Indication, and Computation)
41	CP	Advanced Integrated Collective Protection System
42	CA	NBC Unmanned Ground Vehicle Sensor
43	CA	Stand-off RADIAC
44	CA	Advanced Airborne RADIAC System

CA = contamination avoidance; BM = battle space management; IP = individual protection (also known as personal protection); RES = restoration (decontamination); CP = collective protection

Source: Nilo, 1999.

troops. Their evaluation is then used to develop policy, doctrine, training, and equipment to counter the perceived threat. As the threat changes, approaches to countering the threat should also change.

The mission to protect forces from the effects of CB weapons has developed into a five-pronged approach. The thrust of current doctrine is to avoid contamination/exposure and to prevent adverse health effects. Three major elements of this approach (individual protection, collective protection, and decontamination) will be discussed in detail in subsequent sections of this report.²

Contamination Avoidance

Prior to deployment, the intelligence community provides up-to-date assessments of the potential threat of the use of CB agents to achieve military objectives. This assessment is critical to determining the types of detection equipment, protective equipment, and CB specialists that will be necessary for the deployment. State-of-the-art detector systems, both stand-off and local monitors, can identify potential threats in advance to enable commanders to avoid areas of contamination or to take protective measures to avoid exposures. Detectors can also be used to evaluate levels of contamination so commanders can select appropriate protection for their forces and minimize the length of time spent in protective clothing. The report of Task 2.2 assesses technologies and methods for detecting, tracking, and monitoring exposures of deployed U.S. forces to potentially harmful agents, including, chemical and biological agents and environmental contaminants (NRC, 1999b).

Individual Protection

Individuals can be protected by individual protective equipment (breathing masks with high-efficiency filters that selectively remove noxious agents, chemically treated clothing that can prevent agents from contacting the skin, and gloves and boot covers that are impervious to noxious agents) if they have been properly trained in rapidly donning the equipment and removing contaminated equipment safely, and if they receive adequate warning. Commanders need appropriate doctrine to establish the level of protection to minimize the risk to troops while allowing them to complete their mission.

²Contamination avoidance and medical systems are the subjects of separate detailed reports (IOM, 1999a; NRC, 1999b).

Collective Protection

Collective protection provides a contamination-free area (e.g., passenger compartments of military vehicles, shelters) for eating, rest, and relief from the constraints of individual protective equipment. It also provides a safe working environment for command and control functions and can be used for medical treatment of casualties in the CB environment.

Decontamination

Decontamination may be necessary for equipment and personnel before they can be returned to combat. Decontamination may also be necessary to restore mission-critical assets to operational status. Large-scale decontamination of major resources (e.g., airfields or buildings) may be necessary to support embarkation/debarkation phases of a deployment.

Medical Systems

Medical systems provide predeployment and postexposure treatment for CB-induced health problems and maintain records on health and exposures for deployed personnel. The development of antibodies, vaccines, and medical therapies is a critical part of the medical systems.

CHARACTERISTICS OF CURRENT AND FUTURE CHEMICAL AND BIOLOGICAL AGENTS

Effects and Tactical Utility of Chemical Agents

Chemical agents can be characterized as either lethal or nonlethal (incapacitating) (see Table 2-3); however, these distinctions have more to do with intent and use than with the composition of the agents because all agents are lethal in high concentrations. There are three classifications of lethal agents: nerve agents, choking agents, and blood agents.

Nerve agents inhibit acetylcholinesterase, an enzyme involved in the transmission of nerve impulses. Inhibition of this enzyme results in continuous stimulation of the nervous system. Nerve agents act more quickly and are more lethal than other chemical agents. They can be absorbed through the skin, the eyes, or the respiratory tract. Symptoms include runny nose, tightness in the chest, impaired vision, pinpointing of the pupils, difficulty in breathing, excessive salivation and drooling, nausea, vomiting, cramps, involuntary twitching, loss of bowel and bladder control, headache, confusion, drowsiness, coma, and eventually death.

Choking agents, which are primarily taken in via the respiratory tract,

TABLE 2-3 Categorization of Chemical Agents

Type	Examples
Lethal Chemical Agents	
Blood agents	hydrogen cyanide, cyanogen chloride, arsine
Choking agents	phosgene, diphosgene, chlorine
Nerve agents	tabun, sarin, soman, GF, VX
Incapacitating Chemical Agents	
Blister agents (vesicants)	Levinstein mustard, distilled mustard, nitrogen mustard, mustard-t mixture, lewisite, mustard-lewisite mixture, phenyldichloroarsine, ethyldichloroarsine, methyldichloroarsine, phosgene oxime
Lacrimator agents	bromobenzylcyanide, chloroacetophenone, CNC, o-chlorobenzylidene malononitrile, dibenz-(b,f)-1,4-oxazepine, chloropicrin
Sternutator agents	diphenylchloroarsine, diphenylcyanoarsine, adamsite

are strong irritants that attack lung tissues causing membranes to swell and become "leaky." The lung can then fill with fluid, and death can result from pulmonary edema. Acute nonlethal exposures to choking agents can result in chronic lung disease.

Blood agents are primarily absorbed via the respiratory tract. They inhibit the enzyme cytochrome oxidase or combine with hemoglobin to prevent the normal transfer of oxygen from the blood to body tissues. Exposure to these agents causes seizures due to lack of oxygenation.

Agents classified as nonlethal or incapacitating include vesicants, lacrimators, and sternutators. Vesicants, or blister agents, which affect the eyes and lungs and blister the skin, are often lethal if ingested or absorbed through the lungs. Lacrimators cause tearing and irritate the skin and respiratory tract. Sternutators cause coughing, nausea, and vomiting.

An agent's tactical utility is partly determined by its physical properties including: (1) whether the agent is effective in the short or long term (persistence of the agent in the environment); (2) whether the agent can be targeted to a specific area or is affected by wind and weather conditions; (3) whether the agent presents an inhalation or percutaneous threat, or both; (4) whether the agent is stable during dissemination; and (5) other physical and chemical factors.

Agents are often characterized as persistent (lasting longer than 24 hours as a hazard) or nonpersistent (lasting less than 24 hours as a hazard). Ordinarily, persistent agents are disseminated as liquids, and nonpersistent agents are disseminated as gases. However, most agents, through the use of additives, can be made persistent or nonpersistent.

The actual use of CB weapons may not be necessary because the threat of CB weapons may result in troops taking defensive measures. Forces threatened by CB weapons will be burdened by the need to transport protective gear and decontamination equipment, and the effectiveness of fighting units can be diminished if personnel are forced to operate in protective gear. The threat of CB weapons will also increase the psychological burden of personnel.

Effects and Tactical Utility of Biological Agents

Biological agents can be classified into three main groups: pathogenic microorganisms, viruses, and toxins. The first two groups are living, self-replicating organisms; however, viruses only self-replicate in a host. Toxins are poisons (nonliving) produced by bacteria, plants, or fungi. Table 2-4 gives examples for each category of biological warfare agents.

Pathogenic microorganisms can be classified as protozoa, fungi, bacteria, and rickettsia. Protozoa are one-celled organisms that are motile. Fungi are organisms that do not use photosynthesis, are capable of anaerobic growth, and draw nutrition from decaying vegetable matter. Most fungi form spores.

Because bacteria are much better understood than other biological agents, they are the most likely type of biological warfare agents (Ali et al., 1997). Bacteria are small free-living organisms, most of which can be grown on a solid or in a liquid culture. Bacterial structures consist of nuclear material, cytoplasm, and cell membranes. They vary in shape and size from spherical cells and cocci (with a diameter of 0.5 to 1.0 microns) to bacilli (with a diameter of 1.0 to 5.0 microns). In response to changes in their environment, some types of bacteria can change into spores, which are more resistant to cold, heat, drying, chemicals, and radiation, than bacteria themselves. Diseases caused by bacteria often respond to treatment with antibiotics.

Viruses vary in size from 0.02 to 0.2 microns and must be cultivated in living cells in order to multiply. Rickettsiae have characteristics common to both bacteria and viruses. They resemble bacteria in that they possess metabolic enzymes and cell membranes, utilize oxygen, and are susceptible to antibiotics. They are similar to viruses in that they only grow in living cells.

TABLE 2-4 Categorization of Biological Agents

Type	Examples
Pathogenic Biological Agents	
Protozoa	malaria
Bacteria	<i>Bacillus anthracis</i> , <i>Yersinia pestis</i> , <i>Francisella tularensis</i> , <i>Shigella dysenteriae</i> , <i>Vibrio comma</i> , <i>Brucella suis</i> , <i>Salmonella typhimurium</i> , <i>Shigella dysenteriae</i>
Rickettsiae	<i>Coxiella burneti</i> , <i>Rickettsia rickettsia</i>
Fungi	coccidioides immitis
Viruses	smallpox, Venezuelan equine encephalitis, yellow fever, Rift Valley fever
Toxins	
Bacterial toxins	botulinum toxin, <i>Clostridium perfringens</i> toxin, staphylococcus enterotoxin B
Plant toxins	ricin
Fungal toxins	T-2 mycotoxins

There are three classifications of toxins: plant toxins, bacterial toxins, and fungal toxins. Plant toxins, poisons that are naturally produced by plants, are easy to acquire in large quantities at minimal cost in a low-technology environment. Bacterial toxins, poisons that are naturally produced through the metabolic activities of bacteria, are harder to produce on a large scale than plant toxins, but they are many times more toxic. Fungal toxins, which are produced by various species of fungi, are much less toxic than bacterial and plant toxins in vapor form, but unlike the other toxins they are dermally active.

The tactical utility of biological agents depends on their robustness, their dissemination characteristics, their persistence (see Box 2-1), their ability to multiply and cause infections, and other factors. There are effective means for protection (e.g., antibodies and vaccines) against some biological warfare agents; however, nations that do not adhere to the BWC and CWC are constantly attempting to modify agents to defeat conventional defenses.

BOX 2-1 Persistence of Biological Agents

Anthrax. Spores are very stable but will be destroyed in a matter of hours by sunlight. The vegetative form is very unstable. Spores remain alive in soil and water for many years. Spores can be killed by dry heat at >284°F for one hour, boiling contaminated items in water for 30 minutes or more, or by treating with heat or certain acids (i.e., perchloric acid) or alkalies (i.e., sodium hypochlorite).

***Yersinia pestis* (plague).** Not very hearty once released into the environment but stable and viable in water from 2–30 days and in moist soil for about two weeks. At near freezing temperatures, it will remain alive for years. It can be killed by exposure to heat at 130°F for 15 minutes, steam, three to five hours in sunlight, Lysol, or lime.

***Francisella tularensis* (tularemia).** Not extremely stable when released into the environment but remains viable for weeks in water, soil, carcasses, fur, and hides. In the frozen state, it is viable for years. It can be killed by heat at 113°F for a few minutes or by 0.5 percent phenol in 15 minutes.

***Shigella dysenteriae* (dysentery).** Viable for a considerable period in water, ice, and mucous membranes but can be killed by sunlight, steam sterilization, and common disinfectants.

***Coxiella burnetii* (Q fever).** Very stable and can remain active on surfaces for up to 60 days or in soils for months. It can be killed by 0.5 percent formalin.

***Vibrio comma* (cholera).** Will not remain viable in pure water and is unstable in aerosols but will survive up to 24 hours in raw sewage and six weeks in certain types of impure water containing salt and organic matter. Can be killed by drying.

***Rickettsia rickettsia* (Rocky Mountain spotted fever).** Can be killed by exposure to a temperature of 112°F for 10 minutes and by drying for 10 hours. Is deactivated by 0.1 percent formalin or 0.5 percent phenol.

***Brucella suis* (brucellosis).** Will remain alive for weeks in water, unpasteurized dairy products, and soil, but does not survive long when airborne. Common methods of sterilization or disinfection will kill the organism.

PROLIFERATION OF CHEMICAL AND BIOLOGICAL AGENTS

Both open literature and intelligence assessments indicate that many nations are attempting to develop chemical, and possibly biological, weapons. Although the number of countries that possess CB capabilities is troubling, intelligence assessments also indicate that most of these countries have limited quantities of agents and limited delivery systems. Estimates also indicate that most proliferant countries have neither the industrial infrastructure nor the military logistics capabilities to produce chemical weapons in sufficient quantity to pose an extensive threat to

Salmonella typhimurium. Stable for up to two weeks in water, up to three months in ice and snow, and one to two months in feces. Exposure to heat at 132°F for 20 minutes or exposure for five minutes to 5 percent phenol or bichloride of mercury will kill it.

Smallpox. Highly stable and retains its infectivity for long periods outside the host. Decontamination can be accomplished by exposure of the organism to alcohol and acetone for one hour at room temperature or by exposure to chlorine. Moist heat above 140°F and dry heat above 212°F will also decontaminate the organism.

Venezuelan equine encephalitis. Relatively unstable. Standard decontaminants and methods will sterilize the agent.

Yellow fever. Relatively unstable.

Botulism. Nonpersistent and stable for 12 hours in air, seven days in solution when protected from light and heat, and longer in food not exposed to air. Boiling for 15 minutes or cooking food for 30 minutes at 175°F destroys it.

Staphylococcus enterotoxin B. Nonpersistent but stable in heat and acid and alkali solutions. Resistant to freezing and boiling for 30 minutes. The organism that develops the toxin remains viable after 67 days of refrigeration. Formaldehyde detoxifies it.

Clostridium perfringens. Purified toxin is relatively unstable and very sensitive to heat.

Ricin. Persistent and stable in water or dilute acid. Weak hypochlorite solutions, chlorine, or soap and water will sterilize the organism.

Sources: U.S. Army et al., 1990; U.S. Army, 1995; U.S. Air Force, 1997; Boyle, 1998a.

troops with adequate protective capabilities. These countries are, however, capable of producing chemical weapons that can threaten unprotected or minimally protected forces and fixed sites, can be used in terrorist operations, or can be used as deterrents (Commission to Assess the Organization of the Federal Government to Combat the Proliferation of Weapons of Mass Destruction, 1999). Current assessments also indicate that these nations are not likely to possess novel chemical agents or to have weaponized biological agents. Thus, current U.S. protective approaches are likely to be effective.

Intelligence reports suggest that several agents may be in the process

of development or weaponization in various countries. With recent advances in biomolecular engineering methods, existing pathogens can be modified to increase their toxicity or to defeat available defensive measures (i.e., vaccines). In fact, biomolecular engineering methods can also be used to modify (i.e., mutate) nonpathogenic organisms into disease-causing agents, thus increasing the potential of biological warfare threats. Because of the rapid developments in molecular biology, the spectrum of biological agents will continue to change, and protective measures will have to be continuously adjusted. Although a detailed review of these developments is beyond the scope of this study (for more information see Ali et al., 1997; DoD, 1996; Rose, In press), they should be kept in mind because they greatly complicate contamination avoidance.

Thickened and dusty agents have been areas of intense research, but the capacity for weaponizing these agents is, as yet, limited. New stabilizing agents have been developed that increase the persistence of a chemical agent and impede decontamination under some conditions. These stabilizers can allow degradation products to recombine into toxic forms at a later time, increasing their potential to affect areas contacted by runoff from decontamination (Ali et al., 1997).

The descriptions of threats posed by proliferant nations sharply contrast the descriptions for the former Soviet Union. Most proliferant countries do not have the research or industrial base to build a large-scale military capability that could threaten deployed U.S. forces, much less the logistical infrastructure to maintain a battlefield capability. However, the threat description on which U.S. requirements are based has changed very little (Eck, 1998).

PRODUCTION, WEAPONIZATION, AND DISPERSION

Military organizations worldwide have been working on the weaponization of CB agents. Chemical agents engineered for stability can be delivered from spray tanks, artillery shells, or missile warheads. They can also be introduced directly into food supplies, water supplies, and air-handling systems. Ordinarily, biological agents are much more environmentally sensitive than chemical agents and lose their effectiveness quickly when exposed to the atmosphere, and spreading most biological warfare agents from one infected individual to another (with the exception of smallpox) is difficult. The weaponization of biological agents can also be much more difficult than the weaponization of chemical agents (anthrax spores are an obvious exception).

The weaponization of chemical agents, thus far, has been limited to known delivery systems; and current proliferant nations are not likely to have delivery capabilities equal to the capability of the Soviet Union dur-

ing the Cold War. Thus, even if chemical agents are transferred from a producing country to a nonproducing proliferant nation, the probability of transferring sufficient quantities to threaten massed U.S. forces is low. However, many countries could deploy sufficient amounts of CB weapons to threaten fixed sites and small units (Chow et al., 1998).

THREATENED USE OF CHEMICAL AND BIOLOGICAL WEAPONS

Proliferant nations could use CB weapons for several purposes: battlefield use against neighboring countries with similar military capabilities; battlefield use against U.S. or other asymmetrically powerful forces; as a weapon of terror; or as a means of changing public opinion. Because of logistical limitations and U.S. capabilities, widespread battlefield use against U.S. forces by nations currently known to have CB capabilities seems unlikely. However, the use of CB agents against neighboring countries or as a terrorist weapon against U.S. forces (especially forces occupying fixed sites) or U.S. peacekeeping teams is a legitimate threat.

Understanding the conditions under which an enemy might use CB weapons is central to the U.S. response. Adversaries in regional conflicts may have very different ideas than Cold War adversaries. For example, they may use CB weapons early in a conflict for political and psychological, as well as military, purposes (Joseph, 1996).

ASSESSMENT OF CHEMICAL AND BIOLOGICAL WARFARE RISKS

The threat to U.S. forces can be defined as the capability attributed to an opposing force. The risk for U.S. forces is determined through an analysis of the potential interactions of opposing forces. The decision to assume a protective posture is based on several factors, which are parallel to factors in other areas of risk assessment/risk management. The first stage in any risk assessment is hazard identification. In the context of this study, hazard identification requires evaluating the biomedical effects of individual agents on humans. The next stage is threat assessment, which requires determining the capability of an opponent to mount a CB attack and assessing the opponent's intent. The last step is to assess the probability of exposure for deployed forces and assess their ability to protect themselves. Having assessed the risk, one can then develop an approach to managing that risk.

Hazards: Routes and Levels of Exposure

Agents do not pose a hazard to humans until they are introduced into the body through the respiratory tract, the gastrointestinal tract, the mucous membranes, or the skin. The routes of effective exposure for various agents are described in the following Tables 2-5 through 2-11.

Effects of Chemical Agents

Inhalation/Respiratory Agents. Chemical agents that present inhalation/respiratory hazards are delivered as vapors or aerosols. An aerosol is defined as a particle (either liquid or solid) suspended in a gas (air). The particles in an aerosol, over time, will be removed from the air and deposited on the ground, on equipment, or on personnel by gravity, inertial impaction, or diffusion. The duration of time a particle can remain airborne and the distance a particle can travel depend on wind, humidity, particle size, and the height at which the particle is introduced into the air.

Vapors can form mixtures with air and can travel over great distances. Because vapors diffuse readily into the air, their concentration tends to decrease over time. Vapors can be removed from the air by diffusion to solid or liquid surfaces or by incorporation on, or in, airborne particles. The effects of inhaled agents are generally proportional to the amount inhaled (dose). For the purposes of this discussion, the effects are considered to be cumulative (a reasonable assumption because these agents are acutely toxic and exert their effects over relatively short time intervals). The dosages are presented in terms of concentration \times time (Ct). Thus, an exposure to an agent at a concentration of 30 mg/m^3 for a period of 60 minutes would produce a dose of $1,800 \text{ mg-min/m}^3$ (see Table 2-5). The dose that was incapacitating to 50 percent of a given population (ID_{50}), the Ct dose that was incapacitating to 50 percent of a given population (ICt_{50}), and the Ct dose that caused the defined effect (e.g., edema or death) in 50 percent of a given population (ECt_{50}) are presented in units of mg-min/m^3 .

Dermal Absorption Agents. Agents that are delivered as liquids or droplet aerosols can be absorbed through the skin (percutaneous absorption). Most of the nerve agents in liquid or vapor phase and many of the vesicants can be absorbed percutaneously. Thus, many chemical agents can present a hazard even if personnel are wearing respirators. Chemical agents that can be taken up percutaneously are described in Table 2-6.

Dermal Necrotic Agents. Blister agents can kill or destroy skin cells causing severe chemical burns. Lewisite causes painful injuries almost immediately

upon exposure. Sulfur and nitrogen mustards have a delayed reaction and, therefore, have more insidious effects that may not occur for hours after exposure. The actual delay depends on the intensity of exposure and the area of skin exposed. Dermal necrotic agents are summarized in Table 2-7.

Ocular Agents. Many agents that cause inhalation/respiratory effects are also toxic to the eye, especially vesicant agents, such as sulfur mustard (HD). Available data indicate that temporary blindness could be produced by HD vapor exposures of 200 mg-min/m³. Both GD and GB are known to have ocular effects, but the data are insufficient to establish an ECt_{50} (although GD is 2.5 times more potent as a meiotic agent than GB). The data on ocular effects are included in Tables 2-6 and 2-7.

Ingestion/Gastrointestinal Agents. Both food and water sources can become contaminated during an attack, but very little data are available on the effects after ingestion by humans, and information on animal models is spotty at best. At the present time, few methods are available for the rapid detection of chemical agents in either food or water. Toxic effects following ingestion will probably be similar to those after inhalation or percutaneous absorption.

Effects of Biological Agents

Inhalation/Respiratory Agents. Biological agents can be dispersed as aerosols and inhaled. The number of organisms or spores that represent an effective dose for agents known to be distributed in airborne form are summarized in Table 2-8 along with the expected effects and approximate time of onset of effects. The intensity of the exposure could alter the effect and the time to onset.

Ingestion/Gastrointestinal Agents. Biological agents can be ingested by hand-to-mouth activities or by the consumption of contaminated food or water. The contamination of foodstuffs can be deliberate or can occur as the result of environmental contamination from a more general attack using airborne agents. Information on ingestion and gastrointestinal agents is summarized in Table 2-9.

Percutaneous/Mucous Membrane Agents. The eyes are poorly defended both physically and physiologically and therefore represent a potential route of entry for pathogens. Other mucous membranes are also vulnerable to many agents. The biological agents associated with percutaneous and mucous membrane absorption are listed in Table 2-10.

TABLE 2-5 Inhalation/Respiratory Agents

Agent	Mode of Delivery	Effect
Phosgene	Vapor	Causes fluid buildup in the lungs that can cause drowning
Diphosgene	Vapor	Causes fluid buildup in the lungs that can cause drowning
Tabun	Vapor	Cessation of breath
Sarin	Vapor	Incapacitation; cessation of breath
Soman	Vapor	Incapacitation; cessation of breath
GF	Vapor	Incapacitation; cessation of breath
VX	Vapor	Incapacitation; cessation of breath
Hydrogen cyanide	Vapor	Interferes with the body's utilization of oxygen; accelerates rate of breathing

Effective Dose (mg-min/m ³ except where otherwise noted)	Rate of Action
$ICt_{50} = 1,600$	Delayed, although immediate irritation in high concentrations At low concentrations, no effects for three hours or more
$ICt_{50} = 1,600$ (at rest)	Delayed, although immediate irritation in high concentrations At low concentrations, no effects for three hours or more
$ICt_{50} = 300$ (at rest) Ect_{50} = no existing estimates Ect_{50} = no existing estimates (severe effects) ^a $Ect_{50} = 0.9$ (mild effects) ^a $Ect_{50} = 2-3$ ^b	Very rapid
$ICt_{50} = 75$ (at rest); 35 (mildly active) Ect_{50} = no existing estimates (threshold) ^a $Ect_{50} = 35$ (severe effects) ^a $Ect_{50} = 2$ (mild effects) ^a $Ect_{50} = 3$ ^b	Very rapid
$ICt_{50} = 75-300$ (at rest) Ect_{50} = no existing estimates (threshold) ^a $Ect_{50} = 35$ (severe effects) ^a Ect_{50} = no existing estimates (mild effects) ^a $Ect_{50} = 1-2$ ^b	Very rapid
Ect_{50} = no existing estimates (threshold) Ect_{50} = no existing estimates (severe effects) Ect_{50} = no existing estimates (mild effects)	Very rapid
$ICt_{50} = 50$ (at rest); 24 (mildly active) Ect_{50} = no existing estimates (threshold) ^a $Ect_{50} = 25$ (severe effects) ^a $Ect_{50} = 0.09$ (mild effects) ^a $Ect_{50} = 1-2$ ^b	Very rapid
ICt_{50} varies with concentration $Ect_{50} = \sim 1,500$	Very rapid; incapacitation can occur within 1 to 2 minutes of exposure to an incapacitating or lethal dose, and death can occur within 15 minutes of receiving a lethal dose

TABLE 2-5 Inhalation/Respiratory Agents (continued)

Agent	Mode of Delivery	Effect
Cyanogen chloride	Vapor	Choking, irritation, slows breathing
Arsine	Vapor	Damages blood, liver, and kidneys
Distilled mustard	Vapor	Inflammation of the nose, throat, trachea, bronchi, and lungs
Nitrogen mustard	Vapor	Incapacitation
Mustard-T mixture	Vapor	Incapacitation
Lewisite	Vapor	Incapacitation
Mustard-lewisite mixture	Vapor	Incapacitation
Phenyldichloroarsine	Vapor	Incapacitation
Ethyldichloroarsine	Vapor	Incapacitation
Methyldichloroarsine	Vapor	Incapacitation
Phosgene oxime	Vapor	Coughing, choking, chest tightness on exposure; possible cyanosis following pulmonary edema

^aNATO, 1996a; NRC, 1997a.^bAli et al., 1997.^cExposure via this route is unlikely; no information was found.

Sources: Boyle, 1998b; U.S. Army, 1995; U.S. Army et al., 1990.

Effective Dose (mg-min/m ³ except where otherwise noted)	Rate of Action
$ICt_{50} = 7,000$	Very rapid
$ICt_{50} = 2,500$	Effects delayed from 2 hours to 11 days
$ICt_{50} = 150$ $ECt_{50} =$ no existing estimates (threshold) ^a $ECt_{50} = 200$ (moderate temperature, severe effects) ^a $ECt_{50} = >50$ (mild effects) ^a $ECt_{50} = 10-1,000$ ^b	Effects delayed for 4 to 6 hours
N/A ^c	Effects delayed for ~12 hours
N/A ^c	Delayed action not well known
$ECt_{50} = 1,500$	Rapid acting
N/A ^c	Rapid acting skin irritation, blisters in 13 hours
N/A ^c	Rapid acting
$ICt_{50} = 5-10$	Rapid acting nose/throat irritation, blisters in 12 hours
$ICt_{50} = 25$	Rapid acting nose/throat irritation, blisters in several hours
$ICt_{50} =$ unknown; lowest irritant concentration after a 10 second exposure is 1 mg/m ³ ; effects of the agent become unbearable after one minute at 3 mg/m ³	Rapid acting

TABLE 2-6 Dermal Absorption Agents

Agent	Mode of Delivery	Effect
Tabun (GA)	Liquid; vapor	N/A ^a
Sarin (GB)	Liquid	N/A ^a
Soman (GD)	Liquid	N/A ^a
GF	Liquid	N/A ^a
VX	Liquid	N/A ^a
Distilled mustard	Liquid	Inflammation of the nose, throat, trachea, bronchi, and lungs
Nitrogen mustard	Liquid	Incapacitation
Mustard-T mixture	Liquid	Incapacitation
Lewisite	Liquid	Incapacitation
Mustard-lewisite mixture	Liquid	Incapacitation
Phenyldichloroarsine	Liquid	Incapacitation
Ethylchloroarsine	Liquid	Incapacitation
Methylchloroarsine	Liquid	Incapacitation

^aUnlikely exposure via this route; no information found.

^bAli et al., 1997.

^cNRC, 1997a.

Sources: Boyle, 1998b; NATO, 1996a; U.S. Army, 1995; U.S. Army et al., 1990.

Effective Dose (mg-min/m ³ except where otherwise noted)	Rate of Action
ED_{50} = no existing estimates	Very rapid
ED_{50} = no existing estimates	Very rapid; may be lethal within 15 minutes of absorption
ED_{50} = no existing estimates	Very rapid; may be lethal within 15 minutes of absorption
ED_{50} = no existing estimates	Very rapid
ED_{50} = 5 mg/70-kg man ^b ED_{50} = 1 mg ^c	Very rapid; may be lethal within 15 minutes of absorption
ID_{50} = 2,000 by skin; 200 by eye ED_{50} = no existing estimates ^b ED_{50} = 10 Tg ^c	Effects delayed for 4 to 6 hours
ID_{50} = 200 by eye; 9,000 by skin	Effects delayed for ~12 hours
ID_{50} = very low	Delayed action not well known
ID_{50} = less than 300 by eye; more than 1,500 by skin ED_{50} = 15 Tg	Rapid acting
ID_{50} = 200 by eye; 1,500–2,000 by skin	Rapid acting skin irritation; blisters in 13 hours
ID_{50} = 16 as vomiting agent; 1,800 as blister	Rapid acting
N/A ^a	Rapid acting nose/throat irritation; blisters in 12 hours
N/A ^a	Rapid acting nose/throat irritation; blisters in several hours

TABLE 2-7 Dermal Necrotic Agents

Agent	Mode of Delivery	Effect
Distilled mustard	Liquid	Incapacitation
Nitrogen mustard	Liquid	Incapacitation
Mustard-T mixture	Liquid	Incapacitation
Mustard-lewisite mixture	Liquid	Incapacitation

^a NATO, 1996a; NRC, 1997a.

^b Ali et al., 1997.

Sources: Boyle, 1998b; U.S. Army, 1995; U.S. Army et al., 1990.

TABLE 2-8 Inhalation/Respiratory Agents

Agent	Mode of Delivery
Anthrax (<i>Bacillus anthracis</i>)	Aerosol
Plague (<i>Yersinia pestis</i>)	Aerosol
Tularemia (<i>Francisella tularensis</i>)	Aerosol
Q fever (<i>Coxiella burnetii</i>)	Aerosol
Smallpox	Aerosol
Venezuelan equine encephalitis	Aerosol
Dysentery (<i>Shigella dysenteriae</i>)	Aerosol
Cholera (<i>Vibrio comma</i>)	Aerosol
Brucellosis (<i>Brucella suis</i>)	Aerosol

Sources: Ali et al., 1997; Boyle, 1998a; U.S. Air Force, 1997; U.S. Army et al., 1990.

Effective Dose	Rate of Action
ID_{50} = 2,000 by skin; 200 by eye ED_{50} = no existing estimates ^a ED_{50} = 10 μ g ^b	Effects delayed for 4 to 6 hours
ID_{50} = 200 by eye; 9,000 by skin	Effects delayed for ~12 hours
ID_{50} = very low	Delayed action not well known
ID_{50} = 200 by eye; 1,500–2,000 by skin	Rapid acting skin irritation; blisters in 13 hours

Effect	Effective Dose	Onset Time (days)
75% morbidity; 80% mortality	8,000–50,000 spores	1–5
	100–500 organisms	2–3
80% morbidity; 35% mortality	10–50 organisms	2–3
70% morbidity; <1% mortality	1–10 organisms	14–21
30–35% mortality	10–100 organisms	12
90% morbidity; <5% mortality	10–100 organisms	1–5
25% mortality	10–100 organisms	1–7
15–90% mortality	1,000,000 organisms	1–5
2% fatality	10–100 organisms	5–21

TABLE 2-9 Ingestion Agents

Agent	Mode of Delivery
Anthrax (<i>Bacillus anthracis</i>)	Ingestion
Cholera (<i>Vibrio comma</i>)	Ingestion
Dysentery (<i>Shigella dysenteriae</i>)	Ingestion
Q Fever (<i>Coxiella burnetii</i>)	Ingestion
Tularemia (<i>Francisella tularensis</i>)	Ingestion

^aInformation, if known, was not readily available during the course of the study.

Sources: Ali et al., 1997; Boyle, 1998a; U.S. Air Force, 1997; U.S. Army et al., 1990.

TABLE 2-10 Agents Absorbed via Mucous Membranes or the Skin

Agent	Mode of Delivery
Anthrax (<i>Bacillus anthracis</i>)	Direct contact with contaminated material
Tularemia (<i>Francisella tularensis</i>)	Inoculation of skin or mucous membranes with blood or tissue fluids of infected animals
Brucellosis (<i>Brucella suis</i>)	Through abraded and possibly intact skin
Ebola/Marburg	Through abrasion or via conjunctiva; possibly direct contact with blood or other tissues
Crimean-Congo hemorrhagic fever	Direct contact with animal or human tissues and blood

^aInformation, if known, was not readily available during the course of the study.

Sources: Ali et al., 1997; Boyle, 1998a; Johnson, 1990; LeDuc, 1989; Mikolich and Boyce, 1990; U.S. Air Force, 1997; U.S. Army et al., 1990.

Effect	Effective Dose	Onset Time (days)
75% morbidity; 80% mortality	1,000 spores	1-7
15-90% mortality	$>10^7$ organisms	1-5
25% mortality	10-100 organisms	1-7
70% morbidity; <1% mortality	1-10 organisms	14-21
80% morbidity; 35% mortality rate	N/A ^a	2-3

Effect	Effective Dose	Onset Time
25% mortality	N/A ^a	N/A ^a
80% morbidity; 35% mortality rate	10-50 organisms	N/A ^a
N/A ^a	N/A ^a	N/A ^a
N/A ^a	N/A ^a	N/A ^a
N/A ^a	N/A ^a	N/A ^a

Arthropod Vectors. Several threat agents can be carried by arthropods (e.g., flies, fleas, ticks, and mosquitoes). The agent is most often delivered by the insect's "bite," but other modes of contamination are possible. The number of agent organisms that represent an effective dose delivered by an arthropod and the effects and times of onset are shown in Table 2-11.

Threat Assessment

Threat assessments should be made for each type of conflict and every military operation. (See NRC report [1999c] for a framework for assessing risks to deployed forces in hostile environments.) Each level of military conflict or operation poses different challenges in terms of potential CB use and, therefore, different risks to deployed forces. Military operations range from major regional conflicts involving large numbers of personnel to policing and peacekeeping operations that involve small units. Therefore, commanders must have accurate, timely intelligence on the possible locations, quantities, and types of CB agents, as well as a knowledgeable CB advisor.

TABLE 2-11 Arthropod Vectors

Agent	Mode of Delivery
Plague (<i>Yersinia pestis</i>)	Fleas
Tularemia (<i>Francisella tularensis</i>)	Bites of infected deerflies, mosquitoes, or ticks
Rocky Mountain spotted fever (<i>Rickettsia rickettsi</i>)	Ticks
Yellow fever	Ticks
Rift Valley fever	Mosquitoes
Venezuelan equine encephalitis	Variety of mosquitoes
Crimean-Congo hemorrhagic fever	Ticks

^aInformation, if known, was not readily available during the course of the study. Sources: Ali et al., 1997; Boyle, 1998a; LeDuc, 1989; U.S. Air Force, 1997; U.S. Army et al., 1990.

RISK MINIMIZATION/PROTECTION OF PERSONNEL

The most obvious way to minimize risk from exposure to CB agents is to avoid contact with these materials. The military has developed a four-part strategy for protecting deployed forces based on avoiding exposure: sensing, shaping, shielding, and sustaining. Sensing the NBC conditions throughout the joint battle space is accomplished by means of surveillance, detection, identification, monitoring, and reconnaissance. Shaping includes situation awareness of the battle space and managing, assessing, and recording threats (see the Task 2.2 report [NRC, 1999b]). Shielding joint and coalition forces includes medical pretreatment, personal protective equipment (PPE) and collective protective equipment (CPE). Sustaining the force after NBC attacks includes medical treatment and decontamination.

Avoiding contact depends on the capability and availability of detection equipment. Because the lag in detection time of our present capabilities (10 to 15 minutes) is longer than the time it takes to don protective equipment (Table 2-12), (NRC, 1999b), our current capability has been

Effect	Effective Dose	Onset Time (days)
25–100% mortality	1–10 ³ organisms	2–7
80% morbidity; 35% mortality	1–10 ³ organisms	1–10
7–20% fatal	N/A ^a	3–10
< 5% mortality	N/A ^a	3–6
< 1% mortality	N/A ^a	3–12
90% morbidity; <5% mortality	1–10 ³ organisms	4–20
N/A ^a	N/A ^a	N/A ^a

TABLE 2-12 Time to Achieve MOPP 4

	MOPP LEVELS				
	MOPP0	MOPP 1	MOPP 2	MOPP 3	MOPP 4
Overgarment	Available	Worn	Worn	Worn	Worn
Boots	Available	Available	Worn	Worn	Worn
Mask	Carried	Carried	Carried	Worn	Worn
Gloves	Carried	Carried	Carried	Carried	Worn
Time to MOPP 4 (min)	8	4	0.5	0.25	0

called “detect to treat” (Cain, 1999). A preventive, rather than responsive, posture would be advantageous, of course, but this will require better detection capability.

In 1998, seven joint CB future operational capabilities (FOCs) (i.e., operational capabilities required to develop warfighting concepts to guide military and industrial R&D) were identified (Payne, 1998). One FOC focuses on the need for detecting and identifying prelaunch indicators, launch signatures, flight paths, and release or impact point(s) of theater missiles, including the ability to distinguish between conventional and NBC munitions. The detection system must provide early and selective warning and must be compatible with the current and future joint command, control, communications, computer, and intelligence (C4I) structure; warning and reporting systems; and NBC battle management systems. Because the FOC is far beyond present detection technologies, personnel must be protected by the combined use of PPE, CPE, and medical protective services.

The military approach to individual protection is embodied in the concept called Mission Oriented Protective Posture (MOPP), an ensemble of protective garments, boots, masks, and gloves. MOPP-Ready status is defined as having protective garments available; MOPP 4 status is defined as all components of the protective ensemble being worn. The progression is shown in Table 2-13.

CB battlefield exigencies may require collective protection, a place for medical treatment of casualties and the removal of MOPP gear for eating and recovery periods. Therefore, protective shelters have been developed based on filtering and overpressurization technologies. If individuals or

TABLE 2-13 Levels of Mission-Oriented Protective Posture (MOPP)

MOPP Ready	Soldiers carry protective masks with their load-carrying equipment. The soldier's MOPP gear is labeled and stored no further back than the battalion support area and is ready to be brought forward to the soldier when needed. The time necessary to bring the MOPP gear forward will not exceed two hours. A second set of MOPP gear is available within six hours. Units at MOPP-Ready are highly vulnerable to attacks with persistent agents and will automatically upgrade to MOPP-Zero when they determine, or are notified, that chemical weapons have been used or that the threat of chemical weapons has arisen. When a unit is at MOPP-Ready, soldiers will have field-expedient items identified for use.
MOPP 0	Soldiers carry protective masks with their load-carrying equipment. The standard battledress overgarment and other individual protective equipment that make up the soldier's MOPP gear are readily available (i.e., equipment is either carried by each soldier or stored within arm's reach [e.g., within the work area, vehicle, or fighting position]). Units at MOPP Zero are highly vulnerable to attacks with persistent agents and will automatically upgrade to MOPP 1 when they determine, or are notified, that persistent chemical weapons have been used or that the threat of chemical weapons has arisen.
MOPP 1	When directed to MOPP 1, soldiers immediately don battledress overgarments. In hot weather, the overgarment jacket may be unbuttoned and the battledress overgarment may be worn directly over the underwear. M9 or M8 chemical detection paper is attached to the overgarment. MOPP 1 provides a great deal of protection against persistent agents. The level is automatically assumed when chemical weapons have been used in an area of operations or when directed by higher command.
MOPP 2	Soldiers put on chemical protective footwear covers, green vinyl overboots, or a field-expedient item (e.g., vapor-barrier boots), and the protective helmet cover. The overgarment jacket may be left unbuttoned, but the trousers remain closed.
MOPP 3	Soldiers wear protective masks and hoods. Flexibility is built into the system to allow the soldier relief at MOPP 3. Particularly in hot weather, soldiers may open the overgarment jacket and roll the protective mask hood for ventilation, but the trousers remain closed.

TABLE 2-13 Levels of Mission-Oriented Protective Posture (MOPP)
(continued)

MOPP 4	Soldiers will completely encapsulate themselves by closing their overgarments, rolling down and adjusting mask floods, and putting on the NBC rubber gloves with cotton liners. MOPP 4 provides the highest degree of chemical protection, but it also has the most negative impact on performance.
Mask Only	Only the protective mask is worn. The mask-only command is given in these situations: (1) when riot control agents are being employed and no chemical or biological threat exists; and (2) in a downwind vapor hazard of a nonpersistent chemical agent. The Mask-Only command is not appropriate when blister agents or persistent nerve agents are present.

Source: U.S. Army Office of the Surgeon General, 1997.

equipment are contaminated, however, they must be decontaminated prior to entry into a collective protection area.

Medical treatments can afford additional protection both before and after exposure (IOM, 1999a). Individual protection, collective protection, and decontamination are three means of risk minimization, and each has an associated doctrinal, training, and R&D component.

FINDINGS AND RECOMMENDATION

The following findings are based on information provided for this study during briefings and discussions with individuals involved with the CB RDA process.

Finding. Joint structure and joint service processes were developed to maximize the efficient use of funds and to reduce duplications of effort.

Finding. The purpose of the joint prioritization of system needs (and, therefore, RDA needs) is to ensure that fielded systems meet joint service needs. This requires that CINC priorities and NBC community priorities be coordinated.

Finding. The prioritization and selection of RDA projects are often based on compromises or political trade-offs unrelated to CINC prioritization, technical capabilities, or *bona fide* needs and are focused on service-specific, rather than joint service, needs.

Finding. System development is sometimes based on outdated and possibly inaccurate evaluations of threats and challenges.

Recommendation. The Department of Defense should reevaluate and possibly revise its prioritization process for the development of equipment. The reevaluation should include a reassessment of the use of threat information.