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Report to Congressional Requesters

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CHEMICAL WEAPONS

DOD Does Not Have a Strategy to Address Low-Level Exposures

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The Honorable Robert C. Byrd
Ranking Minority Member
Committee on Appropriations
United States Senate

The Honorable John Glenn
Ranking Minority Member
Committee on Governmental Affairs
United States Senate

The Honorable Carl Levin
Ranking Minority Member
Committee on Armed Services
United States Senate

The possible exposure of U.S. troops to low levels of chemical warfare agents in Iraq in the weeks after the Gulf War ceasefire, along with chemical warfare prophylaxis, vaccines, oil well fire emissions, and other battlefield effluents, is suspected to be a contributing factor in the unexplained illnesses that have plagued some Gulf War veterans. Members of Congress have raised concerns regarding the adequacy of Department of Defense (DOD) policy, doctrine, and technology to identify, prepare for, and defend troops against the possible adverse effects of exposure to low-level chemical warfare agents. As you requested, we examined DOD's approach for addressing U.S. troop exposures to low levels of chemical warfare agents. Specifically, we (1) determined the extent that DOD doctrine addresses exposures to low levels of chemical warfare agents; (2) evaluated the extent that research addresses the performance and health effects of exposures to low levels of chemical warfare agents, either in isolation or combination with other agents and contaminants that would be likely found on the battlefield; and (3) identified the portion of resources in DOD's chemical and biological defense research, development, test, and evaluation (RDT&E) program explicitly directed at low-level chemical warfare agent exposures. Appendix I discusses the scope and methodology of this review, and a glossary of scientific and medical terms appears at the end of this report. A subsequent report will assess chemical and biological defense equipment technology.

Background

Approximately 100,000 U.S. troops may have been exposed to low levels of chemical warfare agents in Operation Desert Storm. The destruction of Iraqi chemical warfare munitions by U.S. demolition units in a pit area at the Khamisiyah Ammunition Depot in March 1991 resulted in the release of sarin/cyclosarin nerve agents.[1] (See app. II for a listing of common chemical warfare agents.) The Central Intelligence Agency (CIA) and DOD estimated in September 1997 that the demolition of Iraqi chemical-filled munitions released plumes of nerve agent gas that extended over U.S. troops located hundreds of kilometers away from Khamisiyah.[2] Even though uncertainties regarding wind, agent purity, released quantities, and unit locations prohibit definitive calculations of the dose and length of exposures, if any, to individual soldiers, the agencies estimated that 98,910 U.S. troops were potentially exposed to at least the general population limit dose.[3] In addition, the CIA estimated that destruction of sarin/cyclosarin-filled rockets in a Khamisiyah Depot bunker conducted several days prior to the pit area demolition may have released additional nerve agents, resulting in further low-level exposures.[4]

The objective of DOD's nuclear, biological, and chemical (NBC) defense program is to enable U.S. forces to survive, fight, and win in NBC warfare environments. The National Defense Authorization Act for Fiscal Year 1994 directed the Secretary of Defense to assign responsibility for overall coordination and integration of the chemical and biological defense program to a single office within Office of the Secretary of Defense (OSD).[5] The legislation also directed the Secretary of Defense to

[1]Chemical warfare agents are categorized based on their primary effects. The categories include nerve, vesicants or blister, pulmonary, incapacitating, vomiting, cyanides, and tear.

[2]Modeling the Chemical Warfare Agent Release at the Khamisiyah Pit, CIA/DOD, Sept. 4, 1997.

[3]CIA modeled the estimated area of chemical warfare agent release at six levels of concentration—lethal, incapacitated/disabled, vision impaired, first effects, 8-hour occupational limit, and 72-hour general population limit. The general population limit dose is defined as the dosage below that the general population, including children and the elderly, could be expected to remain 72 hours with no effects.

[4]Low-level chemical warfare agent fallout could have occurred as a result of U.S. bombing of three Iraqi chemical weapon facilities in central Iraq—Muhammadiyat, Al Muthanna, and Ukhaydir. CIA estimated that low levels of sarin and mustard were dispersed as far as 300 and 130 kilometers, respectively, from Muhammadiyat and that sarin was dispersed up to 160 kilometers from Al Muthanna. Mustard agent released from Ukhaydir would not have exceeded the general population limit beyond 40 kilometers from the site. CIA modeling estimates indicate that chemical warfare agents from these releases did not reach areas occupied by coalition troops. However, these incidents of inadvertent releases of chemical warfare agents due to aerial bombing demonstrate low-level exposure threats to U.S. troops that can be encountered in future contingencies when the adversary possesses chemical warfare research, production, or storage facilities. In addition, DOD identified 12 other instances of suspected chemical warfare agent exposures during Operation Desert Storm.

[5]Title XVII of Public Law 103-160, 50 U.S.C. 1522 (b).

designate the Army as DOD's executive agent to coordinate chemical and biological RDT&E across the services. (App. III discusses the institutional structure and responsibilities derived from this legislation.) As a result, individual service research programs addressing NBC defense issues, including the potential adverse effects of low-level chemical agent exposures, were consolidated into a joint program.

The Army's Chemical School is responsible for the NBC doctrine, which consists of joint doctrine,[6] service field manuals,[7] and training circulars. A Joint NBC Defense Concept provides guidance for protecting a force against existing and emerging threats. Threat information is used to determine the vulnerability of existing systems. The validation of a vulnerability leads to a mission and needs statement and operational readiness document and creates a requirement that can justify additional research, revisions in doctrine, or new NBC defense equipment acquisitions.

Results in Brief

DOD does not have an integrated strategy to address low-level exposures to chemical warfare agents. Specifically, it has not stated a policy or developed a doctrine on the protection of troops from low-level chemical exposures on the battlefield. Past research indicates that low-level exposures to some chemical warfare agents may result in adverse short-term performance and long-term health effects. DOD has no chemical defense research program to determine the effects of low-level chemical exposures. Less than 2 percent of the RDT&E funds in DOD's chemical and biological defense program have been allocated to low-level issues in the last 2 fiscal years.

DOD's current NBC doctrine is focused on mission accomplishment by maximizing the effectiveness of troops in a lethal NBC environment. It does not address protection of the force from low-level chemical warfare agent exposures on the battlefield. According to officials, DOD does not have doctrine that addresses low-level exposures because there is no (1) validated low-level threat, (2) consensus on the definition or meaning of low-level exposures, or (3) consensus on the effects of low-level exposures.

[6]Joint Doctrine for NBC Defense, Joint Publication 3-11, was last issued in July 1995. It is currently being revised to address deficiencies identified in a 1997 review by the Joint Warfighting Center. The revised doctrine is scheduled to be delivered to the Joint Chiefs of Staff no later than September 1998.

[7]The Army maintains 20 field manuals that address a range of NBC defense topics and operations, such as contamination avoidance, fixed site protection, decontamination, potential agents and compounds, and reconnaissance.

Past research by DOD and others indicates that single and repeated low-level exposures to some chemical warfare agents can result in adverse psychological, physiological, behavioral, and performance effects that may have military implications. The research, however, does not fully address the effects of low-level exposures to a wide variety of agents, either in isolation or combination with other agents and battlefield contaminants; chronic effects; reliability and validity of animal-human extrapolation models; the operational implications of the measured adverse impacts; and delayed performance and health effects.

During the last 2 fiscal years, DOD has allocated nearly $10 million, or approximately 1.5 percent of its chemical and biological defense RDT&E budget of $646 million, to fund research and development projects on low-level chemical warfare agent exposure issues. However, these projects were not part of a structured DOD research program focused on low-level effects. Currently, DOD does not have a chemical and biological defense research program designed to evaluate the potential effects of low-level chemical warfare agent exposures, but funding is under consideration for two multiyear research programs addressing low-level effects.

OSD Policy and DOD Doctrine on Low-Level Chemical Warfare Agent Exposures

OSD has not issued a policy, nor has DOD developed doctrine, to address exposures of U.S. troops to low levels of chemical warfare agents on the battlefield. DOD officials explained that low-level exposures were not addressed because there was no validated threat and no consensus on what constituted low-level exposures or whether they produced adverse performance or health effects in humans. Nevertheless, some entities within DOD are preparing chemical defense strategies and developing technologies that are expected to address low-level exposures.

No OSD Policy or DOD Doctrine on Low-Level Exposures

OSD has not issued a policy on the force protection regarding low-level chemical weapon agent exposures, and DOD has not developed doctrine that addresses low-level exposures to chemical warfare agents, either in isolation or combination with other contaminants that would likely be found on the battlefield. DOD officials have characterized the primary intent of existing NBC doctrine for battlefield management as enabling mission accomplishment by ensuring force preservation rather than force protection.

The operational concept that underlies NBC doctrine and drives chemical warfare defense research, development, and acquisition has been to “fight

through" the chemical and biological threat and accomplish the mission, with the assumption that overwhelming conventional capabilities will enable U.S. forces to prevail on the battlefield. Thus, the focus on massive battlefield chemical weapon use has framed the concepts of the role of chemical and biological defense in warfare. In a battlefield scenario, the NBC defense goal is to ensure that chemical exposures to the troops result in less than 1 percent lethalities and less than 15 percent casualties, enabling the affected unit to remain operationally effective.

Nevertheless, DOD doctrine differentiates between possible high-level chemical warfare threats in foreign battlefield scenarios and low-level chemical exposures in domestic chemical weapon storage and destruction facilities. In a domestic chemical storage scenario, facilities and procedures are required to ensure that unprotected workers would receive no more than an 8-hour occupational exposure limit and that the adjacent civilian population would receive no more than a 72-hour general population limit, both of which are not expected to result in any adverse health effects.

According to DOD, its doctrine does not address low-level exposures on the battlefield because there is no (1) validated threat, (2) definition of low-level exposures, (3) or consensus on the effects of such exposures. Moreover, if low-level exposures were to be addressed, DOD officials said that the cost implications could be significant. For example, increased costs could result from the need for more sensitive chemical detectors, more thorough decontamination systems, or more individual and collective protection systems. However, no studies have been done to evaluate the potential cost implications of expanding policy and doctrine to address low-level exposure concerns for force protection. OSD officials said that any future low-level requirements would need to compete for funds with an existing list of unfunded chemical and biological defense needs.

In October 1997, the Presidential Advisory Committee on Gulf War Veterans' Illnesses noted that existing DOD doctrine addresses only exposure to debilitating or lethal doses of nerve or mustard chemical warfare agents on the battlefield. The Committee subsequently recommended that DOD develop doctrine that addresses possible low-level

subclinical exposure to chemical warfare agents.[8] Specifically, the Committee recommended that DOD's doctrine establish requirements for preventing, monitoring, recording, reporting, and assessing possible low-level chemical warfare agent exposure incidents.[9] In his February 1998 testimony before the House Committee on Veterans' Affairs, the Special Assistant to the Deputy Secretary of Defense for Gulf War Illnesses stated that DOD does not believe there is a need for doctrine concerning low-level chemical exposures but that DOD would consider taking action if research indicates a need for such doctrine.

No Validated Low-Level Threat

DOD officials said that there is no validated low-level threat and that the probability of encountering low-level contaminated conditions on the battlefield is minimal. If low-level chemical exposures were to occur, the officials stated that the exposures would likely be inadvertent and momentary—resulting from residual contamination after the use of high-dose chemical munitions. DOD experts on the storage and release of chemical warfare agents have asserted that only in a laboratory could agent dosages exist at a low concentration more than momentarily.

Nevertheless, DOD has studied how the intentional use of low doses of chemical warfare agents could be used to achieve terrorist and military objectives. DOD raised concerns over the intentional use of low-level chemical warfare agents in its 1997 study, Assessment of the Impact of Chemical and Biological Weapons on Joint Operations in 2010, which analyzed the impact of state-sponsored terrorist attacks using chemical warfare agents. The study's threat scenario, which was not validated by any intelligence agency, entailed chemical warfare agents being spread thinly, avoiding lethal levels as much as possible, for the purpose of stopping U.S. military operations and complicating detection and cleanup. The study found that massive battlefield use of chemical and biological weapons is no longer the most likely threat and that U.S. forces must be able to counter and cope with limited, localized chemical and biological

[8]Generally, subclinical manifestations are so slight as to be unnoticeable or not demonstrable. Nonetheless, subclinical levels of exposure to chemical warfare agents can result in changes in brain activity as measured by an electroencephalogram (commonly known as an EEG) and may result in long-term health effects. Clinical levels of exposure result in physiological symptoms ranging from dilation of the pupils or runny nose up to apnea, convulsions, and loss of consciousness.

[9]The Committee had concerns about (1) the lack of doctrine standardizing the reporting and retention of possible chemical warfare agent detections; (2) the incompatibility of doctrine for the M93A1 NBC Reconnaissance System (also known as the Fox) to confirm initial chemical detections with battlefield operations; (3) the capabilities and use of chemical warfare agent detectors of the battlefield to detect low-level, subclinical concentrations; and (4) monitoring, documenting, and reporting early health effects of possible chemical exposure incidents by location.

attacks, including attacks delivered by asymmetrical means.[10] This study exposed serious vulnerabilities to the U.S. power projection capabilities that could be exploited by the asymmetrical employment of chemical and biological weapons both in the United States and in foreign theaters of operation. The study also found that the U.S. intelligence capability to determine small-scale development and intent to use chemical or biological weapons, particularly for limited use, is inadequate. Shortfalls include insufficient ability to collect and assess indications and warnings of planned low-level chemical and biological attacks. The report concluded that OSD should significantly increase its level of attention to vulnerabilities posed by an enemy using asymmetrical and limited applications of chemical and biological weapons.

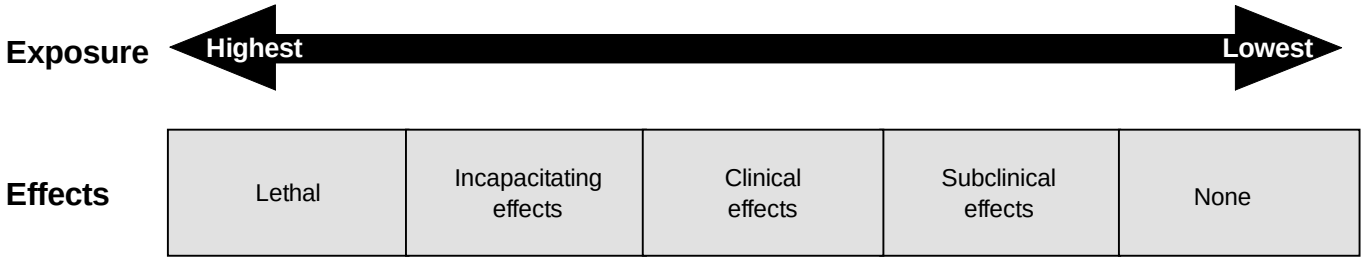
Lack of Consensus on the Definition of Low-Level Exposures

The absence of an OSD policy or DOD doctrine on low-level exposures is partly attributable to the lack of a consensus within DOD on the meaning of low level. DOD officials responsible for medical chemical defense, nonmedical chemical defense, NBC doctrine, and NBC intelligence provided varying definitions of low-level exposure, including the Oxford Dictionary definition, no observable effects, sublethal, and 0.2 LD_{50}.[11] Despite the differing responses, each one can be depicted as a location along the lower end of a chemical warfare agent exposure and effects continuum. (App. IV describes physiological effects from increasing levels of chemical warfare agent exposures.) Figure 1 shows that one end of the continuum is extremely high exposures that result in death, and the other end is no or minimal exposures that result in no performance or health effects. Between these extremes is a range of exposures and resulting effects.

[10]In the study, asymmetrical delivery means included a two-seat helicopter, a crop duster, and a used delivery truck with a makeshift storage tank and discharge valve.

[11]LD_{50} is the median lethal dose, meaning that one-half of a population receiving this dose will die.

Figure 1: Chemical Warfare Agent Exposure and Effects Continuum



Note: The various stages of effects are not shown to scale. The specific exposure that would invoke the various types of effects will vary with the type of chemical warfare agent and the conditions of exposure, such as agent concentration, agent form, route and time of exposure, and characteristics of exposed subject.

Lack of Consensus on the Effects of Low-Level Exposures

In addition to a lack of consensus on the definition or meaning of low-level exposures, there is a lack of consensus within DOD and the research community on the extent and significance of low-level exposure effects. These differences result from several factors. First, the chemical warfare agent dose-response curves can be quite steep,[12] leading some DOD officials and researchers to question the concern over a very narrow range of sublethal dose levels. Second, the extrapolation of findings from studies on the effects of chemical warfare agent exposures in animals to humans can be imprecise and unpredictable. Third, the impacts of different methods of chemical warfare agent exposure, such as topical, injection, and inhalation, may result in varied manifestations and timings of effects, even with comparable concentrations and subject conditions. For example, many of the effects attributable to chemical warfare agent exposure are subjective and either do not occur or cannot be measured in many animal species. Fourth, the preponderance of information on the combined effects of low-level exposures is lacking. Nearly all research on low-level effects addresses single agents in isolation; defining low levels of an agent when present in combination with other battlefield contaminants has not been addressed. In addition, most research has involved single,

[12]The dose-response curve reflects the change in effects for each additional unit of exposure. For highly toxic organophosphate nerve agents, the difference between the dose that creates the first adverse response and the lethal dose can be small. Dose-response curves have been developed for several animal species through laboratory testing; similar testing to develop a dose-response curve in humans has not been done.

acute exposures with observations made over several hours or days. Few studies have examined the possible long-term effects of continuous or repeated low-level exposures.

Last, research is not yet conclusive as to what level of exposure is militarily or operationally significant. The impact of a specific symptom resulting from chemical warfare agent exposure may vary by the military task to be performed. For example, miosis (constriction of the eye's pupil) may have a greater adverse impact on a pilot or a medical practitioner than a logistician. Nonetheless, the dose and effects data are only some of the many factors considered in risk analyses conducted by military commanders. DOD officials told us that trade-offs among competing factors are more often than not based on professional judgment of persons with extensive knowledge based on military and technical education, training, and experience rather than an algorithm with numerical input and output.

Disparate Independent Low-Level Initiatives Are Originating Within DOD

Despite the lack of an OSD policy on low-level exposures, some elements within DOD have begun to address issues involving such exposures. In describing DOD's NBC defense strategy for the future, the Chairman of the Joint Service Materiel Group noted that the presence of low levels of chemical warfare agents will be one of the factors to consider before sending U.S. troops to a contingency. Specifically, the future strategy will no longer be primarily shaped by the occurrence of mild physiological effects, such as miosis, but rather the possible long-term health effects to U.S. forces. Lessons learned from the Gulf War are reflected in DOD's NBC defense strategy, which focuses on the asymmetrical threat. Gulf War Syndrome and low-level threats are identified as two of the concerns to be addressed in the future NBC defense strategy. The Group Chairman added that traditionally the de facto low-level definition has been determined by DOD's technical capability to detect the presence of an agent. However, the Chairman stated that the low-level concept in future chemical defense strategies will need to be defined by the medical community and consider the long-term health effects of battlefield environments.

The Joint Service Integration Group—an arm of the Joint NBC Defense Board that is responsible for requirements, priorities, training, and doctrine—is working with the services to create a joint NBC defense concept to guide the development of a coherent NBC defense program. One of the central tenets of the proposed concept is to provide effective force protection against exposure threats at the lower end of the continuum, such as those from terrorism and industrial hazards. Also, the proposed

concept envisions a single process for force protection to provide a seamless transition from peacetime to wartime. Even though the levels and types of threat can differ, a single overall process can meet all joint force protection needs. Thus, the NBC joint concept will address threats against DOD installations and forces for both peacetime and military conflicts. In addition, the joint concept will provide a conceptual framework for defense modernization through 2010, but the specific programs and system requirements necessary for the implementation of the concept will not be articulated.

The services are concurrently identifying NBC defense joint future operational capabilities to implement the joint concept. Several of these capabilities relate to low-level exposure, such as (1) improving detection limits and capabilities for identifying standard chemical warfare agents by 50 percent, (2) lowering detection sensitivity limits and detection response times for identifying standard chemical warfare agents by 50 percent, and (3) lowering detection response time for standard biological agents by at least 50 percent.[13]

Even in the absence of adopted joint force operational capabilities, DOD is incorporating low-level capabilities in the design of new chemical defense equipment. For example, the Joint Chemical Agent Detector, currently under development, is expected to provide an initial indication that a chemical warfare attack has occurred and detect low-level concentrations of selected chemical warfare agents. The detector will replace currently fielded systems that have a limited ability to provide warning of low-dose hazards from chemical warfare agents.[14] The operational requirements for the detector specify that it will be able to detect low-level concentrations of five nerve agents and two blister agents. However, the low-level requirement necessitates trade-offs between the breadth of agents that the detector can identify and its ability to monitor low-level concentrations for a select few agents. Thus, the next-generation chemical warfare agent detector is expected to have a capability to detect lower chemical warfare agent concentrations in more locations. In the absence of policy—or additional research on low-level effects—it cannot be known whether the

[13]Although the joint concept and the joint future operational capabilities reflect a need to improve force protection capabilities, these initiatives do not define what level of protection is appropriate. Therefore, we cannot determine if the improved capabilities are either necessary or adequate.

[14]According to the operational requirements document for the Joint Chemical Agent Detector, existing systems, such as the M-8 paper, M-9 tape, and M8A1 and M256A1 kits are time-consuming, labor-intensive, and subject to false readings. The Chemical Agent Monitor and M90 Automatic Agent Detectors are not sensitive enough to provide warnings of low-dose hazards, leading to miosis. Other detection systems are limited by shortcomings in mobility; usefulness on aircraft; and sensitivity to nonchemical warfare agent exposures, such as organic vapors or electromagnetic interference.

current, less capable detectors would have the appropriate capabilities to meet the requirements of a low-level exposure doctrine.

Research on Performance and Health Effects of Low-Level Exposures

Research on animals and humans conducted by DOD and others has identified some adverse psychological, physiological, behavioral, and performance effects of low-level exposure to some chemical warfare agents. Nonetheless, researchers do not agree on the risk posed by low-level exposures and the potential military implications of their presence on the battlefield, whether in isolation or in combination with other battlefield contaminants. DOD has no research program to address the remaining uncertainties regarding the performance and health effects of low-level exposures to chemical warfare agents; however, two new research initiatives are currently under consideration.

Previous Research

The majority of the chemical warfare agent research has been on organophosphate[15] nerve agents and related pesticides. At low doses, nerve agents produce a wide range of effects on the central nervous system, beginning with anxiety and emotional instability. Psychological effects in humans from nerve agent VX on skin have been noted earlier than physical effects (e.g., nausea and vomiting) or appeared in the absence of physical effects. The psychological effects were characterized by difficulty in sustaining attention and slowing of intellectual and motor processes. Doses considerably below the LD_{50} can degrade performance and alter behavior. These performance and behavioral effects have clear military implications because affected service personnel exposed to chemical warfare agents might not only lose the motivation to fight but also lose the ability to defend themselves and carry out the complex tasks frequently required in the modern armed forces. Moreover, the detrimental effects of exposure to single doses of nerve agents may be prolonged.[16]

Concern about low-level chemical warfare agent effects predate Operation Desert Storm. In the 1980s, the Air Force conducted research on the

[15]Organophosphates are a family of chemical compounds that inhibit cholinesterase and can be formulated as pesticides and nerve agents.

[16]The North Atlantic Treaty Organization's Handbook on Medical Aspects of NBC Defensive Operations states that (1) daily exposure to concentrations of a nerve agent insufficient to produce symptoms after a single exposure may result in the onset of symptoms after several days and that continued daily exposure may result in increasingly severe effects and (2) after symptoms subside, increased susceptibility may persist for up to 3 months. The degree of exposure required to produce recurrence of symptoms and the severity of these symptoms depend on the dose received and the time since the last exposure. Increased susceptibility is not limited to the particular nerve agent initially absorbed.

bioeffects of single and repeated exposures to low levels of the nerve agent soman due to concerns about the effects of low-level chemical agent exposures on vulnerable personnel—such as bomb loaders, pilots, and medical personnel—who may be required to work in low-level contaminated environments.[17] The Air Force found that the nerve agent degraded performance on specific behavior tasks in the absence of obvious physical deficits in primates. Thus, even for extremely toxic compounds, such as organophosphate nerve agents, which have a steep dose-response curve, task performance deficits could be detected at low levels of exposure that did not cause any overt signs of physical toxicity. This research was unique because low-level exposures were thought at that time to be unlikely or unrealistic on the battlefield.

Table 1 shows examples of research conducted or funded by DOD on the behavioral and performance effects of organophosphate nerve agents. The research examples reveal that sublethal exposures of an agent can have a variety of effects (depending on the species, exposure parameters, time, and combination of exposures) and produce measurable, adverse effects on physiology and behavior (both motor and cognitive[18] performance).

[17]The Navy also was interested in low-level effects and directly supported the Air Force's research projects in the late 1980s.

[18]Cognitive thought processes are based on perception, memory, and judgment.

Table 1: Examples of Research on the Effects of Low-Levels of Organophosphorus Chemical Nerve Agents in Animals

Source	Agent
Air Force Armstrong Laboratory, Brooks Air Force Base, Tex.[a]	Soman
Air Force Armstrong Laboratory, Brooks Air Force Base, Tex.	Soman
Battelle Memorial Institute, Columbus, Ohio; and Army Chemical Research and Development Center, Aberdeen Proving Ground, Md.[c]	Soman
Neurophysiology Laboratory, Children's Hospital Center, Harvard Medical School, Boston, Mass.; and the Biomedical Laboratory, Edgewood Arsenal, Aberdeen Proving Ground, Md.[d]	Sarin
Medical College of Georgia Research Institute, Augusta, Ga.[e]	DFP (Diisopropyl fluorophosphate)
Air Force School of Aerospace Medicine, Brooks Air Force Base, Tex.[f]	Ionizing radiation and anticholinesterase physostigmine

Species	Exposure	Performance or response test	Performance effects
Rhesus monkeys	2.5 μg/kg, acute (e.g., single) dose; given by injection (dose is less than one-third of LD_{50})	Primate equilibrium platform,[b] observations in 5-minute intervals up to 90 minutes after injection	Reliable decrements in sensory-motor equilibrium performance noted in the absence of any obvious physical signs of toxicity
Rhesus monkeys	0.97 μg/kg/day, repeated; single doses on 5 consecutive days, given by injection	Primate equilibrium platform, observations daily	50 percent of primates experience performance decrements (e.g., ED_{50})
Rats	90, 103, 116 μg/kg, given by injection (LD_{50} is 185 μg/kg)	Behavioral parameters: grip strength; startle response, conditioned avoidance measured on days 0, 1, 3, 7, 14, and 21	Sublethal doses of soman can cause marked and often long-lasting changes in behavior, such as impaired grip strength, increased latency, increased spontaneous motor activity, and hyperexcitability
Rhesus monkeys	1 μg/kg, weekly for 10 weeks, given by injection	EEG; 24 hours and 1 year postinjection in three states of consciousness	Significant increase in beta activity persisted for 1 year
Rats	Daily doses of 0.25 mg/kg for 14 days, given by injection	Water maze and delayed stimulus discrimination task, 7 to 16 days after completion of agent regimen	Withdrawal from repeated exposures impaired acquisition of novel cognitive tasks but not the performance of memory tasks dependent on reference concepts
Rats	7 Gy and 0.1 mg/kg, acute dose, given by injection	Rotarod (balance) and four general motor activity measures, observations preirradiation and 45 minutes, 4 days, and 8 days postirradiation	60 percent performance decrement at 45 minutes in combination versus 30 and 40 percent decrements from radiation- or physostigmine-only exposures, respectively

Note: The examples were judgmentally selected to illustrate the types of methodologies that have been applied to the variety of effects that have been observed. This information table is not meant to be representative of the research literature. See the glossary of terms at the end of the report for definitions of units of measurement.

[a]Hartgraves, S.L., and M.R. Murphy. "Behavioral Effects of Low-Dose Nerve Agents." In: ed. S.M. Somani. Chemical Warfare Agents. San Diego: Academic Press, 1992.

[b]The primate equilibrium platform test is a sensory-motor equilibrium task requiring both fine motor control (for joystick manipulation) and the integrity of the complex sensorimotor system for maintaining equilibrium and orientation in space.

[c]Haggerty, G.C., et al. "Duration and Intensity of Behavioral Change After Sublethal Exposure to Soman in Rats." Neurobehavioral Toxicology and Teratology, vol. 8 (1986), pp. 695-702.

[d]Burchfiel, J.L., et al. "Persistent Effects of Sarin and Dieldrin Upon the Primate Electroencephalogram." Toxicology and Applied Pharmacology, vol. 35 (1976), pp. 365-379.

[e]Buccafusco, J.J., "Chronic Organophosphorus Exposure and Cognition." Annual Report, U.S. Army Medical Research and Materiel Command, 1997.

[f]Wheeler, T.G., and R.E. Cordts. Combined Effects of Ionizing Radiation and Anticholinesterase Exposure on Rodent Motor Performance. U.S. Air Force School of Aerospace Medicine, Report number USAFSAM-TR-83-30, July 1983.

In our prior report on Gulf War illnesses,[19] we summarized research on the long-term health effects of chemical warfare agents, which were suspected of contributing to the health problems of Gulf War veterans. The report cited research suggesting that low-level exposure to some chemical warfare agents or chemically related compounds, such as certain pesticides, is associated with delayed or long-term health effects. Regarding delayed health effects of organophosphates, we noted evidence from animal experiments, studies of accidental human exposures, and epidemiological studies of humans that low-level exposures to certain organophosphorus compounds, including sarin nerve agents to which some U.S troops may have been exposed, can cause delayed, chronic neurotoxic effects.[20]

We noted that, as early as the 1950s, studies demonstrated that repeated oral and subcutaneous exposures to neurotoxic organophosphates produced delayed neurotoxic effects in rats and mice. In addition, German personnel who were exposed to nerve agents during World War II displayed signs and symptoms of neurological problems even 5 to 10 years after their last exposure. Long-term abnormal neurological and psychiatric symptoms, as well as disturbed brain wave patterns, have also been seen in workers exposed to sarin in manufacturing plants.[21] The same abnormal brain wave disturbances were produced experimentally in nonhuman primates by exposing them to low doses of sarin.[22] Delayed, chronic neurotoxic effects have also been seen in animal experiments after the administration of organophosphate. In other experiments, animals given a low dosage of the nerve agent sarin for 10 days showed no signs of

[19]Gulf War Illnesses: Improved Monitoring of Clinical Progress and Reexamination of Research Emphasis Are Needed (GAO/NSIAD-97-163, June 23, 1997).

[20]This syndrome is characterized by clinical signs and symptoms manifested 4 to 21 days after exposure to organophosphate compounds. The symptoms of delayed neurotoxicity can take at least two forms. A single large dose may cause nerve damage with paralysis and later spastic movement or repetitive low doses may damage the brain, causing impaired concentration and memory, depression, fatigue, and irritability. These delayed symptoms may be permanent.

[21]Duffy, F.H. et al. "Long-Term Effects of an Organophosphate Upon the Human Electroencephalogram." Toxicology and Applied Pharmacology, vol. 47 (1979), pp. 161-176. Sidell, F.R., "Soman and Sarin: Clinical Manifestations and Treatment of Accidental Poisoning by Organophosphates." Clinical Toxicology, vol. 7 (1979), pp. 1-17.

[22]Burchfiel, J.L., et al. "Persistent Effect of Sarin and Dieldrin Upon the Primate Electroencephalogram." Toxicology and Applied Pharmacology, vol. 35 (1976), pp. 365-379.

immediate illness but developed delayed chronic neurotoxicity after 2 weeks.[23]

Nonetheless, some DOD representatives in the research community have expressed considerable doubt that low-level exposures to chemical warfare agents or organophosphates pose performance and long-term health risks—particularly in regard to the likelihood that low-level exposures are linked to Gulf War illnesses. These doubts stem from the lack of a realistic scenario, the lack of adverse long-term health effects observed in studies of controlled and accidental human exposure or animal studies, and results that are viewed as incompatible with the principles of biology and pharmacology.[24] Researchers we interviewed did agree that the work that has been done to date is lacking in several aspects, including (1) the effects of exposure to low levels of chemical warfare agents in combination with other agents or contaminants likely found on future battlefields; (2) extrapolation of animal models to humans; (3) the breadth of agents tested, types of exposure routes, and length of exposure; and (4) the military or operational implications of identified or projected low-level exposure effects.[25]

Proposed Research Initiatives

Consistent with the absence of an OSD policy on low-level exposures, there is no research objective under DOD's Joint Service Chemical and Biological Defense Program to evaluate the potential effects of low-level exposures. However, even in the absence of a requirement, there is a consensus within the research and doctrinal communities that additional research on low-level effects is needed. Researchers told us that, although they do know that low-level exposures to chemical warfare agents can have performance and health effects, more was unknown than known about the effects of low-level exposures of agents—either in isolation or in combination—and that more research would be desirable. According to

[23]Husain, K., et al. "Assessing Delayed Neurotoxicity in Rodents after Nerve Gas Exposure." Defense Science Journal, vol. 44 (1994), pp. 161-164. Husain, K., et al. "Delayed Neurotoxic Effect of Sarin in Mice After Repeated Inhalation Exposure." Journal of Applied Toxicology, vol. 13 (1993), pp. 143-145. Husain, K., et al. "A Comparative Study of Delayed Neurotoxicity in Hens Following Repeated Administration of Organophosphorus in Compounds." Indian Journal of Physiology and Pharmacology, vol. 39 (1995), pp. 47-50.

[24]The human body has a natural ability to scavenge or neutralize organophosphates. For example, natural scavengers can neutralize approximately 0.2 LD_{50} of soman while the agent is in the blood and before it can affect the central nervous system. Therefore, for each nerve agent there may be a threshold of exposure below which no effects will result.

[25]Much of the historic toxicological research on exposure effects was conducted for an offensive chemical weapons program; therefore, the results are likely not appropriate for a defensive chemical weapons program.

one DOD scientist, "Research can improve our understanding of the relationships among the many factors, such as effects, time of onset of effects, duration of effects, concentration, duration of exposure, dosage, and dose. Improved estimates of effects in humans resulting from exposure to chemical warfare agents are a requirement that has existed since World War I."

Consistent with that assessment, the Army's Medical Research and Materiel Command is proposing a science and technology objective[26] to establish a research program on the chronic effects of chemical warfare agent exposure. Because previous research efforts have emphasized the acute effects of high (battlefield-level) exposures, there is little information on the repeated or chronic effects of low-dose exposures. The Command's research effort is in response to this lack of information and joint service requirements for knowledge of the effects on personnel in sustained operations in areas that may be chemically contaminated, thus creating the possibility of a continuous low-level exposure.[27]

Additionally, the Joint Service Integration Group has tasked a panel of experts to determine an accepted definition for low-level chemical warfare agent exposure. The panel has proposed a series of research efforts to the Joint NBC Defense Board to analyze the relationships among dose, concentration, time, and effects for the purpose of determining safe exposure levels for sustained combat operations.[28]

DOD has funded two National Academy of Sciences studies to support the development of a long-term strategy for protecting U.S. military personnel deployed to unfamiliar environments. These studies will provide guidance for managing health and exposure issues, including infectious agents; vaccines; drug interactions; stress; and environmental and battlefield-related hazards, such as chemical and biological agents. One study is assessing approaches and technologies that have been or may be used by DOD in developing and evaluating equipment and clothing for physical protection and decontamination. The assessment is to address the efficacy of current policies, doctrine, and training as they relate to

[26]An approved science and technology objective validates an area as worthy for research and helps provide a "fence" to protect funding to the area being investigated or researched.

[27]We have not analyzed this or other draft research plans to determine if the proposals, if implemented, would likely achieve their objectives.

[28]Because the research programs sponsored by the Army Medical Research and Materiel Command and the Joint Service Integration Group have not been approved or implemented, we cannot assess their objectives, scopes, or methodologies.

potential exposures to chemical warfare agents during deployments. The second study is assessing technology and methods for detection and tracking of exposures to a subset of harmful agents. This study will assess tools and methods to detect, monitor, and document exposures to deployed personnel. These studies do not address issues of risk management; those will be the focus of a third study.

Low-Level Chemical Research Funding

Although DOD and congressional interest concerning the effects of low-level chemical exposure increased after events in the 1991 Gulf War, relatively limited funding has actually been expended or programmed in DOD's RDT&E programs in recent years to address issues associated with low-level chemical exposure on U.S. military personnel. However, DOD has developed proposals to fund two low-level research efforts, which are under consideration for implementation.

Chemical and Biological Defense Program Research Funding

For fiscal years 1996 through 2003, DOD has been appropriated in excess of $2.5 billion for chemical and biological defense RDT&E programs. (See app. V for general DOD chemical and biological program funding allocations and trends for fiscal years 1990 through 2003). Fiscal year 1996 was the first time that RDT&E funding for all of DOD's chemical and biological defense programs was consolidated into six defensewide program element funding lines. These program elements are (1) basic research, (2) applied research, (3) advanced technology development, (4) demonstration and validation, (5) engineering and manufacturing development, and (6) management support. Table 2 shows total actual and projected research funding by RDT&E program element for fiscal years 1996 through 2003.

Table 2: Chemical and Biological RDT&E Funding, Fiscal Years 1996-2003

Dollars in millions

Program element	Amount programmed	Percent
Basic research	$215.4	8.6
Applied research	518.1	20.6
Advanced technology development	319.7	12.7
Demonstration and validation	356.4	14.2
Engineering and manufacturing development	944.2	37.5
Management support	161.7	6.4
Total	**$2,515.5**	**100.0**

Recent Low-Level Research Funding

Three low-level research efforts—totaling about $10 million—were included in DOD's fiscal year 1997 and 1998 chemical and biological defense RDT&E programs. These research efforts represented about 1.5 percent of the approximately $646 million in combined obligational authority authorized for chemical and biological defense RDT&E for these 2 fiscal years.

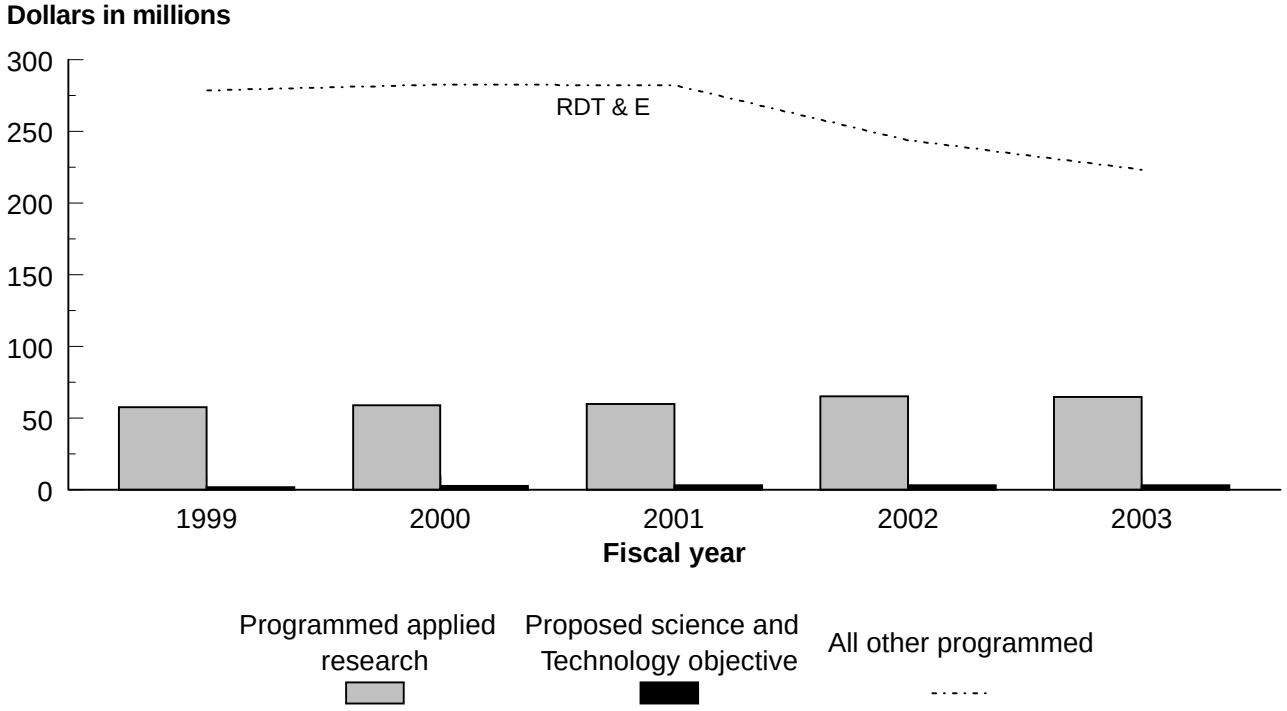
Funding for the largest of the three—an $8-million effort in the fiscal year 1998 program that dealt with chemical sensor enhancements—was provided by the Conference Committee on DOD Appropriations.[29] Another fiscal year 1998 effort—costing almost $1.4 million—involved the development of sensitive biomarkers of low-dose exposure to chemical agents. The remaining effort, included in the fiscal year 1997 program, developed in vitro and in vivo model systems to evaluate the possible effects of low-dose or chronic exposures to chemical warfare agents. This project cost approximately $676,000. DOD officials told us that these projects were not part of a structured program to determine the performance and health effects of low-level exposures. However, two elements within DOD have proposed multiyear research programs on low-level issues.

Proposed Low-Level Research Funding

DOD has requested funding for the U.S. Army Medical Research and Materiel Command's science and technology objective on the chronic effects of chemical warfare agent exposure. If approved, this research program is projected to receive an average of about $2.8 million annually in research funds for fiscal years 1999 through 2003. The purpose of this undertaking would be to investigate the effects of low-dose and chronic exposure to chemical agents to (1) gain a better understanding of the medical effects of such exposure, (2) provide tools for a medical assessment of personnel, and (3) develop protocols for subsequent protection and treatment. Figure 2 reflects DOD's programmed RDT&E funding for fiscal years 1999 through 2003 and shows the proposed science and technology objective in relation to other research program efforts.

[29]The fiscal year 1998 Appropriations Conference Report, House Report 105-265, added funds to the Chemical and Biological Defense RDT&E program. Specifically, an additional $10 million was added to the applied research program element for chemical agent sensor technology. Subsequently, the Assistant to the Secretary of Defense for NBC Defense Programs earmarked $8 million of the $10 million for low-level chemical detection and monitoring technology.

Figure 2: Programmed RDT&E Funding, Fiscal Years 1999-2003



Another research program involving low-level chemical exposures will be proposed in the near future to the NBC Defense Board for approval. A panel of experts, tasked by DOD to study the issue of defining low-level and chronic chemical exposure, has proposed a series of research efforts to be undertaken over the next several years to address the definitional dilemma surrounding this issue. Funding levels for this effort have not been established.

Conclusions and Recommendation

DOD's current NBC policy and doctrine do not address exposures of U.S. troops to low levels of chemical warfare agents on the battlefield. NBC defense doctrine is focused on ensuring mission accomplishment through the prevention of acute lethal and incapacitating effects of chemical weapons and is not designed to maximize force protection from exposure

to clinical and subclinical doses. Moreover, DOD has no chemical defense research plan to evaluate the potential performance effects of low-level exposures or the implications they may have for force protection. Even though research funded by DOD and others has demonstrated adverse effects in animal studies, the literature does not adequately address the breadth of potential agents; the combinations of agents either in isolation or in combination with battlefield contaminants; the chronic effects; animal-human extrapolation models; or the operational implications of the measured adverse impacts.

We recommend that the Secretary of Defense develop an integrated strategy for comprehensively addressing force protection issues resulting from low-level chemical warfare agent exposures. The strategy should address, at a minimum,

- the desirability of an OSD policy on the protection of troops from low-level chemical warfare agent exposures;
- the appropriateness of addressing low-level chemical warfare agent exposures in doctrine;
- the need for enhanced low-level chemical warfare agent detection, identification, and protection capabilities;
- the research needed to fully understand the risks posed by exposures to low levels of chemical warfare agents, in isolation and in combination with other contaminants that would be likely found on the battlefield; and
- the respective risks, costs, and benefits of addressing low-level chemical warfare agent exposures within DOD's chemical and biological defense program.

Agency Comments and Our Evaluation

In oral comments on a draft of this report, DOD concurred with our recommendation that the Secretary of Defense develop a "low-level" strategy but disagreed with the implied priority order. DOD stated that it is also concerned with force protection and the possible impact that low-level chemical agent exposures might have on a service member's health and emphasized that a valid data-based risk assessment must serve as the foundation for any change in policy or doctrine. In addition, DOD provided us with updated plans and proposals to develop an overall requirements and program strategy for low-level chemical agent monitoring.

DOD agreed that the absence of an OSD policy or a DOD doctrine on low-level exposures is partially attributable to the absence of a consensus within

DOD on the meaning of low level. However, DOD expressed concern that we did not assert a working definition of low level as it might apply to a force projection or battlefield scenario. DOD disagreed with our selection of examples of low-level research illustrated in table 1, stating that the studies were more appropriately categorized as "low dose" rather than low level. Finally, DOD believed that we misinterpreted the report, Assessment of the Impact of Chemical and Biological Weapons on Joint Operation in 2010, by failing to understand that the asymmetrical application of chemical agents does not equate to "low level" for the purpose of producing casualties, but rather for the purpose of disrupting operations by the mere detectable presence of these agents at levels that may have no medical effects.

In our recommendation, we listed a number of elements that should be addressed in developing such a strategy, but we purposely did not articulate a priority order beginning with research. Rather, we advocate that DOD develop a strategy to analyze policy, doctrine, and requirements based on existing information and to reassess policy, doctrine, and requirements as the results of a low-level research program are reported.

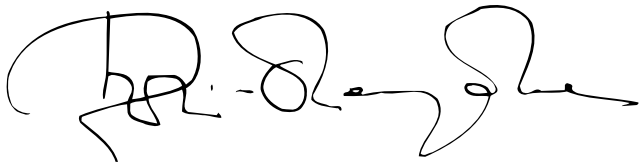
We did not define low level in our report because the definition requires an interpretation of both exposure effects data and military risk and performance data—analyses best performed by DOD. Furthermore, because a consensus of the meaning or definition of low level is lacking, we find no basis for DOD's characterization of the research examples in table 1 of the report as "low dose," rather than "low level."

Regarding the 2010 Study, we disagree with DOD's statement that there may not be medical effects for low-level chemical agents. Rather our work shows that low-level exposure can have medical effects that cannot only result in casualties, but also disrupt operations.

The plan of action and low-level toxicological and technical base efforts provided by DOD did not fully address the strategy that the report discusses. The strategy will require a plan of action incorporating medical and tactical analyses, as well as the nonmedical research and development projects described by DOD.

As agreed with your offices, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days after its issue date. At that time, we will send copies to other congressional committees and the Secretary of Defense. We will also make copies available to others on request.

If you have any questions concerning this report, please call me at (202) 512-3092. Major contributors to this report were Sushil Sharma, Jeffrey Harris, Foy Wicker, and Betty Ward-Zukerman.



Kwai-Cheung Chan
Director, Special Studies and Evaluation

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Abbreviations

CIA	Central Intelligence Agency
DFP	diisopropyl fluorophosphate
DOD	Department of Defense
NBC	nuclear, biological, and chemical
OSD	Office of the Secretary of Defense
RDT&E	research, development, test, and evaluation

Scope and Methodology

The scope of our study was limited to chemical defense and low-level exposures that may cause adverse effects on performance. To determine the extent to which low-level exposures are addressed in doctrine, we reviewed Department of Defense (DOD) documents and interviewed agency officials. We asked questions designed to elicit the treatment of low-level issues within the nuclear, biological, and chemical (NBC) doctrinal architecture (i.e., Joint Publication 3-11; field manuals; training circulars; and tactics, techniques, and procedures). After determining that low-level issues were not addressed in the war-fighting doctrine, we asked representatives of the doctrinal, intelligence, and research communities why low-level issues were not addressed and under what circumstances they would be addressed.

To identify research on the performance effects of low-level exposure of chemical warfare agents, we reviewed relevant government and academic research (published and unpublished) and interviewed researchers within and outside of DOD. To identify relevant literature, we interviewed DOD officials currently responsible for prioritizing chemical and biological defense research needs. We also interviewed DOD researchers at the Army's primary center of medical chemical defense research and development (the Army Medical Research Institute for Chemical Defense) and nonmedical chemical research and development (the Edgewood Research, Development, and Engineering Center at the Aberdeen Proving Ground). We interviewed staff at the laboratory used by the Air Force to conduct low-level exposure effects on animals before the Army was designated as executive agent for chemical defense and the Air Force's effort ceased. We sought historic programmatic information from the Naval Medical Research and Development Command, which funded portions of the Air Force's low-level animal studies. We monitored ongoing DOD-funded Gulf War illnesses research that addresses potential long-term health effects from low-dose or chronic chemical exposures. Last, we discussed current research with leading academics in the field.

We reviewed the compilation of relevant low-level research literature to characterize coverage (variety and combinations of agents or contaminants), methodologies employed, and effects observed. These observations were discussed and validated in our interviews with researchers in chemical defense, both within and outside of DOD. In addition, we employed a research consultant from academia to review the literature to substantiate both the comprehensiveness of our compilation and the validity of our conclusions.

To determine what portion of the chemical defense budget specifically addresses low-level exposures, we reviewed DOD documents and interviewed DOD program officials. We examined DOD planning and budget documents, including the NBC defense annual reports to Congress and joint service chemical and biological defense program backup books for budget estimates. In addition, we analyzed chemical defense-related data for fiscal years 1991 through 1999 contained in DOD's Future Years Defense Program—the most comprehensive and continuous source of current and historical defense resource data—to identify annual appropriation trends and ascertain the level of funds programmed and obligated for research, development, test, and evaluation (RDT&E), as well as procurement, and the destruction of chemical munitions. We interviewed DOD officials to verify our observations about low-level efforts and to obtain information about potential programs currently being developed to expand DOD's efforts to understand the effects of chronic and low-level exposure of chemical warfare agents on military personnel.

We contacted the following organizations:

- Armed Forces Radiobiological Research Institute, Bethesda, Maryland;
- Defense Intelligence Agency, Washington, D.C.;
- DOD Inspector General, Washington, D.C.;
- Department of Energy, Washington, D.C.;
- Edgewood Research, Development, and Engineering Center, Aberdeen Proving Ground, Maryland;
- Israel Institute for Biological Research, Ness-Zonia, Israel;
- Joint Program Office, Biological Defense; Falls Church, Virginia;
- National Ground Intelligence Center, Charlottesville, Virginia;
- National Research Council, Washington, D.C.;
- Office of the Secretary of Defense, Washington, D.C.;
- Oregon Health Sciences University, Portland, Oregon;
- University of Texas Health Center at San Antonio, San Antonio, Texas;
- University of Texas Southwest Medical Center, Dallas, Texas;
- Air Force Armstrong Laboratory, Brooks Air Force Base, Texas;
- Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio;
- Army Chemical School, Fort McClellan, Alabama;
- Army Medical Research and Materiel Command, Frederick, Maryland;
- Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Maryland;
- Navy Bureau of Medicine and Surgery, Washington, D.C.; and
- Walter Reed Army Institute of Research, Washington, D.C.

We performed our review from September 1997 to May 1998 in accordance with generally accepted government auditing standards.

Chemical Warfare Agents

Type of agent	Common name	Symbol
Nerve	Tabun	GA
	Sarin	GB
	Soman	GD
	Cyclosarin	GF
	[a]	VX
Vesicant or blister	Mustard	HD
	Lewisite	L
Pulmonary toxicants	Phosgene	CG
	Diphosgene	DP
Incapacitating	[a]	BZ
Vomiting	Adamsite	DM
Cyanides	Hydrogen cyanide	AC
	Cyanogen chloride	CK
Tear gases	[a]	CN
	[a]	CS

[a]No common names exist for these agents.

The National Defense Authorization Act for Fiscal Year 1994

The institutional structure and responsibilities for NBC defense research, requirements, and doctrine derive from provisions in the National Defense Authorization Act for Fiscal Year 1994.[1] The act directed the Secretary of Defense to assign responsibility for overall coordination and integration of the chemical and biological program to a single office within the Office of the Secretary of Defense. The legislation also directed the Secretary of Defense to designate the Army as DOD's executive agent to coordinate chemical and biological RDT&E across the services.

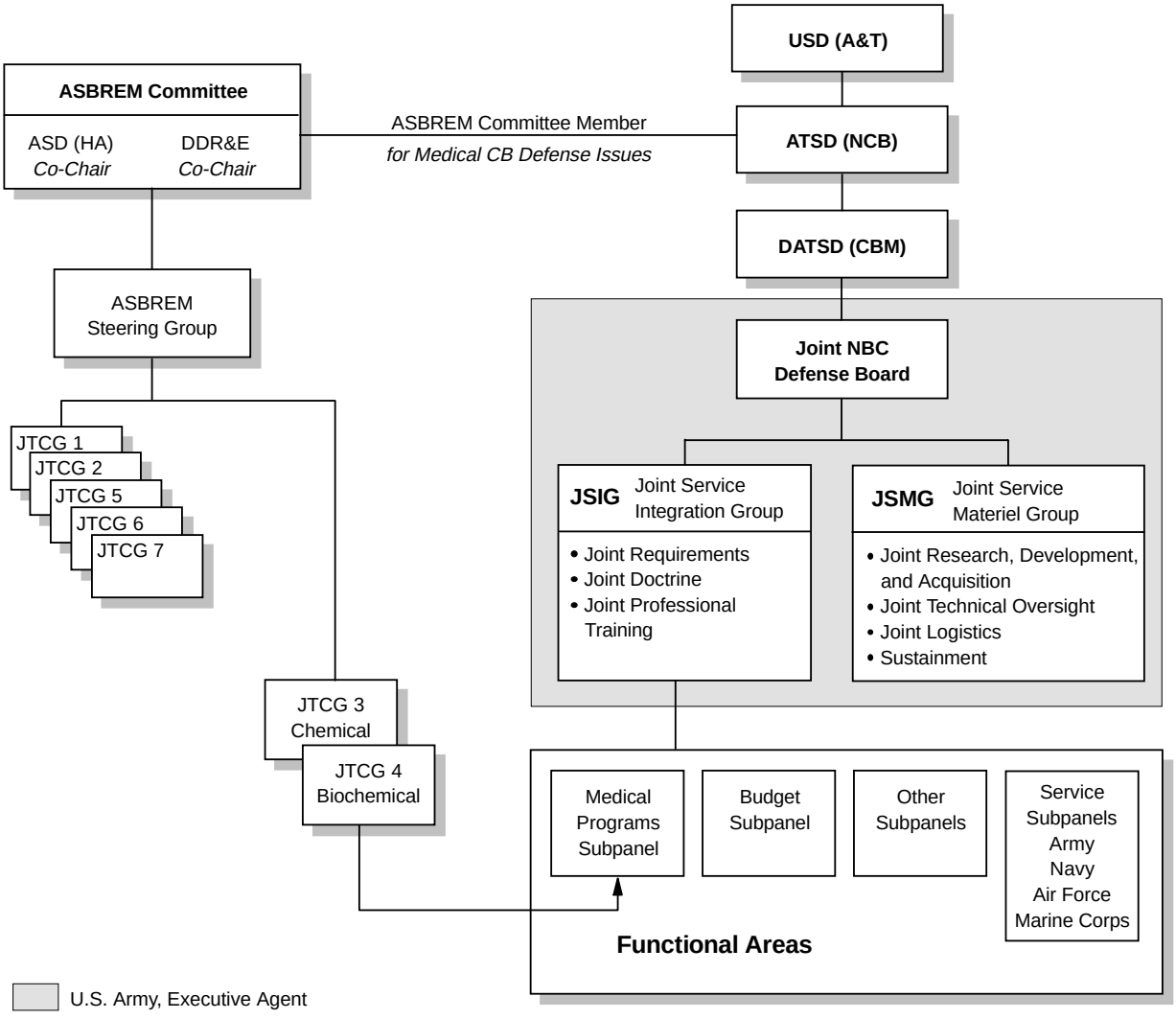
The Joint NBC Defense Board, which is subordinate to the Under Secretary for Acquisition and Technology, provides oversight and management of the NBC defense program within DOD. The NBC Board approves joint NBC requirements; the joint NBC modernization plan; the consolidated NBC defense program objective memorandum; the joint NBC research, development, and acquisition plan; joint training and doctrine initiatives; and the joint NBC logistics plan.

The Joint Service Integration Group and the Joint Service Materiel Group serve as subordinates to the NBC Board and execute several of its functions. Both groups are staffed with representatives from each of the services. The Joint Service Integration Group is responsible for joint NBC requirements, priorities, training, doctrine, and the joint modernization plan. The Joint Service Materiel Group is responsible for joint research, development, and acquisition; logistics; technical oversight; and sustainment.

These two groups and the NBC Board are assisted by the Armed Forces Biomedical Research Evaluation Management Committee, which provides oversight of chemical and biological medical defense programs. The Committee is co-chaired by the Assistant Secretary of Defense for Heath Affairs and the Director, Defense Research and Engineering. Figure III.1 illustrates the relationships among the various organizations responsible for NBC defense.

[1]Title XVII of Public Law 103-160, 50 U.S.C. 1522, as amended.

Figure III.1: Joint Service NBC Defense Program



Legend

ASBREM - Armed Service Biomedical Research Evaluation and Management
ASD (HA) - Assistant Secretary of Defense for Health Affairs
ATSD (NCB) - Assistant to the Secretary of Defense for Nuclear and Chemical and Biological Defense Programs
CB - Chemical and Biological
DATSD (CBM) - Deputy Assistant to the Secretary of Defense for Chemical and Biological Matters
DDR&E - Director, Defense Research and Engineering
JTCG - Joint Technical Coordinating Group
RDA - Research, Development, and Acquisition
USD (A&T) - Under Secretary of Defense for Acquisition and Technology; serves as the chairman of the Defense Acquisition Board

Chemical Warfare Nerve Agent Exposures and Effects

Chemical exposure level	Effects
Clinical	
Lethal	Death
Severe	Loss of consciousness, convulsions, flaccid paralysis (lack of muscle tone and an inability to move), and apnea (transient cessation of respiration)
Moderately severe	Severe dyspnea (difficult or labored respiration), gastrointestinal or neuromuscular signs
Moderate	Miosis, rhinorrhea, moderate to severe dyspnea, reflex nausea, and vomiting
Mild	Miosis, rhinorrhea, mild dyspnea, reflex nausea, and vomiting
Minimal	Miosis, with or without rhinorrhea; reflex nausea, and vomiting
Subclinical	
No observable effects	Measurable changes in EEG and brain anticholinesterase activity
8-hour occupational limit[a]	Exposure would not create any adverse health effect
72-hour general population limit[a]	Exposure would not create any adverse health effect

Note: The specific dose-response relationship varies with the specific agent, time of exposure, environmental factors (i.e., wind, humidity, and temperature), method of exposure (i.e., inhalation, intravenous, and dermal), activity level of subject, and the presence of other contaminants.

[a]Occupational and general population exposure limits for chemical warfare agents stored by DOD are determined by the Centers for Disease Control based on linear extrapolations of experimental results of experiments involving human volunteers as well as animal reactions to higher doses. The National Academy of Science's Committee on Toxicology is reviewing the scientific validity of reference doses developed by the Army for the six chemical warfare agents currently stored by the U.S. military. The focus of the work is to determine whether all the relevant toxicity data have been appropriately considered. Particular attention will be paid to the uncertainty, variability, and quality of data and the appropriateness of the assumption applied when the current reference doses were developed. In addition, the committee will incorporate new research as appropriate, identify gaps in the research, and recommend additional research as necessary.

Funding Trends in DOD's Chemical and Biological Defense Program

This appendix provides general information on the funding trends for DOD's Chemical and Biological Defense Program for fiscal years 1990-97 and 1998-2003. Funding is shown in four categories: disposal, which includes the costs associated with the chemical stockpile disposal program; RDT&E; procurement; and operations and maintenance, including the costs for military personnel.

After the end of the Cold War, DOD funding for chemical and biological programs increased from about $566 million in fiscal year 1990 to almost $1.5 billion in fiscal year 1997. These funds include all military services and the chemical munitions destruction program.[1] Adjusted for inflation, the total program funding has more than doubled (see fig. V.1) over that period and is programmed to continue growing—peaking in fiscal year 2002 with a total obligational authority in excess of $2.3 billion (see fig. V.2).

[1]In 1985, Congress passed Public Law 99-145, the National Defense Authorization Act of 1986, section 1412 of which directed the Army to destroy the U.S. stockpile of obsolete chemical agents and munitions. To comply with this direction, the Army established the chemical stockpile disposal program to incinerate the agents and munitions on site in specially designed facilities. The stockpile consists of rockets, bombs, projectiles, spray tanks, and bulk containers, that contain nerve and mustard agents.

Figure V.1: Chemical and Biological Program Funding, Fiscal Years 1990-1997

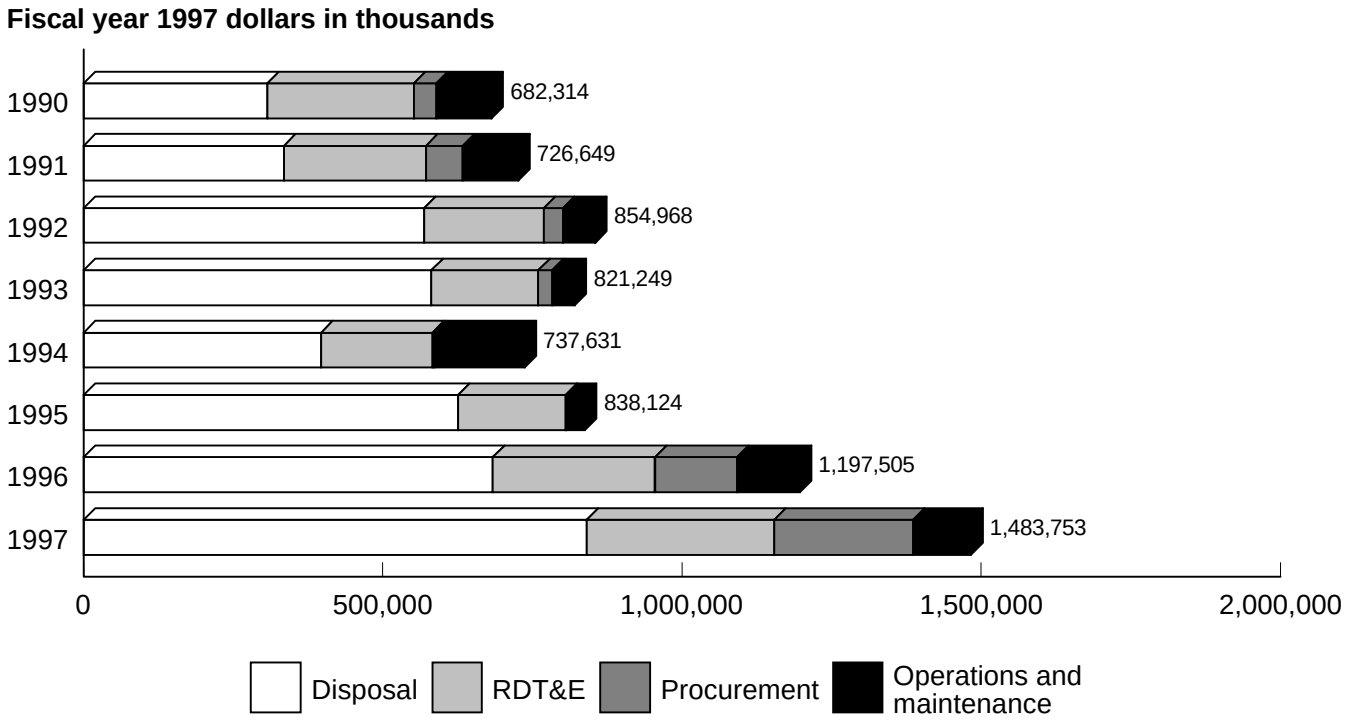
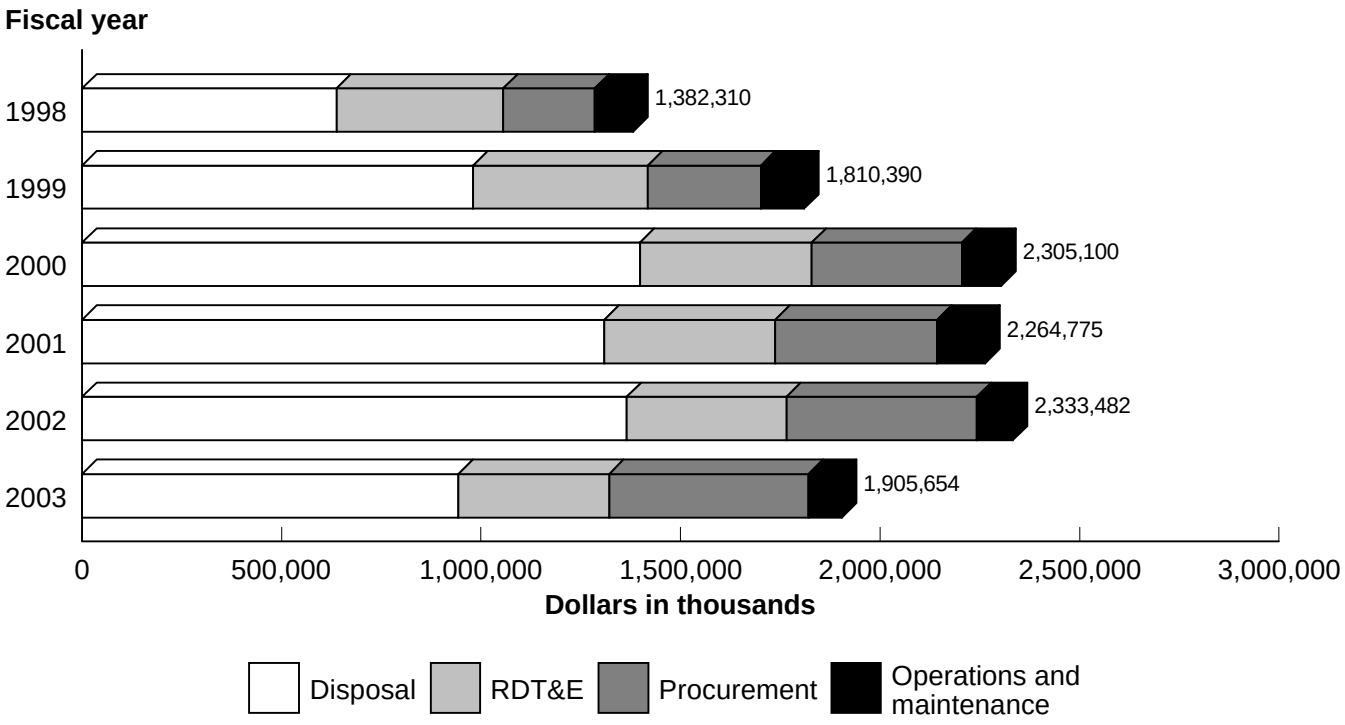


Figure V.2: Planned Chemical and Biological Program Funding, Fiscal Years 1998-2003



Glossary

Anticholinesterase	Agent that inhibits the enzyme acetylcholinesterase.
Apnea	Transient cessation of respiration.
Clinical	Symptoms as observed by a physician.
Cognitive	Process based on perception, memory, and judgment.
Dose-Response	Effects resulting from a specific unit of exposure.
Dyspnea	Difficult or labored respiration.
Effluent	Waste material discharged into the environment.
Flaccid Paralysis	Lack of muscle tone and an inability to move.
Gy	Gray unit of radiation.
kg	Kilogram.
LD_{50}	Median lethal dose.
mg	Milligram.
Miosis	Constriction of the pupil of the eye.
Neurotoxic	Toxins that exert direct effects on nervous system function.
Organophosphate	Family of chemical compounds that inhibit cholinesterase and can be formulated as pesticides and nerve agents.
Prophylaxis	Measures designed to preserve health and prevent the spread of disease.
Rhinorrhea	Nasal secretions.
Subclinical	Manifestations of an exposure that are so slight as to be unnoticeable or not demonstrable.

µg	Microgram.
Vesicant	Agent that produces vesicles or blisters.

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