Chapter 6

HISTORY OF ARMY OCCUPATIONAL HEALTH, 1991–2015

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INTRODUCTION

The Vietnam War (1956–1975) became associated with exposure to the defoliant Agent Orange through the persistence of health complaints with no identified syndrome or specific cause and resulting debates about the appropriateness of compensation for affected veterans.[1–3] Consequently, practitioners of military preventive medicine worked to identify ways to prevent future similar problems, including improving capabilities for the early recognition and thorough assessment of potentially harmful exposures to hazardous materials. The Persian Gulf War (1990–1991) was short, but exposures to potentially hazardous materials such as plumes from burning oil wells occurred, and long-term health effects among deployed service members again became a national concern.[4] Later, when US peacekeeping forces entered the former Yugoslavia in 1995, quick identification and characterization of potentially hazardous materials enabled commanders to take appropriate action to avoid or minimize exposures.[5] Unfortunately, the protracted Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF), beginning in 2001, produced many exposures. Again there were concerns about long-term health effects and complaints of illnesses, many of which could not be linked to defined exposures or characterized by a recognized symptom complex.[6] The concerns about deployment-related exposures and health effects are documented in multiple reports from the Institute of Medicine, at least three medical journal special editions, and a monograph.[7–12]

A primary focus of military medicine is taking care of military members while they are training and performing their global missions, with emphasis on the prevention of illnesses and injuries. Therefore, military medicine is the practice of occupational and environmental medicine in support of the critical workforce that is responsible for protecting and defending the country.[13] This chapter identifies and summarizes the challenges that faced military occupational and environmental medicine physicians, environmental health scientists, and others in the military occupational health and preventive medicine communities in dealing with environmental exposures and novel or poorly defined medical problems in deployed US service members since the beginning of the Persian Gulf War.

PERSIAN GULF WAR (1990–1991)

The anxiety associated with concerns about health and related costs that followed the use of Agent Orange in Vietnam have been staggering.[2,3] However, it was not until the Persian Gulf War that leaders in the US Department of Defense (DoD) recognized the need to address environmental exposures in service members with the objective of preventing these and any related adverse health outcomes.[4,5] Previously, DoD was primarily concerned with arthropod-borne infectious diseases and microbial contamination of food and water that could quickly produce large numbers of casualties, significantly reducing the fighting strength and jeopardizing the success of the military mission. DoD planners considered potential chemical warfare agent use and burning oil well fires, but other concerns were identified only after the conflict ended.

The Persian Gulf War consisted of a build-up phase (Operation Desert Shield, August 2, 1990–January 17, 1991) and a combat phase, Operation Desert Storm (January 17, 1991–February 28, 1991).[1] During the Persian Gulf War, Iraqi forces set fire to more than 750 oil wells that burned between February 2, 1991, and October 29, 1991, significantly decreasing the air quality over much of the country of Kuwait (Figures 6-1 and 6-2).[4]

After the Persian Gulf War, over 200,000 veterans claimed they had developed Gulf War illness (GWI), an illness that correlated with their exposures, while deployed.[14] The medical community struggled to identify a medical explanation for the variable and nonspecific constellation of symptoms, sometimes referred to as “mystery illness” and more popularly “Gulf War Syndrome,” experienced by these veterans.

Figure 6-1. Burning oil wells seen at night from Camp Freedom, Kuwait, May 1991.
Photograph courtesy of Jack M. Heller, PhD, US Army Center for Health Promotion and Preventive Medicine.

Figure 6-2. Formation of a composite "super plume" over the Ahmadi Oil Fields, Kuwait, May 1991.
Photograph courtesy of Jack M. Heller, PhD, US Army Center for Health Promotion and Preventive Medicine.

Figure 6-3. Burning oil wells emitting different-colored smoke, indicating different combustion products, Ahmadi Oil Fields, Kuwait, May 1991.
Photograph courtesy of Jack M. Heller, PhD, U S Army Center for Health Promotion and Preventive Medicine.

The symptoms included some combination of chronic headache, chronic shortness of breath and breathing difficulties, widespread pain, memory and concentration problems, persistent fatigue, gastrointestinal problems, skin abnormalities, and mood disturbances. Most of the symptoms did not fit the diagnostic criteria for established medical or psychiatric conditions.[6,15] The Persian Gulf War was unusual in that returning veterans reported these kinds of symptoms in much larger numbers than were reported in previous wars.[16–19]

On December 5, 1991, Public Law 102-190, National Defense Authorization Act for Fiscal Years 1992 and 1993 (10 USC 1086),[20] was passed, requiring the secretary of defense to establish and maintain a record of service members exposed to the combustion products from the burning oil wells (Figure 6-3). Section 734 of this law and Section 704 of Public Law 102-585, Veterans Health Care Act of 1992 (38 USC 101)[21] required development of a means to define DoD service members' exposures to oil well fire emissions.[4,22] These legislative actions represented a prompt response by the US Congress to address service member exposures and related potential health consequences.

Following the 1991 legislation, DoD preventive medicine personnel conducted required deployment occupational and environmental health (OEH) surveillance for most major conflicts, exercises, and humanitarian and peacekeeping operations. Over 25,000 air, water, soil, and other types of samples were collected worldwide by deployed military members, civilian employees, and contractors in preventive medicine, engineering, and civil affairs. A key question that consistently faced military preventive medicine personnel was how to effectively use the results generated by environmental sampling. They realized that the emphasis had to be placed on prevention. Simply describing an event after a potentially harmful exposure had occurred could not be the primary objective.

Kuwaiti Oil Well Fires

"The Kuwaiti oil well fires were a result of the scorched earth policy of Iraqi military forces retreating from Kuwait after conquering the country because they were being driven out by Coalition military forces."[4] "The Gulf War Oil Spill, regarded as the worst oil spill in history, was also caused by the Iraqi forces when they opened valves at the Sea Island Oil Terminal, dumping oil from several tankers into the Persian Gulf."[4] The Kuwaiti oil fires burned for almost a year, exposing American and other allied forces to the products of combustion from the burning oil. Some military personnel complained of respiratory and other symptoms that became part of what came to be called GWI.

DoD and allied personnel exposed to the burning and gushing oil wells were concerned about potential health effects.[4] The US Environmental Protection Agency (EPA), the Kuwait Environmental Protection Department, French and Norwegian teams, and groups from other countries conducted environmental monitoring and reported that pollutants from the oil wells were not at levels that would cause severe short-term health problems.[4] However, the data were inadequate to evaluate the potential for long-term health effects. Concern persisted, so the US Army Office of the Surgeon General, at the direction of the assistant secretary of defense for health affairs, chaired a triservice medical working group to evaluate potential health effects of the oil smoke. Medical personnel from each US military service and representatives from the US Department of Veterans Affairs (VA), Office of the Assistant Secretary of Defense for Health Affairs, and Office of the Deputy Assistant Secretary of Defense for the Environment, Safety, and Occupational Health formed the working group.

In support of this effort, a team from the US Army Environmental Hygiene Agency (USAEHA), Aberdeen Proving Ground, Maryland, was sent on May 1, 1991, to collect samples and monitor health effects in US forces in southwest Asia, and to prepare a health risk assessment (HRA). The HRA considered health risks from multiple sources such as oil fire smoke; industrial pollution (which was difficult to separate from oil fire smoke contaminants); natural background pollution (eg, heavy metals); and radioactivity, both naturally occurring (in association with oil bearing strata) and resulting from the military use of depleted uranium (DU).

An HRA is the determination of a quantitative or qualitative estimate of health risk related to a well-defined situation and a recognized threat. The steps include the evaluation of health risks, utilization of a dose-response approach to predict health risk, and quantification of exposures to use in risk estimation. This methodology was developed for use in evaluating contaminated environmental sites in the United States prior to cleanup. The original goal of an HRA was to identify a level of risk that was acceptable as a target for remediation, not to identify a level above which health effects will develop. Numerous uncertainties are associated with this methodology, such as the ability to assess only the hazards that are identified and measured, the recognition that concentrations of hazards vary over time and location, the inability to consider the effect of mixtures in the assessment, and the frequent lack of toxicological or epidemiological studies addressing the specific exposure concentration and duration without extrapolation.

Overall, the Kuwaiti oil well fire response consisted of three parts: (1) an environmental monitoring effort, with subsequent HRA; (2) an industrial hygiene (IH) sampling study; and (3) a biological surveillance initiative (BSI).[4,23] The BSI was a unique component that measured health parameters in a unit before they deployed, while they were deployed, and upon their return. The BSI is not a typical component of an HRA, since the HRA is generally used to support risk-related decisions made prior to initiating cleanup at a site.

A troop unit exposure model was needed to support the HRA because data were collected at fewer than 10 fixed sites in the theater of operations while troops operated throughout the entire theater, and sampling did not start until 2 months after the fires started. Because actual sampling data did not exist for many points in space and time, the model was used to determine service members' probable exposure levels to oil fire emissions. The exposure levels were used to generate health risk assessments in accordance with Public Laws 102-190 and 102-585.[20,21] The delay in sampling occurred because, even though a USAEHA monitoring team was prepared for deployment in December 1990, the team's priority for travel into the theater was so low that monitoring efforts did not commence until May 5, 1991.[4]

The large-scale environmental monitoring study conducted by a USAEHA team characterized the concentration of pollutants. The study was complicated because the periods and locations of exposure were extremely variable for the 550,000 US personnel who occupied sites across 880,000 square miles in Kuwait, Saudi Arabia, and Iraq. The USAEHA monitoring effort ended on December 3, 1991. When monitoring began, 558 oil wells were burning. Over 5,000 environmental study samples were collected before all fires were extinguished on November 6, 1991. Sampling was continued from November 6 to December 3, 1991, to collect background pollutant levels. The Army set up permanent ambient air monitoring stations at four sites in Saudi Arabia and six sites in Kuwait where US troops were stationed. Two sampling sites in Kuwait were shut down almost immediately because of logistical problems. National Oceanic and Atmospheric Administration scientists performed modeling to help estimate pollutant concentrations across the battle space where troops were located.

Soil samples and air monitoring data collected by USAEHA in the study were used to calculate exposure point concentrations. Exposure point concentrations for both air and soil were calculated by assessing the concentrations of all contaminants present at the time and location of collection to determine service members' exposure levels and risk by the air and soil pathways. Risk assessments were done at the seven permanent sites and at the Ahmadi Hospital site in Kuwait, which was adjacent to the burning Ahmadi Oil Field.

In 1994, USAEHA became the central part of a new organization, the US Army Center for Health Promotion and Preventive Medicine (CHPPM). In response to Public Laws 102-190 and 102-585, CHPPM developed a database and public website that included an exposure model.[20,21] Persian Gulf War veterans could go to the website and determine if they were at risk for health effects from their exposures in the Gulf, and they could request a copy of the information.[4,20–22] Individual exposures were modeled for specific locations and depended upon an individual knowing where he or she had been and for how long.

The risk estimated included risk of cancer, which addressed the risk associated with exposure to each carcinogenic hazard using a linear, non-threshold model most applicable to radiation. Noncancer risk was evaluated by comparing air concentrations to what was considered a threshold safe daily exposure (above which health effects may occur). The result was expressed as a numeric index based on a value of one. One means the acceptable daily dose is equivalent to the average daily exposure; a number larger than one means the dose was higher; and a fraction of one means the dose was lower. Daily risks were not added, so this methodology did not reflect changes with longer duration exposures.

This method involved a great deal of uncertainty. Given the methodology employed and the fact that it was not expected to be well understood by the general public, it is unknown whether requesters of exposure information were reassured or became more concerned after obtaining their personal exposure profile.

Separate from the environmental monitoring effort, IH air sampling was done from May 3, 1991, to June 17, 1991, in Kuwait and Saudi Arabia. Personal, breathing zone air samples were obtained for people working outdoors and, to assess what was considered a worst-case exposure, similar samples were collected on workers in the oil fields next to Kuwait City. The results of the IH air sampling were compared to Occupational Safety and Health Administration (OSHA) standards to permit an assessment of health risk.

The BSI was conducted to simultaneously evaluate acute findings for those exposed and to assess long-term health risks in a cohort of US soldiers.[23] USAEHA occupational and environmental physicians looked for a military unit that might be suitable for the BSI. A US Army unit, the 11th Armored Cavalry Regiment, was selected for the surveillance project. It was stationed in Germany and scheduled to deploy to Kuwait and then return to Germany.[23] A team from USAEHA and other agencies conducted the BSI. Service members from the 11th Armored Cavalry Regiment were given questionnaires and had blood and urine collected for analysis between June 1 and October 14, 1991.[23–26] Analytes studied included heavy metals, sister chromatid exchanges, blood volatile organic compounds, and deoxyribonucleic acid adducts. Data and specimens were collected prior to, during, and after deployment to Kuwait.[23] The participating service members were also screened at this time for breathing problems and other self-reported symptoms.[23] The BSI data from the exposed unit did not identify significant health consequences from oil fire exposures.[23–26] A lesson learned from this initiative was that some bio-monitoring tests are not useful if the results have no prognostic significance. Also, at that time many biomarkers of exposures had no reference ranges outside of occupational groups and were difficult to interpret.

The predictive results from the HRA (which were generated from environmental data) found no expected significant health consequences from oil fire exposure to exposed troops. In the years that followed, epidemiological studies were conducted utilizing available healthcare data on units identified as exposed to the oil well fires. Unfortunately, since electronic records were limited to hospitalizations, the health outcomes assessed were limited to those conditions requiring hospitalization and did not reflect the relative rate of any more common, less serious conditions.

Public Law 102-190 both required the development of a way to determine the exposures to substances from the oil well fires, and required the secretary of defense to establish and maintain a record of each service member's exposure to the combustion products of the burning oil wells.[20] Section 734 of this law included a requirement to determine the exposure levels of air contaminants resulting from the oil well fires in both military and civilian personnel who deployed to the Persian Gulf War.[20] The record also had to document the length of time exposed, the circumstances surrounding the exposure, and the location of the exposure. The task of developing a permanent record, in the form of a registry, to characterize and document the exposures of Persian Gulf War veterans was assigned to CHPPM.[4]

The US Armed Services Center for Unit Records Research (CURR) was responsible for determining the locations of all troops on a daily basis from February to November 1991. CHPPM worked with CURR and obtained a copy of the CURR Troop Movement Database for this period. The database was constructed by studying all Persian Gulf War records, including unit logbooks and situation reports that contained daily unit location data by latitude and longitude. CURR provided over 5 million records to develop the database. The Defense Manpower Data Center (DMDC) then created the Persian Gulf War Registry of military personnel, which tracked individuals assigned to the units in the CURR database. The database also included the date individuals entered and left the theater of operations, which was necessary to determine the length of time people were potentially exposed.[4]

The National Oceanic and Atmospheric Administration Air Resources Laboratory assisted CHPPM in the exposure modeling effort by providing output from its Hybrid Single-Particle Lagrangian Integrated Trajectories model to help determine the exposure of each service member. To determine the level of exposure and where the oil fire plume impacted service members, CHPPM analyzed this model in combination with Advanced Very High Resolution Radiometer satellite images.[4] The model predicted concentrations of each contaminant at the breathing zone (2 m) for 40,000 points (15 km grid spacing) in the area affected. The CHPPM team then calculated each service member's exposure level on a daily basis. Finally, CHPPM used standard EPA risk assessment methods to determine health risk using the modeled exposure data and toxicity factors including reference dose, concentration, and cancer slope factor.[4] Cancer slope factors are used to estimate the risk of cancer associated with exposure to a carcinogenic substance. A slope factor is an upper bound estimate on the increased cancer risk from a lifetime exposure to an agent by ingestion or inhalation.

The Kuwaiti oil well fire exposure assessment considered multiple variables. The oil fire combustion products exposures of interest included suspected carcinogens, noncarcinogenic compounds, and particulate matter. The number of days exposed was factored into the risk assessment model, and the exposure levels were compared to EPA standards to determine risk to individual service members.

The risk of cancer from the oil well fires was added to the risk of getting cancer from other sources, which may include smoking, diet, solar rays, and other environmental and occupational exposures. The excess cancer risk likely attributable to oil fire combustibles was calculated using EPA toxicity factors (cancer slope factor) and includes all cancer-causing compounds in the oil well fire smoke emissions, as well as other cancer risk factors, to determine the total excess cancer risk.

To assess the risk for noncarcinogenic compounds in oil well fire smoke, CHPPM compared the air concentration to an EPA toxicity reference concentration that equates to the amount of a chemical in the air a person could be exposed to for their entire lifetime without causing any adverse health effects. These levels were set to protect sensitive individuals such as the elderly and young children. An additive model was used to assess the impact of multiple, simultaneous noncarcinogenic chemical exposures in the air from the oil well fire smoke. The output was used to obtain a hazard index for the total exposure, which was compared to EPA's established noncarcinogenic compounds. As long as the hazard indices for the individual noncarcinogenic chemicals total less than 1, no adverse effects are expected.

The total particles in the oil well fire smoke were measured as total suspended particulates. The EPA National Ambient Air Quality Standards mandated by the Clean Air Act of 1970 (Public Law 101-549, Section 812, 1990 Amendments[27]) for total suspended particulates at the time was 75 $\mu g/m^3$ of air (annual standard) and 260 $\mu g/m^3$ of air (daily standard). CHPPM used 1986 total suspended particulates daily standards because the data were available and the troops were exposed for less than a year (so the annual standard was not appropriate).[4]

The development of the exposure registry for the Kuwaiti oil well fires consumed considerable resources and involved many US government agencies. The response addressed the mandates of Congress, but the quality of the assessment has never been evaluated.

Depleted Uranium

DU is used in munitions and military or civilian equipment because of its high density and relative availability. DU has multiple uses including helicopter rotor counter balances, radiation shielding, components of munitions, and armor on military vehicles.[28] DU is a potential health hazard because uranium is a toxic metal and it is weakly radioactive. Uranium can affect the normal functioning of the kidney, brain, liver, and heart. The impact of DU munitions and combustion of DU-containing materials can generate aerosols that may contaminate wide areas. Some DU aerosols can be inhaled.[28,29]

Natural uranium (NU) is one of the most common elements on Earth and can be found in rocks, soil, rivers, and oceans. NU is radioactive and is one of the main elements that contributes to terrestrial radioactivity. It is a mixture of different isotopes: uranium-238, uranium-235, and uranium-234. Uranium-238 is the most common isotope, comprising about 99% of the mass of NU.

DU contains the same three isotopes as NU; however, the proportions are different. In DU, much of the uranium-234 and uranium-235 has been removed, and as a consequence, DU is 40% less radioactive than NU. DU arises as a byproduct during the enrichment process of NU to make fuel for nuclear reactors. During the enrichment process the composition of uranium is changed by separating the uranium-234 and uranium-235 from the uranium-238.[29] In short, the more radioactive components are removed from the element and the less radioactive uranium-238 remains, hence the name DU.

DU is widely known for its use as a large-caliber, antiarmor munition penetrator. During the Persian Gulf War, when DU-containing munitions were first used, a number of soldiers raised health concerns. They were exposed to DU aerosols when in vehicles struck by DU munitions. Other soldiers presumed they were exposed when their battlefield duties required them to enter vehicles hit by DU munitions or to be in areas containing DU residues. Responding to the DU health concerns of Persian Gulf War veterans, the VA and DoD initiated a medical follow-up program for exposed individuals and a research program to assess the health risks associated with DU. Supporting this effort were the US Army, Battelle Memorial Institute, Pacific Northwest National Laboratory, and the Lovelace Respiratory Research Institute. These organizations collaborated to create the Capstone Depleted Uranium Aerosol Characterization and Risk Assessment, which was sponsored by the Office of the Special Assistant for Gulf War Illnesses (OSAGWI) and the US Army. An outgrowth from OSAGWI was the publication of *Depleted Uranium Aerosol Doses and Risks: Summary of US Assessments* (the Capstone Report).[30]

The authors of the Capstone Report intended to provide rigorous, peer-reviewed scientific estimates of the health risks to military personnel from DU aerosol exposure, primarily those soldiers exposed "to DU aerosols inside perforated armored vehicles."[30] Information on exposures to military personnel near perforated or burning ammunition was also included.[30] The Capstone Report included both exposure assessments and health risk assessments, with the goal of developing accurate data for health risk assessors to use in evaluating soldiers exposed to DU as a result of being in or around a vehicle perforated by a DU munition.[30]

The exposure assessment portion of the Capstone study involved a series of field tests on vehicles struck by DU penetrators. It was conducted in four phases and focused on the concentration and characteristics of aerosols and residues generated inside the vehicles at the time of impact, during settling, after settling had occurred, and in the residues found outside the vehicles. During Phase I and Phase II of the field testing, Bradley fighting vehicles and ballistic hull and turret versions of Abrams tanks without DU armor were used to simulate the battlefield conditions of the Persian Gulf War. Phase III and Phase IV were designed to simulate future conflicts. In these later phases, Abrams tanks with DU armor were used as targets.

The human HRA portion of the Capstone study "used internationally recognized models to estimate the radiological dose and chemical concentrations in the body and translate these values into estimates of risk."[30] Radiation health risks were evaluated based on radiation doses and risks to individual organs and tissues rather than estimates of whole-body or effective doses. The primary organ of interest with respect to health effects of uranium exposure is the kidney.[31] Because of the concern for adverse effects on the kidneys, the authors of the Capstone Report developed a system to quantify chemical risks based on the concentration of uranium in the kidney.[30] The Capstone Report concluded, "the chemical and radiological doses and risks to human health in inhaling DU aerosols in a perforated vehicle are relatively low when compared to many other combat risks."[30] The Capstone Report provided quantitative estimates of risk for various exposure scenarios. For example, among the mostly highly exposed populations, the median lifetime fatal cancer risks ranged from 0.005% to 0.45%.[30]

The National Academy of Science's Committee on Toxicology (NAS-COT) reviewed the Capstone Report and found "the methods and results of the Capstone exposure assessment to be appropriate and well done" and "the Capstone exposure results are reasonable and appropriate for human health-risk analysis of DU."[32] However, the NAS-COT report also recommended future assessments. The NAS-COT review of the Capstone Report found the study's approach to assessing cancer risks to be "appropriate because it allows for the lack of uniformity in dose distribution among organs."[32] With respect to the chemical risks to the kidney, the NAS-COT review recommended that the authors of the Capstone Report review the accuracy of data presented to support its values for the concentration of uranium in the kidneys associated with minimal or no detectable health effects, and that the Army avoid giving the appearance that these uranium concentration values are precise demarcations of the potential for adverse health effects.[32] The authors reviewed the interpretations in the Capstone Report and "identified some apparently conflicting results that might have led to the NAS-COT's uncertainties."[33] The authors concluded that their original analyses were correct but recognized that the human data used to develop the risk model were not as robust as desired, adding to the overall uncertainty of the results.[34] To ensure wide dissemination of the results of the Capstone study, the entire March 2009 issue of *Health Physics, The Radiation Safety Journal*, was dedicated to publishing the results.[34]

DU's potential for causing adverse health effects derives from both its radiological and chemical properties. However, the chemical toxicity of DU is the principal health concern and the radiological hazards are generally of less concern, because both NU and DU are only weakly radioactive.[32] Uranium is distributed mainly in the bones, liver, and kidneys once it is taken into the body. The bones form a long-term repository for uranium with a half-life of 70 to 200 days.[32] Most of the remaining uranium in the body has a half-life of about 7 to 14 days.[32] Because uranium can accumulate in the kidneys, these organs are of main concern when evaluating human health risks. Kidney damage has been seen in humans and animals after ingestion or inhalation of uranium into the body.[32] However, among soldiers with embedded fragments containing DU, kidney damage has not been seen thus far.[31] It is possible that for more insoluble forms of DU, the radiation dose to the lungs could become the major concern.[35] In summary, the Agency for Toxic Substances and Disease Registry, Atlanta, Georgia, reported that "no other health effects, other than kidney damage, have been found in humans after inhaling or ingesting uranium or in soldiers with uranium metal fragments in their bodies."[31]

The DoD addressed service members' concerns about potential exposure to DU through a variety of DoD and service-level policies and directives. The Deployment Health Clinical Center established a website for service members and healthcare providers seeking information regarding DU exposures. This website lists policies, directives, clinical guidance, and fact sheets on DU.[36] The DoD has arranged with the University of Maryland and the Baltimore VA office to maintain a medical screening program to track service members who may have been exposed to DU. A service member who reports DU exposure and requests follow up for DU exposure may be referred to the VA. The VA maintains a registry of service members with embedded DU fragments and others with confirmed exposure to DU, and it has followed these service members since 1993 to identify the long-term health outcomes of exposure.[36]

Overall, the risks associated with exposure to DU on the battlefield are comparable to other battlefield risks. DU garnered considerable attention because it is a radioactive heavy metal, and the health of military personnel is of paramount concern to the DoD. DU and its residues are neither "innocuous nor are they a 'deadly poison,'" and although risks of exposure are predicted to be low, these risks should be discussed with affected personnel and their family members.[30]

The Institute of Medicine continued to study the potential for health effects in service members potentially exposed to DU long after the Persian Gulf War, and the VA biennial health surveillance program for veterans with DU exposures continues follow-up of this group.[37–41] A 2008 Institute of Medicine report included information from the VA that indicated veterans with embedded fragments continue to have elevated urine DU concentrations. However, since the study began in 1993, the VA has found minimal effects on proximal tubule function, cytotoxicity, or pulmonary function.[41]

Chemical Weapons and the Khamisiyah Storage Facility

Chemical agent exposures, both from directed enemy threats and from the destruction of enemy storage sites, were concerns during the Persian Gulf War. US troops were frequently ordered to don their gas masks and protective suits because of chemical warfare agent detections by Czech, French, and American forces.[42,43] The nerve agents tabun (GA), sarin (GB), and cyclosarin (GF) and the blister agents sulfur-mustard and lewisite were detected by Coalition forces.[42] Fortunately, no large-scale Iraqi employment of chemical weapons occurred during the war. There were no service members seen for severe chemical injuries, nor were there any fatalities that resulted from nerve agent exposure.[42] The tactical situation on the battlefield prevented Iraqi forces from using their chemical weapons: the speed of the Coalition advance and the effectiveness of the strategic bombing campaign in disrupting Iraq's military command-and-control system made it difficult for commanders to select targets for chemical attacks. In addition, the prevailing winds shifted to the southeast toward the Iraqi lines at the start of the war.[42] The London *Sunday Times* reported that "Iraqi military communications indicated that Iraqi President Saddam Hussein had authorized commanders to use chemical weapons at their discretion as soon as Coalition forces began their ground offensive."[44] A British signals officer who monitored the Iraqi command net "heard the release order to front-line commanders to use chemical weapons against Rhino [coalition] force if they crossed the border."[42,44]

Although chemical weapons were not broadly used, US units discovered chemical munitions in Iraqi bunkers during and after the ground war and noted these discoveries in their unit logs. Troops reported acute symptoms of toxic chemical exposure and sought treatment in troop medical clinics. The incidents were described in intelligence reports, operations logs, and command chronologies on DoD websites.[42,43,45]

Storage areas that posed a potential risk to US service members included four Iraqi chemical weapons sites, the major one being Khamisiyah because of the possibility of a large number of troops having been exposed there. The sites are as follows:

- Muhammadiyat housed bombs containing mustard and nerve agents GB and GF. Exposures may have occurred during aerial bombing.
- The Al Muthanna bunker contained GB. Exposures may have occurred during aerial bombing.

- Ukhaydir housed artillery shells containing mustard. Exposures may have occurred during aerial bombing.
- Khamisiyah contained rockets with GB, GF, and mustard agent. US forces destroyed the weapons cache by demolition.[46]

On March 4, 1991, a total of 37 large ammunition bunkers were destroyed, and Iraq confirmed that Bunker 73 at the Khamisiyah Ammunition Supply Point contained 2,160 rockets filled with chemical warfare agents. On March 10, 1991, another 40 ammunition bunkers and 45 warehouses were destroyed. Soldiers also destroyed approximately 1,250 rockets outside the Khamisiyah Ammunition Supply Point, which the United Nations Special Commission later confirmed contained chemical warfare agents. The demolition operations at Khamisiyah continued through April 1991. The were no reports of chemical warfare agents in the inventories conducted before the bunkers were destroyed, but that may be due to mislabeling or poor recognition of the markings on the munitions. Throughout the US occupation of Khamisiyah, no medical encounters were reported for soldiers seeking treatment for chemical warfare agent exposures.

After the end of the Persian Gulf War and after soldiers of the US Army's XVIII Airborne Corps destroyed munitions there, US Army units occupied an area in southeastern Iraq that encompassed Khamisiyah. In September 1996 the secretary of the Army directed the department of the Army inspector general to conduct an inquiry to determine the facts surrounding the demolition of ammunition at Bunker 73 at the Khamisiyah Ammunition Storage Facility in March 1991.[47] The inspector general's findings led the intelligence community to conclude that chemical munitions were present when the facility was destroyed. They concluded that 2,160 rockets filled with GB and GF were present at Khamisiyah, and that 1,400 of these rockets were destroyed in Bunker 73 and an adjacent pit area. Furthermore, 6,000 mustard-filled shells were present at Khamisiyah, and about 2,000 of them were destroyed in Bunker 73. Approximately 430 soldiers participated in the destruction of the facility. The Central Intelligence Agency (CIA) and Defense Intelligence Agency estimates were that chemical munitions destroyed at Khamisiyah may have exposed 100,000 soldiers to low levels of GB (greater than the general population background level of 0.01296 mg-min/m^3, but below the health effects level of 1 mg-min/m^3).[48]

The analysis of the Khamisiyah bunker site, where US forces may have been exposed to chemical agents when they detonated the bunker contents in March 1991, used the troop exposure assessment model to analyze chemical agent release data provided by DoD and other US government agencies. CHPPM provided support for modeling, mapping, and merging the results of the different dispersion and meteorological models, and identifying exposure standards for agents. Its personnel contributed to outreach efforts, including town hall meetings. Additionally, CHPPM staff identified the service members who may have been exposed to chemical agents following the detonation and collaborated with DoD and other government organizations on epidemiological studies of these troops.[49–52] CHPPM scientists also determined chemical agent exposures for US forces at three other sites: Al Muthanna,[53] Muhammadiyat,[54] and Ukhaydir.[55]

The initial work of the OSAGWI examined the US military operations at Khamisiyah. On February 21, 1997, OSAGWI published its first report on Khamisiyah.[56] The events were described and the units involved were identified. OSAGWI contacted thousands of service members as part of the effort to do computer modeling of exposures to determine the size and path of the hazard area downwind from the demolition activities. DoD sent 100,000 notification letters to inform individuals of their exposure to chemical warfare agents. The model used computer simulations, based on the best available science, to predict individual exposures. The letters alerted individuals to the exposure but did not address the potential for long-term health effects. The VA did not accept these letters as proof of exposure when veterans submitted claims for compensation.

The OSAGWI computer model was refined by adding improved meteorological data, obtaining better estimates of the quantities released based on CIA estimates, using deposition and decay factors, and taking the toxicity of sarin and cyclosarin into account. Further, the DoD destroyed munitions similar to those found at Khamisiyah using chemicals with similar physical properties to sarin to better predict the downwind dispersion of chemical agents released. These open field demolition tests on 122-mm rockets, conducted in May 1997 at Dugway Proving Ground, Utah, were used to help determine how chemical warfare agent in Iraq's rockets might have been released by the demolitions at Khamisiyah. Although the fundamental modeling methodology had not changed between 1997 and 2000, modifications were made to obtain improved modeling output, including the revision of the meteorological models, updating the CIA estimate of how much chemical warfare agent was released, and the addition of deposition and decay to the models.[46,57] The final model was run in January 2000, and the redefined hazard area included an additional 752 veterans who were potentially exposed to low levels of nerve agent.

In the revised 2000 model, CHPPM incorporated better toxicity data on cyclosarin that was not available in 1997. CHPPM noted that the quantity of sarin was three times that of cyclosarin, but the toxicity of cyclosarin was almost three times that of sarin. Cyclosarin is less volatile than sarin, so it evaporated more slowly. With this refined toxicity data, the revised model produced more precise hazard-area estimates.

CHPPM scientists also recommended that the final January 2000 model use a general population limit based on short-term exposures because the release occurred over a 4-day period. The general population limit represents the limit below which any member of the general population could be exposed over a lifetime without experiencing any adverse health effects. The general population limit was modified with the addition of uncertainty factors and adjustments for the average person, making it more representative of military personnel and less representative of more sensitive seniors and children.

The CURR contributed to the exposure estimates by developing a database beginning in 1993 that contained daily company-level unit geographic locations for the Persian Gulf War Theater. This effort was based on experience gained by developing the Agent Orange Exposure Database after the Vietnam War. For the Persian Gulf War Troop Movement Database, the CURR gathered all the unit history data archives such as log reports, after action reports, and other pertinent information. This amounted to over 5 million pieces of paper from which over 800,000 unit grid coordinates were created.

Beginning in April 1997, Army division and battalion operations officers performed data gap fills at the CURR to provide unit movement records as completely as possible. The CURR finished these efforts in 1999, but continued to work with personnel from other units to improve and update the database. With the CURR Troop Movement Database, CHPPM scientists could identify daily company-level unit identification code (UIC) locations and associate them with potential individual service member exposures in the identified units based on the DMDC Persian Gulf War Registry.

CHPPM combined data from CURR's Troop Movement Database of 855,000 unit locations with information from DMDC on which troops were assigned to those units to determine which were exposed to chemical agents. The 2000 model produced graphic representations of the projected hazard area with associated levels of exposure for service members from March 10 to 13, 1991. CHPPM scientists overlaid data on US troop unit locations on the graphic representation of the projected hazard area to create a plot that shows the exposed troop units.

The methodology used to locate troops possibly exposed to a particular environmental agent, at a designated time and place, included the following:

- A geographic information system operational base map for the region of interest was prepared with the political boundaries included.
- Troop units were geo-referenced by UIC for the particular time frame in question (eg, March 10–13, 1991) by using the CURR troop unit movement database. For the above assessment, the CURR troop unit movement database used was from November 2000.
- The particular geographic area of interest (Figure 6-4) and the exposure area (derived from meteorological and dispersion modeling) was geo-referenced with the troop units. Using geographic information system techniques, the exposure area was generated by combining modeled outputs from the Defense Threat Reduction Agency, the Naval Surface Warfare Center, and the CIA.
- Using geographic information system techniques, company-level units within the potential hazard area were identified. These units were then sent to OSAGWI, which queried the DMDC Desert Shield/Desert Storm Personnel File (containing 696,693 records) to determine which individuals were in the identified units. The database not only had the last UIC the individual was assigned to, but also contained UIC lists for six distinct time frames for active duty personnel and two additional time frames for reserve units.

Incidents of reported exposures to chemical weapons in the Persian Gulf War were assessed by the OSAGWI from its initial assessment in 1997, to 2002. Summary reports were placed on the website.[45] The investigators reaffirmed earlier findings that chemical warfare agents were present at Khamisiyah and US soldiers destroyed many, but not all, chemical agent weapons in the Khamisiyah pit and Bunker 73.[46]

United Nations Special Commission inspectors also verified the presence of chemical agent rockets in the Khamisiyah pit in October 1991, and the OSAGWI investigation, supported by DoD agencies and the intelligence community, confirmed that US units damaged or destroyed some 2,000 rockets on March 10, 1991. The investigators concluded that demolition of rockets in the pit exposed US units to low levels of chemical warfare agents. However, they were less

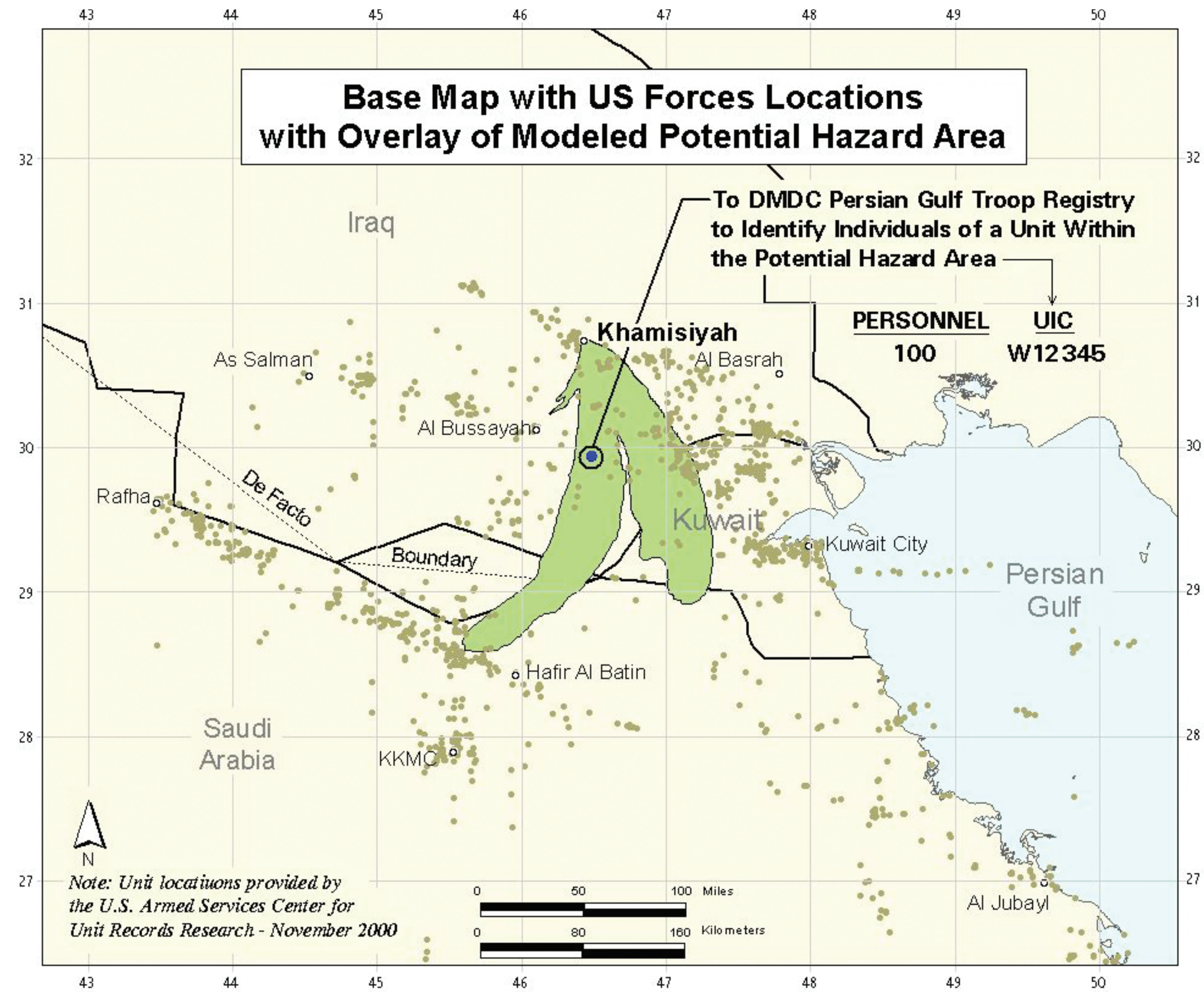

Figure 6-4. The Defense Manpower Data Center Troop Identification base map shows unit locations in the area of interest. The modeled potential hazard area overlay depicted on Day 1 (March 10, 1991) following the destruction of chemical agent munitions at the Khamisiyah ammunition storage facility shows that numerous units were within the potential hazard area. Map courtesy of Jacqueline Howard, US Army Public Health Center.

certain that the destruction of Bunker 73 exposed US service members to chemical agents. Units in the area were a safe distance from the site, and the demolition was thought to have completely destroyed Bunker 73. Additionally, they believed that rains after the event dissipated the chemicals and that prevailing winds blew the chemicals away from US forces. In 1999, the CIA estimated that the amount of agent released was only 5% of that estimated in 1996, further supporting the conclusion that veterans were not likely exposed to chemical warfare agents. The investigators found no evidence that any soldiers at Khamisiyah reported symptoms consistent with exposure to a chemical warfare agent.[45,46]

OSAGWI also concurrently investigated other incidents of reported exposures to chemical agents among US forces in 1990–1991 at sites other than Khamisiyah. Anecdotal reports, documentary and physical evidence, and reports of interviews with eyewitnesses and key personnel were analyzed. Investigators looked for evidence that chemical warfare agents were present at the sites and rated each one using a five-point scale ranging from "definitely" to "definitely not," with intermediate assessments of "exposures likely," "unlikely," or "indeterminate." All incidents were determined to be in either the "definitely not" or "unlikely" category.[45,46]

Jet Propellants JP-5 and JP-8

The major jet fuels used by military aircraft of the United States and its North Atlantic Treaty Organization (NATO) allies include jet propellant–5 (JP-5) and jet propellant–8 (JP-8). The US Navy chose JP-5 as its primary jet fuel because it is safer to use on ships with its higher flash point and lower volatility, and it provides better Navy jet performance.[58,59] JP-8 was adopted by the US Army and Air Force for all aircraft, ground vehicles, and heating and lighting devices.[60] Both JP-5 and JP-8 are refined from crude petroleum.[61] Both fuels are colorless liquids that smell like kerosene, the primary ingredient, and both often contain additive ingredients that permit specialized use. They are liquid at room temperature, but they do vaporize and are considered flammable. The US and NATO effort to adopt a common jet fuel began in the 1980s and finally succeeded in 2000, taking over 20 years to complete because jet engines, vehicle engines, heaters, and other military equipment had to be converted for JP-8 use.[62]

Military service members are exposed to jet propellants in the occupational setting when they work with transporting and storing JP-5 and JP-8, or during refueling operations. Also, environmental exposures occur when cold engine starts of aircraft are conducted. In the occupational setting, maintenance mechanics are required to enter military aircraft fuel cells to look for damage and structural cracks, and often the fuel is not completely removed before their entry. Many service members are exposed when they fill tent heaters and when they perform maintenance on military vehicles (cleaning and degreasing parts) using JP-8.[63,64] The routes of entry of JP-8 into the body include inhalation, dermal absorption, and ingestion. Environmental contamination of ground water occurs from spillage or underground storage tank leaks, and may lead to people drinking water containing JP-8. Military fuel handlers are at risk of breathing in vapors of JP-8 when they refuel aircraft and vehicles.

Often maintenance personnel work without the protective coveralls specially made to resist penetration by the fuels. This leads to dermal absorption from coveralls that are soiled and saturated with JP-8. The US Air Force developed a specially designed set of coveralls for its fuel handlers and maintenance personnel that is both nonsparking and resists penetration by JP-8. In addition to coveralls, workers are required to wear impermeable gloves and boots. Because of the low vapor pressure, a respirator is not usually required in most applications.[65]

Carbon monoxide is one of the byproducts of incomplete combustion of JP-5 and JP-8.[61] This represents the most significant health hazard associated with JP-5 and JP-8 and has resulted in more deaths among service members than any other health effect related to these two fuels. Animal studies show that JP-5 and JP-8 are distributed to organs including the brain, lungs, liver, spleen, and kidneys. However, toxicological studies have not well documented the absorption, distribution, metabolism, and excretion of these fuels in humans.

Many of the toxicological properties of JP-5 and JP-8 are dependent upon the refining process and the source of crude oil used in production.[61] Health effects are dependent on the dose of exposure, duration of exposure, route of entry, and sex and age of the affected individual. Many of the health effects related to these fuels can be predicted based on the toxicological properties of kerosene. Case studies involving children who drank kerosene report that they experience vomiting, diarrhea, stomach cramps, drowsiness, restlessness, irritability, and loss of consciousness. In some cases, children who drank large amounts of kerosene developed convulsions followed by coma and death. If kerosene enters the lungs, children experience coughing, pneumonia, and difficulty breathing.[61] As predicted, inhalation of large amounts of JP-8 vapors causes difficulty breathing as well.[61]

The central nervous system effects of exposure to JP-8 or JP-5 vapors include headache, lightheadedness, anorexia, poor coordination, and difficulty concentrating.[61,66] Dermal exposure to JP-8 may cause itchy, red skin and occasional blisters. Toxicological studies in animals show that repeated skin exposure to JP-8 causes skin cancer in mice.[64] Studies also found that JP-8 is genotoxic because it induces unscheduled deoxyribonucleic acid synthesis.[65] Metabolic degradation products of JP-5 and JP-8 include benzene, toluene, and xylene, which can be detected in blood and urine.[61] Naphthalene has been suggested as a biomarker of exposure to jet fuel.[67] The International Agency for Research on Cancer classified JP-5 and JP-8 as probable carcinogens but noted that more information is needed for humans.[68]

The Department of Transportation classified JP-5 and JP-8 as hazardous materials that pose a risk to health, safety, and property when moved. OSHA has regulated exposure to these fuels in the workplace.[69] The permissible exposure limit for JP-8 is 400 mg/m^3.[69] The military exposure guideline for exposure to JP-8 is similar to the OSHA standard. One toxicological study of JP-8 in humans noted immune suppression following moderate to high exposures in a long-term study.[70] Many people are exposed to JP-5 and JP-8 at work, and long-term studies are needed to examine the health effects of chronic exposure to these jet fuels.[71]

Gulf War Illness in Summary

The DoD began a long-term research effort in 2006 to understand the causes of GWI and to better characterize the medical condition. Despite several hundreds of millions of dollars being spent on research, a medical explanation for what caused GWI is still not available, nor is there a single diagnosis for the condition. The search for possible causes never ended.[6,7,9,14,24]

Persian Gulf War veterans questioned possible links between their symptoms and the hazardous substances they encountered while deployed. Some of the exposures causing concern included the following:

- The greatest concern among service members was the smoke generated by oil wells burning in Kuwait for much of 1991.[4]
- Deployers were worried by the chemical agent alarm warnings and nerve agent exposures resulting from the destruction of chemical agent storage facilities in Iraq.
- Some mistrusted the pyridostigmine bromide pills they were given to protect against the acute effects of nerve agents.[1,6]
- All military personnel who deployed to the Gulf were given anthrax and smallpox vaccines, and many were anxious about side effects.
- Service members were exposed to pesticides and given insect repellants to protect against diseases transmitted by biting insects.
- The military used DU in ammunition fired from tanks and armored vehicles, as well as in the armor of many vehicles.

Personal breathing zone samples were not collected on service members who deployed to the Gulf. As a result, investigators who were trying to determine the cause of GWI were hampered by the lack of available data. Epidemiologic studies that relied on veterans' self-reported exposures during deployment suffered from recall bias, but some studies still noted poor health outcomes.[72,73] Some studies pointed to a limited number of significant risk factors for GWI.[74–76] Other studies found many exposures to be highly correlated, suggesting that confounding errors were present in the studies that evaluated associations between exposure and GWI.[77–79]

In 2008, a congressional federal advisory panel reviewed the scientific literature on the health of Persian Gulf War veterans.[80] The federal advisory panel report noted limitations in the epidemiologic studies in that they failed to assess risk factors for GWI using appropriate analytic methods for complex Persian Gulf War exposures. The panel recommended that studies of GWI include risk factors that are relevant to the outcomes of interest and that analytic methods take into account confounding due to concurrent exposures.[80]

Few studies of GWI provided insights into its causes or the distribution in Persian Gulf War veterans. Further, some studies noted differences in the distribution of disease based on deployment location in theater.[18,81] GWI was more prevalent in veterans who deployed to Iraq or Kuwait, where all battles took place, compared to veterans who went elsewhere.

Studies of GWI that controlled for confounding factors due to multiple exposures[75–78] found that few exposures were significantly associated with GWI. Only the use of pyridostigmine bromide pills and pesticide exposures were consistently identified risk factors for GWI.[74,75,77,78,80] During the Persian Gulf War, US military personnel were poorly informed about pesticide use.[79] Service members tended to overuse pesticides to control swarming and biting insects because they were concerned about sand flies and the diseases they carried.[79] The studies considered the interactions possible between permethrin, used to treat uniforms, and DEET (N,N-diethyl-meta-toluamide), which was applied to the skin to repel insects.

Epidemiologic studies of Persian Gulf War veterans suggested that significant results needed to be adjusted for multiple comparisons and that findings may be due to chance alone. The research community developed several GWI case definitions, including criteria from the Centers for Disease Control and Prevention and a Kansas study.[16,18] When the Centers for Disease Control criteria for developing a case definition were applied, the results were consistently in the same direction (positive or negative) but were considerably weaker compared to the Kansas GWI criteria.[16,18] GWI is likely a set of conditions that have overlapping symptoms, which makes detecting cases difficult. The etiology of GWI is complex, and many deployment-related exposures probably contributed to the development of the constellation of symptoms known as GWI.[80]

BOSNIA, HERZEGOVINA, AND KOSOVO (1995–1999)

In the mid-1990s, the US military deployed troops to the former Yugoslavia to provide security and promote stability among groups engaged in what was to become a decade-long series of brutal ethnic conflicts.[5] With the long-term health concerns from Vietnam and the Persian Gulf War fresh in their minds, leaders in the

DoD and the military services looked for ways to avoid or mitigate potentially harmful deployment exposures, including improving field sampling to identify harmful agents, improving risk assessment processes, and improving policies and doctrine.[5]

Operations Joint Endeavor, Joint Guard, and Joint Forge

The Dayton Accords, the framework for peace in Bosnia and Herzegovina, was signed on December 14, 1995.[5] That same month, about 20,000 US forces arrived in Bosnia as part of NATO's Operation Joint Endeavor. US Army–Europe became concerned about potential exposures among US forces and tasked CHPPM to assess ambient air quality at Lukavac Base and Tuzla Air Base.[5] Personnel at Lukavac Base were near a coal storage area with operating coal-fired boilers and were exposed to airborne soot and other air pollutants from burning coal and fugitive emissions (Figure 6-5). Similar conditions existed at Tuzla Air Base, where coal-fired boilers provided electricity and heat. Beginning in February 1996, CHPPM scientists conducted air and soil sampling to document the conditions.[5]

Environmental surveillance for Operation Joint Endeavor, Joint Guard, and Joint Forge (Operation Joint Endeavor transitioned to Operation Joint Guard on December 20, 1996; Operation Joint Guard transitioned to Operation Joint Forge on June 20, 1998) was the most comprehensive surveillance effort for any deployed US force to date. It involved a coordinated approach between military tactical and support organizations. The surveillance plan initiated by the 30th Medical Brigade, which provided theater medical support for Europe, became a template for future joint medical surveillance systems as envisioned in DoD Directive 6490.2, *Joint Medical Surveillance*, August 30, 1997. The surveillance work was done by the US Army 520th Theater Army Medical Laboratory, CHPPM, and CHPPM satellite organizations in Europe and the United States. Samples were collected from all US base camps in Bosnia and from several other international forces camps in Bosnia, Croatia, and Hungary (Figure 6-6**)**. In excess of 2,300 environmental samples were collected and analyzed for over 120,000 different analytes. The environmental media sampled included air, water, and soil. Sampling parameters included volatile organic compounds, semi-volatile organic compounds, metals, pesticides, herbicides, radiation, and particulate matter.

When samples were analyzed, it was sometimes difficult to determine the significance of the pollutant level relative to a potential health effect. Reference standards did exist, such as the National Ambient Air Quality Standards for criteria pollutants (certain pollutants known to be hazardous to human health), occupational exposure limits, and some comparative values for other chemicals for the general population. However, it was determined that workplace standards were inappropriate for individuals whose exposure might be constant, as opposed to those exposed during an 8-hour workday. Also, the applicability of general population standards for deployed military forces was questioned. There were no comparable standards for some chemicals, so in order to provide context and determine the significance of a finding, the measured level was compared to typical levels in urban and rural environments in the United States. While this did not guarantee that the pollutant level had no associated health effect, it did reflect the fact that US air is not pristine, and is not routinely monitored for many hazards, apart from the National Ambient Air Quality Standards.

Air Sampling Summary

Various compounds were detected in the ambient air of base camps. These results were compared to US environmental standards and guidelines such as the National Ambient Air Quality Standards that address the criteria pollutants (particulate matter, carbon monoxide, ozone, oxides of sulfur, oxides of nitrogen, and lead) and EPA Region 3 risk-based concentrations.[82] These standards and the EPA guidelines are based on lifetime exposures for the entire US population, including sensitive individuals such as young children, those with asthma, and the elderly.

Figure 6-5. Emissions from coal-fired power plants impacted air quality where US forces were located, Bosnia, 1999.
Photograph courtesy of Brad Hutchens, US Army Public Health Center.

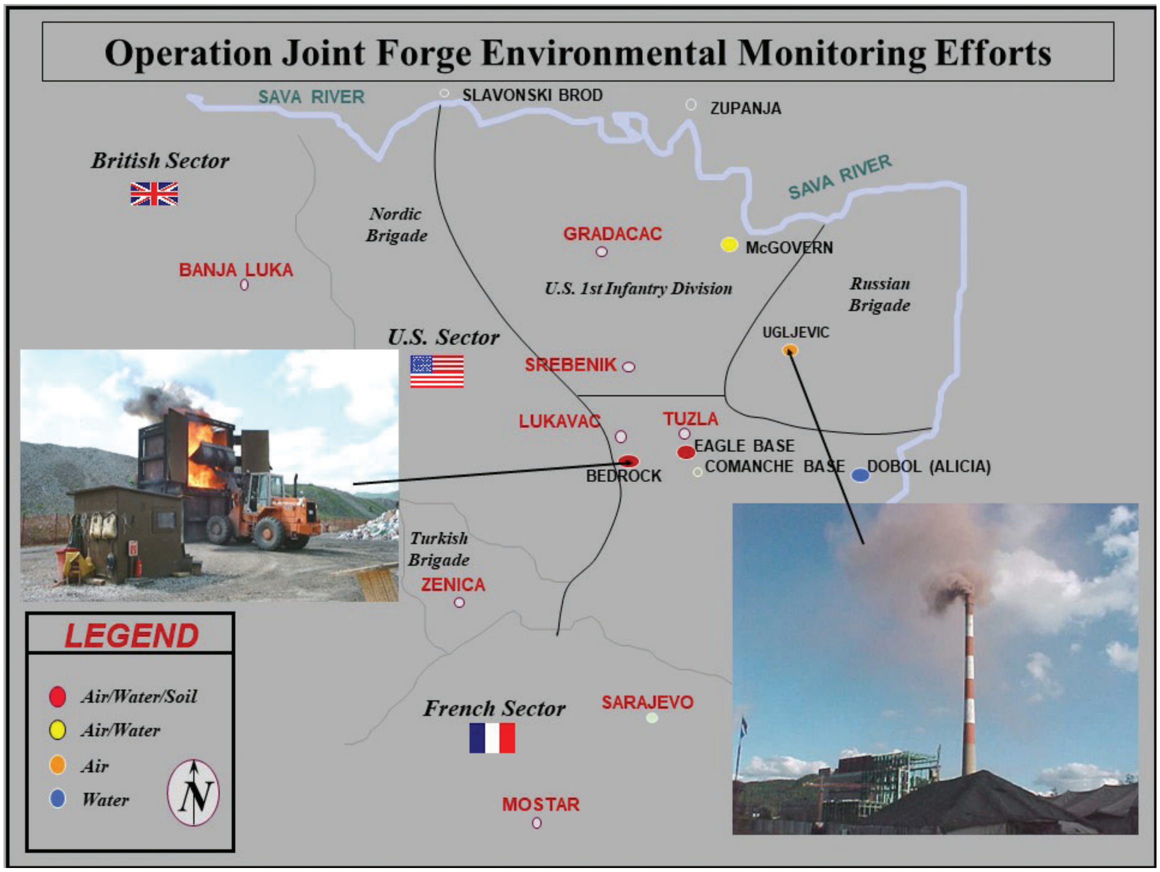

Figure 6-6. The map shows environmental sampling locations for Operation Joint Forge, Bosnia, Herzegovina, and Kosovo, June 20, 1998–December 2, 2004. The photos in the graphic are of Camp Bedrock and Ugljevic, Bosnia, August 1996. Graphic courtesy of Brad Hutchens, US Army Public Health Center.

Particulate matter levels were occasionally elevated up to 2 to 3 times above EPA standards in air samples collected from the base camps. Most of the other compounds detected during the monitoring did not exceed published guidelines. Those compounds that did exceed the standards and guidelines (such as volatile organics, which are not criteria pollutants) were detected at concentrations similar to those present in typical urban areas within the United States. These levels were not expected to pose significant health risks to US forces because the deployed service members were primarily healthy young adults and the duration of their exposures was short.

Water Sampling Summary

US forces primarily used bottled water for consumption and restricted the use of local water to sanitary activities such as showers, laundry, and dishwashing. All water supplies intended for US forces were sampled and analyzed prior to use. Analytical results were compared to health-based standards and guidance such as the EPA primary and secondary maximum contaminant levels (MCLs) established December 16, 1974, under Public Law 93-523, the Safe Drinking Water Act of 1974 (42 USC § 300f),[83] and EPA health advisories when an MCL did not exist. The EPA initiated the nonregulatory Health Advisory Program in 1978 to provide information on pollutants that can affect drinking water but were not regulated under the Safe Drinking Water Act. Primary MCLs apply to contaminants that can pose a health threat, while secondary MCLs apply to parameters that may affect the aesthetic quality of water. Overall, very few sources contained compounds at concentrations greater than the primary MCLs. A few sources were contaminated with the pesticide dibromochloropropane in excess of the MCL. The levels detected were not expected to pose a significant health risk to US forces due to the consumption of bottled water. Occasionally, secondary contaminants such as iron and manganese exceeded the secondary MCLs, but no adverse health effects were expected.

Soil Sampling Summary

Various compounds were detected in the surface soils of the base camps. These were compared to the EPA Region 3 risk-based concentrations for soils in industrial settings.[82] The only compounds detected that exceeded these guidelines were total petroleum hydrocarbons from fuel spills at several of the camps and semivolatile organic compounds from coal combustion. These compounds were not of great concern because exposure to the soil could be avoided or mitigated. The observed radiological concentrations in the soil samples from various base camps fell within the expected ranges for naturally occurring radiological materials when compared to the typical concentrations as outlined by the United Nations Special Commission on the Effects of Atomic Radiation Report.[84] With the exception of cesium-137, other anthropogenic or manmade radioisotopes (eg, cobalt-60 and americium-241) were not detected in any samples. The cesium-137 concentrations were slightly elevated when compared to soil samples collected from Hungary and may have been attributable to the fallout from the 1986 Chernobyl Nuclear Power Plant accident.

Pesticide Wipe Sampling Summary

Pesticide residues were detected, such as malathion, chlorpyrifos, malaoxon, and gamma-hexachlorocyclohexane (also known as lindane) in wipe samples collected throughout troop living areas. Several of the pesticides detected were not commonly used in indoor applications. Their presence in the living areas may have been the result of improperly cleaned pesticide application equipment or improperly cleaned shoes and clothing being brought into the living area. Lindane presented the most concern due to its persistence and toxicity. Lindane dust was previously a component in military unit field sanitation team supplies; however, at the time of the surveillance it was not approved for this use. It is possible that unit-level field sanitation team supplies were contaminated from earlier lindane use. Fortunately, the levels detected were low and not considered to pose a threat to US personnel.

Operation Joint Guardian

CHPPM scientists and others in the DoD studied the environmental surveillance events of Operation Desert Storm, Operation Joint Endeavor, Operation Joint Guard, and Operation Joint Forge and took action to further improve their response for future operations. In June 1999, when US forces entered Kosovo as part of the NATO-led Kosovo forces in Operation Joint Guardian,[5] improvements in the tools for planning and conducting environmental health assessments and surveillance contributed to a well-constructed and well-executed environmental surveillance plan. This plan facilitated identification, documentation, and effective communication of environmental health risks to commanders, who could then take action to avoid or mitigate the risks. Preliminary threat assessments included identification of all known industrial facilities at a location, with a consideration of safe zones surrounding these facilities in the event of a catastrophic event. All pertinent data, reports, and assessments were archived for future use in systems that would eventually become the Military Exposure Surveillance Library (MESL) and the Defense Occupational and Environmental Health Readiness System Industrial Hygiene (DOEHRS-IH) Environmental Health module. In addition, to address the health risk to military personnel while deployed, CHPPM initiated a project to establish military-specific exposure levels for use in the interpretation of sampling results. The resulting Military Exposure Guidelines were based on existing limits with some modifications, such as addressing duration where an 8-hour daily occupational limit would be divided by three to reflect the 24-hour exposure in a deployed setting. These were eventually developed for air, water, and soil at varying military health effect levels (eg, severe, significant, and minimal).

The environmental surveillance activities in the former Yugoslavia reflected the culmination of years of effort by the DoD and the military services to prevent adverse health effects associated with environmental exposures among service members after the 1991 Persian Gulf War. In several instances, the results of monitoring were used by commanders in decision-making. For example, a medical facility was moved due to its proximity to an incinerator, and a lead smelter was closed due to high levels of lead measured in the air. The development of DoD and military service environmental surveillance doctrine led to improved equipment and sampling methods as well as more and better training, and these efforts were credited for the successful environmental surveillance efforts in the former Yugoslavia in the 1990s.[5]

OPERATION IRAQI FREEDOM AND OPERATION ENDURING FREEDOM (2001–2015)

On September 11, 2001, terrorist attacks were launched against the World Trade Center (WTC) in New York City and the Pentagon in Washington, DC. The attacks were attributed to the Islamic terrorist group al-Qaeda, which operated out of Afghanistan under the protection of the Taliban regime. On October 7, 2001, the US initiated Operation Enduring Freedom–Afghanistan (OEF-A) to destroy al-Qaeda's safe base of operations in Afghanistan and end the Taliban's protection of al-Qaeda. OEF also included antiterrorism operations on a smaller scale in other areas of the world, such as the Philippines (OEF-P) and the Horn of Africa (OEF-HOA). On March 7, 2003, the United States began military operations against Iraq (OIF) because the administration of President George W. Bush claimed Iraq possessed and manufactured weapons of mass destruction and supported terrorist groups, including al-Qaeda. On September 1, 2010, OIF was renamed Operation New Dawn (OND). On December 15, 2011, the United States ended its military mission in Iraq, and on December 28, 2014, the US combat mission in Afghanistan was terminated.

US Army Medical Department OEH personnel provided support on a small scale to US Army Reserve and National Guard troops who responded to the WTC attack. On a much larger scale, they provided immediate and follow-up support for the Pentagon attack. They also assisted with the response to terrorist attacks using anthrax spores sent in the US mail. The very long Second Gulf War produced even more challenging occupational and environmental exposures in deployed forces than was observed in the Persian Gulf War.[6,85]

9/11 Attacks on the World Trade Center and Pentagon

The 9/11 attacks consisted of four coordinated suicide attacks on major landmarks in the United States. Nineteen al-Qaeda terrorists hijacked four fully fueled passenger airliners from airports on the US east coast and flew the airplanes toward their intended targets. Two planes hit the WTC; American Airlines Flight 11 crashed into the North Tower, and United Airlines Flight 175 hit the South Tower. Both towers collapsed within 2 hours of the attack. Debris and fires resulting from the fall of the two towers destroyed the other building in the WTC complex and significantly damaged ten surrounding buildings. The hijackers flew a third plane, American Airlines Flight 77, into the west side of the Pentagon, causing a partial collapse of that wing of the building. Passengers on the fourth plane were successful in battling the terrorists and caused United Airlines Flight 93 to crash into a field near Shanksville, Pennsylvania, before it reached its intended target in Washington, DC. The attacks killed 2,996 people and caused many billions of dollars in property damage.[86]

In October 2001, following the attack on the WTC, CHPPM was tasked to identify Department of the Army military and civilian personnel who had supported the rescue and relief efforts. CHPPM was also tasked to document potential exposures and activities performed by these people, determine their subjective current health status, identify perceived injuries or illnesses related to their participation, and offer them an opportunity to have their concerns addressed. A total of 256 WTC rescue and relief participants from the US Army Corps of Engineers and the New Jersey Army National Guard were identified and, beginning in January 2002, asked to complete a survey; 162 (63%) responded, most of whom were in the Army Reserve or National Guard. Respondents identified exposures to dust (87%), chemicals (67%), and smoke (44%); 26% requested medical consultation and were contacted by a CHPPM physician.

The Pentagon attack caused structural, fire, and water damage. Various DoD response teams were dispatched to the Pentagon immediately to determine the levels of hazardous contaminants present in all media in and around the Pentagon, recommend mitigation of any hazards that posed a health threat to occupants and personnel conducting response operations, and measure and assess the health impact of contaminants present from the aircraft and building fire and damage. Response teams included a Special Medical Augmentation and Response Team–Preventive Medicine (SMART-PM) from CHPPM and other personnel from the Pentagon Office of Safety and Health and the Uniformed Services University of the Health Sciences (in Bethesda, Maryland) Department of Preventive Medicine and Biometrics.

The mission of the advance party SMART-PM was to assess initial, acute occupational health hazards for personnel occupying the Pentagon and to recommend actions to assess chronic health risks. The advance team used direct reading instruments to measure volatile organic compounds; aldehydes; dusts; carbon monoxide; hydrogen sulfide; oxygen content; radiological hazards (alpha, beta, and gamma radiation); and combustible gases. The mission of the SMART-PM then transitioned to a systematic evaluation of damaged Pentagon corridors and work areas. The team was assigned to determine if personnel were at risk in their work areas from health hazards and contaminants following the attack and the resulting building fire in a structure approximately 60 years old.

A comprehensive sampling plan was developed, with recommendations from subject matter experts outside the DoD, to determine if levels of contamination in and around the Pentagon were safe for workers to resume normal operations with respect to long-term health risks associated with ongoing exposure. Sampling was conducted throughout the building, moving from the most contaminated areas near the crash site to the least contaminated areas of the building. Samples were collected from areas of personnel concentration. These included common areas such as corridors and intersections, and private areas, such as offices and conference rooms. Samples were collected on all floors including the basement, courtyard (Figure 6-7), and Child Development Center. Samples were collected to assess the health consequences of particulate and chemical emissions from fires and impact damage caused by the aircraft crash.

A wide variety of contaminants and products of incomplete combustion could have accumulated in the building because of the burning aircraft, fuel, and materials contained in the Pentagon. Therefore, numerous sampling methods were used to collect the contaminants. Samples were collected to identify and measure metals, volatile organic compounds, polyaromatic hydrocarbons, dioxins, furans, silica, and asbestos. Air samples were collected to assess the inhalation route of exposure, and wipe samples were collected to assess surface contamination and the risk from dermal exposure and incidental ingestion. In particular, wipe samples were analyzed for dioxins on the recommendation of outside consultants. In addition, water samples were obtained to determine if the drinking water system was contaminated. Occupational samples were also collected to assess exposures to personnel working inside and outside the Pentagon. Samples collected at the Pentagon by CHPPM, US Navy, and US Air Force personnel were analyzed at CHPPM and at certified contract laboratories.

A total of 3,273 precleanup samples, including those tested by direct reading instruments, were collected at the Pentagon. An additional 443 postcleanup wipe samples were also collected. Of the precleanup samples, only 14 asbestos and 41 lead wipe samples exceeded American Conference of Governmental Industrial Hygienists or National Institute for Occupational Safety and Health standards. While dioxin was detected frequently in the precleanup wipe samples, particularly near areas of fire, there was no standard available to determine associated health risks. A decision was made to clean and resample areas with high levels so that they could be deemed clean for comparison purposes. Apart from dioxin, only seven asbestos and one lead wipe sample were above health-based standards after cleanup. Conclusions drawn from the sample results were as follows:

- the only samples that exceeded health-based criteria were one lead wipe sample and seven asbestos wipe samples;
- dermal and incidental routes of exposure presented the greater, although still small, risk compared to the inhalation (air) route;
- contamination was concentrated in the area of the incident (corridors 5 and 6) and on the upper floors (4 and 5), because smoke and contamination tended to rise; and
- sampling data supported the conclusion that the health risks from all sampled parameters in the Pentagon, including lead and asbestos, both before and after cleanup, were minimal if any.

Figure 6-7. Environmental sampling conducted in the courtyard at the Pentagon after September 11, 2001.
Photograph courtesy of US Army Public Health Center.

Anthrax Attacks

Later in September 2001, letters containing *Bacillus anthracis* were mailed to media organizations and US senators.[87,88] The first anthrax letters were mailed from Trenton, New Jersey, with a postmark dated September 18, 2001.[87] Letters addressed to Senators Tom Daschle of South Dakota and Patrick Leahy of Vermont were mailed from the same post office on October 9, 2001.[87] The government mail service was immediately shut down when a staffer in Senator Daschle's office opened the letter on October 15, 2001. Senator Leahy's letter was later found unopened in an impounded mail bag by State Department workers in Sterling, Virginia.[88]

At least 22 people contracted anthrax and five died.[87] A worker at American Media, Inc, in Boca Raton, Florida, died as a result of his anthrax exposure. The EPA found anthrax spores wherever the mail was distributed in the building, requiring extensive cleanup and decontamination of the buildings.[89] The cleanup and decontamination of the US Postal Service Brentwood Processing and Distribution Center, which served the Washington, DC, area, took 26 months and cost $100 million.

The CHPPM commander dispatched an industrial hygiene SMART-PM to help clean up the Senate Hart Office Building. The Capitol Incident Management Team determined the extent of contamination and developed a remediation plan. The SMART-PM provided consultation to the Defense Advanced Research Projects Agency and the Capitol Incident Management Team regarding the sampling plan and how to remediate the building.

US Army mail handling facilities downstream from the Brentwood Processing and Distribution Center tested positive for anthrax at both federal and nonfederal locations. Army mail facilities not originally impacted had to prepare for possible anthrax attacks by evaluating their mail handling procedures and testing their facilities. CHPPM prepared guidance for how to do the risk assessment in mail and nonmail handling facilities, such as offices and break rooms, on Army installations. The goal was to help installations systematically evaluate mail handling facilities to identify vulnerabilities and develop remediation measures if necessary. The Centers for Disease Control and Prevention and the US Army Medical Research Institute for Infectious Diseases helped develop this technical guidance.

A biological contamination response plan consists of a site safety and health plan to protect the responders, and a sampling plan to characterize the extent of contamination. The response plan included instructions for packaging, labeling, and transporting samples; a risk communications strategy; and decontamination procedures. Only industrial hygienists and environmental and preventive medicine professionals with the required training and experience were permitted to carry out the plan. All installation stakeholders were invited to participate to ensure the success of the mission.

CHPPM developed Technical Guide 316, *Microbial Risk Assessment for Aerosolized Microorganisms*, published in August 2009,[90] which details the procedures to assess aerosolized microbial hazards and characterize risk as a result of environmental, occupational (eg, a laboratory accident), or intentional (eg, terrorist) exposures. Technical Guide 316's Supplement A1 and C1 through C7[91–98] were designed to provide exposure guidelines for managing non-weapons-grade *Bacillus anthracis* incidents. The technical guide was intended to initiate collaboration among subject matter experts to develop peer-reviewed exposure guidelines for aerosolized *B anthracis* and other bio-aerosols. However, the effort was hampered by the lack of dose-response information on these biological hazards. The supplements discussed issues of pretreatment with medication or vaccination, whether isolation or other administrative controls were needed, what should be used to disinfect or eliminate exposure, and how the space should be cleared for reentry.[90–98]

Qarmat Ali Water Treatment Plant Chromium Exposures

In March 2003, the Army contracted with Kellogg Brown and Root to restore the infrastructure of the Rumallah oil fields in Basra, Iraq, including restoration of the Qarmat Ali Water Treatment Plant (QA WTP), which treated water for industrial (nonpotable) use.[99] During the summer of 2003, US Army National Guard soldiers were assigned to escort and guard DoD civilian and Kellogg Brown and Root contract workers. From April through September 2003, US Army National Guard troops from four states served on a rotating basis at QA WTP. The worksite had been damaged during military action and vandalized before the restoration began. Containers holding a water treatment chemical containing sodium dichromate had been ruptured, and the powdered chemical contaminated the site. Sodium dichromate, a corrosion inhibitor that contains hexavalent chromium (Cr VI), was found on the ground as a visible powder and detected in the air (Figure 6-8). Eventually, contractors cleaned the area and covered the contaminated sites with asphalt and gravel.

Cr VI can cause acute and long-term health effects, including lung cancer if inhaled at high enough

Figure 6-8. Yellow sodium dichromate, a source of hexavalent chromium, on the ground after bags of the chemical were opened at the Qarmat Ali Water Treatment Plant, Iraq, April–September 2003.
Photograph courtesy of US Army Public Health Center.

levels.[99,100] The inhalation of dust containing Cr VI at the QA WTP was considered a potential health risk.[99] Cr VI can irritate the eyes, nose, sinuses, lungs, and skin. Symptoms of nasal irritation include a runny or itchy nose, sneezing, nosebleeds, nasal ulcers, and a perforated nasal septum. Asthma, skin irritation, and skin ulcers have also been associated with exposure to Cr VI.[99] Lung cancer can develop from breathing high concentrations of Cr VI over months to years. Cr VI has been labeled a human carcinogen by the EPA.

In September 2003, CHPPM was asked to assess the QA WTP site risks and potential health risk to soldiers and Department of the Army civilians.[99,100] The SMART-PM conducted an environmental exposure assessment and medical evaluations of the soldiers there at the time. This evaluation took place in September and October 2003, approximately 1 month after the QA WTP grounds were cleaned and any chemical on the ground was covered by asphalt and gravel to prevent exposure.

Personnel providing security at the time of the health assessments (137 soldiers) were medically evaluated with a history, physical examination, and other testing (described below). The assessment was modeled after the medical surveillance examination used for workers routinely exposed to Cr VI in their occupation, with the addition of other tests. The self-reported average exposure at QA WTP was 18.5 8-hour working days. This exposure, compared to the months and years of occupational exposure cases in which long-term adverse health findings to Cr VI have been documented, was relatively short. Approximately one-fourth of the individuals complained of irritation to the eyes, nose, throat, and lungs. Physical findings were also consistent with mild irritation or inflammation, but only marginally in those who had complained of symptoms, and did not correlate with time spent on the site. There were no nasal perforations or skin findings consistent with "chrome holes," which are associated with Cr VI exposure. All of the self-reported symptoms and physical findings were nonspecific and could have been related to the desert environment and austere living conditions.

Blood and urine tests uncovered only mild, nonspecific abnormalities, possibly related to dehydration, protein and creatine food supplement use, or preexisting conditions. Abnormal findings were uncommon and only slightly outside the normal ranges. All chest x-rays were normal. One-third of the pulmonary function tests (PFTs) had mild abnormalities, but no baseline tests were available for comparison. The PFT abnormalities were related to inadequate patient effort (making the test indeterminate), mild airway obstruction related to smoking or preexisting asthma, and changes possibly due to the general high particulate matter in and around the base camps. No individuals with abnormal test results reported symptoms, except for those with a history of mild asthma, who generally only noted symptoms related to exertion.

Whole-blood tests for Cr levels were performed as a marker of exposure because whole-blood testing identifies Cr outside red blood cells as well as the Cr taken into red blood cells, which is where Cr VI is likely to reside. Sixty percent of Cr VI that does not enter red blood cells is excreted within 8 hours, but Cr VI stays in red blood cells for their 120-day life span and thus gives some indication of Cr VI exposure during the past 3 to 4 months. Additionally, serum Cr levels reflect mostly trivalent Cr, which is usually not toxic, reflects dietary intake, and would not be an accurate measure of Cr VI levels.

The whole-blood test was selected because remediation had taken place and serum Cr would not be related to exposure prior to remediation. The results for Cr were below analytical detection limits, so there was not a significant systemic uptake of Cr VI. However, low levels of Cr exposure still could have caused or contributed to the symptoms reported by soldiers at the time of their medical evaluations. The whole-blood tests were done at the Armed Forces Institute of Pathology in Washington, DC. Although the choice of test was appropriate, few reference ranges were available for comparison of results. Given the cost and complexity, whole-blood Cr levels are rarely performed, particularly in those not occupationally exposed.

The resulting assessment, including a complete medical evaluation and whole-blood Cr testing of the personnel present at the site, concluded that the site hazards were being mitigated by the contractor; the soldiers and civilians evaluated who were serving at the site during the summer of 2003 did not show any specific findings associated with overexposure to Cr VI; and the site hazards did not create an elevated risk of future adverse health effects for those who had served there. The medical team concluded that exposure levels were so low that long-term health effects were unlikely. The soldiers and civilians evaluated were given fact sheets that discussed the results and their meaning. They were directed to follow up with their primary care provider if they had any examination findings or medical test results outside the normal range. Soldiers were also encouraged to note any concerns on their postdeployment health assessment. The medical team report also noted that both physical signs and self-reported symptoms related to the eyes, nose, throat, and lungs were nonspecific; they may have been associated with the desert environment and harsh living conditions. Long-term adverse health effects, such as cancer, were not expected from the estimated average service on site of 18.5 days (with a range from 2 to 720 hours).

Since 2003, this incident has continued to receive media and other attention, which has continued to raise health concerns. The conclusions of the SMART-PM were validated by the Defense Health Board in November 2008.[99] Overall, the medical response to the QA WTP incident was exemplary according to the Defense Health Board. Based on reevaluations and the Defense Health Board review, CHPPM scientists considered it unlikely that any current symptoms or long-term health problems were likely to be related to this short-term exposure. CHPPM scientists acknowledged, however, that there were uncertainties relating to the possible exposure levels prior to the September–October 2003 environmental and clinical assessments.

In 2008, contractor employees filed a lawsuit alleging exposure to toxic chemicals while working on the site. Due to concerns from Army National Guard units from Oregon, West Virginia, Indiana, and South Carolina, and others who were present for some period at the Qarmat Ali facility prior to the SMART-PM assessment, the DoD and VA encouraged those who had served at Qarmat Ali to participate in a medical surveillance program in 2010. The Army and VA established similar but separate Qarmat Ali medical surveillance programs for active duty service members, US Army Corps of Engineer civilians who were present on the site, and veterans who may have been exposed to Cr VI at Qarmat Ali. While the DoD and VA did not expect to find serious illnesses, it was prudent to monitor the health of those who may have been exposed.

The first VA surveillance examinations were conducted in 2011. The veterans enrolled in the program received a complete physical examination with emphasis on the ears, nose, throat, lungs, and skin, and a chest x-ray and PFT. Of the 808 veterans eligible for the examination, 124 participated.[100] There are a limited number of medical diagnoses that may be consistent with previous exposure to Cr VI. These include cancer of the nasal passages, lung cancer, chronic dermatitis, perforated nasal septum, scarring of nasal passages, and occupational asthma. For this participant group, the mean number of reported days of exposure was 21, and 78 individuals provided a history of respiratory symptoms at the time of exposure. Skin symptoms at the time were reported by 38 individuals. No abnormalities specific to Cr VI exposure (eg, nasal septal perforation) were identified.

For the initial DoD follow-up surveillance examination, 74 individuals were identified for follow-up, of which 9 were ineligible and 3 were not located. Thus, 62 were invited to participate. Ten declined, and the remaining 52 were evaluated, for a participation rate of 82% of those eligible. The time on site reported by these individuals was a median of 12 hours. The majority of individuals were not concerned about the exposure, and only two were concerned about cancer. There were no nasal septal perforations noted on examination, and although a number of skin findings were reported, none were consistent with "chrome holes." There were no chest films suspicious for lung cancer. Spirometry, the measurement of the air capacity of the lungs, was an optional procedure, so not all participants had it performed. Of the 44 that did, there were only 3 with mild obstruction, none with moderate or severe obstruction, 6 with mild restriction, 2 with moderate restriction, and none with severe restriction. Two participants reported an onset of asthma, which they associated with onsite work at Qarmat Ali. In one case, a former smoker attributed asthma to "deployment in Iraq" rather than specifically to time spent at Qarmat Ali. This person reported spending approximately 16 hours on site. A second individual, who was never a smoker, reported spending up to 120 hours on site and reported that the asthma symptoms began in May 2003. Other respiratory disorders noted from history, physical exam, or laboratory studies included chronic bronchitis, possible interstitial lung disease, and possible chronic obstructive pulmonary disease. Reported cancer diagnoses included squamous cell cancer of the tongue, liposarcoma, prostate cancer, melanoma, and basal and squamous cell carcinomas. Sinusitis was reported by 12 or 14 participants (depending upon the question answered) representing a prevalence of 23% to 27%, which was somewhat higher than published prevalence rates of 14% to 16%.

The Army included a follow-up survey; 34 individuals returned the questionnaires, for a response rate of 67%. Most individuals participated because, although they considered themselves healthy, they wanted to be examined to ensure that they had no related issues or they wanted to ensure the sodium dichromate exposure was documented in their medical record. On a scale from 1 to 5, individuals reported an average knowledge of Cr-related health effects of 2.29, which rose to 3.67 (more knowledgeable) after the evaluation. The average level of concern about specific potential health effects related to Cr was typically around 2.0, but rose to almost 3 after the evaluation. This may reflect more specific concerns after the evaluation. Providers were trained in risk communication prior to participating in the evaluations, and the evaluations were limited to four locations to facilitate consistent risk messaging.

Additional follow-up examinations were planned to occur every 5 years, beginning in 2017, but the exams will no longer include chest x-rays, which are not a very sensitive tool to screen for lung cancer. Instead, the evaluations will include low-dose computed tomography scans when appropriate. Soldier and US Army Corps of Engineer evaluation results were provided to the individual to share with their medical provider and are stored in DOEHRS. Veterans' examination results are part of the VA Gulf War Registry. Veterans were advised of their right to file a disability claim for any problem that they thought was related to Cr exposure at the QA WTF. Any veteran with abnormal exam findings was referred to a specialist for further evaluation. Civilians were advised to file a claim under the Federal Employees Compensation Act.

Al Tuwaitha Nuclear Complex

Al Tuwaitha Nuclear Research Center in Iraq was contaminated due to military operations in the Persian Gulf War in 1991.[101] The site was bombed during OIF and looted by civilians in 2003. The looting worsened the contamination, which caused great concern on the part of nearby residents, the Iraqi government, and the international community. During the 2003 looting, residents from nearby towns carried barrels from the site into the villages of Ishtar and Al Riyadh, less than 3 km away. Significant dispersion of the radioactive material occurred when the barrels containing yellowcake, a uranium oxide powder, were washed out and the contents scattered near the storage facility and along the roads to Ishtar and Al Riyadh. The barrels were then used to store food and household items.

A team from Texas Tech University, in Lubbock, Texas, conducted sampling at the site and determined the extent of contamination. They determined how the radioactive materials were disbursed and what the sources of contamination were, and assessed the risk to cleanup crews at the site and in the nearby village.[101]

The Al Tuwaitha site had radioactive waste generated from fuel reprocessing. This was determined from the mixture of cesium-137, uranium, cobalt-60, strontium-90, americium-241, and barium-133 that was found on site. Samples collected at the site also showed there was no enriched uranium present.[101] Approximately 6% of the samples collected at the site had elevated levels of radionuclides that required cleanup, removal, and disposal to meet US guidelines. Building surveys indicated there was a substantial amount of material in several buildings, which Iraqi teams had to remove before they could dismantle the most contaminated buildings. Iraq needed a functional radiation analysis facility and a trained technical staff to begin the cleanup, so Iraqi teams attended the required training in Vienna and began to develop proper radio-analytical capabilities.

Efforts to reconstruct the Iraq science and technology sector continue, but these efforts depend on active involvement and collaboration of the international scientific community. Cleanup was estimated to take 15 years.[101]

Ash Shuaiba Port

In support of the Persian Gulf War, Operation Vigilant Warrior (October 8 to December 15, 1994), and OIF, US forces utilized a portion of the Shuaiba Port Industrial Area in Kuwait as a sea port of debarkation/embarkation (SPOD/E). The SPOD/E provided a portal to transport heavy equipment in and out of the theater of operations. The Shuaiba Port Industrial Area contained petroleum refineries, a cement plant, a fertilizer plant, a chlorine plant, and other petrochemical industries (Figure 6-9). Beginning in March 2002, a mobile ambient air monitoring station monitored five of the six EPA criteria pollutants at the SPOD/E. The pollutants monitored comprised particulate matter less than 10 µm in diameter, carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NOX), and ozone (O_3). From January 2003 through approximately July 2005, a life support area, known as Camp Spearhead, provided living accommodations for US service members supporting the mission of the SPOD/E (Figure 6-10). The life support area closed in summer 2005, after which service members primarily working at the SPOD/E were housed at other sites, such as Camp Arifjan and the Kuwait Naval Base, largely due to the concerns identified by environmental monitoring.

Figure 6-9. Flares and smoke from petrochemical plants near the life support area, Ash Shuaiba Port, Kuwait. Photograph courtesy of US Army Public Health Center.

Figure 6-10. Air sampling for particulate matter at Ash Shuaiba Port, Kuwait, August 1999.
Photograph courtesy of Brad Hutchens, US Army Public Health Center.

Several environmental incidents occurred at the port. These included SO_2 emissions from a nearby petroleum refinery on April 2, 2004. At approximately 9:45 AM, service members reported strong sulfur odors and a few complained of headaches and nausea. Noticeable and atypical smoky plumes were emanating from the refinery north of Camp Spearhead. The health, safety, and environment contractor for the camp used a handheld sensor to measure concentrations of sulfur and instructed outdoor and non-mission-critical personnel to seek temporary refuge inside air-conditioned structures. Handheld sensor measurements showed maximum concentrations of 8 ppm (20.94 mg/m^3) to 10 ppm (26.18 mg/m^3). At this site, a mobile ambient air monitoring station trailer was located to provide near-continuous measurement for the criteria pollutants (the mobile ambient air monitoring station reported a maximum concentration of about 6 ppm [15.17 mg/m^3] during the Mishraq sulfur fire episode). For reference, the OSHA permissible exposures level is 5 ppm (above this level nearly all individuals will experience irritation). People with asthma may be sensitive to levels as low as 3 ppm. SPOD/E leadership and safety personnel contacted the Kuwait Port Authority safety office to report the emissions and asked them to cease the operations causing the emissions. By 11:40 AM, the emissions were no longer affecting the camp, and the SPOD/E leadership and safety personnel announced the all-clear status so personnel could return to normal duties.

Service members at the site also sporadically reported strong smells of other industrial emissions, such as hydrogen sulfide, chlorine, and ammonia, associated with symptoms such as headaches, throat and eye irritation, and nausea. Monitoring devices measuring concentrations of those chemicals showed, except for ammonia, levels below the Military Exposure Guidelines. Reports of these types of incidents were infrequent, and information regarding medical assessments and number of service members affected was seldom recorded. Based on the limited information, possible exposures to events such as these appeared to be localized and short in duration.

Another example of this type of incident was reported in February 2006. Service members reported headaches and throat irritation from what was thought to be exposure to ammonia or unspecified volatile organic compounds. Limited monitoring capabilities reported concentrations of ammonia ranging from 8 ppm (5.8 mg/m^3) to 20 ppm (14.4 mg/m^3). These levels are above the odor threshold but below the level associated with health effects. Information on the number of personnel experiencing symptoms and extent of the symptoms was scant.

Similar to most areas in southwest Asia, the site also experienced periodic dust storms. Data for the period from August 2005 to March 2006 showed a maximum 24-hour concentration of 1,300 μg/m^3 for particulate matter less than 10 μm in diameter, which was likely the result of a dust storm. Data from the same reporting period showed an average concentration of 210 μg/m^3 for particulate matter less than 10 μm in diameter In contrast, the EPA's acceptable 24-hour level for PM 10 (inhalable particulate matter with diameters that are generally 10 μm and smaller) is 150 μg/m^3. CHPPM teams conducted routine and incident-specific environmental monitoring activities at Shuaiba Port while US forces lived and worked at the port. In addition to successful efforts to relocate the life support area away from the industrial area, frequent town hall meetings were held to communicate findings and their significance to service members on site. At various times, particularly when new units arrived and others left, concerns would resurface, so regular risk communication was encouraged. Industrial hygiene assets evaluated the sites and conducted limited personal sampling (actual individual exposure levels, measured in a person's breathing zone) on those performing guard duties. Individuals were notified of their results, and all results were entered into medical records.

Mishraq Sulfur Mine Fire and Firefighting Operations

The Mishraq State Sulfur Mine in northern Iraq was set on fire on June 24, 2003 (Figure 6-11). The fire burned for 3 weeks and released 100 times more SO_2

than the Mount Saint Helen's volcanic eruption in 1980. The satellite photos show that the smoke plume varied in direction and distance, and the plume was visible for miles.[102] The fire released 42 million pounds of SO_2 per day, and the plume contained particulate matter, SO_2, and hydrogen sulfide (H_2S).[102] These gases normally cause nose, throat, and eye irritation but can also burn the skin and cause severe airway obstruction, hypoxemia, pulmonary edema, and even death at high concentrations. At levels over 5 ppm, most individuals begin to experience irritation; those with asthma react at lower levels. The National Institute for Occupational Safety and Health immediately dangerous to life or health values for SO_2 and H_2S are both 100 ppm.[103]

The sulfur-fire plume extended 25 km to the south and was thought to be the cause of widespread reports of odors and mucous membrane irritation. SO_2 and H_2S were detected near Qayyarah Airfield West, where the 101st Airborne Division was located. The smoke plume also reached Mosul, approximately 50 km to the north, as seen on satellite imagery. Approximately 3,000 personnel from the 101st were within a 50-km radius of the fire. Field environmental air sampling data collected by an Army preventive medicine detachment confirmed that SO_2 concentrations were very high and above safe levels. The concentrations of SO_2 measured in the air were expected to cause health effects that ranged from mild to moderate irritation, coughing, and choking. It is likely that exposure levels varied by distance from the mine, time exposed, and activities performed during exposure. However, it was not possible to determine an individual's actual dose of exposure because no sampling data were available, and individual location and activities were not recorded.[102]

Figure 6-11. US forces patroling the perimeter of the Mishraq sulfur mine fire, Iraq, July 2003.
Photograph courtesy of US Army Public Health Center.

Among the personnel within the 50-km radius were 191 firefighters and support elements from the 52nd Engineer Battalion, 326th Engineer Battalion, and 887th Engineer Battalion. This group represented the majority of personnel involved in firefighting and was considered the most exposed to sulfur dioxide. The personal protective equipment used by firefighters was inadequate for the high levels of SO_2 and H_2S encountered. At these high concentrations, the respiratory protective mask filters need to be changed frequently, but not enough filters were available to permit changing the canisters at the required frequency.[104] Some firefighters on site experienced irritation, minor burns, and blood-tinged nasal discharges, but the medical staff on site recorded no serious health consequences. Medical personnel on site evaluated those with symptoms and conducted a PFT on each of them. Troops providing security for the firefighting operations were likely significantly exposed to the SO_2 as well. Other troops were also likely exposed; there was a 20% increase in sick call visits at Qayyarah Airfield West during the fire, and there was one reported case of an exacerbation of asthma.

It is likely the mixture of H_2S and SO_2 produced a more severe irritation than would be anticipated with an exposure to one of the gases alone. At very high concentrations of SO_2, permanent lung injury may result. Long-term exposure to levels of SO_2 over 5 ppm have caused permanent pulmonary impairment apparently due to repeated episodes of bronchoconstriction. People with asthma and other sensitive individuals who are exposed to relatively low concentrations can experience a decrease in lung function and bronchial constriction.

Preventive medicine personnel at Ft Campbell, Kentucky, who had deployed with the 101st Airborne Division, believed that thousands of returning troops were exposed to the plume at Qayyarah Airfield West.[105] CHPPM became aware of the pulmonary function testing at Ft Campbell in 2004, reviewed the postdeployment health assessments, and noted numerous concerns regarding exposure to sulfur fire smoke.[104] Soldiers with immediate health concerns were medically evaluated and offered a screening PFT. Soldiers with symptoms and an abnormal PFT were referred to Vanderbilt University Medical Center in Nashville, Tennessee, for further evaluation. At that time there were no clear indications of sulfur-fire exposure related health problems in the redeployed troops, although many of them were still in the evaluation process.

In 2007, CHPPM physicians visited Vanderbilt to review the work that had been done and obtain the medical records of the soldiers referred from Ft

Campbell. Individuals who complained of dyspnea on exertion sufficient to impair their physical training performance had been referred to the Vanderbilt specialist, and many underwent open lung biopsy and received a diagnosis of constrictive bronchiolitis (CB).[105] CB, an inflammatory disease process that occurs in the terminal bronchioles of the lungs, is irreversible and is hard to treat. It has been seen in individuals with prior inhalation exposures. Individuals with CB can experience symptoms of shortness of breath with exertion. The chest x-ray and PFT may be normal. These findings are similar to those in patients who have asthma or chronic obstructive pulmonary disease. The literature supports the conclusion that small-airway disease can be difficult to diagnose with routine tests, which is why the small airways or bronchioles are often referred to as the silent zone of the lung. However, in a population offered voluntary PFTs, without the benefit of baselines, some will ultimately be referred for either abnormal test results or symptoms. Predictive values from an appropriate reference population are important. Additionally, in the absence of a baseline test, results may be read as normal but actually represent a decline for that individual.

From among the group referred to Vanderbilt, those individuals who complained of dyspnea without a known etiology were evaluated with a protocol that had a low threshold for biopsy. The results from their screening tests were variable, and deviations from normal were categorized as "minimal." The pool of those referred for dyspnea on exertion did not uniformly have a history of exposure to the sulfur fire, yet CB was frequently diagnosed. As of July 2007, 49 people had undergone an open lung biopsy, and all of the biopsy samples were abnormal. Thirty-eight were diagnosed with CB. Eleven did not have CB but were diagnosed with sarcoidosis, respiratory bronchiolitis interstitial lung disease, hypersensitivity pneumonitis, respiratory bronchiolitis, or another condition. After December 2009, CB was diagnosed in nine more soldiers in the study group. The CB case series was published in 2011.[6,85,105,106]

The case series represented a unique population that was the product of a potential exposure, a screening program, and a referral process that led to specific diagnostic interventions, possibly with some surveillance bias. The majority of those with a history of potential exposure to the sulfur fire complained of symptoms at the time of the fire, which is compatible with an exposure. Since SO_2 is water soluble, and water soluble compounds react with moist tissues of the eyes, nose, and throat, the most likely presentation for an individual who is at risk of long-term pulmonary damage is significant upper airway damage. Some individuals are very susceptible to the presence of SO_2 and react to concentrations that elicit a milder response in most people. This hyperreactive response occurs the first time the individual is exposed and is not a sensitization. It is important to consider whether a history of an acute upper respiratory response at the time of the fire identified individuals at risk for long-term respiratory sequelae. It is clear that a significant portion of individuals who react acutely to short, high-level exposures (and even to some short, relatively low exposures) to irritants can develop a variety of long-term respiratory outcomes. It is not clear what minimum magnitude of acute response is required to produce long-term adverse outcomes. It is also not clear if the magnitude of the acute response can be used definitively to identify individuals at increased risks for long-term sequelae.

When individuals from the 101st Airborne Division redeployed to Ft Campbell, the screening process was voluntary. Individuals could be symptomatic and screened, symptomatic and not screened, asymptomatic and screened, or asymptomatic and not screened, without regard to exposure potential. Therefore, it was not possible to correctly identify the true population at risk and ensure that they were screened. Of those who ultimately received a diagnosis of CB, approximately a third did not have a clear history of exposure to the sulfur fire. It appeared that with time, more individuals were offered biopsy based on the growing case series and a desire to establish a diagnosis and document potentially disqualifying medical conditions.

The outcome of CB appears to be relatively rare (< 1%, based on the presumed exposed population), although it is difficult to sort out the degree of exposure by location and thus estimate a true incidence. The outcome is also rare in this age group, and serious, with many diagnoses ultimately resulting in an inability to perform military duties. Given that some individuals with a CB diagnosis were not deployed to northern Iraq during this time frame, it is difficult to develop a unifying theory as to potential exposure and outcome.

Apart from the clinical assessment, the original roster of 191 firefighters and support personnel who fought the Mishraq fire was provided to the US Army Public Health Command (USAPHC, which was formed from CHPPM in 2010) for archival purposes (there were no significant adverse health outcomes identified in this group). There was little overlap between this group and those seen on referral to

Vanderbilt, indicating that the individuals seeking care at Vanderbilt were not part of the group thought to be most exposed.

In addition to the firefighters and support staff, USAPHC evaluated the entire group of 6,000 troops who were within 50 km of the Mishraq State Sulfur Plant during the fire. This was a cohort of potentially exposed personnel, since no personal sampling was conducted. The predeployment health outcomes for this group were compared with their postdeployment health outcomes. In addition, two control groups were constructed: a similar size group deployed to the same location after the fire, and a group deployed at the same time as the fire but at different locations. Based on completed predeployment and postdeployment health assessment questionnaires, a substantial proportion of all troops returning from OIF and OEF reported medical problems, respiratory symptoms, health concerns, and air pollution concerns associated with their deployments. Those exposed to the Mishraq sulfur fire were more likely to have reported these problems and concerns compared to unexposed personnel.

Based on clinical encounter data in the Defense Medical Surveillance System, returning veterans of OIF and OEF were at increased risk of requiring clinical assessment or care of chronic and ill-defined respiratory conditions compared to their predeployment conditions.[107] This observation was the same across the population groups analyzed in relation to the Mishraq sulfur fire, although not always with statistical significance. The postdeployment increase in respiratory-related healthcare encounters among firefighters who were in the immediate vicinity of the fire did not differ significantly from the increase among unexposed personnel. Troops who deployed to Camp Q-West, not far from where the sulfur fire had burned, but well after the fire had been extinguished, were more likely than sulfur-fire exposed personnel to have an initial postdeployment respiratory disease medical encounter.

These findings provided one of the first indications that there may be some increase in postdeployment encounters for respiratory conditions apart from a specific exposure of concern such as the sulfur fire. This indication was supported in subsequent studies. The above exploratory analysis did not show a definite link between sulfur-fire exposure in Iraq and either chronic or recurring respiratory diseases. However, the results do not rule out the possibility of such an association. Apart from the possible net effects of the sulfur fire on specific subpopulations, it is significant that a sample of all returning OIF and OEF veterans experienced more respiratory problems after their deployment, compared to before deployment.

Due to the lack of information on prognosis over time with CB, discussion among the pulmonary medical community resulted in a recommendation that those diagnosed with CB be evaluated on a periodic basis. The cluster of cases of CB described above and a cluster of 18 cases of acute eosinophilic pneumonia in US service members deployed in or near Iraq during 2003 to 2004 continue to spur professional discussion regarding possible causative or contributing exposures, as well as finalizing appropriate screening and diagnostic criteria.[85,105,106,108] Recommendations of the Defense Health Board sulfur fire report included long-term follow-up of the cohort in the military health system, establishment of a registry, consideration of standardized medical evaluations of troops presenting with dyspnea on exertion, and baseline PFTs on all service members given the inhalation hazards encountered in deployed settings. These recommendations have not yet been initiated.[109] Education of healthcare providers, including military, civilian, and VA physicians, was recommended to raise awareness about health effects associated with sulfur-fire exposures. These topics were the subject of joint VA-DoD symposium on airborne hazards related to deployment, professional publications, the Defense Health Board review, and a monograph.[12,109–111]

Iraq Chemical Warfare Agent Exposure Review

On October 14, 2014, the *New York Times* published an article entitled "The Secret Casualties of Iraq's Abandoned Chemical Weapons."[112] CJ Chivers reported that "from 2004 to 2011, American and American-trained Iraqi troops repeatedly encountered, and on at least six occasions were wounded by, chemical weapons remaining from years earlier in Saddam Hussein's rule."[112] Contact with the chemical warfare agents (CWAs) occurred during destruction of what were believed to be conventional weapons caches. The chemical weapons found dated to 1991 or before. The service members conducting these operations, their leaders, and the medical personnel who examined those exposed and injured were not prepared to deal with what they encountered.[112] The author noted that the above events underscored intelligence failures, failure to prepare combat personnel to deal with the aged weapons, and failure to prepare medical personnel for the exposures and injuries that would occur.[112] In addition, existing Army policy mandated lifetime follow-up for all service members with CWA exposure, but this was not being done.[113,114]

Following the *New York Times* report, the Army acknowledged its failures and said it would identify and follow those exposed.[115] The under secretary of the Army apologized for the military's treatment of exposed service members and promised medical support for those with persistent health effects.[115] A formal process for doing this was initiated by the under secretary of defense (personnel and readiness), who designated the Army as the lead agent to develop and implement a process to identify and evaluate current and former service members who were exposed to CWAs in Iraq during OIF (March 20, 2003, to August 31, 2010) or OND (September 1, 2010, to December 18, 2011). He also directed the Army to develop and publish CWA exposure implementation guidance for the services to execute.[6,116,117] CWAs were defined as toxic chemicals used in warfare (eg, incorporated into a munition or device specifically designed to cause injury or death). These agents included sarin, soman, tabun, VX, sulfur mustards, lewisite, nitrogen mustard, saxitoxin, ricin, toxic industrial chemicals used as CWA (eg, chlorine and ammonia), and unknown substances.[117]

The implementation plan had four initial goals and one added later:

1. To identify, contact, and evaluate service members and veterans for potential symptomatic CWA exposure.
2. To offer and provide service members and veterans who had a likely or confirmed symptomatic CWA exposure a medical examination.
3. To document the results of these efforts in the DOEHRS and the individual Service Treatment Record and ensure the VA was informed of the findings.
4. To consider appropriate recognition, such as the Purple Heart award, for service members and veterans with injuries resulting from likely or confirmed CWA exposure.
5. To identify the medically and scientifically appropriate level of follow-up for affected service members and veterans, develop the appropriate policy documents, and then implement this follow-up across the services.

Service members and veterans with potential exposures were grouped into four cohorts to facilitate management of the project. Cohort 1 included individuals identified by name in media reports such as the *New York Times* article as having been potentially exposed. Cohort 2 designees were assigned to the units of Cohort 1 group members at the time of Cohort 1's reported exposures. Cohort 3 included those potentially exposed based upon a review of DoD operational reports on CWA exposures in Iraq during OIF or OND and reports on deployment health (eg, Post Deployment Health Assessment and Post Deployment Health Reassessment questionnaires). Cohort 4 individuals self-identified as having been potentially exposed to CWAs while deployed to Iraq in support of OIF or OND using the Office of the Deputy Assistant Secretary of Defense for Force Health Protection and Readiness telephone hotline.[112,115–118]

Electronic service medical records for members of all four cohorts were obtained and electronically searched for any mention of CWA exposure using a very broad list of search terms. Service members and veterans in Cohorts 1 and 4 who could be contacted and consented to be interviewed received a standardized, structured interview with a knowledgeable occupational and environmental medicine clinician. Individuals in Cohorts 2 and 3 were offered a structured interview only if the service medical records screening revealed any of the key words that might be associated with an exposure. If the medical provider conducting the interview determined that the service member or veteran experienced a likely or confirmed symptomatic CWA exposure, a medical examination at the Walter Reed National Military Medical Center in Bethesda, Maryland, was recommended. Even when the interviewing clinician concluded there was no evidence of a likely or confirmed symptomatic CWA exposure, if the service member or veteran requested a medical examination, one was provided at Walter Reed National Military Medical Center. Service members and veterans were fully informed at relevant points in the process that participation in the program was entirely voluntary and that if they opted out, they could opt back in at any time. A number of fact sheets regarding both short- and long-term health effects of exposure to various CWAs were developed and provided to program participants. More detailed informational documents were distributed to providers.

When appropriate, the medical point of contact for each service provided the human resources point of contact for their service with information from the structured interviews. For service members and veterans deemed to have injuries resulting from a likely or confirmed symptomatic CWA exposure, the services contacted them and provided information on the requirements for consideration of the Purple Heart and assisted with the submission packet. The services were directed to ensure that all service members and veterans identified as having a likely or confirmed symptomatic CWA exposure had their clinical information documented in their Service Treatment Record, and applicable disposition information documented in the DOEHRS. Pertinent information was provided to the VA.

Each military service managed its own group of possible symptomatically exposed service members and veterans in Cohorts 2, 3, and 4 for the medical record screening and structured interview. All members of Cohort 1, all medical record screenings interviews of Army personnel, and the scheduling of all examinations at Walter Reed National Military Medical Center were handled by the USAPHC. As of April 2016, 6,023 Army service members or veterans were enrolled in one of the four CWA investigational cohorts and had a record in the DOEHRS. Medical records screenings were completed for 5,926, and 1,155 had participated in structured interviews. There was no evidence of a symptomatic CWA exposure in 5,092 individuals. Structured interviews identified 255 Army service members or veterans with symptomatic CWA exposures, and these were offered a medical examination. An additional 76 were authorized a medical examination on their request. For all services, 190 service members or veterans were examined at the Walter Reed National Military Medical Center, and 24 more were scheduled for examinations. For the 190 examined, no association between a CWA exposure and chronic health effects has been observed. A few individuals who had developed blistering after exposure to a blister agent (eg, mustard) had scars.

Burn Pits in Iraq and Afghanistan

Waste generated by military forces training in the field or deployed has long been recognized as a concern because it may attract rodents and insects and contribute to disease transmission. Open air waste burning was an accepted, expedient solution to the problem and did not draw much attention when the amount of waste was small and large numbers of troops did not stay in the same location for long periods of time.[6] When US forces entered Afghanistan in 2001 and Iraq in 2003, open-air burning was thus considered an accepted, expedient, short-term solution for solid waste disposal. Deployments to these two countries produced large volumes of waste, much of it novel waste not associated with earlier military operations. These military forces relied heavily on bottled water that was delivered in plastic bottles on large, shrink-wrapped pallets; disposable plates, cups, and eating utensils made of plastic or Styrofoam; and electronic equipment for duty and personal use.[8,119] DoD estimated an average of up to 10 pounds of waste was generated per person per day, with up to 200 tons of waste burned at an installation in one day.[8] The burning pits were large and operated continuously, with plumes that contained soot and ash of varied composition, depending on what was being burned (Figure 6-12). People exposed to burn pit emissions complained of red, irritated eyes; respiratory irritation; and cough, which could persist.[8]

The installation of long-term waste disposal systems, such as incinerators, was hampered by contracting or money problems, and the open burn pits were maintained at least until 2009, some reaching many acres in size and burning all types of waste.[8,119] Comprehensive burn pit guidance was slow in being developed and implemented, and existing guidance was not always followed. For example, items prohibited from being burned because of their harmful emissions, such as plastics, tires, batteries, petroleum products, aerosol cans, and hazardous and medical wastes, were not segregated. Additionally, burn pit emissions were not monitored or sampled.[120] Anecdotally, Pentagon officials noted that most of the troops returning from war zones reported exposure to burn pit smoke, and most did not have respiratory protection.

Concern mounted, and in August 2009, President Obama declared that "burn pits will not become another Agent Orange."[121] VA Secretary Eric Shinseki asked, "How do we change what has been the 40-year journey of Agent Orange, the 20-year journey of Gulf War Illness, and prevent a similar journey for burn pit smoke?"[121] Lawsuits were filed in over 40 states in which former and current service members alleged they were exposed to air pollutants that caused health problems as a result of a contractor's negligent management of burn pit operations.[120] Service members who had deployed to Afghanistan and Iraq

Figure 6-12. Emissions from an open burn pit drifting toward the life support area, Balad Air Base, Iraq, August 2006. Photograph courtesy of LTC Scott Newkirk, US Army Public Health Center.

complained of severe respiratory disease, including asthma and CB, and cancers such as leukemia. Affected individuals anecdotally associated or attributed these to exposures to the burn pits.[8,106] However, attempts to assess possible associations between exposure to burn pit emissions and disease were hampered because data on exposures and medical conditions were lacking and epidemiological studies were conflicting or inconclusive.[8] Nevertheless, multiple long-term epidemiological studies of troops living or working near burn pits and studies of respiratory disease are ongoing.[12,110,122–130]

The American Legion and Veterans of Foreign Wars stood up for concerned service members and their families and called for the creation of a national burn pit registry, which would include a listing of all military personnel exposed to burn pits. On January 10, 2013, Public Law 112-260, Dignified Burial and Other Veterans' Benefits Improvement Act of 2012 (38 USC 101 note),[131] was passed. It required the secretary of veterans affairs to establish and maintain an open burn pit registry, to notify eligible individuals of developments in the study and treatment of conditions associated with toxic airborne chemical exposures, and report to Congress on the effectiveness of actions taken to collect and maintain information on the health effects of toxic exposures.[131]

The VA Airborne Hazards and Open Burn Pit Registry was pilot tested in April 2014 and opened nationally on June 19, 2014. The purpose of the registry was to ascertain and monitor potential health effects from exposure to airborne environmental hazards with the overall goal of improving outreach, communication, and VA programs for eligible veterans. It was established as a database of information provided by veterans and people still in the military, using a website and self-reported questionnaires.[132,133] It intentionally included all deployment-related airborne exposures, including burn pits, and was opened to any veteran or active duty service member who deployed to the southwest Asia theater of operations on or after August 2, 1990, and those who deployed to Afghanistan or Djibouti after September 11, 2001.[132]

The USAPHC prepared supporting documentation for the VA Airborne Hazards and Open Burn Pit Registry and noted that:

> Over 3.5 million individuals were eligible to participate in the registry. Participation was voluntary and was accomplished by completing an online self-assessment questionnaire. The detailed questionnaire was designed to give a broad picture of the participant's health and current and past exposures. Registry participants were encouraged to report deployment exposures to all airborne hazards, such as burn pit emissions, oil-well fires, pollution, and dust from sand storms they experienced, and their health concerns.[132]

The registry was considered useful because it established a baseline of health information that might be used to identify future changes in health, copies of completed questionnaires could be used to discuss concerns with healthcare providers, and completion of the questionnaire linked the individual to the VA, a link through which information could be provided on follow-up care and benefits.[132,133]

The VA has completed a series of reports that showcase registry participant characteristics, common health concerns, and other information.[133–135] A June 2015 report summarized the information entered into the registry from April 2014 through December 2014. By June 2015, over 28,000 participants had joined the registry. The 2015 VA report noted, "the most common physician-diagnosed problems were insomnia and neurological problems and other diagnoses included allergies, high blood pressure, and lung disease such as emphysema, chronic bronchitis, and asthma."[131] A total of 309 registrants reported physician-diagnosed CB.[131] The report presented descriptive data and did not implicate any exposures as causing specific diseases or conditions. Participants ranged in age from 20 to 79 years, with about 70% under age 45. More than two-thirds served in the Army, most were men (over 85%), and they represented a range of races and ethnicities. About 89% reported they had trouble doing at least one daily activity such as walking, running, or stair-climbing because of a neck or back problem (59%), knee problem (38%), breathing problem (34%), arthritis (29%), and/or a mental health problem (24%). Over 53% reported an interest in having the registry's optional medical examination.[131–133]

The 2011 Institute of Medicine report on burn pits noted the following:

> There is not yet enough medical or scientific information to conclude that long-term health effects on a population-level have occurred due to burn pit smoke. However, DoD medical leaders have acknowledged that acute symptoms related to smoke exposure may occur, including reddened eyes, irritated respiratory passages, and cough, and these may persist for some time. A small number of Service Members may experience longer-term health effects, related to combined exposures of sand, dust, industrial pollutants, tobacco smoke and other agents, and individual susceptibilities, to include pre-existing health conditions or genetic factors. Veterans and Service Members who were closer to burn pit smoke or exposed for longer periods may be at greater risk for health problems. Individual health effects will

> vary and may depend on a number of other factors, such as the type of waste being burned and wind direction. The high level of fine dust and pollution common in Iraq and Afghanistan may pose a greater danger for respiratory illnesses than exposure to burn pits.[8]

VA, DoD, and academic researchers continue to collaborate and study deployment-related airborne hazards, burn pit exposures, and the health of deployed veterans and service members.[110,122–130] Joint national symposia have been held, and a book describing the state of the science of deployment-related airborne hazards has been published for exposed service members, veterans, and the physicians who care for them.[12] Future research plans include studying the exposures and clinical outcomes of registrants who elect to have the no-cost registry medical examination, as well as further study of the registry-reported cases of physician-diagnosed CB and other health conditions that may rise to levels of concern. The last report on data from the Airborne Hazards and Open Burn Pit Registry was in June 2015.[134] The VA plans to issue periodic summary reports on the registry, and these and earlier reports will be available on the VA website.[133]

OCCUPATIONAL AND ENVIRONMENTAL HEALTH INFORMATICS

In the 1990s, DoD officials had to respond to questions from Persian Gulf War veterans regarding their environmental and occupational exposures while deployed and the possible association of these exposures with their medical conditions.[133] Additionally, the decade following the Persian Gulf War rapidly became a decade of deployments with new health concerns, with US forces being sent to Africa, the Caribbean, the Balkans, and southwest Asia.[133] Analysis of this situation at the DoD led to initiatives aimed at better protecting the health of service members, particularly those deployed into hazardous areas, under the heading of force health protection. These initiatives were directed toward improving communication about health risks, improving medical record keeping, increasing biomedical research to improve countermeasures to protect troops, and improved health surveillance to better capture and store occupational and environmental exposure data.[133] The surveillance activities resulted in the popular use of the term "deployment health surveillance." CHPPM was given an important role in improving OEH surveillance in support of deployment health surveillance.[133,135,136]

CHPPM was designated the DoD executive agent for deployment OEH surveillance measures, databases, data analyses, and support items.[135] In 1996 CHPPM formed the Deployment Environmental Surveillance Program to execute these responsibilities.[135] Deployments were occurring, and potentially important exposure data from occupational and environmental samples were being analyzed. The Deployment Environmental Surveillance Program faced the challenge of how to expeditiously and meaningfully capture and manage this information. In 1996 the program staff developed an internal database to capture, processes, analyze, interpret, and report all environmental samples collected during military deployments. However, this database was inadequate to meet the occupational and environmental informatics needs of future decades, so systems such as the DOEHRS and the MESL were developed.

Defense Occupational and Environmental Health Readiness System

Prior to 1996, in an attempt to better deal with the data challenges described above, military medical leaders looked at the possibility of building upon already operating systems. Beginning in the early 1980s, the US Army Medical Department took steps to modernize and standardize occupational health data collection, storage, retrieval, and use.[137] The Occupational Health Management Information System was developed as an integrated system that included the following:

- a Medical Information Module to assist with the management of clinical services and clinical medical surveillance programs;
- a Hearing Evaluation Automated Registry System to facilitate collection, capture, and storage of audiometric testing data; and
- a Health Hazard Information Management system to support the Army industrial hygiene effort by capturing and maintaining workplace hazard data and information on hazard controls.[137]

In the late 1990s, the DoD selected the Hearing Evaluation Automated Registry System and the Health Hazard Information Management modules to become platform components for the new DOEHRS. In 1999, the Hearing Evaluation Automated Registry System became the foundation for DOEHRS Hearing Conservation (DOEHRS-HC) module. Later, the Health Hazard Information Management system became the foundation for DOEHRS Industrial Hygiene (DOEHRS-IH) module.

The DOEHRS-HC system consisted of a web-based data repository and a desktop application to administratively support the provider. It improved personal auditory readiness by supporting education and the proper use of hearing protection, and helped to prevent significant hearing loss by detecting early hearing changes through audiometric testing. Using DOEHRS-HC in its entirety, hearing conservationists and audiologists collect, maintain, compare, and report hearing conservation, hearing readiness, and deployment data for DoD personnel. The desktop application consisted of a stand-alone government application and commercially available audiometer software. The system automated instructional programs and hearing test procedures for up to eight concurrent test stations from a single computer at a testing site. Hearing tests were recorded in the DOEHRS-HC stand-alone application and were uploaded to the DOEHRS-HC data repository. Staff used DOEHRS-HC to analyze the test results and determine if changes in hearing had occurred and if a significant hearing loss existed. The DOEHRS-HC data repository maintained approximately 60 million hearing test records for current and former service members and DoD civilian employees.

The DoD deployed DOEHRS-IH in 2006 to capture occupational exposure data. Before 2006, each military service used its own automated information system. Federal employees were covered under the Occupational Safety and Health Act of 1970 through Executive Order 12196. The DOEHRS-IH automated information system was designed to support compliance with the act by facilitating the development of an employee exposure record that met the act's criteria. The act's requirements for an exposure record included data obtained by monitoring or measuring toxic substances or harmful physical agents in the workplace, safety data sheets for materials used by civilian workers and military personnel in performing their jobs, and chemical inventories or records that documented where and when a toxic substance or harmful physical agent was used. DOEHRS-IH records contained information on predeployment, deployment, and postdeployment worker exposures. These data permit exposure-based medical surveillance, allocation of resources, implementation of controls, and development of training programs. Environmental, safety, and occupational health practitioners can analyze the data to prioritize preventive countermeasures to protect health.

The medical information module component of the Occupational Health Management Information System was never funded for migration to DOEHRS. Attempts were made to include functionalities from the medical information module in the Armed Forces Health Longitudinal Technology Application, the clinical documentation engine developed for DoD healthcare providers for recording clinical notes, orders, and procedures performed. An Armed Forces Health Longitudinal Technology Application template library was developed for hazard-specific medical surveillance encounters to complement the Composite Health Care System, the medical informatics system used by DoD military health system facilities. Many occupational health clinics adopted the Navy PC Matrix software, which provided much of the functionality of the medical information module of the Occupational Health Management Information System but produced only a hardcopy printout that had to be scanned and uploaded to the Armed Forces Health Longitudinal Technology Application.

Defense Occupational and Environmental Health Readiness Environmental Health Module and Military Exposure Surveillance Library

The USAPHC needed an information technology system that was capable of capturing and managing OEH data and stood up the Environmental Surveillance Integration Program (ESIP) to perform the mission. The ESIP was assigned the responsibility to assemble and archive all DoD deployment and environmental health surveillance data and reports required by DoD Directive 6490.2. ESIP staff initially developed the Occupational and Environmental Health Data Portal, a password-protected Internet site that allowed the management and archiving of electronic files associated with OEH surveillance activities. In addition, ESIP staff maintained an in-house database to record environmental sample results.

Personnel needed ESIP's information technology system to capture, process, analyze, interpret, and report all OEH data from DoD sources. In conjunction with the restructuring of the Deployment Environmental Surveillance Program in 2006, the DoD expanded the capabilities of DOEHRS-IH to capture deployment environmental sampling data, creating an environmental health module in DOEHRS-IH. In 2011 the ESIP scientists, working with representatives from the other military services, expanded the functionality of the EH module to include sanitation inspection reports, waste management inspection reports, entomological surveillance reports, and OEH site assessments (OEHSAs). In addition, DOEHRS-IH was expanded to contain incident reporting, food protection, radiation and registry modules. The DOEHRS-IH registry module now houses data for the Persian Gulf War oil well fires, Operation Tomodachi (the response to the 2011 earthquake and tsunami in Japan), and the OIF CWA exposure investigation.[4,112,138]

The DOEHRS-IH Environmental Health module was to be used by all military services for the management of unclassified environmental samples and other preventive medicine surveillance surveys. In October 2007, an Occupational and Environmental Health Data Portal application was developed on the SIPRNet (the Secret Internet Protocol Router Network used by DoD for classified information) to manage classified OEH documents. Both the classified and unclassified Occupational and Environmental Health Data Portal applications were rebranded and named the MESL in October 2011. The concept for maintaining these separate systems was that the DOEHRS-IH Environmental Health module was the system of record for all OEH computable data. The NIPRNet (the DoD Non-Secure Internet Protocol Router Network for exchanging unclassified information) MESL was the official system of record for OEH non-computable data (eg, memoranda, photos, and situational reports) and computable data that DOEHRS-IH Environmental Health module could not accept (eg, pesticide application data and basecamp assessment team reports). In addition, the NIPRNet and SIPRNet MESL were the only systems with the ability to search the contents of electronic documents. There was overlap of system capabilities, but maintaining separate systems was considered necessary to acquire and manage all OEH data.

A 2015 Government Accountability Office (GAO) review concluded that policy should be clarified to note which system, DOEHRS-IH or the MESL, should be used for specific types of OEH data. The GAO report noted the following:

- inconsistent quality assurance processes among the military services that brought into question the reliability of the stored OEH surveillance data;
- inconsistent DoD and military service-specific policies that resulted in duplication and fragmentation in the storage of OEH surveillance data with confusion about utilization of the DOEHRS and the MESL; and
- an absence of documentation showing that the potential health risks identified through OEH surveillance were being addressed and actions were being taken to mitigate health threats.[139]

The GAO report generated interest at the congressional level. In response, revision of DoD Instruction 6490.03, *Deployment Health*, published in August 11, 2006, was initiated to address the GAO recommendations.[140] This revision specified that all unclassified OEH data shall be managed in DOEHRS-IH and all classified OEH data shall be managed in the SIPRNet version of the MESL (MESL-S).

The ultimate goal for DOEHRS-IH and MESL-S was the formation of an integrated system that could provide every service member a longitudinal record of individual environmental and occupational exposures over the course of their military career. The DOEHRS-IH is the DoD system of record for entering, assessing, managing, and reporting unclassified occupational and environmental exposure data. DOEHRS-IH was designed for use in both garrison and deployed operations. It contains environmental health surveillance data beginning with Operation Joint Endeavor in 1995 and is expected to continue to receive data for future deployment operations.[5] DOEHRS-IH is the foundation for the future DoD Individual Longitudinal Exposure Record.

Unfortunately, the DOEHRS-IH and MESL systems are not integrated into the current medical record system nor the new electronic health record system being developed by the DoD. Therefore, a medical provider requiring access to environmental surveillance or workplace surveillance data may not know about, nor can they query, these databases to obtain exposure data.

Occupational and Environmental Health Site Assessment Report and Periodic Occupational and Environmental Monitoring Summary

The OEHSA process is an ongoing, information organizing process that provides reports to support OEH risk management on military installations in operational environments.[141] The OEHSA process supports the documentation of environmental conditions and identification of potential OEH threats, and guides OEH data collection, risk assessments, and risk mitigation actions. It also supports data collection and risk assessments over time, including health risk assessment and health risk management activities. An end product of the OEHSA process is the Periodic Occupational and Environmental Monitoring Summary (POEMS).[142] POEMS reports describe exposure hazards (eg, airborne pollutants and infectious diseases); summarize the data and information collected; and provide assessments of known or potential short- and long-term (including postdeployment) health effects for people deployed to specific sites. OEHSA and POEMS reports are managed in DOEHRS.[141,142] POEMS reports can be downloaded from the USAPHC website (https://phc.amedd.army.mil/topics/envirohealth/hrasm/Pages/POEMS.aspx) and are used by clinicians, medical epidemiologists, and deployed service members themselves to identify exposures and to assess possible relationships between deployment exposures and existing medical conditions. From December 2015 through January 2017, 10,052 POEMS reports were downloaded.

SUMMARY

Even though symptoms and diseases in Vietnam veterans that were considered to be related to their deployment, and particularly to exposure to Agent Orange, caused great pain, anxiety, frustration, and cost, the US Army was not prepared to avert a similar occurrence in the short Persian Gulf War of 1991.[1–3,6,143] As symptoms and diseases developed in the veterans, many potentially harmful exposures were identified and suspected as contributors to the ills of those who had carried the burden of battle in the Persian Gulf War. Many committees and panels reviewed the available data and noted that while no causal link was established, health effects from exposures to pesticides, chemical and biological warfare agents, vaccines, pyridostigmine bromide, infectious diseases, DU, oil well fire smoke, and petroleum products were possible. Exposures occurred, but investigations into them were superficial and inadequate because very little personalized exposure information was collected.[143] “Defining the exposed and relevant control groups and obtaining data for them would be very difficult. The lack of exposure data limited even the most expert and well-funded investigation to identify health outcomes linked to specific exposures or risk factors.”[144] The GAO noted, “without accurate exposure information, the investment of millions of dollars in further epidemiological research on risk factors or causes for veterans’ illnesses may result in little return.”[144]

As a result, a strong effort was put forth to quickly identify and assess potentially harmful exposures in future deployments and to expeditiously provide data and information to informed military leaders who could take action to prevent or mitigate the exposures. This effort seemed to produce the intended results when US forces were deployed to Bosnia, Herzegovina, and Kosovo in the former Yugoslavia.[5] Available data was sometimes timely and sufficient to allow a commander to make decisions about troop facility locations relative to hazards. To date, however, sampling data has rarely been sufficient to assuage concerns of those potentially exposed, or to negate potential health effects. The Institute of Medicine of the National Academies and other groups studied the exposures and medical problems of Vietnam and Persian Gulf War veterans and provided recommendations for protecting the health of US service members in future deployments.[1,7] These recommendations are still out of reach for full implementation. Unfortunately, and in spite of the efforts of many, history was repeated in the protracted military actions during OEF and OIF.

The various symptoms and diseases that service members bring home with them after their battles have ended may never be fully understood, successfully treated, or prevented. However, potentially hazardous exposures that are amenable to prevention or mitigation do occur during hostile deployments, and their rapid identification and assessment, with appropriate command action to avoid or mitigate the threat to service members, could prevent future anxiety and even disease. Collecting samples and storing data and information are not ends in themselves. Modeling potential exposures, identifying those who may have been exposed after an incident, and forming registries for those who may have been exposed have value but are not substitutes for preventing or mitigating a potentially harmful exposure. While acute exposures at levels high enough to immediately affect soldiers are easier to identify and easier to relate to predictions of long-term health outcomes, poorly defined lower level exposures typically involve much more uncertainty.

In 2007, the Office of the Chairman of the Joint Chiefs of Staff issued a memorandum requiring commanders to factor long-term health risk into their operational decision-making.[145] In order to do so, military leaders must identify, be knowledgeable about, and respect potentially harmful exposures. This requires the professional support of informed military occupational and environmental medicine physicians and other military occupational health professionals who can facilitate the rapid identification and assessment of the hazards and provide timely and sound advice to prevent or limit disease, injury, and even death.

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