Assessing Potentially Hazardous Environmental Exposures Among Military Populations

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To all of the speakers and attendees!

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Bethesda, Maryland
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Acknowledgements

Supplement Guest Editors

Joel C. Gaydos
Timothy M. Mallon
Erin E. Richards

The hosting organizations would like to recognize the following individuals for their contributions:

Supplement Reviewers

Joseph Abraham
Coleen B. Baird
Kimberly A. Beck
Michael R. Bell
Glenn Berckman
Kelley Brix
Jean-Paul Chretien
Tifani Grizzell
Deanna K. Harkins
Jack M. Heller
Nikki N. Jordan
Joseph M. Kaczmarczyk
Victor H. Macintosh
Kelly T. McKee, Jr.

William G. Meyer
Richard N. Miller
John Muller
James S. Neville
Francis L. O’Donnell
Forrest W. Oliverson
Laura A. Pacha
Manmohan V. Ranadive
William A. Rice
Jennifer A. Rusiecki
Anne I. Scher
John S. Scott
Steve R. Smith
William Yang

Administrative Support

AFHSC
Priya Baliga
Steve R. Gubienia
Robert J. Lipnick
Robin A. Miliner
Annette M. Von Thun

CDHAM/USUHS
Claudia S. Creenan
Margot E. Craig-Louden
Kevin F. Riley
Sharon Willis
Jeff Zimmerman
Assessing Potentially Hazardous Environmental Exposures Among Military Populations

a scientific symposium hosted by:
ASSESSING POTENTIALLY HAZARDOUS ENVIRONMENTAL EXPOSURES AMONG MILITARY POPULATIONS – A SYMPOSIUM & WORKSHOP

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RADM Gerald V. Quinnan, Jr., USPHS (Ret.)
COL Robert F. DeFraites, MC, USA
CAPT Trueman Sharp, MC, USN

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COL Timothy M. Mallon, MC, USA

COL Robert F. DeFraites, MC, USA; CPT Erin E. Richards, MS, USA

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Panel 3: Conducting Environmental Surveillance Sampling to Identify Exposures
LTC Robert W. Batts, MS, USA; CPT Diana Parzik, MS, USA

CDR Mark Reddie, MC, USN; CAPT Mark Lyles, DC, USN

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CREDITS

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Burn Pits

Oil Well Fires
Burning oil wells of the Ahmadi Oil Field. Photo taken by Jack M. Heller, PhD, from Camp Freedom, Kuwait, in May 1991. Provided courtesy of Dr. Heller.

Dust Storms

Group Picture
Provided courtesy of the Uniformed Services University of the Health Sciences, Bethesda, MD.
June 28, 2010

Dear Colleagues:

The Uniformed Services University of the Health Sciences (USU) is proud to be a sponsor of this year’s Military Public Health Symposium and Workshop, “Assessing Potentially Hazardous Environmental Exposures Among Military Populations.”

This symposium covers military deployment-relevant environmental exposure topics whose understanding is critical to the success of our Nation’s current global deployments. USU is committed to ensuring that our healthcare providers not only treat diseased and injured warriors, but to additionally focus on preventing potentially harmful environmental exposures that cause disease and illness.

The environmental conditions our forces operate in can be harsh and it is important for us to understand the threat, as well as effective interventions to mitigate exposure, as we strive to meet our commitment to “care for those in harm’s way.” One of the strengths of this symposium will be to look back to historic deployment-related public health environmental exposures and follow through the course of how they impacted operations, as well as their resulting impact on chronic health effects. USU, and the Armed Forces Health Surveillance Center symposium organizers, have invited experts with firsthand experience in responding to Agent Orange in Vietnam, Depleted Uranium in the former Yugoslavia, and oil fires in Kuwait to explore how these experiences can assist us in dealing with our current environmental exposure issues in Iraq, Afghanistan and into future operations.

This symposium provides an opportunity for USU faculty and students to interact with environmental exposure experts within DoD, other federal agencies and throughout academia to share environmental exposure-related public health experiences, as well as discuss the way forward as our nation continues to conduct combat operations in challenging environments on multiple fronts.

Environmental and occupational health may not garner media attention praising how much disease and illness its efforts have prevented, but safe drinking water, adequate wastewater disposal, safe food, clean air, waste disposal, heat and cold injury prevention, as well as health surveillance, are all critical to the current and future health of our uniformed service members.

Our curriculum, including that of our graduate programs in public health, incorporates many of the topics presented during the symposium. USU is proud to offer environmental exposure related courses such as: Environmental Health, Environmental Health Risk Assessment, Deployment Environmental Exposures, Industrial Hygiene, Toxicology, Environmental and Occupational Epidemiology, Environmental Chemistry, Solid and Hazardous Waste Management, Hydrology, Water and Wastewater
Treatment, Health Risk Communication, and much more to our Master of Public Health, Master of Science in Public Health, Doctor of Public Health and Doctor of Philosophy students. We will continue to work to better understand how the environment affects the health of our uniformed service members deployed around the globe. These courses serve to meet the requirements for our Accreditation Board of Engineering and Technology (ABET) and the Council on Education for Public Health (CEPH). We are very proud of these accreditations and they serve to signal USU’s commitment to preserving our nation’s fighting forces by preventing unnecessary exposure to physical, chemical and biological agents encountered during deployment.

Sincerely,

William T. Bester
Brigadier General, U.S. Army (Ret.)
Acting President
June 28, 2010

Dear Colleagues:

Welcome to the symposium, “Assessing Potentially Hazardous Environmental Exposures among Military Populations.” As you all know, consequences of environmental exposure during military operations can be significant at the time of exposure and later. Environmental health has significant ramifications for the effectiveness of operations and for the long term health of personnel. The Uniformed Services University is pleased to have the opportunity to support this symposium and help advance the state of knowledge regarding how to protect those who go into harms way. Your contributions to this effort are most appreciated.

Most sincerely,

Gerald V. Quinnan, Jr., M.D.
RADM (Ret), USPHS
Professor and Chair

Learning to Care for Those in Harm's Way
Dear Colleagues:

Welcome to the Military Environmental Exposures Symposium. I hope you find this topic to be as important, engaging, and challenging as I do. I look forward to working with you for the next two and a half days to develop a better appreciation and understanding of the technical and scientific challenges of this topic.

By their nature, military contingency operations often place troops in contact with physical, chemical, biological, and psychological hazards posed by the environment in ways that often cannot be anticipated or prevented. The military medical community faces the daunting tasks of predicting and preventing exposure to these hazards when possible and operationally feasible, recognizing and mitigating effects of the exposures that do occur, and recommending procedures and practices to improve performance in the future. Also, many of the protective and mitigating procedures called for in these circumstances exceed the authority of the military medical community. Commanders are ultimately responsible for adherence to procedures such as avoidance of known hazards and provision and proper use of personal protective equipment. Medical professionals are the commander's subject matter experts whose major tasks are to first advise, recommend, and persuade the leaders on appropriate policy and procedures, and to monitor the situation for effectiveness of these measures. Often the exigencies of combat operations preclude the optimal employment of protective measures; the medical community is thus also tasked with documenting the health consequences and assuring that appropriate individual screening and treatment are provided.

We in the military preventive medicine community have benefitted from a rich history of accomplishments in assessing and mitigating environmental hazards to troops. We will review some of this history during our symposium, with an eye towards applying lessons learned from these historical examples to the problems we are encountering today, and to better prepare those who will follow us.

Sincerely,

Robert F. DeFraitas, MD MPH
Colonel, US Army
Dear Colleagues,

Welcome to the symposium, “Assessing Potentially Hazardous Environmental Exposures among Military Populations.” From the Vietnam War to the present, our forces have been and are being confronted with various hazards and environmental exposures during military operations. One of the great challenges for military preventive and occupational medicine is to make sense of those exposures and to be able to advise our service members what are the short and long term health effects of those exposures.

The Uniformed Services University (USU) and the Department of Military and Emergency Medicine are very pleased to have the opportunity to support this conference. This department is actively engaged in the education of our future medical officers as well as residents in preventive and occupational medicine. This conference will help our department identify pertinent literature and resources, develop a bibliography and contacts, and use the manuscripts produced from the conference to teach medical students and residents about military operational and preventive medicine. In addition, the lessons learned from our dealing with these hazards and addressing the health concerns of our service members will help drive our curriculum reform for future classes of physicians at USU.

Most Sincerely,

Trueman W. Sharp
CAPT, MC, USN
Associate Professor and Chair

Learning to Care for Those in Harm’s Way
Assessing Potentially Hazardous Environmental Exposures Among Military Populations

An educational symposium & workshop sponsored by:
The Armed Forces Health Surveillance Center (AFHSC)
Silver Spring, MD
&
The Uniformed Services University of the Health Sciences (USU)
The Center for Disaster & Humanitarian Assistance Medicine (CDHAM) of the USU
Bethesda, MD
19-21 May 2010

~Agenda~

Day One* - May 19, 2010 - Moderator: COL Robert F. DeFraites, AFHSC

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   Acting President, USU
   COL Robert F. DeFraites
   Director, AFHSC

Introduction
   CPT Erin E. Richards
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Key Exposure Incidents in Military History
   Dale C. Smith, PhD*
   USU

Rapporteur’s Challenge
   COL (Ret.) Joel C. Gaydos
   AFHSC

Agent Orange Exposure and Attributed Health Effects in Vietnam Veterans
   Col (Ret.) Alvin L. Young
   AL Young, Consulting, Inc., Cheyenne, WY

Impact of Operations in Kuwait, Bosnia, & Kosovo On Environmental Health Surveillance
   Jeffrey S. Kirkpatrick, Brad E. Hutchens
   Army Public Health Command (APHC)
   Aberdeen Proving Ground, MD

Oil Well Fires of Desert Storm—Defining Troop Exposures & Determining Health Risks
   Jack M. Heller, PhD
   Bel Air, MD

The Kuwait Oil Fire Health Risk Assessment Biological Surveillance Initiative
   COL (Ret.) David P. Deeter
   Deere & Company, Moline, IL

Linking Exposures & Health Outcomes to a Large Population-Based Longitudinal Study:
The Millennium Cohort Study
   Tyler C. Smith, MS, PhD
   Naval Health Research Center
   San Diego, CA

Medical Surveillance & Other Strategies to Protect the Health of Deployed Forces: Revisiting After 10 Yrs
   Lois M. Joellenbeck, DrPH
   Institute of Medicine, Washington, DC

Challenges: Identifying Individuals Exposed,Defining Exposures & Linking to Health Outcomes
   COL (Ret.) Joel C. Gaydos
   AFHSC

Discussion and Closing
   COL Robert F. DeFraites
   AFHSC

* The published proceedings do not include manuscripts by Drs. Dale C. Smith, Timothy J. Buckley or Thomas Sinks. Mark A. Brown, MS, PhD, Washington, DC, formerly of the US Department of Veterans Affairs, did not present but provided a manuscript.
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<td>Detecting, Characterizing, and Documenting Exposures: The Institute of Medicine &amp; Beyond</td>
<td>Timothy J. Buckley, MS, PhD* Ohio State University, Columbus, OH</td>
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<td>National Health &amp; Nutrition Examination Survey (NHANES) National Report: Human Exposure to Environmental Chemicals &amp; Applications to Military Populations</td>
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<td>Kelley Brix, MD Office of the Assistant Secretary of Defense Falls Church, VA</td>
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<td>Panel 5 Presentation: Educating Leaders on Identifying &amp; Mitigating Environmental Exposure Risks</td>
<td>Col (Ret) Alvin L. Young AL Young, Consulting, Inc., Cheyenne, WY</td>
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### Group Discussion - Questions & Answers

### Closing Remarks

* The published proceedings do not include manuscripts by Drs. Dale C. Smith, Timothy J. Buckley or Thomas Sinks. Mark A. Brown, MS, PhD, Washington, DC, formerly of the US Department of Veterans Affairs, did not present but provided a manuscript.
Editorial: Protecting Those Who Serve

Rosemary K. Sokas, MD, MOH

ABSTRACT The May 19 to 21, 2010 symposium “Assessing Potentially Hazardous Environmental Exposures Among Military Populations” brought military and civilian preventive medicine practitioners and scientists together to review the current state of exposure and outcome measurement, prevention, and compensation. Placed in recent historical context, the strides presented are remarkable, yet important challenges remain. Operational as well as ethical imperatives within the military and the growing complexity of civilian disasters demonstrate the need for continued and enhanced collaboration across military and civilian sectors.

The Symposium report in this supplement to Military Medicine provides a thoughtful exploration of the experiences, lessons learned, and remaining gaps in “Assessing Potentially Hazardous Environmental Exposures among Military Populations.” It includes follow up to a decade-old series of recommendations from the Institute of Medicine Committee on Strategies to Protect the Health of Deployed U.S. Forces that had been tasked to address concerns stemming from the first Gulf War. These updates offer important information about advances in exposure assessment, outcome tracking, and medical records surveillance, as well as persistent limitations, all provided in the context of historic military experience and recent research as well as legislative developments. The many layers enrich the discussion. For example, Heller’s description of the congressionally mandated, extraordinary efforts to assess individual-level exposure to the Kuwaiti oil fires is juxtaposed against Mallon’s call for inclusion of pulmonary function testing as part of routine medical surveillance, and against Deeter’s concerns about the limitations of attempts to train personnel in appropriate spirometric techniques late in an engagement, and a plea for adequate planning. Joellenbeck, on behalf of the IOM, notes that even in the absence of widespread acute casualties, “war takes its toll on human health and wellbeing.” Sadly, as current debates about budgets and foreign policy demonstrate, the message that there is no such thing as a “Nintendo war” needs to be relearned by Congressional committees at every level. DeFraites and Richards remind us that “Deployment exposure science is not cut and dry. A model that includes multiple stressors, not just one, must be strongly considered when looking at deployment records.” Brown, Richards, and others place compensation issues in the complex arena of caring for those who have borne the burden of war regardless of the ability to determine causality. Congressionally mandated post-deployment care for returning combat veterans that includes National Guard and Reserve units offers an enormous step forward in compassionate care.

The Symposium itself took place from May 19 to 21, 2010, against the backdrop of the April 20, 2010 Deepwater Horizon blow-out and the ongoing spill and cleanup efforts that continued after the well was capped on July 15, 2010. Lingering questions from that spill once again place military preventive medicine in a leadership position within the field of public health, one it has held frequently, but often without recognition. Even the most thorough outcome assessments of prior oil spills are based on extraordinarily limited exposure assessments, and all would have greatly benefited from the elegant work produced by military exposure scientists over the past 2 decades. The challenge of real-time communication across sectors has not yet been met. A decade ago, postal workers sickened and died from anthrax exposure while civilian public health agencies that had not appropriately integrated available military information provided disastrously erroneous risk assessments. This past summer, military information also provided much of the basis for meeting the preventive health needs for heat stress for workers conducting clean-up efforts in the Gulf, with the glaring exception of medical clearance for exposed workers, which, for the most part, simply didn’t happen.

In a civilian world in which baseline medical examinations of any kind are rarely conducted and even when conducted, are often unavailable, in which only the most global of atmospheric exposure assessment may be readily obtainable, in which there are currently no large-scale prospective cohort studies based on occupation, and in which the nascent development of Electronic Medical Records has as yet been unable to agree to include occupation as a field of information worth capturing, the opportunities available within the military, for

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Division of Environmental and Occupational Health Sciences, University of Illinois at Chicago School of Public Health, 2121 W. Taylor Street, M/C 933, Chicago, IL 60612.

This editorial reviews the products of a Symposium and workshop entitled “Assessing Potentially Hazardous Environmental Exposures Among Military Populations,” Bethesda, MD, May 19 to 21, 2010. The symposium and workshop were sponsored by the Armed Forces Health Surveillance Center, Silver Spring, MD, and the Uniformed Services University of the Health Sciences, Bethesda, MD.

This editorial represents the views of the author and does not necessarily represent the positions of the U.S. Department of Defense, the Military Services or any other U.S. Government organization.
all the limitations attached, appear to offer boundless promise. At the same time, the challenges faced by the National Institute of Environmental Health Sciences as it develops appropriately sampled biomarkers and study protocols for Gulf residents for a study that will begin a full 7 months after the cessation of exposure also serve as a reminder that the creation of generalizable knowledge requires researchers to adopt stringent human subjects protections, particularly when dealing with vulnerable populations. On the one hand, military efforts may indeed represent our best chance to characterize emerging issues; on the other, the ethics of conducting research on military populations is fraught with serious questions about informed consent and implied or overt coercion.

The development of the Millennium Cohort Study, initiated in 2001, that will prospectively track information with each participant’s informed consent offers the opportunity for important research, although concerns remain about the extent to which appropriate occupational and environmental exposure information is being captured. On the one hand, imprecise exposure information biases toward the null, although the ability to measure smaller and smaller quantities of exposures may add little of value if stripped of basic dose/response/absorption information. While to date the publications generated by the study team have chiefly focused on personal behaviors and mental health, potentially service-related mental health conditions (such as post-traumatic stress disorder) have been linked with otherwise unexpected outcomes (such as diabetes mellitus). These kinds of exposure-outcome epidemiologic studies greatly enhance our understanding of a variety of pathophysiologic mechanisms, but do not in themselves solve issues of compensation in that attributable risk is likely to remain relatively small; on the other hand, such information in the long run might point to better preventive approaches. Although questions have been raised about whether the Millennium Cohort Study will be able to address unexplained medical symptoms, it may not be appropriate to attempt to prove a negative and premature closure of study hypotheses or the use of presumptive diagnoses may in themselves carry adverse consequences. The extent to which qualitative methods allow the concerns of the study population to be elicited may serve to provide insights into communication strategies or possible interventions more effectively than focusing exclusively on the surveys themselves.

Rather than research, however, the primary goal of the Symposium was to improve applied public health assessment of exposures leading to chronic as well as acute adverse health outcomes for the purpose of providing direct benefits to the personnel involved, whether these benefits are the recognition and immediate reduction of hazardous exposure or the detection of adverse health consequences for which therapeutic or palliative care can be offered. The distinction is critically important—whatever efforts at data collection and assessment are undertaken take place for the primary if not sole purpose of directly benefiting the individuals participating. Questions that might be framed as investigational—increasing the precision of exposure assessment by improving individual assessment, improving outcomes assessment by integrating Department of Defense and Veterans’ Affairs electronic records systems, and by improving capture of information such as vaccinations in the former—may also be understood as improving quality. Surveillance systems are public health systems, and must be tied to feedback loops that develop, implement, and assess preventive actions.

The rich information captured in the Symposium’s presentations and discussions aims to address the fundamental question (how do we know what we don’t know?) in the context of why we need to know and how we can use the answer to find and fix the problem. In the real-world setting of a military operation, the issues are clear: What is the minimum amount of information needed to get the job done, while ensuring both the short-term and the long-term health and safety of troops?

The question of short-term health risks is relatively straightforward and well outlined in predeployment, deployment-related, and post-deployment public health measures that clearly address operational concerns. Because the primary need is to track and document exposure for immediate prevention, research and development of equipment and training methods are still needed to improve field equipment characteristics, for example, lightweight, rugged, portable, reliable, valid, easy-to-use and interpret, able to process small samples and to provide real-time results. Another goal may be to decentralize exposure assessment where possible to allow exposed individuals to operate, interpret, and respond to certain threats in much the same way current battlefield training reinforces the ability of the individual to access and use information. On the other hand, as Baird points out, sampling information has to be conducted for a purpose, with clear action levels and communication strategies that convey the actions to be taken at those levels. The ability to detect exposures at increasingly lower levels requires care in interpretation and communication. As described by Deeter, biomarkers did not prove to be clinically useful for those exposed to Kuwaiti oil fires. However, important questions remain about the potential to develop appropriately sensitive and specific biomarkers for other exposures that could be readily measured, easy to sample and store without rapid degradation, and that provide useful information that will guide clinical decision making. The potential for baseline comparisons with linked specimens from the Department of Defense Serum Repository raise interesting epidemiologic possibilities that might translate into preventive practice. Challenges remain in capturing medical outcomes in the field, but the advances described are impressive. Advanced planning and anticipatory sampling and guidance still require prioritization.
Haut and Young report the panel discussion addressing “Educating Leaders on Identifying and Mitigating Environmental Exposure Risks” and emphasize that “it is also crucial that military populations trust their leaders to protect their health….”, that a clear, unified, tri-service message about identifying and mitigating hazards is needed, and that “the identification and mitigation of environmental hazards will not only reduce exposures and expenditures of money, equipment and time, but will also, and very importantly, enhance mission accomplishment.”18 Leaders build trust but need exposure assessment methods that are feasible, suitable, acceptable, and that mitigate risk.

The challenge to convey actionable information in a meaningfull way is more difficult in conveying whether and why long-term health outcomes matter. For preventive medicine practitioners, the ethical considerations of beneficence, autonomy, and justice apply in military occupational medicine settings, as do the specific occupational ethical needs to apply population measures for the benefit of the worker/warrior. The American College of Occupational and Environmental Medicine has recently adopted an updated ethical code that integrates population needs into individual ethical considerations.19 These issues are all the more striking in military populations because society has asked these men and women to be prepared to make the ultimate sacrifice for the common good, with the explicit understanding that this sacrifice will not be trivialized or squandered. If we are to expend resources going to war, we must expend all the necessary resources to ensure the safe return of those conducting that war insofar as possible, and must not cut corners.

Unfortunately, this understanding has not always been honored, and contempt for venal or incompetent military and/or civilian leadership has filled bookshelves and cartoon columns throughout most of the 20th century, continuing through the present day.20 Mutual respect and trust have been hallmarks of high performing units and organizations, however. Disregard for available safety measures or perceived disregard for long-term health outcomes may engender immediate and chronic adverse consequences, potentially compounded by perceived unfair treatment or lack of post-service care.

On the other hand, prevention of long-term adverse outcomes needs to be incorporated into risk communication that takes into consideration short-term outcomes. In the same way the World Health Organization recognizes and classifies different levels of water safety (the first, simply having water; the second, having water that is free of immediately lethal pathogens; last, having water that is free of long-term carcinogens or other toxicants), communication of long-term hazards has to incorporate recognition of the importance of both short-term hazards and operational success, or it risks seeming either irrelevant or worse, obstructionist. It may be helpful to clarify whether the acute and the chronic adverse health outcomes may be inter-related (for example, “World Trade Center cough” and subsequent airways disease), and this example may also be helpful to ward off the temptation to dismiss acute symptoms not perceived to be serious enough to impede immediate readiness. Trust functions at different levels, has a role in operational success, and requires some efforts at transparency. Although implementing transparency will be constrained by the very real security needs of the personnel involved, the more transparent the risk assessment, communication, and mitigation strategies can be, the greater the opportunity for educational or training interventions. It is always useful to explicitly acknowledge that the concept of “acceptable risk” is a societal value that changes over time and in differing circumstances, and both Gaydos and Richards provide clear context to demonstrate the evolution of both safety and health within the military culture over time.8,21

Kirkpatrick’s paper raises interesting questions about what can be learned from the absence of disease or syndromes following military engagement in Kosovo.22 Were increased efforts at hazard identification and tracking coupled with a comprehensive approach responsible? Was it the limited scope of the engagement itself? Did infrastructure support play a role? Trust? Other aspects of the mission? If it is the old truism, “when public health works, nothing happens,” how do we find out what worked?

Finally, the purpose of this Symposium was not to address civilian exposures caused by military operations or activities, although these recurrently raise important concerns. While recent attempts to apportion blame to the military for overall civilian cancer mortality are of dubious quality, the underlying issue, that environmental contamination produced by military operations at home and abroad has been chronic, massive, and of undeniable public health import, is well established. Efforts going forward to mitigate resultant stockpiles and contamination sites continue to require community advisory participation and active and careful remediation. This may represent yet another reason for meaningful communication within both civilian and military members of the public health and preventive medicine communities.

REFERENCES


Military Occupational and Environmental Health: Challenges for the 21st Century

COL Joel C. Gaydos, MC USA (Ret.)

ABSTRACT In May 2010, a Symposium and Workshop entitled “Assessing Potentially Hazardous Environmental Exposures among Military Populations” was held in Bethesda, MD. Participants were particularly interested in environmental exposures that are challenging to identify and characterize and that may be associated with a delayed health impact. Speakers and discussion groups reviewed past exposures and the ability of the U.S. military to: predict, identify, quantify, and prevent or mitigate potentially harmful exposures; identify, assess, and follow up military members potentially exposed; accurately determine risks of disease or injury and actual health outcomes; and expeditiously and effectively communicate to military and other leaders needed interventions, individual risks and data to support or refute associations between exposures and health outcomes. Improvements in military capabilities and shortcomings were evaluated using reports on strategies to protect the health of deployed U.S. Forces that were published by the Institute of Medicine and National Research Council in 1999–2000. Significant improvements have occurred, but many shortcomings need attention.

INTRODUCTION The profession of arms is a dangerous occupation. Military people have been exposed to traditional weapons, psychological stress and trauma, and biological, chemical, and physical agents. These agents may have been weapons, naturally occurring or the result of industrial or municipal pollution. For much of history, military commanders considered these exposures to be important only when they caused death or morbidity to the extent that the successful completion of the military mission was jeopardized. Recognition of members of the military as an occupational group that deserved protection from potentially harmful exposures that could be avoided or mitigated without endangering the successful completion of the mission is relatively recent.

Exposures of military people may be viewed from several perspectives: exposures that occur in combat or other hostile environments and during training for combat; hazards associated with industrial tasks at fixed military installations or at sites supporting combat or training operations; and environmental exposures that occur as a result of contamination of the air, soil, or water in areas of military operations. These perspectives are not exclusive nor do they cover all possible hazardous exposures that military people may encounter. They do provide a basis for discussion.

PROTECTING WARRIORS Historically, injury and death from the enemy’s weapons and from one’s own equipment, such as exploding cannon, were accepted as risks of the profession of arms. This acceptance changed during the Civil War (1861–1865) with the appearance of weapons that could significantly threaten the health of the soldiers who used them.1,3 An example is the Union “coffee mill gun.”1 It had a single barrel, a revolving cylinder, a hand crank, and a hopper into which cartridges were dropped and inserted into the barrel using the hand crank.1 The gun was rejected by military commanders because the poorly machined soft metal parts sheared when the gun was fired, wounding the gun crew.1 World War I (WWI) brought the machine gun and tank to the battlefield.2,3 Sealed emplacements designed to protect machine gunners from enemy chemical agents, like chlorine, and the closed environment of tanks resulted in carbon monoxide casualties.2,3 During WWII, the hazards to those who operated and maintained the modern implements of war were recognized by U.S. Army leaders. Studies of toxic gases and other potentially hazardous exposures were done at The Armored Force Medical Research Laboratory, Fort Knox, KY, and recommendations were made for dealing with the hazards.2,4

Concern again surfaced in the late 1970s and 1980s as U.S. military developers crafted a cannon that created blast waves that ruptured the airway blood vessels of the artillery crews that fired it.3,7 Additionally, tanks were manufactured that were tightly sealed to protect against chemical agents on the battlefield.3,8 When ventilation was inadequate, tank crew members became incapacitated by carbon monoxide.3,8–10 The lessons learned about carbon monoxide in WWI had to be relearned.3,8–10 The Army responded by publishing a regulation establishing the Health Hazard Assessment Program, which required medical reviews with mandatory medical reports assessing the identified hazards for all items in the military Material Acquisition and Decision Process.3,7

THE INDUSTRIAL SETTING The Occupational Safety and Health Act (OSHA) of 1970 and legislation that followed made employers responsible...
for protecting their workers from harmful exposures, for providing safe and healthful workplaces and for ensuring the development and enforcement of meaningful workplace standards. Implementation of the protections specified in these laws occurred much earlier for civilian employees than for members of the military who were performing industrial tasks similar to those of the civilian workers. In 1984, the Army initiated an Occupational Health Program for Soldiers at Fort Campbell, KY. There were 769 different industrial operations being performed at Fort Campbell and 530 of these were performed exclusively by soldiers. A survey revealed about 95 eye injuries each week in soldiers, and about half of these could have been prevented if the soldier had been wearing proper eye protection. Eye injuries resulted in the loss of over 89,000 soldier-hours each year. Data like these convinced military commanders to provide funding for, and to support, eye protection, respiratory protection, and other occupational health programs for soldiers. The Fort Campbell program became a model for other military installations.

**MILITARY OCCUPATIONAL MEDICINE**

Leaders in all military services eventually realized that their trained personnel were valuable assets, who should be protected to the greatest degree possible from potentially harmful occupational exposures in all their workplaces, from the installation motor pools to the battlefields. In 1992, Drs. Legters and Llewellyn of the Uniformed Services University of the Health Sciences (USUHS), Bethesda, MD, emphasized the need to identify and assess all military exposures by describing military medicine as “a unique brand of occupational medicine, one that deals with the prevention and treatment of diseases and injuries resulting from work in the military occupations and operational environments.”

Work done in the 1980s and before documented the potentially hazardous exposures of military members from their weapons and from the industrial tasks they performed in garrisons and in the field. These aspects of military occupational medicine still need attention, but programs are in place to systematically and effectively address the associated hazards. However, despite improvements and innovations in field water treatment, the provision of food in austere environments and environmental sampling technology, environmental exposures have continued to be especially problematic to military members, military leaders, the Department of Defense (DoD), the Department of Veterans Affairs (VA), and civilian government officials. Many, but not all, of these problematic environmental exposures have been airborne in nature.

**SYMPOSIUM AND WORKSHOP**

During May 19 to 21, 2010, a Symposium and Workshop was held at the USUHS to address currently relevant exposures of military personnel. The primary interest of participants was exposures that may occur because air, water, or soil is contaminated in areas where military members are operating.

Some potentially harmful exposures were not considered and others were mentioned only briefly. Infections with some biological organisms can go undetected but later result in the appearance of disease. *Coxiella burnetti*, the agent of Q Fever, is a naturally occurring biological organism that may be an environmental exposure and that can cause delayed disease. Q fever and other infectious diseases of concern in the current conflicts in Iraq and Afghanistan have been considered elsewhere, along with the problems associated with early agent detection and identification of the diseases they cause. Biological agents, both naturally occurring and manufactured or modified by man for the purpose of doing harm, were excluded from the focus of this Symposium and Workshop.

Chemical and physical agents can also be manufactured or modified for the purpose of inflicting harm. Sometimes it may not be apparent if exposures to these agents are hostile acts or associated with industrial or agricultural accidents or improper disposal of industrial, agricultural, or municipal wastes. It was not the intent of this Symposium and Workshop to emphasize exposures to sarin (GB) or other recognized warfare chemicals. Radiation exposure also was not emphasized. However, participants were made aware of past exposures of military personnel to radiation during training exercises, military experiments, and through contact with military weapons that contained radioactive material. Participants were also reminded of potential exposures of U.S. Forces to chemical nerve agent during the deliberate destruction of a captured enemy weapons bunker at Khamisiyah, Iraq, in Gulf War I.

Exposures from military weapons, psychological stress and trauma, infectious diseases agents, and defined industrial tasks were not emphasized at the Symposium and Workshop. Participants were focused on exposures that are challenging to identify and characterize and that may be associated with a delayed health impact. The presence of potentially harmful agents may not be suspected or detected but contact with people may occur. A related injury or disease may not become apparent for a long period after exposure, even years. Determining if an illness is related to an exposure that may have occurred decades earlier, and under circumstances that lacked adequate documentation, presents an extremely difficult and often impossible task. The DoD and VA have been dealing with such situations since the 1970s.

The focus of the Symposium and Workshop entitled “Assessing Potentially Hazardous Environmental Exposures among Military Populations” was formed by concerns about specific occupational exposures of U.S. military personnel during wars over the last 50 years: Agent Orange during the Vietnam War; Kuwaiti oil well fire emissions and chemical nerve agent released by the destruction of the Khamisiyah munitions storage bunker in Gulf War I (Operation Desert Storm); and exposures to U.S.-operated burn pits, chromium powder at an industrial site and burning sulfur pits in Iraq during Operation Iraqi Freedom. U.S. burn pits were also used in Afghanistan.
Dr. Alvin L. Young told Symposium participants that the U.S. military had exceptionally detailed records regarding the aerial application of Agent Orange and insecticides, and had defined and enforced policies to prevent exposing service members in Vietnam. Dr. Mark A. Brown noted in his article in this Supplement that these records and policies were not sufficient for the U.S. Government to conclude that selected, delayed health problems in Vietnam veterans, even those associated with aging, were not the result of Agent Orange exposure. Detailed data on the locations of U.S. Forces in Vietnam were not available, and U.S. Government officials were unable to conclude that exposures had not occurred.

The Kuwaiti oil well fires were identified as potential hazards before the wells were ignited. Military medical personnel began planning and preparation for this potential hazard in December 1990. When the burning started in February 1991, dealing with the delays and limitations associated with war, medical personnel collected the data and information needed to provide health risk assessments for specific geographical areas. However, this initial response had to be greatly expanded when the U.S. Congress passed Public Law 102-190 (Section 734) in December 1991, requiring a means for calculating oil well fire combustion product exposures for individual U.S. service members. The military medical community responded by developing a complicated retrospective determination of where service members had been located and complex modeling of what their exposures to oil well fire emissions may have been. This effort culminated in a database and website where DoD personnel could obtain their estimated individual exposure and associated health risk (U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, MD, Final Report. Kuwait Oil Fire Health Risk Assessment. No. 39-26-L192-91, February 18, 1994). After U.S. Forces exploded the bunker at Khamisiyah on March 10, 1991, not knowing it contained sarin, determining who may have been exposed and the extent of exposure has been challenging. The aftermath of this incident has also raised the question of why this potential exposure could not have been prevented.

The exposure concerns following Gulf War I (1991) led to concern about and a careful assessment of potential environmental exposures when U.S. forces entered the Balkans in the 1990s and to improvements in the way DoD addressed these types of exposures. Unfortunately, later events in Operation Iraqi Freedom demonstrated that we still had much to learn about preventing and responding to potential environmental threats to U.S. Forces. Large, open burn pits were used for management of waste of all types for long periods of time; civilian contractors worked on an industrial site contaminated by hexavalent chromium, a carcinogen, with U.S. Forces providing security at the site without the exposure threat being recognized; and U.S. Forces who fought sulfur fires are now suspected of having serious and unusual respiratory disease.

**LOOKING TO THE FUTURE**

The Symposium speakers and the Workshop discussions identified many areas where attention is needed: education of military Preventive Medicine (PM) personnel, other military medical personnel, and nonmedical military leaders; planning for environmental exposures before these occur and taking action to prevent or mitigate them; placing on commanders’ staffs qualified people who can quickly assess potential exposures and make appropriate recommendations; having current monitoring equipment and laboratory capabilities where these are needed and operated by people trained in their use; and, having PM specialists who are skilled in the art of risk communication to inform and advise military and civilian leaders. Symposium and Workshop participants noted that we must continue to improve our ability to link defined exposures to military members who may have been exposed and to follow these people for adverse outcomes throughout their military service and beyond. All of these things must be done in a standardized manner across service lines and between U.S. Government Departments.

The above are not new recommendations. Much of what was stated at the Symposium and Workshop can be found in the National Research Council and Institute of Medicine reports of 1999–2000, which were compiled following concerns about military exposures in the 1990s. It is important for the military medical community to study these reports and to not only ask how we have improved, but to also ask what more needs to be done. It is also important for the military medical community to critically assess how to effectively implement the recommendations of the 2010 Symposium and Workshop. In this Supplement to Military Medicine, COL Timothy Mallon addresses the former and CPT Erin Richards and COL Robert DeFraites address the latter.

As we look to the future, the U.S. military must continue to upgrade field monitoring and laboratory capabilities and to pursue feasible means for biomonitoring of our deployed forces. However, it is more important for the medical communities of the military services to evaluate, improve, and standardize their educational and training programs and equipment procurement programs, and to clearly define responsibilities. All military people, medical and nonmedical, deployed and nondeployed, at all levels of command must know at all times who has responsibility for identifying and assessing potentially hazardous environmental exposures in a timely manner and who is responsible for effectively communicating the risks and possible responses to military commanders who can make decisions about preventing or mitigating the risks.

**REFERENCES**

INTRODUCTION
Following the first Gulf War (Operations Desert Shield and Desert Storm), the Deputy Secretary of Defense met with leaders of the National Research Council (NRC) and the Institute of Medicine (IOM) of the National Academy of Sciences and challenged them to conduct an unbiased evaluation of the efforts of the Department of Defense (DoD) to protect deployed U.S. Forces in four areas: (1) assessment of health risks, (2) technologies and methods for detection and tracking of exposures; (3) physical protection and decontamination; and (4) medical protection, health consequences and treatment, and medical record keeping. However, much more remains to be done and this underscores the need for a continued commitment to implement the long-term strategy for force health protection. This article summarizes some of the major improvements, highlights areas where more work is necessary, and identifies obstacles that must be overcome to achieve the recommendations of the IOM and the NRC.

THE LONG-TERM STRATEGY FOR FORCE HEALTH PROTECTION
Many of the IOM and NRC recommendations for the long-term strategy for force health protection have been only partially or incompletely implemented in a variety of DoD Instructions and Directives. DODI 6490.03 implemented a comprehensive approach to force health protection in 2006. It required the services to perform comprehensive predeployment health threats and countermeasures briefings, completion of a pre-deployment health assessment with a serum sample, and completion of all necessary immunizations and dispensing of all preventive medications and personal protective equipment before deployment. In addition, it required baseline, routine, and incident-related occupational and environmental monitoring and documentation in the medical records of any hazardous exposures encountered during deployment.

There were neither sufficient sampling resources nor laboratory analytic capabilities in theater to complete the monumental tasks in DODI 6490.03 in an acceptable manner. The DODI required service members to complete a postdeployment health assessment and postdeployment health reassessment 3 to 6 months after returning from deployment, including answering questions about health concerns and occupational and environmental health (OEH) exposures, and required them to provide a serum sample within 30 days of returning home. The service surveillance centers had great difficulty making sense of self-reported exposures, particularly because environmental exposure data that was collected was area sampling that was often not representative of individual exposures. Almost no individual breathing zone samples were collected for any deployed service members during Operation Iraqi Freedom (OIF) or Operation Enduring Freedom (OEF) in Afghanistan. Further, although pre- and postdeployment sera were collected, there was no plan for analysis of the samples to look for evidence of exposure in sera biological monitoring results. Lastly, DODI 6490.03 required that service members be referred to a health care provider for follow-up and evaluation of health concerns reported on the postdeployment health assessment or reassessment.

Service members who had complaints or concerns about exposures were routinely referred to health care providers who had little to no training or experience dealing with service members who were exposed to occupational or environmental hazards. Thus, the service members often were unable to get their questions answered and health concerns addressed.
The Chairman of the Joint Chiefs 2007 Memorandum on Deployment Surveillance calls for the development of a health surveillance system that spans the service life cycle and that continues after separation from service. The DoD electronic health record (EHR) system, known as the Armed Forces Health Longitudinal Technology Application, or AHLTA, has been developed as the joint computerized patient record that permits documentation and access to outpatient medical encounters for all service members throughout their military career. Although recent improvements have enabled AHLTA to display information from theater patient encounters, not all outpatient encounters are recorded due to unstable electronic communications and high operational risk in some areas.

Though AHLTA can display information from theater encounters, it has no intrinsic query tool. In order to trend data from the continental United States (CONUS) and from the theater of operations, adjuncts to AHLTA must be used. Moreover, inpatient clinical information does not yet reach AHLTA. Additional work remains, to enable the EHR systems to meet the information needs of both the individual medical provider and the military public health. The service members health information maintained in AHLTA stays in the clinical data repository (CDR) and has not until recently been made available for use by the Department of Veterans Affairs (VA) for subsequent health care following discharge from military service. Further, AHLTA does not have a way of capturing civilian health care provided to Reserve and National Guardsmen for deployment-related health issues after they leave active duty.

ASSESSMENT OF HEALTH RISKS BEFORE, DURING, AND AFTER DEPLOYMENTS

Citing the hazards and lack of controls encountered in previous wars, the NRC recommended in their 2000 report that improvements be made in conducting pre-, during, and post-deployment health risk assessments and preventing adverse health outcomes in future deployments. In response to this challenge, the U.S. Army Public Health Command-Provisional (USAPHC-P), Aberdeen Proving Ground, Maryland; the Navy and Marine Corps Public Health Center (N&MC); Portsmouth, Virginia; and the U.S. Air Force School of Aerospace Medicine (USAFSAM), Brooks City-Base, Texas, and their predecessor organizations worked with operational planners for the Combatant Commanders and tried to arrange for OEH site assessments before troops deployed to locations in Iraq and Afghanistan in support of OIF and OEF. However, the results of these efforts in the area of health risk assessments have been mixed. The large number of required base camp assessments in OIF and OEF were not always completed, nor were all potential exposures identified because unit commanders did not tell Preventive Medicine (PM) personnel where camps were being set up. Further the OEH threats that were identified were not sampled in a systematic way for individual service member exposures due to a lack of sampling and analysis capability in theater, so no health risk assessments could adequately be completed in most cases.

The USAPHC-P, N&MC, and USAFSAM commenced a vigorous educational effort and developed a commander’s guide and fact sheets for service members on OEH threats that explained the need to do health risk assessments before deploying troops to areas where OEH hazards may be present. This proactive posture permitted environmental health teams to deploy when requested by unit commanders with the advanced party to assist the commander in developing an operational risk management plan and managing the risks encountered. Despite this proactive approach, troops were still exposed to OEH threats in Iraq and Afghanistan.

In the early years of OIF, members of the Army National Guard provided security at the Qarmat Ali Water Treatment Plant and were inadvertently exposed to sodium dichromate, yet the environmental health threats that they faced at Qarmat Ali were not unique. Troops were put in tents adjacent to suspected radiological materials and petroleum products at Kharsi Khanabad Air Base in Uzbekistan. In 2003, troops from the 101st Airborne Division fought a sulfur plant fire at Al Mishraq Sulfur Plant in Iraq for weeks. Several of those troops subsequently developed pulmonary complaints, and 19 were diagnosed with constrictive bronchiolitis that the USAPHC-P personnel believe to be associated with exposure to the 2003 Mishraq State sulfur fire. Troops were also potentially exposed to ionizing radiation hazards at the Al Tuwaitha Nuclear Research Center in Iraq and to depleted uranium and toxic chemicals at Al-Samawah in Iraq. In Ash Shuaiba Port in Kuwait, troops were housed downwind of a large industrial operation at the port. Troops were potentially exposed to airborne lead at Camp War Eagle in Iraq. Lastly, troops worked and were housed in barracks downwind from burn pits in Iraq and Afghanistan and complained of respiratory irritation and difficulty breathing. As the theater matured and operational risks subsided, military PM personnel were able to sample and characterize the occupational and environmental hazards present in smoke from the burn pits. Even though no significant health hazards were evident in the samples collected, large industrial waste incinerators.
were installed at bases in Iraq including Joint Base Ballad and Camp Victory and are being installed in the large bases in Afghanistan to permit the proper disposal of theater waste generated by the troops and to alleviate the concern of troops regarding the inhalation of smoke from the burn pits.  

Early on, the risk assessment efforts were hampered by a lack of senior leader support, particularly during high operational periods. Units would move to base camps without advising the PM people in theater or the PM people were denied access to troop locations because of operational concerns, so base camp environmental assessments were not performed in a timely manner. The early OEH threat assessments also lacked coordination within the area of operation because Occupational Medicine (OM) and PM physicians with knowledge of industrial and environmental sampling protocols and health risk assessment skills and experience were not on the Corp Commander’s medical staff to spearhead these efforts. The positioning of PM and OM assets on the Corp Commander’s medical staff in the command surgeon’s office would permit the PM physician to be a champion for coordination of sampling efforts and for command support for these activities in the future.

SAMPLE COLLECTION AND DOCUMENTATION IN DEPLOYED SETTINGS

Sampling efforts by the services have varied in their success and ability to collect samples of OEH threat agents in OIF and OEF. The Air Force has Bioenvironmental Engineers (BEEs) assigned to individual units, and they have been able to sample for individual exposures. The Army Environmental Science and Engineering Officers (ESEOs) and PM Technicians, and Navy Environmental Health Officers (EHOs) and Navy Corpsmen have been less successful in obtaining area sampling or individual breathing zone samples for OEH threats encountered in theater. This is because sampling is the responsibility of the Army and Navy PM units, which are extremely limited in personnel who can conduct sampling and often have to cover a large region supporting an entire division operating area while the BEEs support a single air base. Due to broad area of responsibility, the Army and Navy PM personnel tend not to conduct sampling of individual exposures, but rather focus on collecting area samples that are usually not representative of an individual’s exposures.

Area sampling can be routine or incident driven. Incident-driven sampling was conducted during the sulfur fires. A U.S. Army Medical Command Specialty Medical Augmentation Response Team that provided focused PM assistance (SMART-PM) collected area samples at the Qarmat Ali Water Treatment Plant, and health physicists collected samples and data at Al Tuwaitha Nuclear Research facility. Typically, the teams collecting the samples produced classified reports. Separate unclassified fact sheets were developed to educate soldiers, leaders, and health care providers about the potential exposures encountered at the sites. Often, there was no troop roster or listing of the exposed population at risk, so medical follow-up would have been difficult or impossible.

Routine area sampling is generally conducted for particulate matter, metals associated with the particulate matter, and occasionally volatile organic compounds. Assessments for dioxins and semivolatile organic compounds occur much less commonly. Sampling events are typically tied to a specific base camp location and cover a specified time period. These efforts can be described as somewhat limited in scope, and definitely limited in time, and the population exposed is not well defined. The data from periodic sampling events is summarized in an Operational Risk Management report. These reports do not allow for the assessment of chronic risk from long-term exposure because the sample data are not representative of individual soldiers’ exposures.

The information contained in the Defense Occupational and Environmental Health Readiness System Industrial Hygiene Module (DOEHRS-IH), an automated information system for assembling, comparing, using, evaluating, and storing environmental and occupational exposure and related information, consists of installation civilian employee exposure data and rarely contains exposure data for service members. A new module, the Defense Occupational and Environmental Health Readiness System Environmental Health Module (DOEHRS-EH), is being developed and will serve as the repository for deployment exposure data collected for service members.

The services have struggled with creating interfaces between DOEHRS-IH and DOEHRS-EH and service members’ EHRs because of data quality concerns. At issue is the degree to which area sampling data are representative of an individual’s exposure and whether these data should be added to the medical record when it is not clear whether a service member was actually exposed to the hazard.

TECHNOLOGIES AND METHODS FOR DETECTION AND TRACKING OF EXPOSURES

Significant efforts have been made to reduce the logistical requirements for placing and using sampling and analysis equipment in theaters of military operations and to gain command support for sampling OEH exposures. The results of these efforts have been mixed. The operational tempo and hazards present in the area of operation, to include hostile fire from rockets, road side bombs, and suicide bombers, limit sampling opportunities. The exposure assessment efforts have also been hampered by the lack of sampling protocols to take into account the variability present in the deployed environment, including weather, elevation, topography, prevailing wind direction, changes in work processes, and troop locations relative to the hazard, e.g., burn pits. For example, if all plastics were burned only one day a week in a burn pit, sampling at any other time would not detect the products of plastics combustion. Further, collecting area samples would not define the exposures for individual service members needed to make informed judgments about risks to individuals.
If we could identify service members with the greatest risk of exposure at the highest levels of hazards encountered, there would be a greater likelihood of determining which long-term health effects may be related to those exposures. Further, risk communication efforts could be targeted to this highest risk group. The data collected to date represents a cataloging of potential exposures on a particular base camp but because there is no individual breathing zone sampling, the data will not be placed in the soldiers’ medical records. Biological monitoring has been proposed as a surrogate for individual environmental exposure monitoring. The DoD has developed an approval process for potential agents that could be selected for biological monitoring and has approved the use of biological monitoring for two hazards to date, lead and depleted uranium. Biological monitoring is mandated by the Occupational Safety and Health Administration for lead. The Nuclear Regulatory Commission requires monitoring for radiation exposure in occupationally exposed individuals, and biological monitoring in this setting has been successful in identifying health risks in exposed individuals. However, more work is necessary for the services to expand the list of hazards for which biological monitoring could be approved for use in service members. The CDC National Biomonitoring Program recently sampled participants for the presence of 450 environmental chemicals in the latest National Health and Nutrition Examination Survey (NHANES) and reported on 212 of these chemicals in its 2009 report. These chemicals should be prioritized, on the basis of the chemicals encountered in theater, for inclusion on the list of DoD-approved agents for biological monitoring.

**MEDICAL SURVEILLANCE, MEDICAL TREATMENT, AND MEDICAL RECORD KEEPING**

On the basis of the IOM and NRC recommendations, the services have sought to prevent adverse health outcomes that could result from multiple diverse exposures, including chemical and biological warfare and infectious agents, psychological stress, and injuries during OIF and OEF. The services have used the results of analysis of battle injuries to redesign battle armor and redesign the Kevlar helmets, so they are lighter and more resistant to ballistic impact. These efforts have reduced casualties during battle. In addition, the services have significantly improved the pre- and postdeployment screening of service members using the health risk assessment, postdeployment health risk assessment, and the postdeployment health reassessment. Further, the USAPHC-P, N&MCPhC, and USAFSAM have proactively developed fact sheets for service members and providers to improve health risk communication and conduct health risk education efforts more effectively than during prior deployments in the Gulf War of the early 1990s.

Surveillance for short- and long-term health outcomes, to include adverse reproductive outcomes, has improved through the efforts of the USAPHC-P; the Naval Health Research Center, San Diego, California; and the Armed Forces Health Surveillance Center (AFHSC), Silver Spring, Maryland. Improvements have also occurred in maintaining medical records, documenting exposures, and treating and tracking individuals through the medical evacuation system.

One area where the services recognize the need for improvement in preventing adverse outcomes is in the area of psychological stress, posttraumatic stress disorder (PTSD), and suicides. The rates of psychological stress, PTSD, and suicide are increased compared to the first Gulf War, and the services have struggled to find answers that would help service members reduce stress and suicides. An Army report released in 2010 identified several problem areas to include: erosion in adherence to existing Army policies and standards; increase in illicit drug use, crimes, and suicide attempts; lapses in surveillance and detection of high risk behavior; increased use of prescription antidepressants, amphetamines, and narcotics; and degraded accountability of disciplinary, administrative, and reporting processes. The situation is exacerbated because service members face multiple deployments and have little control over the situation.

**Medical Surveillance**

The IOM and NRC provided recommendations to improve medical surveillance. Predeployment blood draws, periodic health assessments, and baseline health surveys have been initiated or continued on the basis of the IOM recommendations. The services initiated a periodic health questionnaire, the Health Evaluation and Assessment Review (HEAR), which has been replaced by the annual Health Risk Assessment and which all service members are required to complete. The Health Risk Assessment collects annual demographic, medical, psychosocial, occupational, and health risk factor data on all U.S. military personnel. Further, the services implemented an improved electronic medical record for the tracking of inpatient care, namely the Theater Medical Information Program Composite Health Care System (TMIP-CHCS) or TC2 Caché. TC2 allows military health care providers to document and view inpatient medical data collected in theater anytime, anywhere, worldwide. TC2 gives health care providers at combat support hospitals the same capability as the military’s fixed facilities have for documenting inpatient care. TC2 provides the capability for recording doctors’ and nurses’ notes (both pre- and postoperative); ordering and viewing of pharmacy, radiology, and laboratory test results; and compiling discharge summaries for wounded or ill service members. When TC2 patient encounters are completed and signed, they are sent directly to the Theater Medical Data Store (TMDS), where they can be viewed through the Non-classified Internet Protocol Router Network (NIPRNet) as part of a consolidated chronological patient record. TC2 patient encounters are also put into the Medical Situational Awareness in the Theater (MSAT) program where they support medical surveillance and are available for viewing through the Secret Internet Protocol Router Network (SIPRNet). In the future, TC2 patient records will be available for viewing through the Secret Internet Protocol Router Network (SIPRNet).
transmitted to the AHLTA CDR, where they will become part of service members’ lifelong electronic medical record.

Outpatient care is captured in several systems. AHLTA Mobile, also known as the Battlefield Medical Information System Tactical-Joint (BMIST-J), is a software application on a handheld computer that is used by field medics to record patient encounter data, usually at the point of injury. Patient encounters recorded in AHLTA Mobile are transmitted to AHLTA Theater, which transmits them in near-real-time to a system in Virginia, as long as the devices are properly configured and connected on the network. That system distributes the AHLTA Mobile encounters to the Joint Medical Workstation (JMeWS) and the Theater Medical Data Store (TMDS), where they can be used to support medical surveillance, and to the CDR, where they will become part of the service members’ longitudinal health record. The JMeWS was developed and rapidly deployed on the SIPRNet as a standalone capability in response to a need for commanders to have online, near-real-time medical situational awareness for forward-deployed forces during OIF. JMeWS provides medical situational awareness, medical surveillance, and force health decision support. It also reports on medical trends and analyzes the overall status of theater health. JMeWS provides the ability to drill down to specific medical units and individual encounters. It also shares medical intelligence with the Global Combat Support System and Global Command and Control System, serving as the medical component to the Combatant and Joint Task Force (JTF) Commander’s common operating picture.

The JMeWS was deployed in OIF and OEF and collects static and nonbattle injury (DNBI) data reported directly by system users using aggregate reports from AHLTA-T supplemented by individual facility logs, and dynamic DNBI information retrieved from electronic medical records in TMDS. Important unit identification information needs to be gathered from the service member and correctly entered in AHLTA-T in order to be presented to JMeWS so that illnesses and injuries can be tracked down to the unit level. Unfortunately, there is insufficient emphasis or control for this important data element. This is needed to define the population of soldiers in theater so that DNBI rates can be calculated with accurate denominators. Further, when units depart theater, incoming units must be certain to reset all workstations so that new information is not reported with the previous medical unit’s identification. Again, there is insufficient control for this process to ensure accuracy of the important data element “reporting facility.” Despite increased emphasis since February of 2010, reports in TMDS continue to show 30 to 40% of reporting facilities improperly recorded in TMDS. If one wants to look longitudinally over time, one must include both old and new facility identification codes (IDs) in the filter, based on medical unit ID, not patient unit ID.

The transition from service-specific patient encounter modules (the Air Force Global Expeditionary Medical Surveillance System [GEMS], the Navy-Marine Corps Shipboard Automated Medical System [SAMS], and the Army CHCS II-T) to AHLTA-T for ambulatory data did a great deal to improve and standardize outpatient data capture. Further, the fielding of the TC2 inpatient module permitted the capture of all inpatient data in the joint TMDS where previously the data was housed in service-specific stove-piped systems with system incompatibilities which rendered it less useful for subsequent analysis.

The MSAT program provides Combatant Command and JTF Surgeons and their staff with actionable knowledge and enhanced medical situational awareness for critical decision making. The MSAT concept is to fuse current and emerging technologies and apply computerized decision support systems to transform data from stovepipe systems into timely, actionable information and knowledge for Combatant Commanders and JTF Surgeons. MSAT leverages Service Oriented Architecture (SOA), combining medical, patient tracking, mapping, logistics, personnel, weather, and intelligence information to support decision making for current and planned operations. The MSAT standards-based information sharing approach enables rapid connection to current and emerging information sets. The AFHSC was established in 2008 and given leadership authority and accountability for coordination of health surveillance across the services between the USAPHC-P, N&MCPHC, and USAFSAM.

Medical surveillance for OEH exposures seeks to assess the presence or absence of disease relative to specific exposures presumed to be present on the basis of a measurement of an agent above an action level. The standards used are hazard specific. Sometimes medical surveillance assesses impact to a target organ, such as kidneys or lungs, based on presumed exposure to a specific hazard which targets those organs or systems. For many hazards, if there has been no discernable impact to the target organ or system at the time of the assessment, it may be concluded that no health impact occurred. This will not be true if the hazard is carcinogenic with a latency period.

Most current environmental hazards are inhalation hazards. As such, baseline and follow-up pulmonary function tests (PFTs) might be reasonable to perform. This is not currently done. PFTs are a very common occupational medical surveillance tool, and military subsets of the 2002 NHANES identified military occupation as a risk factor for abnormal PFTs, after controlling for smoking. Additionally, if examinations included liver function tests and standard electrolytes, these would provide screens of sorts for liver and kidney effects of exposures.

The laboratory capability for public health surveillance has been expanded within the military. The Army, Navy, and Air Force sent medical laboratories with clinical infectious disease and OEH threat sample analysis capability to OIF and OEF that facilitated faster laboratory analyses. Further, central reporting of laboratory findings of reportable conditions is required, which facilitates the service’s medical surveillance efforts.
**Medical Treatment**

The Veterans Benefits Improvement Act of 1998 (P.L. 105-368) ensured that service members would be eligible for medical care for a period of 5 years after their return from service in a theater of combat operations. Provision of this care without the need to establish service connection provided a valuable opportunity to ascertain the health needs of this population. The AFHSC studies health care utilization during the 2 years after a deployment. The VA also follows service members who have separated from service from 2 to 5 years to track their health status and identify health concerns including medically unexplained symptoms.

**Medical Record Keeping**

The electronic patient record is essential for DoD to meet Medical Record Keeping needs of service members before, during, and after deployments. AHLTA is the current military health system outpatient EHR. AHLTA does not adequately support immunization tracking or give providers reminders regarding age-appropriate preventive health services. The DoD has fielded AHLTA-T to capture outpatient encounters in-theater. TMDS captures medical care delivered in theater and recorded in AHLTA-T or other health surveillance systems, provided they are configured properly and have adequate network connections. AHLTA-T can run on individual laptop computers which can be linked to a server in a local area network. Additionally, there are handheld mobile devices that can be linked to AHLTA-T computers when available. The AHLTA-T system is “store and forward,” able to hold data and send all new data to the network once connections are established. Outpatient care delivered at any level can therefore be documented in AHLTA-T and uploaded to TMDS when connectivity permits, even when there are communications problems or limited bandwidth much of the time in a given location. This permits limited real-time population health surveillance of the total force because TMDS is linked to the JMeWS database. When the military member seeks medical treatment, however, the unit identification code (UIC) of the service member is not routinely captured with accuracy. The unit name is often captured in free text but a mechanism for automatic and accurate recording of the unit identification code when service members present to a clinic or hospital is sorely needed to permit faster and more accurate DNBI rate calculations in JMeWS. The laboratory data that are routinely recorded in TC2 are displayed in TMDS, but at this time NOT sent to the JMeWS database, so the ability of PM personnel to accurately track DNBI rates and examine health outcomes is limited and requires use of multiple medical databases to generate the required results.

AHLTA permits maintenance of the outpatient EHR from the time the service member enters active duty until the time of discharge. AHLTA now receives input through TMDS of AHLTA-T documentation, to include dispensed medications, but inpatient medical record information from TC2 does not reach it. This information can be accessed through a Bidirectional Health Information Exchange (BHIE) system for individual patient lookup, but this system does not presently allow any query of information across patients. The BHIE systems also allow all information from AHLTA and the theater systems to be viewed by VA providers.

Further, TMDS data are housed separately from the DoD Military Health System (MHS) data captured from fixed higher level (level 4 and 5) medical facilities in CONUS. Until the TMDS and CONUS record system data are combined and linked with the VA EHR, a longitudinal health record for service members extending past the time of discharge from the military will not be possible.

The IOM and NRC recommended integrating the efforts of environmental surveillance, PM, clinical medicine, and medical informatics to ensure the inclusion of medically relevant environmental and other exposure information into the individual medical record. DODI 6490.03 requires the services to document all representative individual exposure information in the medical records of service personnel. The Air Force Central Command (AFCENT) developed a policy in 2004 to document on a medical Standard Form (SF600) overprint a summary of the sampling results and the environmental conditions for a specific base in the medical record of personnel assigned to the base. The Air Force was able to complete the tasks because they have BEEs assigned to each unit who can sample for OEH threats at the base. By contrast, the Army has found it quite difficult to collect representative individualized sampling data, summarize the results, and place the information in the medical record. Despite there being PM assets at brigades, at divisions, and at Corps and three to four PM Detachments in theater at any given time, the large numbers of base camps and work sites have made the task of sampling individual exposures nearly impossible to accomplish. This represents a strategic change in how we fight insurgencies. We used to rely on fewer larger bases, but an effective counterinsurgency strategy now requires many more, smaller sites, which are frequently challenged when it comes to force health protection issues. However, our PM inspection and assessment policies as well as manpower and distribution of personnel have not kept up with these changes.

The Joint Environmental Surveillance Working Group (JESWG) attempted to develop a consensus document for various locations where OEH threats were present. Because the JESWG determined that area sampling results were not representative of individual exposures, the DoD Office of Force Health Protection and Readiness concluded that area sampling data should not be recorded in the medical record. There are currently only eight locations globally with completed Periodic Occupational and Environmental Monitoring Summary (POEMS) information sheets that include an interpretation of the area sampling data such that a non-OH provider could interpret the exposure data and understand the potential for long-term health outcomes related to the exposure. These environmental sampling data reside in the DOEHRS-EH.
RISK COMMUNICATION
The IOM and NRC recommended that the DoD designate and provide resources to a lead agent for risk communication within the DoD, with primary responsibility for developing and implementing a risk communication plan. This recommendation is still not realized. Development of the needed plan must involve service members, families, and experts to craft explicit risk communication goals. The commander of the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM, the predecessor of USAPHC-P) led a DoD/VA Working Group on Risk Communication for OEH threats to develop the risk communication goal articulated in the Presidential Review Directive 5.19 The USACHPPM had success in changing the culture within DoD and the military services so that dialogue about risks was facilitated at all levels. The DoD/VA Risk Communication Working Group was supported by all the services and spearheaded efforts to incorporate risk communication into training programs for line commanders and health care providers. The DoD/VA Working Group was discontinued in 2004 but the USAPHC-P still maintains two substantial Health Information Operations and Risk Communication Programs that provide tri-service support for OEH threat issues that arise. However, a DoD lead agent responsible for risk communication is needed and should be designated and fully supported.

RESERVE AND NATIONAL GUARD COMPONENTS
Another major issue involves providing National Guard and Reserve personnel the same predeployment preparation and postdeployment health surveillance afforded the active duty component.20 Dramatic efforts have been made to improve the preparations for deployment, health care, and postdeployment surveillance for members of the Reserve and National Guard. Coordination between the service public health commands and the Guard and Reserve Headquarters has helped disseminate information about OEH threats encountered in theater that facilitated predeployment planning, and implementation of improved during and postdeployment health surveillance, record keeping, and risk communication for the affected service members. Congress has passed legislation that provides 2 years of eligibility for health care after returning from deployment, and this has helped improve care and postdeployment surveillance for Reserve and Guard members. However, many of these service members seek care in the civilian sector, and a surveillance strategy is still needed to capture information about this health care.

DISCUSSION
After the 1991 Gulf War and deployments to Bosnia and Somalia, DoD demonstrated greater awareness of the importance of medical surveillance and record keeping in protecting the health of its deployed forces. Many of the recommendations of the IOM and NRC on Strategies to Protect the Health of the Deployed U.S. Forces have been implemented but much more remains to be done to fully implement those recommendations.1-2 More work is needed in the area of developing appropriate risk assessment strategies for OEH threats. Sampling should be redirected to focus on individual exposures and prioritized to identify those at greatest risk of exposure to OEH threats so that countermeasures can be taken to eliminate the exposure or minimize the health impact to exposed populations. The sampling strategy for OEH threats should address the reason for sampling, the parameters to be measured, the range of results expected, and the actions that will be taken in response to the range of results. The DoD should expand the approved list of agents for biological monitoring as this will permit the services to better document exposure to OEH threats, which will help to confirm the results of individual exposure monitoring and may enhance the services’ capability to perform comprehensive health risk assessments. In addition, the DoD needs a better capability to capture ALL EHR information into a system that will allow meaningful aggregation and query of data, as well as an ability to include data from the VA EHR to permit longitudinal health surveillance for service members for the members time-in-service and postservice periods.

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COL Robert F. DeFraites, MC USA*; CPT Erin E. Richards, MS USA†

ABSTRACT  From May 19 to May 21, 2010, the Armed Forced Health Surveillance Center and the Uniformed Services University cosponsored an educational symposium and workshop on the assessment of potentially hazardous environmental exposures among military populations. Symposium participants reviewed and analyzed historical exposure events, from herbicides in Vietnam to the 1991 Gulf War oil well fires and World Trade Center dust exposure in 2001, using the framework that the Institute of Medicine developed for addressing environmental exposures and their possible impact on military populations. Historical exposures were critically assessed in terms of methods used to identify and define harmful exposures, to prevent or limit exposures, and to define the health risks to exposed people. The lessons learned were then used during small group discussions to deliberate on the current scientific approach for dealing with hazardous environmental exposures. This article summarizes the major conclusions and proceedings of the symposium and provides suggestions to improve the U.S. military's current strategy on identifying and assessing potentially hazardous environmental exposures.

INTRODUCTION AND BACKGROUND
From May 19 to May 21, 2010, the Armed Forced Health Surveillance Center (AFHSC) and the Uniformed Services University (USU) cosponsored an educational symposium and workshop on the assessment of potentially hazardous environmental exposures among military populations.\(^1\) Several well-documented historical examples provided the focus for discussions of the participants. Among others, U.S. military hazardous environmental exposure incidents include Agent Orange in Vietnam, oil well fires and possible release of the nerve agent sarin during Operation Desert Storm (1991), and sodium dichromate at the Qarmat Ali Water Treatment Plant in Basrah, Iraq, in 2003 (Operation Iraqi Freedom).\(^2-5\)\(^\) During each of these events, a hazardous substance was released into or encountered in the environment in and around deployed U.S. troops and resulted in concern and claims by many service members that the release was responsible for subsequent illness or other harm.

Discussions during the symposium resulted in three major conclusions. First, many of the effective measures needed to protect against adverse health consequences of harmful substances involve relatively simple procedures and practices that can generally be accomplished given the proper resources, orientation, and command emphasis. Second, the resources needed to progress beyond the current state of the science and art include focused and devoted assets and related research. Third, participants agreed that U.S. service members have and will continue to face potential exposure to environmental hazards, so we must always be prepared for these events, during war and in peacetime. Lessons learned from past events need to be applied and acted upon if the military is to progress from repercussions like those of Agent Orange in Vietnam and move toward the establishment of procedures to scientifically capture environmental hazard data and apply them to reduce risk and positively account for service members who have come in contact with hazardous agents.

DISCUSSION
Consideration of the Exposure Pathway
Considering the tremendous destructive forces deployed in the modern battlefield, often in industrial and urban or suburban environments, it can be assumed that troops share the environment with a wide variety of potentially harmful substances, including toxic industrial materials used in production, hazardous waste, building debris, and naturally occurring infectious agents and toxins from ecosystems disturbed or disrupted by warfare. But the simple juxtaposition of troops and any substance, be it chemical, radiological, or biological, does not assure that the substance or agent will be absorbed or ingested by persons in a manner that leads to illness. In accordance with a conceptual framework of exposure science, given a source of environmental contamination, a person must be exposed via a viable route with a dose of sufficient size to alter tissue function or structure that may culminate in biologically plausible damage, dysfunction, or disease. Figure 1 further depicts the processes by which environmental exposures can result in disease in humans.\(^6\) Our understanding of currently described and future hazards in the environment must include recognition of the requirements to assess all aspects (steps) of the pathway—too often, potential hazards are assumed to
have caused adverse effects without confirmation of a completed pathway. Equally damaging is the communication and perpetuation of this incomplete understanding to troops, family members, and the public at large.

**Capability Gaps and Solutions**

As discussed during the symposium, the risk of troops encountering environmental hazards is more likely to be effectively reduced through the full integration of efforts across the military. Also, the most effective interventions required to minimize environmental hazards and reduce risk to soldiers are basic, common sense processes that may be integrated into work and daily life support processes during deployments. A common theme discussed by participants was a tendency to disregard effective personal protective equipment (e.g., barriers, masks, gloves, goggles) and practices by deployed troops, citing the “exigencies of combat” precluding employment of normal precautions and practices.

The U.S. military establishment utilizes a more formal and deliberate assessment of capabilities, shortcomings, gaps, and the identification of potential solutions to these problem areas. Using the Joint Capabilities Integration Development System (JCIDS), the Department of Defense (DoD) defines gaps in capabilities and develops solutions to them; these are categorized as either doctrine, organization, training, materiel, leadership and education, personnel, or facilities (DOTMLPF). The DOTMLPF framework facilitates a disciplined approach to address large capability gaps through prior planning and the full integration of worthy ideas and practices throughout the DoD. Using this framework, the Joint Staff, U.S. Joint Forces Command, and Office of the Assistant Secretary of Defense (Health Affairs) have recently completed a thorough review and assessment of battlefield health and medicine published as the Initial Capabilities Document for Joint Force Health Protection in February 2010. In this analysis, health surveillance, intelligence, and preventive medicine (HSIPM) were considered together as one of eight functional areas, along with command and control, patient movement, human performance enhancement, casualty management, medical logistics and infrastructure support, medical support to homeland defense/civil support, and medical support to stability operations. Notable gaps identified in HSIPM are summarized in Figure 2. Many of these same gaps and problem areas were recognized by participants and presenters at the symposium. These observations may also be viewed through the DOTMLPF analytic framework, to characterize gaps and potential effective measures to minimize environmental hazards and reduce risk to service members and missions (Table I). Although the apparent congruence of the conclusions drawn through the formal JCIDS analysis and our symposium is somewhat reassuring, a more satisfying result of these efforts would be evidence of effective actions taken to address the shortcomings identified.

**Getting Beyond, or Ahead of, the Environmental “Incident”**

Presentations and discussions at the symposium focused on several remarkable episodes of environmental exposures, illustrating the DoD’s understandable tendency to invest significant energy and attention on these “incidents”. These

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**FIGURE 1.** Exposure Science Continuum: the processes by which environmental exposures can result in disease in people.6
incidents are generally felt to be rare, almost always unan-
ticipated, and their potential impact on health is often mis-
understood. As a result, most actions taken in the military
operational environment to address them have been delayed
and, by definition reactive, limiting their effectiveness. As a
more distal result of delayed and ineffective documentation and
characterization of potentially harmful exposures from these
incidents, the U.S. Government (through the Department of
Veterans Affairs [VA]) has been constrained from performing
robust risk assessments and accurate assignment of attribution
of adverse health outcomes. The end result of this limitation
is the inclination toward providing overarching compensation
for all troops involved in these incidents in lieu of establish-
ing scientific causality and specificity of expected effects. The
economic impact of this approach is compounded by the loss
in public confidence and undermined credibility of the sci-
entific method and the institutions that employ it. The substances
and circumstances involved in most highly publicized “inci-
dents” are rarely typical, and do not accurately represent the
environmental risks faced by most deployed troops.

To progress beyond our current situation, resources must
be allocated to support effective environmental surveillance,
from planning to collection and analysis of specimens, to deci-
sion-making for hazard elimination or mitigation, to follow-
up of those with potentially harmful exposures. Symposium
and workshop participants reached a consensus that environ-
mental surveillance and all the actions that must follow must
be improved. Early comprehensive planning is essential. Data
on industrial and chemical factories, hazardous storage areas,
and areas of known or suspected contamination (e.g., from
agricultural activities), with data from initial but comprehen-
sive air, water, and soil sampling, must be used to define and
characterize risks for an area prior to occupying that area.
Competent, trained personnel in adequate numbers must be
sent to theaters of operation to develop specific sampling plans and to effectively communicate important data and


TABLE I. Environmental Health Surveillance, Intelligence, and Preventive Medicine Improvement via the DOTMLPF Framework  

<table>
<thead>
<tr>
<th>DOTMLPF Strategy</th>
<th>Recommendations for Improvement</th>
</tr>
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<tbody>
<tr>
<td>Doctrine</td>
<td>Improve Policy, Field Manuals, and Training Circulars to Indoctrinate and Enforce Ideas and Allocate Resources to Predeployment Assessment, Soldier Tracking in-Theater, and Planned Deliberate and Meaningful Environmental Sampling.</td>
</tr>
<tr>
<td>Organization</td>
<td>Organize Governmental and Joint Service Preventive Medicine, Intelligence, Scientific, and Technological Assets to Work Toward the Achievement of Common Goals.</td>
</tr>
<tr>
<td>Training</td>
<td>Educate Service Members From Basic Training to Advanced Individual Training and General Staff College on Environmental Hazard Recognition and Risk Reduction.</td>
</tr>
<tr>
<td>Materiel</td>
<td>Provide Robust Equipment to Personnel on the Ground So They Can Provide Comprehensive and Reliable Data to Line Commanders and Interested Researchers.</td>
</tr>
<tr>
<td>Leadership and Education</td>
<td>Prepare Leaders Through Education and Access to Knowledge Databases.</td>
</tr>
<tr>
<td>Personnel</td>
<td>Allocate Qualified People for Preventive Medicine Work, and Provide Qualified Personnel In-theater to Complete Predeployment Assessments and Environmentally Characterize Deployed Areas.</td>
</tr>
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Facilities were not considered in this discussion.

MILITARY MEDICINE, Vol. 176, July Supplement 2011
Assessing Potentially Hazardous Environmental Exposures Among Military Populations

information to military leaders in a manner that they will understand and can act on. These data and information, to include actions taken and not taken, must be assessed and archived after military operations to expand our knowledge base, provide material for training and education programs, and inform future research.

A more comprehensive approach involving DoD partnerships with other agencies in the Federal government and non-governmental organizations is needed to focus the expertise on the planning and execution of scientific research related to hazardous environmental exposures in U.S. service members. This research would ideally combine battlefield stress and environmental exposure agents and would involve the development of a disease risk model for service members on the basis of a combination of stressful and environmental exposures. This determination must include the expected routes of exposure, and host susceptibility factors including internal dose, metabolism, and excretion, genetic makeup of the host, and resiliency factors such as nutrition, hydration, fitness, and others. Deployment exposure science is not cut and dry. A model that includes multiple stressors, not just one, must be strongly considered when looking at deployment records and illness trends.

Linking the Past, Present, and Future

Past environmental exposure incidents have provided us many lessons. In some cases, this knowledge has led to the creation of new agencies such as the Armed Force Health Surveillance Center, Silver Spring, Maryland, and the development of a new surveillance system, like the Defense Occupational and Environmental Health Readiness System (DOEHRs) data portal and repository at the U.S. Army Public Health Command (Provisional), Aberdeen Proving Ground, Maryland. Regarding our ability to track those who may have been exposed, definitive action has not yet been taken. For example, past incidents have shown that a joint computerized patient record that could be shared by the DoD and the VA would be extremely beneficial in tracking the health of service members in and out of deployment and after service completion. A concerted effort to establish such a system awaits action. Without commitment, genuine effort, and teamwork between the military services and other government agencies to complete a joint computerized patient record, the problem of lack of connectivity between the DoD and the VA health systems will persist.

Another example of a lesson learned from past exposure incidents but still not fully addressed is a strategy to deal with medically unexplained symptoms in populations that have deployed. A large prospective health study, the Millennium Cohort Study (MCS) of the Naval Health Research Center, San Diego, California, was launched in 2001 with the intent to evaluate the long-term health effects of military service to include deployments. Although the MCS is one of the largest advances in service member health research, it is not designed to evaluate medically unexplained symptoms in troops. The MCS is limited by a number of factors concomitant with the unique battlefield environment, multiple environmental exposures, and the inherent stresses of war. Effort must be devoted to resolve these challenges and support research directed toward understanding causality.

The symposium and workshop participants felt that improvements should be approached first through policy development. New policies should address needed changes to doctrine, education, training, research, communication, leadership, and material acquisition, as described above and in many other reports in this supplement to Military Medicine. Policies must be tied to well-defined, meaningful, and understandable procedures to be followed prior to deployment, during deployment, and after deployment. The outcome must include environmental assessments and sampling that meets rigorous, systematic, and objective scientific standards, and methodologies capable of linking exposure data not only to large populations but also to specific individuals.

CONCLUSIONS

The U.S. military is better able to deal with environmental hazards today than we were 50 years ago. However, the current problems, as described by the National Research Council and the Institute of Medicine (IOM) and at this symposium and workshop, are not new. These problems can be expected to continue in future operations if not addressed, and could increase in severity and importance. Meaningful planning with conviction to bring about the needed improvements must occur. Despite the technology and advanced intelligence systems available in modern military operations, nothing can be accomplished without a commitment to significantly improving our situational awareness of service members on the ground. The ideas discussed and presented during the symposium have been examined and reviewed many times over the last 40 years. We must take action to bring about change in the way we deal with environmental hazards. We must use the experiences of the past to improve current and future situations.

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Responses to Occupational and Environmental Exposures in the U.S. Military—World War II to the Present

CPT Erin E. Richards, MS USA

ABSTRACT Since the Civil War, a proportion of U.S. service members continues to return from war with new health problems and continues to reference battlefield exposures as the cause. Hence, one of the most pressing public health debates in military policy, the determination of causality and linking of battlefield exposures to health outcomes in veterans, continues. The advances in military environmental and occupational epidemiologic research and Department of Defense policy concerning battlefield exposures are summarized and examples from World War II through the first Gulf War are provided. The limitations associated with the unique battlefield environment, multiple environmental exposures, and the inherent stresses of war, beget challenges for researchers responsible for determining causality. In light of these difficulties, six strategies for addressing environmental exposures and their possible impact on veterans were recommended by the Institute of Medicine post Operation Desert Storm. These strategies, along with their respective progress and remaining gaps, are addressed.

INTRODUCTION

In the military the wartime mission is foremost. In a theater of war, the military leader must give mission completion the highest priority, while at the same time considering the impact of morbidity and mortality in his troops. Recognizing the extremely hazardous nature of war, the Government of the United States accepted the responsibility “to care for him who shall have borne the battle and for his widow and his orphan, . . .”1 Although the U.S. government has provided pensions for disabled war veterans since 1776, the notion of war-related disability and compensation for war survivors has evolved over time. Physically incapacitating and disfiguring injuries have traditionally been recognized as deserving consideration for disability compensation. However, 20th Century warfare introduced chemical, biological, and nuclear weapons on a large scale along with the recognition that these weapons could inflict physical and mental harm in a manner that may not be immediately apparent. Along with industrialization came the increasing occupational use of chemicals and the recognition that acute or delayed adverse health effects could occur not only from weapons of war, but also indirectly from environmental and occupational exposures. Concepts with regard to what uniformed members could be exposed to without full disclosure of potential risks and informed consent also changed over time. Although requirements for informed consent for potentially hazardous exposures were developed in the latter 20th Century, these came too late for many military members who knowingly or unknowingly had already participated in experiments that might have damaged their health.

Recent media reports have brought attention to service member exposures while serving in Iraq and Afghanistan. Often the symptoms of concern experienced by contemporary veterans are not unlike symptoms experienced by veterans of past wars, to include fatigue, headache, muscle and joint pain, diarrhea, skin rashes, shortness of breath, and chest pain. These are common nonspecific symptoms experienced by veterans returning from battle since the Civil War.2 The frequency of the many disparate claims and limited, if any, objective characterization of the agent or agents to which they were exposed, highlights major issues confronting health officials. These issues include determining if sufficient evidence exists to identify an exposure that is likely to have adverse health outcomes and the linking of specific military exposures to outcomes of interest. The complex relationship between environment, exposures, and veterans’ diseases continues to be problematic and to be explored.3,4 Study designs to assess health outcomes of war veterans and to relate these to military jobs and geographic assignments have been, and continue to be very challenging. These challenges relate to the retrospective characterization of exposures, and to determining associations and ascertaining causation. To provide background information for participants in the scientific symposium entitled Assessing Potentially Hazardous Environmental Exposures among Military Populations, Bethesda, Maryland, held May 19-21, 2010, major service-related exposures and associated disease concerns in U.S. troops from World War II (WWII) to the present were identified. Past epidemiologic research on these exposures and related disease outcomes were summarized.

METHODS

A search of the published medical literature for the years 1940 to 2010 was completed. Additionally, people knowledgeable about occupational and environmental exposures of service
members were consulted to identify publications not obtainable through a traditional medical literature search.

RESULTS

World War II

Following the enemy use of chemical weapons during WWI, the U.S. military positioned itself to retaliate with chemical weapons in case they were used again. On December 12, 1943 the “SS John Harvey,” carrying 2,000 100-pound liquid mustard bombs, was docked at Bari, Italy, waiting to unload its cargo. It was attacked during a German air raid and its dangerous cargo was released into the water, mixing with the other petroleum and oil products that entered the water from the many damaged ships in the harbor. The Chemical Officer onboard, the only person who knew about the classified mustard munitions, was killed. No one at the harbor, to include the many victims of the attack who entered the water, had knowledge of the toxic contamination. Unaware of the mustard agent, many survivors remained in medical triage areas or were admitted to medical facilities covered in the oil, some for up to 24 hours. In all, there were 617 known mustard casualties and 83 deaths attributed to mustard exposure. Many of those exposed died within the first 2 weeks of exposure.\textsuperscript{5,6} No data were collected on urine, blood, or kidney function from the casualties, and no research was done to determine if those exposed to the mustard had any resulting injury or illness. Service members exposed at Bari were unaware of their exposure at the time of the incident and nothing was found in the literature reviewed to show that long-term follow-up was attempted or considered, or that compensation for the exposed survivors was addressed.

The Cold War

After WWII, military research was influenced by Cold War fears and government interest in the use of chemical, radiological, and biological weapons, and was focused on acute effects. Weapons were intended to immediately incapacitate enemy forces, so little if any attention was paid to long-term effects in those who participated. The lack of preserved exposure data in research studies made retrospective exposure and related outcome analyses on affected personnel difficult.

During this period, Aberdeen/Edgewood experiments, the Shipboard Hazard and Defense (SHAD) project, and Smokey experiments were conducted to study the results of chemical, biological, and radiological exposures on troops.\textsuperscript{7} Classified chemical experimentation involving nerve agents, nerve agent treatments, psychochemicals (hallucinogenic drugs), irritants, and blistering agents occurred at Edgewood Arsenal, Aberdeen Proving Ground, Maryland, from 1955 to 1975. The Army exposed approximately 7,000 consenting participants to a number of different chemicals with the goal of determining near-term health effects associated with low-dose exposures, efficacy of pre- and post-exposure medical treatments, and the effectiveness of personal protective equipment in preventing exposure.\textsuperscript{7} Recorded notes on these experiments were “brief and anecdotal,” documenting acute effects with little or no long-term follow-up.\textsuperscript{8} The National Academy of Sciences, National Research Council, retrospectively studied these experiments and the participating service members. Their final report on chronic adverse health effects on Servicemen of experimental exposure at Edgewood revealed no long-term health effects associated the experiments.\textsuperscript{9} Because of the limitations inherent in the study and the fact that many of the volunteers subsequently served in Vietnam, their study would only be able to detect very large health effects in the participants; there were none.

Like the Aberdeen experiments, the Project SHAD experiments, which included 50 separate testing events from 1962 to 1973 (declassified in 1998), were also ambiguous. But unlike the Aberdeen experiments which used consenting volunteers, service members and civilians in the SHAD experiments were exposed unknowingly. During Project SHAD, a series of tests of biological and chemical agents were conducted on naval ships by the U.S. Department of Defense (DoD). The official purpose of Project SHAD was “…to identify US war ships vulnerabilities to attacks with biological or chemical warfare agents and to develop procedures to respond to such attacks while maintaining a warfighting capability.”\textsuperscript{10} Because the DoD did not acknowledge the existence of Project SHAD until 1998, a large number of the potentially exposed personnel remain unidentified. Medical follow-up of the 5,842 service members that have been identified was not conducted until, in some cases, 40 years after the initial event.\textsuperscript{11} Possibly as result of the many inherent limitations, research on the SHAD veterans identified in these experiments has shown no consistent, specific patterns of ill health.\textsuperscript{4}

Another concern during the Cold War was the ability of military forces, especially ground troops, to survive a nuclear detonation and operate in the post-detonation battlefield. Possibly the largest study of troops who had participated in chemical and radiological exposure research done during the post WWII era was a retrospective cohort study done to determine if the nuclear test known as “Smokey” conducted on August 31, 1957 in Nevada was causally associated with Leukemia and other cancers. During testing, troops were located 29 to 2,700 meters from the nuclear detonation, and many may have witnessed more than one detonation or have been exposed to fallout from previous nuclear explosions. Exposures from the Smokey incident were captured on radiation dosimetry film badges; the Armed Forces Radiobiology Research Institute later provided these badges and data on individuals at the site for research. Although exposure data was captured for each service member involved in the Smokey experiment, follow-up of these individuals was not done until August 1977. Research on the Smokey participants revealed that men who witnessed the Smokey detonation were diagnosed with leukemia more often than men who did not witness the event ($p < 0.01$).\textsuperscript{12,13} While this research effort provided 20 years of follow-up time and had quantifiable exposures
(albeit controversial), many service members who had participated in the numerous radiation experiments could not be located, were not included in the study, and have not received compensation for their involvement.

Although each of these three experimental exposure events conducted on U.S. service members during the Cold War have similarities, negative health outcomes were only found to be significantly related in those exposed during the Smokey experiments. The overwhelming research limitations and negative findings from the Aberdeen/Edgewood and Project SHAD research studies have limited compensation benefits to those veterans involved. Despite involvement in what many consider unethical experimentation, priority for hospital care, medical services, and nursing home care for these veterans is not provided by the Department of Veterans Affairs.

**Vietnam War**

During the latter half of the 20th Century, medical knowledge of and concern about carcinogens grew, and human experimentation guidelines became more stringent. During the Vietnam era, concern for troop exposure to environmental contaminants evolved beyond acute exposures and experimentation to encompass long-term occupational and environmental hazards encountered on the battlefield. Vietnam has become synonymous with Agent Orange, the herbicide used to expose enemy troops, and the reputed illnesses it has afflicted on U.S. and allied troops and Vietnam civilians. Agent Orange is the common name of the phenoxy herbicide used during Vietnam defoliation missions from 1965 to 1971 that contains the carcinogen 2,3,7,8-tetrachlorodibenzo-p-dioxin, also known as dioxin. The aerial dispersion of Agent Orange was done by Operation Ranch Hand personnel. Ranch Hand Airmen and Army Chemical Corps personnel worked closely with Agent Orange, and up to 2 million service members may have been exposed to the chemical. Many of these veterans contend that they were heavily exposed to Agent Orange during their Service. Hundreds of thousands of service members and civilians who were located in Vietnam between 1965 and 1972 have attributed a number of health problems ranging from skin rashes to rare cancers and birth defects to their exposure to dioxin during the Vietnam War.

Civilian and government researchers undertook the seriousness of the task of determining the extent of the dioxin burden on veterans potentially exposed to Agent Orange and have conducted an extensive amount of research over the past 4 decades on the subject. Studies were conducted comparing dioxin levels in adipose tissue of Vietnam veterans to non-Vietnam veterans and nondeployed civilians, and comparing levels in veterans who worked closely with Agent Orange to other Vietnam veterans. Troop location and recorded Agent Orange spray missions were also analyzed. Many of these studies found no significant difference between the cohorts of potentially exposed ground troops and unexposed personnel. While many study results suggested that heavy exposure to Agent Orange or dioxin was unlikely for most U.S. troops during Vietnam (excluding Ranch Hand Airmen and Army Chemical Corps personnel), the belief among many veterans remains that they were exposed to Agent Orange during their Service and that their disease is attributed to this exposure.

The lack of causal association in the research and the public need for compensation for its drafted veterans placed a large burden on Congress and the Department of Veterans Affairs. The result of this predicament led to a decision that has since shaped disability compensation with regard to environmental exposures in the U.S. military. After the Congressional law, the “Agent Orange Act of 1991” was passed, the Institute of Medicine (IOM) began to review the link between service in Vietnam and a number of health outcomes thought to be associated with dioxin exposure. In the years since, the IOM has identified a number of chronic illnesses that are significantly associated with Vietnam service, all of which are compensated for by the Department of Veterans Affairs under the Agent Orange Act.

**First Gulf War (Operations Desert Shield and Desert Storm)**

The U.S. military interest in environmental hazards was reawakened during the First Gulf War, August 1990 to February 1991. During this short period of time, the Iraqis set fire to the Kuwaiti oil wells, the Khamisiyah ammunition storage area was detonated, and depleted uranium (DU) was used extensively in munitions and in protective armor on tanks. Smoke from the oil well fires, sarin gas in Khamisiyah, and DU were the top three environmental exposure hazards of the Gulf War. Post-conflict, the term Gulf War syndrome was created by the media to encompass the myriad of adverse health effects claimed by Gulf War veterans. Included were a wide range of acute and chronic symptoms including fatigue, headaches, neurological problems, memory loss, muscle and joint pain, gastrointestinal problems, skin rashes, cancers, and birth defects. Past lessons learned and satellite technology allowed for a new approach to be taken with regard to environmental hazards. This new approach was used to look at the health impact of both the oil well fires and release of sarin gas in Khamisiyah.

Although the DoD suspected that Iraqi forces would set the Kuwaiti oil wells on fire, the U.S. military’s main focus was on the war time mission and concern over ensuing environmental health hazards remained reactionary despite prior intelligence of this event. Several U.S. government agencies, including the DoD and the National Oceanic and Atmospheric Administration were involved in the geographic reconstruction of the oil well fire smoke plumes. The geographical reconstruction of the smoke plumes, coupled with ground troop location, and ambient ground sampling during the fires, allowed researchers to predict the amount of exposure to troops. For the oil well fires, the simulation models, while still a proxy for individual exposure data, provided invaluable exposure information and greatly assisted health outcome research. Researchers used the fire smoke plume model to
look at excess morbidity in Gulf War veterans and assess the possible causes of Gulf War syndrome.\textsuperscript{30}

On March 10, 1991, just before leaving Iraq, U.S. troops demolished munitions bunkers in Khamisiyah, Iraq. The destruction of one bunker, Bunker 73, caused the unintentional release of sarin/cyclo-sarin nerve-agent. The Central Intelligence Agency and the DoD collaborated to model the potential hazard; simulation models indicated that an area around the bunker at least 2 km in all directions and 4 km downwind could have been contaminated at or above levels that cause acute symptoms (runny nose, headache, and miosis), and an area up to 25 km downwind and 8 km wide could have been contaminated at or above the general population dosage limit.\textsuperscript{31} The exposure simulation model assisted in morbidity and mortality research by identifying Gulf War veterans potentially exposed to sarin.\textsuperscript{17,32,33} Results of these studies showed that service members located within the sarin plume had an increased risk of dying from brain cancer (Relative Risk [RR] = 1.94; Confidence Interval [CI] = 1.12, 3.34), and that service members who were in the plume for 2 or more days had a greater risk of dying from brain cancer than those in the plume for only 1 day and those outside the plume (RR = 3.26; CI = 1.33, 7.79).

In addition to simulation modeling, biomonitoring was also used proactively during the Gulf War to determine health effects from exposure to polycyclic aromatic hydrocarbons from the oil well fires.\textsuperscript{34} Overall, results of research on Gulf War syndrome using both biomonitoring and simulation modeling indicated no causal link between environmental exposures and Gulf War syndrome, and pointed toward battlefield stress as a possible cause of Gulf War syndrome. Furthermore, despite statistically significant findings that associated sarin exposure with brain cancer, the National Academy of Science rejected this finding as not biologically plausible based on the lack of acute poisoning that always precedes long-term effects.\textsuperscript{35}

Biomonitoring research has also been conducted to determine the toxicity of DU in exposed veterans. Because service members with embedded DU fragments excrete elevated concentrations of uranium in their urine, it is possible to document the systemic exposure in the body directly through urine analysis. Biennial biomonitoring of a cohort of DU-exposed Gulf War veterans began in 1993.\textsuperscript{36–38} Uranium was only found in urine specimens provided by veterans with retained embedded DU fragments. These data have shown that personnel without DU fragments or who had inhaled DU were not at risk for prolonged uranium toxicity.\textsuperscript{39}

It has been suggested that the Gulf War reopened one of the most pressing public health debates afflicting military policy.\textsuperscript{40} Despite the successful efforts to provide exposure data via geographic modeling and a large amount of literature indicating no correlation between possible exposures and disease, the responsibility of the U.S. government to provide compensation for ill veterans remains. Recently, the IOM concluded that Service during the Gulf War has caused post-traumatic stress disorder and is associated with multisymptom illness; gastrointestinal disorders (irritable bowel syndrome); alcohol and substance abuse; and anxiety disorders and psychiatric disorders.\textsuperscript{41}

**Post-Gulf War Initiatives**

In the years following the Gulf War, a number of initiatives were taken to address gaps in the assessment of exposure and medical surveillance of service members during deployment. In 1998, the report titled “A National Obligation” was written by the National Science and Technology Council following a Presidential Review Directive for an interagency plan addressing health preparedness for future deployments.\textsuperscript{42} Like many written before it, this document provided a comprehensive vision for protecting deploying forces. The report outlined a plan for enhancing deployment health, improving military health record keeping, improving research, and provided recommendations for various federal agencies. However, little progress toward the implementation of recommended programs was made. In 2000, the IOM published “Protecting Those Who Serve,” a five-book series, which reiterated past policy suggestions and recommended six strategies for addressing environmental exposures and their possible impact.\textsuperscript{43} The strategies focused on resolving past public health issues surrounding Smokey, Agent Orange, and Gulf War syndrome. Many of these initiatives looked toward proactive actions to, for example, ensure medical encounters in theater are recorded in individuals’ medical records, document locations of service members during deployment, and integrate environmental and medical hazards in information provided to commanders.

Now, a decade since this report was published, as environmental and occupational health issues arise in Operation Iraqi Freedom and Operation Enduring Freedom in Iraq and Afghanistan, it is clear that a great deal of growth remains. Nonetheless, the U.S. military and DoD have evolved significantly in the public health arena. Table I outlines each of the strategies recommended by the IOM in 2000 and the progress that has been made to-date to address it.

**DISCUSSION AND CONCLUSIONS**

When the U.S. response to the mustard-exposed survivors of Bari in 1943 is compared to the response to Agent Orange exposure in Vietnam veterans, a drastic change in perception can be seen. The progress during these years in medical knowledge of occupational and environmental hazards and evolving cultural norms has changed the way the military responds to and compensates for environmental exposures. The exposure fears of the Vietnam era also intensified the concern over other past veteran exposures resulting in a great deal of DoD retrospective epidemiologic research during the 1970s; during this time the link between exposure and illness was explored not only for those deployed to Vietnam, but also in personnel involved in other past environmental events, such as the SHAD, Smokey, and Aberdeen experiments.
The DoD has come a long way toward filling the occupational and environmental gaps needed to better serve our deployed service members. As the DoD continues to progress, the media acts as a consistent reminder of the significant gaps that preclude us from knowing for certain if exposures encountered during Service have caused disease in our veterans. One of the main gaps that remains, and has no foreseeable solution, is the lack of individual exposure data for deployed service members. Even with the availability of geospatial information systems and high-resolution satellite imagery as proxies, the need for exposure data specific to individuals’ remains. Other information gaps that are currently moving toward a resolve are the joint computerized patient record, and leader education to improve risk assessment, management, and communication skills. Although the services within the DoD and the VA have been working together to support the sharing of health data via a joint patient record, there are still a number of logistic hurdles to overcome before this comes to fruition. Likewise, leader education on the identification of environmental and occupational hazards and an emphasis on preventive medicine continue to develop and change our military culture. As the military looks toward the future, we will need to reconsider the reductionist (single agent by single agent) model currently used for one that is more appropriate for the battlefield and incorporate the complex interaction of stress and environmental exposures.

Whether the exposure in question is experimental in nature, a chemical used to expose enemy troops, or particulate matter from oil fires, a proportion of service members continues to return back from war with new health problems, and an emphasis on preventive medicine continue to develop and change our military culture. As the military looks toward the future, we will need to reconsider the reductionist (single agent by single agent) model currently used for one that is more appropriate for the battlefield and incorporate the complex interaction of stress and environmental exposures.

The 6 Strategies listed above were developed by the IOM in “Protecting Those Who Serve: Strategies to Protect the Health of Deployed U.S. Forces.”

<table>
<thead>
<tr>
<th>IOM Strategy</th>
<th>Progress to Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategy 1.</td>
<td>Use a systematic process to prospectively evaluate nonbattle-related risks associated with the activities and settings of deployments. The mission of the National Center for Medical Intelligence (formerly Armed Forces Medical Intelligence Center) is to protect the health of deployed forces through prospectively evaluating nonbattle-related risks during deployment using medical intelligence.</td>
</tr>
<tr>
<td>Strategy 2.</td>
<td>Collect and manage environmental data and personnel location, biological samples, and activity data to facilitate analysis of deployment exposures and to support clinical care and public health activities. The Defense Occupational and Environmental Health Surveillance data repository allows preventive medicine personal the ability to submit, search, and retrieve environmentally important documents.</td>
</tr>
<tr>
<td>Strategy 3.</td>
<td>Develop the risk assessment, risk management, and risk communication skills of military leaders at all levels. Although a risk communication program has been developed for use in the military, which incorporates risk-based scientific information and community values, perceptions, and needs, risk communication and leadership education remain as issues in military public health.</td>
</tr>
<tr>
<td>Strategy 4.</td>
<td>Accelerate implementation of a health surveillance system that spans the service life cycle and that continues after separation from service. The Armed Force Health Surveillance Center was initiated to provide comprehensive health surveillance to all military services.</td>
</tr>
<tr>
<td>Strategy 5.</td>
<td>Implement strategies to address medically unexplained symptoms in populations that have deployed. The Defense Medical Surveillance System is a database operated by Armed Force Health Surveillance Center, which contains current and historical data on diseases and medical events (e.g., hospitalizations, ambulatory visits, reportable diseases, human immunodeficiency virus tests, acute respiratory diseases, and health risk appraisals) and longitudinal data on personnel and deployments.</td>
</tr>
<tr>
<td>Strategy 6.</td>
<td>Implement a joint computerized patient record and other automated record keeping that meets the information needs of those involved with individual care and military public health. The Millennium Cohort Study was launched in 2001, and is the largest prospective health project in military history. The intent is to evaluate the long-term health effects of military service, to include deployments.</td>
</tr>
</tbody>
</table>

The Defense Occupational and Environmental Health Readiness System (DOEHRS) is currently being implemented. This information database will integrate Force Health Protection information and provide automated support for the Military Health System, Industrial Hygiene, Environmental Health, and Hearing Conservation communities. The DOEHRS is also designed to allow for exposure based Occupational Medicine and Industrial Hygiene interventions.

The Defense Manpower Data Center (formerly Defense Security Service) manages joint service personal security information data by collecting location and other personnel identification data on all service members.

The DoD Serum Repository contains over 50 million frozen serum specimens and is the largest of its kind in the world. This data are collected on all service members and can be linked to a variety of disease and exposure markers.

Although a risk communication program has been developed for use in the military, which incorporates risk-based scientific information and community values, perceptions, and needs, risk communication and leadership education remain as issues in military public health.

The DoD and VA continue to support the sharing of health data, but 2-way electronic exchange of patient health information has not yet been achieved.
practitioners and epidemiologists to continue to look for a cause. Because of the multitude of toxic exposures and the increased stress experienced on the battlefield, a strong answer to the question “Did an exposure during my Service result in my disease,” may never be revealed.

REFERENCES

INTRODUCTION
For 4 decades, controversy has surrounded the use of tactical herbicides, i.e., herbicides developed by the U.S. Department of Defense (DoD) for use in military operations in Southeast Asia. These tactical herbicides are generally distinct from commercial herbicides in a number of important ways, including their formulation, concentration, and in most circumstances in the equipment used for application. Few environmental or occupational health issues have received the sustained international attention that has focused on the tactical herbicide known as “Agent Orange” and its associated dioxin contaminant. The DoD controlled all military operations involving the use of tactical herbicides. Accordingly, in 2002 the senior author of this article was commissioned by the Office of the Under Secretary of Defense (Installations and Environment) to provide documentation on the history, use, disposition, and environmental fate of Agent Orange and its associated dioxin. This effort resulted in the publication of a book and numerous reports, as well as two workshops conducted in Vietnam with Vietnam’s Ministry of National Defense in August 2005 and June 2007. 1-5 In addition to reviewing thousands of DoD’s records, the authors were able to review records archived by other Federal Agencies. The authors also were able to review records of various chemical companies that provided expertise during and after Defoliation Conferences held in July 1963, August 1964, and August 1965, as well as publicly available records, particularly those based on the work of the National Institute for Occupational Safety and Health, and of the manufacturers of the tactical herbicides used in Vietnam.1

BACKGROUND ON THE USE OF TACTICAL HERBICIDES IN SOUTH VIETNAM
Five nations provided military forces to support the Republic of South Vietnam (South Vietnam) from 1961 through March 1973. Australia and New Zealand deployed 46,852 military personnel, the government of Thailand contributed 11,790 military personnel, the Republic of Korea sent 312,853 military personnel, and 2,644,000 military personnel from the United States served within the borders of South Vietnam.6

With the full concurrence and support of the South Vietnamese government and military, the U.S. Army’s Chemical Corps from Fort Detrick, MD, evaluated various herbicide formulations in 1961. 3 Subsequently, on January 1962, the United States Air Force (USAF) initiated Operation RANCH HAND, using fixed-wing aerial application from UC-123 aircraft.7 Operation RANCH HAND aircraft applied 95% of the tactical herbicides sprayed in Southern Vietnam, whereas helicopters and ground equipment of the Army Chemical Corps sprayed the remaining 5%, primarily on base perimeters and other limited targets.1-3 The barrels of herbicides were color-coded to facilitate identification. Thus, the code names Orange, Blue, White, Pink, Green, and Purple were used to differentiate between different tactical military formulations, with Orange being the most widely used (Table I).

Only the U.S. Army Chemical Corps and USAF Logistics Command were authorized to purchase tactical herbicides, and only the Army Chemical Corps and USAF Operation RANCH HAND were authorized to spray these tactical herbicides in Vietnam. However, many commercial pesticides, including commercial herbicides, were used on U.S. and

ABSTRACT  Serum dioxin studies of Vietnam (VN) veterans, military historical records of tactical herbicide use in Vietnam, and the compelling evidence of the photodegradation of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and other aspects of environmental fate and low bioavailability of TCDD are consistent with few, if any, ground troop veterans being exposed to Agent Orange. That conclusion, however, is contrary to the presumption by the Department of Veterans Affairs (DVA) that military service in Vietnam anytime from January 9, 1962 to May 7, 1975 is a proxy for exposure to Agent Orange. The DVA assumption is inconsistent with the scientific principles governing determinations of disease causation. The DVA has nonetheless awarded Agent Orange–related benefits and compensation to an increasing number of VN veterans based on the presumption of exposure and the published findings of the Institute of Medicine that there is sufficient evidence of a “statistical association” (a less stringent standard than “causal relationship”) between exposure to tactical herbicides or TCDD and 15 different human diseases. A fairer and more valid approach for VN veterans would have been to enact a program of “Vietnam experience” benefits for those seriously ill, rather than benefits based on the dubious premise of injuries caused by Agent Orange.

<table>
<thead>
<tr>
<th>Tactical Herbicide</th>
<th>Components</th>
<th>Number of Drums</th>
<th>Number of Litters</th>
<th>Years of Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>2,4,5-T</td>
<td>365</td>
<td>75,920</td>
<td>1962</td>
</tr>
<tr>
<td>Pink</td>
<td>2,4,5-T</td>
<td>1,315</td>
<td>273,520</td>
<td>1961–63</td>
</tr>
<tr>
<td>Purple</td>
<td>2,4-D: 2,4,5-T</td>
<td>12,475</td>
<td>2,594,800</td>
<td>1962–65</td>
</tr>
<tr>
<td>Blue</td>
<td>Cacodylic Acid</td>
<td>29,330</td>
<td>6,100,640</td>
<td>1966–72</td>
</tr>
<tr>
<td>White</td>
<td>2,4-D: Picloram</td>
<td>104,800</td>
<td>21,798,400</td>
<td>1966–72</td>
</tr>
<tr>
<td>Orange</td>
<td>2,4-D: 2,4,5-T</td>
<td>208,330</td>
<td>43,332,640</td>
<td>1965–70</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>356,615</td>
<td>74,175,920</td>
<td></td>
</tr>
</tbody>
</table>

2,4-D, 2,4-Dichlorophenoxyacetic acid. 1 Data based on U.S. Defense Supply Agency and Air Force Logistics Command records. Data as of March 2008.
2 These tactical herbicides contained 2,4,5-T and its trace contaminant, 2,3,7,8-TCDD. The most recent data from the analysis of 1,083 samples of Agent Orange or archived 2,4,5-T established the mean concentration of TCDD in Agent Orange as 1.88 ppm, and the total amount of TCDD released in Vietnam was between 130 kg and 144 kg before photodegradation. 3 All herbicide drums sent to Vietnam were of 18-gauge steel and held 208 liters or 55 gallons of product in concentrated, undiluted form.

Allied Bases in Vietnam for purposes of routine maintenance of Bases. These commercial pesticides were purchased under Federal Specifications, and their uses were regulated by the Armed Forces Pest Control Board. 2

The Civil Engineering units assigned to U.S. and Allied Bases were responsible for acquisition and certified use of commercial pesticides. These units were not authorized to use the tactical herbicides Orange, White, or Blue. This distinction between tactical and commercial herbicides has been a continuing source of misunderstanding by the general public, Vietnam (VN) veterans, the Department of Veterans Affairs (DVA), and the Vietnamese. 2 Detailed policies and procedures for approval and execution of tactical spray missions by RANCH HAND crews ensured that friendly forces were not in the areas targeted for spraying. 3 One frequent misconception regarding summary statistics on the application of tactical herbicides in Vietnam is that all of the dioxin (2,3,7,8-Tetrachlorodibenzo-p-dioxin or TCDD) in the case of Agent Orange, and other herbicides containing trace amounts of TCDD, ended up as a contaminant to the environment. TCDD in the environment has very low bioavailability and even if ground troops came into sprayed areas, absorption was very unlikely. In addition, nearly 90% of the dioxin contaminant released would have been destroyed by photodegradation before it ever reached a place where ground troops might have had an opportunity to come in contact with it. 4

In addition to commercial herbicides used in Vietnam, large quantities of insecticides, especially malathion, were sprayed initially by helicopters, but later by aircraft from the RANCH HAND unit. The deployment of major U.S. combat forces into South Vietnam beginning in 1965 found them susceptible to the disease-ridden conditions, specifically malaria, they encountered. In late 1966, USAF directed that one of the UC-123 herbicide-spray planes be modified to an insecticide-spray configuration to counter the Anopheles mosquit (Operation FLYSWATTER). By March 1967, a second RANCH HAND aircraft was reconfigured to spray insecticide. From 1967 through 1972, these “Silver Bug Birds” routinely sprayed malathion insecticide over 14 bases and their adjacent South Vietnamese cities; and by 1970, the respray interval had been reduced from every 14 days to every 9 days. 5,6 The frequent anecdotal reports of UC-123s directly spraying troops in Vietnam with herbicides likely reflected RANCH HAND’s support of Operation FLYSWATTER. 5,6 On October 31, 1971, all tactical herbicide activities under U.S. control were terminated. The remaining inventories of White and Blue herbicide were expended by tactical operations in 1972 by the Vietnamese Air Force using the few remaining in-country UC-123 aircraft. 5,6 The remaining amounts of Agent Orange were removed from Vietnam in April 1972 in Operation PACER IVY and stored on Johnston Island, Central Pacific Ocean. 2,7

THE PUBLIC AND GOVERNMENT RESPONSE

The first media reports about the use of tactical herbicides in Vietnam concerned a petition by the American Association for the Advancement of Science in 1967 urging the DoD to stop the use of tactical herbicides in Vietnam, primarily on the basis of ecological effects. 8 In October 1969, a White House Science Advisory Committee reviewed the results of a study by the Bionetics Research Laboratories of Bethesda, MD, that had been commissioned by the National Institutes of Health, and described the teratogenicity in laboratory mice exposed to massive doses of the herbicide 2,4,5-Trichlorophenoxyacetic acid (2,4,5-T), a component of Agent Orange. A subsequent analysis revealed that a contaminant, 2,3,7,8-TCDD, was the cause of the toxicity, and 2,4,5-T in itself was not teratogenic. 9,10 The White House Science Advisory Committee concluded that the use of 2,4,5-T represented a potential risk to human health that outweighed the benefits of its use domestically or by the DoD in Vietnam. 11 On April 15, 1970, the Secretaries of the Department of Health, Education, and Welfare, the Department of Agriculture, and the Department of the Interior announced the immediate suspension of all uses of 2,4,5-T herbicide, except for registered applications on noncrop lands such as ranges and pastures. 12 The Secretary of Defense followed their lead and announced, “The Department of Defense will temporarily suspend the use of 2,4,5-T in all military operations pending a more thorough evaluation of the situation.” 13

In 1977, the USAF disposed of the remaining inventories of Agent Orange in Operation PACER HO. At about the same time, veterans of Vietnam service began to complain of health problems that they believed resulted from exposure to Agent Orange while on duty in Vietnam. 11 The basis was press reports related to TCDD following the 1976 massive exposure from an industrial accident in Seveso, Italy, and the continued concern over the domestic use permitted by the U.S. Environmental Protection Agency. 11,12 In 1978, with the help of a reporter from CBS, the issue of Agent Orange and its possible impact on veterans’ health was widely disseminated.
to veterans and to the general public in a television documentary entitled “Agent Orange, Vietnam’s Deadly Fog.” A special presentation was given to the Congress of the United States. Attempts by the scientific community to refute the inaccuracies of the documentary failed to correct the record and simply aroused suspicions of a cover-up within the veteran community.

The perception that government has done little to resolve whether Agent Orange, its associated dioxin, or other causes were responsible for the many health problems in the VN veteran population is not based on fact. President Ronald Reagan elevated the issue of Agent Orange to a unit in the Executive Office of the President by forming “The Agent Orange Working Group” (AOWG). The AOWG was “… to guide and monitor all Federal research into the possible adverse health effects of Agent Orange and similar chemicals on humans, with a particular focus on the health of VN veterans.”

The AOWG undertook a massive effort encouraging, supporting, and monitoring studies conducted by Federal Agencies and the international community (particularly Australia and New Zealand). Between 1979 and 1990, U.S. Federal Departments and Agencies committed vast sums of research funds and scientific expertise in addressing the health effects that were allegedly caused by exposure to Agent Orange. More than 50 major health studies, many involving VN veterans and applicators of commercial herbicides, were conducted and reported. These studies failed to substantiate higher rates of mortality (except by suicides and accidents) from soft tissue sarcomas, Hodgkin’s disease, non-Hodgkin’s Lymphoma, or testicular cancer among VN veterans. Even a study of the health status of a self-selected group of 104,000 VN veterans who had participated in the Agent Orange Registry between 1982 and 1988 and who claimed to having been exposed to Agent Orange failed to find significant differences in prevalence for any cancer site compared to veterans who did not serve in Vietnam. The dilemma for AOWG was that many of the study results should have been viewed by the Veteran community as “good news,” but the question of health effects of herbicide exposure remained shrouded in controversy and mistrust. In addition, when exposures of most Vietnam service personnel to herbicides could not be specifically documented, a presumption was established by the DVA that all those who set foot on Vietnam soil were exposed to Agent Orange.

CURRENT SITUATION
Ignoring the outcome of the extensive research conducted by the Federal Agencies throughout the 1980s, while acknowledging the demands and concerns of VN veterans, the U.S. Congress passed Public Law 102-4, the “Agent Orange Act of 1991.” This legislation directed the Secretary of the DVA to request that the National Academy of Sciences’ Institute of Medicine (IOM) conduct a comprehensive review and evaluation of available scientific and medical information regarding the health effects of exposure to Agent Orange, the other tactical herbicides used in Vietnam, and their components, including the TCDD contaminant. In February 1992, the IOM signed an agreement with DVA to review and summarize the strength of the scientific evidence concerning the statistical association (not causation) between herbicide and/or dioxin exposure during Vietnam service and each disease or condition suspected to be associated with such exposure. Additional mandates were included in the agreement, including making recommendations on the need for additional scientific studies. To carry out the tasks, the IOM established “The Committee to Review the Health Effects in Vietnam Veterans of Exposure to Herbicides,” a committee that was to act independently of the DVA and other government agencies. Although the makeup of the Committee has changed over the years (1992 to the present), it has been composed almost exclusively of academic scientists trained in medicine or related fields (versus governmental or academic scientists trained in agriculture or forestry), most without experience or knowledge of either the agricultural or forestry use of herbicides, or what actually occurred with their use in Vietnam. Evidence of the DoD commitment to the development and evaluation of safe tactical herbicides and the historical military records of their controlled use in the Vietnam War, which are central to the issue of exposure, have been largely ignored by the IOM.

The results of IOM comprehensive reviews of occupational, environmental, and veterans’ studies conducted over the past 16 years have been provided periodically to the Secretary of Veterans Affairs, together with an extensive list of IOM’s findings “regarding the association between specific health problems (illnesses) and exposure to herbicides.” IOM has not provided evidence or findings of the Veterans likely levels of exposure to or absorption of herbicides or 2,3,7,8-TCDD. Indeed, the IOM’s reports of linkages between herbicides or TCDD and human disease are based not on causality, but on “statistical association.” The term “statistical association” was not defined, but was interpreted by IOM committee members as evidence of an increased risk in as little as one study for which bias, confounding and chance could be reasonably dismissed without weighing contrary or conflicting evidence. In fact, most evidence of association is derived from populations highly exposed to TCDD or herbicides in manufacturing or accident situations rather than in veteran populations.

In addition, the U.S. courts that have considered Agent Orange injury claims have consistently held that the evidence presented was insufficient to establish that VN veterans were injured by their alleged exposure to Agent Orange in Vietnam. Most recently, the U.S. District Judge who has presided over the Agent Orange litigation for the last 23 years, Judge Weinstein, reaffirmed that conclusion when he observed that, “the scientific basis for that conclusion of lack of any substantial proof of causality, either general or specific to individuals, remains much the same” (in re “Agent Orange” Product Liability Litigation, 304 F. Supp.2d 404, 407 (E.D.N.Y. 2004).

Based upon the IOM reports, the various Secretaries of Veterans Affairs have presumed that all military personnel who served in Vietnam were exposed to Agent Orange and...
other tactical herbicides. Thus, Federal policy now presumes that certain illnesses are a result of those exposures, making VN veterans eligible for associated compensation and health care. The diseases that the DVA currently associates with Agent Orange exposure include: acute and subacute peripheral neuropathy, AL amyloidosis, chloracne (or similar acneform disease), chronic lymphocytic leukemia and B cell leukemias, diabetes mellitus (Type 2), Hodgkin’s disease, ischemic heart disease, multiple myeloma, non-Hodgkin’s lymphoma, Parkinson’s disease, porphyria cutanea tarda, prostate cancer, respiratory cancers, and soft tissue sarcoma. Spina bifida in offspring of VN veterans is also compensated (http://www.publichealth.va.gov/exposures/agentorange/diseases.asp).

CONSEQUENCES OF THE IOM REPORTS AND VA PRESUMPTIONS

The DVA now receives annually approximately 15,500 requests from VN veterans for participation in the Agent Orange Registry Examination Program. Each such participant becomes eligible for compensation and health care for those diseases on the Department’s Agent Orange list of presumptive disabilities. The indications are clear; if a VN veteran has any of the disabilities or diseases associated with Agent Orange exposure, then that veteran receives financial compensation and health care regardless of the actual cause of that disease. This is so even though the IOM has acknowledged that the evidence on which its conclusions on health outcomes are based comes primarily from studies of people exposed to TCDD or herbicides in occupational and environmental settings, rather than from studies of VN veterans. Moreover, the IOM admitted that the available quantitative and qualitative evidence about herbicide exposure among various groups studied suggested that VN veterans as a group had lower exposure to the herbicides and TCDD than the subjects in many occupational and environmental studies. The expense of the veteran’s program is enormous. The DVA recently added Parkinson’s disease, ischemic heart disease, and certain leukemias to its list of Agent Orange–related diseases and said in its most recent notice in the Federal Register, in which the cost of doing so is reported:

“We estimate VBA’s [the Veterans Benefits Administration] total cost to be $13.4 billion during the first year (FY2010), $24.3 billion for five years, and $39.7 billion over ten years” (75FR14394).

The recent IOM Report on the presumptive disability decision-making process noted:

“Both prostate cancer and type 2 diabetes illustrate situations in which the contribution of military exposures should be assessed against a background of disease risk that has other strong determinants: age in the case of prostate cancer and family history and obesity in the case of type 2 diabetes. For both…the magnitude of the relative risks observed for pesticide exposure implies that the contribution of military exposures is likely to be small in comparison to those of other contributing factors.”

It has become increasing obvious that in many cases the evidence of association is quantitatively and qualitatively far below the level of proof needed to support a finding of causation. The DVA has erred in deciding to compensate when the evidence is insufficient to establish that exposure can and did cause the veteran’s illness. In the same IOM report on presumptive disability, the Committee recommended a change in the approach used for Agent Orange as future assessments of disability are evaluated:

“The Committee recommends a two-step approach for evaluation of scientific evidence on exposures of military personnel and risks to health. The first step is to determine the strength of evidence in support of causation and to classify the strength of the causal classification. The second step is to describe the magnitude of the disease burden caused by the exposure in a specific group of veterans.” (IOM 2008, p. xii)

Indeed, we are now experiencing the impact of a “phantom Agent Orange” in which some VN veterans have come to the misguided conclusion that all their health problems are related to this cause. This failure has occurred because both the IOM and the DVA have failed to examine fully the totality of the historical records of the use of tactical herbicides in Vietnam, and to understand the science associated with the distribution and environmental fate of the phenoxy herbicides and the associated TCDD contaminant. Instead they contracted for a study of exposure opportunity, which might provide some indication of the potential for exposure, but is severely flawed.

The IOM’s endorsement of the flawed exposure opportunity model has unfortunately permitted what is at best a measure of exposure possibility to be widely misinterpreted as an estimation of actual exposure. A more complete examination of the historical records and the science leads to a very different assessment.

REVIEW OF THE HISTORICAL RECORDS

During the Vietnam conflict, the RANCH HAND operation, initially a 3-plane flight of the 309th Air Commando Squadron and later a squadron (the 12th Air Commando Squadron) of over 20 aircraft, kept higher headquarters agencies apprised of their operations through a Daily Air Activity Report (DAAR). These reports detailed most, but not all, the elements of each spray mission flown, including number of effective aircraft, type and amount of herbicide expended, Universal Transverse Mercator grid coordinates of only the lead aircraft spray track, and information concerning aborts, hits taken, and target area weather. The J3 Chemical Office at the Military Assistance Command, Vietnam, Headquarters entered these data into a logbook that, in 1970, was converted into a computerized program called the Herbicide Reporting System, the oft-cited...
HERBS Tape. However, as noted by Christian and White,22 “To use military records created for combat purposes in an entirely new and complex manner, e.g., for epidemiological studies, may not be accomplished within the capabilities of the existing records.”

Although the HERBS Tape may have some uses that do not rely too heavily on precise data for the spray missions, the Tape contains data generated over several years by different personnel and undoubtedly contains errors of fact, is missing some records (particularly pre-1966), and does not include certain critical mission information. The original HERBS Tape was “updated” by subsequent researchers using project planning documents, “imputing” likely flight paths for missing information by using target planning documents, or simply by dropping entries that appeared to have errors.19 A data quality analysis by the MITRE Corporation in 1971 of an earlier “cleaned up version” found 2% of the records had missing data, 6% serious transcription or measurement errors, and that 25% of the records with complete track data resulted in a spray “track length that is in error by 50%.” In 2006, the junior author of this article cross-checked the current cleansed HERBS Tape against the available original DAARs and still found transcription and interpretation errors.1 For example, of the 310 verifiable fixed-wing entries in January 1967, 14.2% contained entry errors of some kind, and the quantities of herbicides reported sprayed (432,655 gallons) exceeded by 19,360 gallons the amount reported issued (413,295 gallons). Although the early databases developed during the Vietnam War and before the computerization of records that is in place today may be useful for some purposes, they may not be useful for precise determinations, such as estimating exposure from exact spray locations in relation to troop locations.1,22 On the other hand, when the entire corrected HERBS Tape (re-titled by Cecil as “RANCH HAND Revised Tape”) was cross-checked against the available original DAARs, against the chemical supply reports in the 315th Wing historical records, and against the DoD herbicide purchase reports and PACER HO destruction data, quantitative differences were insignificant and essentially in agreement with the Table I.

Furthermore, various attempts to develop an exposure index model have failed to take into account the procedures actually used during the spray operations.8,19 Mission reports did not give details such as formation alignment or multiple passes, nor did exposure model creators address the issue of mixed-load formations. As a result, the exposure models are based on some misleading assumptions concerning spray procedures, mission documentation, and the resultant spray areas.20,21 Ironically, the exposure models fail to take into account critical information concerning the temperature, wind speed, and wind direction data recorded for every mission.

Most important to the issue of exposure, these researchers have ignored the role of command directives that prohibited fixed-wing herbicide operations when and where Allied personnel were present on the ground.5,9,19 The actual purpose of the directives was to avoid friendly fire casualties because of fire from the escorting fighters. It is also evident from historical records that Allied soldiers were not present in the areas being sprayed. “Free Fire” zones were mandatory for RANCH HAND. All units that could possibly have troops in the target area were notified of the mission parameters during the planning stages to insure the areas were clear of friendly forces. Then, immediately before each mission the Forward Air Controller (FAC) responsible for the geographical area made an aerial survey to see that it was clear; and finally, just before RANCH HAND descended to start spraying, the FAC had to contact by radio the appropriate Direct Air Support Center to check for any last minute troop movements into the planned spray area.1,7 Compliance with these policies is reflected in the existing RANCH HAND abort records. These records verify that when friendly forces were reported in areas targeted for spraying, the missions were aborted and the cause cited as a result of “friendly forces in the area” or “free fire zone not approved.”1 The costs and man-hours associated with rescheduling and recoordinating the lost spray missions were substantial (they directly involved 3 to 4 and occasionally as many as 12 spray planes, at least 1 FAC, and 4 to 8 escort fighter aircraft), but were acceptable in order to avoid any possibility of “friendly fire” casualties. Significantly, in the history of the RANCH HAND operation, no U.S. Army findings were recorded of “friendly fire” deaths or injuries to ground personnel as a direct result of fixed-wing spray operations.7,9 Although the actual purpose of the directives was to avoid injury as a result of fire from the escorting fighters, it is also historical evidence that Allied soldiers were not present in the areas being sprayed.

REVIEW OF THE ENVIRONMENTAL FATE OF TCDD

In 2004, a team of professors affiliated with six universities and knowledgeable about the environmental fate of dioxin and phenoxy herbicides and the military use of Agent Orange in Vietnam published three articles22,23,24 addressing the question, “Does our knowledge about the environmental fate of Agent Orange and TCDD support the conclusions that ground troops could have been contaminated, if not by direct exposure, perhaps by entering previously sprayed areas?” They concluded that the prospects of exposure to TCDD from Agent Orange in ground troops in Vietnam was unlikely in light of the environmental dissipation, low bioavailability, the protection by overhead canopy, the properties of the herbicides, and circumstances of application that occurred. Indeed, the only appreciable accumulation of TCDD in serum was found in veterans of Operation RANCH HAND and the Army Chemical Corps, who were subjected to repeated, long-term, direct skin contact with the liquid herbicide during the course of their duties applying Agent Orange in Vietnam.25 Serum TCDD analyses beginning in the late 1980s and 1990s failed to produce evidence of exposure to other veterans who served in areas of Vietnam where Agent Orange had been sprayed.26,27 These studies suggest neither the soldier 1 hour and 1 kilometer away from a RANCH HAND mission, nor the soldier...
30 days and 5 kilometers away were likely to absorb any significant quantity of TCDD from Agent Orange. Further, the failure to detect TCDD in sprayed areas supports the loss to photodegradation. TCDD detected in soil is limited to areas where storage and handling occurred and spills to soil prevented photodegradation. Thus, historical and environmental data are consistent with results of serum TCDD analyses and further call into question assumptions of exposure to Agent Orange.

CONCLUSION

The postwar question asked was HOW IS AGENT ORANGE to blame for illnesses in VN veterans. The question should have been WHAT IS THE CAUSE of illness among VN veterans. The extensive medical and scientific studies of Agent Orange over the past 35 years tell us that very few veterans had contact with Agent Orange, and hence exposure, unless their jobs required them to actually handle the herbicide, e.g., the Army Chemical Corps. They also show that even those with measurable exposure (via serum TCDD analysis) have not suffered the diseases identified by the IOM and presumed by the DVA. But we should also acknowledge that many VN veterans do appear to be at risk for a range of diseases and health problems due to the “Vietnam experience” as a whole. In hindsight, instead of artificially focusing on Agent Orange as a means of providing compensation, we could have been fairer and more generous to all VN veterans with a program of “Vietnam experience” benefits, which would include medical treatment and possibly some compensation, rather than Agent Orange medical benefits and compensation for specific diseases. The current situation of identifying studies to “link” more diseases to Agent Orange compromises important scientific principles in the process and sets a precedent of unwisely spending massive resources that favor neither the veterans as a group nor the Nation.

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INTRODUCTION
Recently, Congress and others have raised serious questions about the fairness and soundness of the 1991 Agent Orange Act, which has been the basis of disability compensation policy for 2 decades for Vietnam War veterans with Agent Orange–related health conditions.1 Questions include: How can we know heart disease in a Vietnam veteran in his/her late 50s or 60s is somehow tied to service 40 years ago?2 Why assume all Vietnam veterans were exposed to Agent Orange, and are not there better biological tests today for determining who was exposed?3 Why do we extrapolate from studies of nonveteran populations, typically with significantly different exposures, to the health of Vietnam veterans?2 On the basis of 1991 law, the U.S. Department of Veterans Affairs (VA) recently announced new presumptive service connections for Parkinson’s disease, hairy cell leukemia, and ischemic heart disease diagnosed in Vietnam veterans. It is estimated that this decision will cost more than $13 billion over the next 18 months.4 Growing costs along with an unclear scientific basis clearly have exasperated both public health scientists and policy makers alike. As we shall see, many of these questions are not new and have been systematically addressed in the decades following the Vietnam War.

HISTORY
Vietnam veterans during the 1960s and 1970s voiced increasing concerns about how exposure to herbicides including Agent Orange, and their dioxin contaminant, had affected their health. During the manufacture of one of the two herbicides contained in Agent Orange, small but significant amounts of the chemical dioxin, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), were formed as a contaminant. Although dioxins are actually a class of closely related chemical compounds, the main dioxin contaminating Agent Orange was specifically the single compound, TCDD, referred to hereafter simply as dioxin. Many cited Agent Orange as the cause of a wide range of health problems, extending to birth defects among veterans’ children. Congress held the first of many hearings on herbicide use in Vietnam in 1970, and congressional interest in this topic remains high to this day.

At first, the U.S. government had great difficulty in responding. Initially, scientists were only beginning to evaluate how dioxins affected health. Similarly, VA initially lacked well-developed policies and procedures for evaluating and compensating illnesses potentially related to military environmental and occupational hazards.

In fact, for virtually all combat deployments, veterans and their families, the public, government leaders, and the media all demand to know how deployment may impact health. Scientists point out that well-designed, longitudinal mortality and morbidity studies focusing on veterans from a specific deployment are the best response. However, veterans and their supporters often focus on the immediate health care and disability needs of new combat veterans, and generally have limited patience for governmental statements that relevant scientific studies take time.5,6 Suggestions for exclusive use of a scientific and research approach are inevitably viewed as non-responsive or even as governmental stonewalling. Similarly, experience has shown that a paucity of combat exposure data means that epidemiological studies are typically inconclusive for tying specific illnesses to a specific deployment-related environmental hazard.5,6

Fortunately, these limitations, while significant, do not rule out development of effective policies for providing health care to veterans and compensating them for most deployment-related disabilities.

EARLY ATTEMPTS AT AGENT ORANGE COMPENSATION POLICY
Early observers in the late 1970s saw the ideal way for evaluating potential Agent Orange health effects was a well-designed
veteran epidemiological study. In 1979, Congress supported this approach in Public Law 96-151, which directed VA to “conduct an epidemiological study of the long-term health effects on individuals from exposure to dioxins (including ‘Agent Orange’) used during the Vietnam conflict.” Four years later, VA researchers had to announce they had been unable to develop such a study, primarily because of inadequate exposure data.\(^7\)

In frustration, Congress next urged VA to transfer the study to the Department of Health and Human Services, Centers for Disease Control and Prevention (CDC).\(^8\) VA and CDC subsequently signed an interagency agreement transferring funds ($70.4 million dollars in 1980s appropriated VA dollars), staff, prior work, and the authority for CDC to conduct the study.\(^8\) Several years and many tens of millions of dollars later, CDC also reported that available military records could not establish meaningful herbicide exposure data, and that an Agent Orange epidemiological study was not feasible.\(^8\)

As we shall see, this was hardly the end of the story. Nevertheless, this experience illustrates how the lack of usable exposure data can severely undermine occupational health-type studies on combat-deployed troops. From a preventive medicine and research study standpoint, well understood models of workplace occupational exposures monitoring generally do not translate to the battlefield. Limitations in accurately recording individual troop location during hectic wartime deployments compound this problem. Similarly, nearly 2 decades of research on veterans of the 1991 Gulf War have been unable to link specific military environmental or occupational exposures to health effects among most veterans.\(^5,6\) A similar history might be expected in the aftermath of the current conflicts in Iraq and Afghanistan.\(^9\)

**IMPACT OF POOR EXPOSURE DATA**

We know that many Vietnam War veterans were exposed to herbicides and their dioxin contaminant, even if we can not be certain which veterans were exposed, or about the exposure magnitude. Nearly 19.5 million gallons of herbicides, some contaminated with dioxin, were sprayed over Vietnam between 1961 and 1971 by U.S. military forces during the conflict.\(^10,11\) Although these same herbicides were approved for domestic use, wartime application rates were considerably greater.\(^10\) Maps of military spray operations suggest that major areas of Vietnam were sprayed, leading to potential troop exposure both directly or by contact in contaminated areas following spraying.\(^11\) However, limited military records make it difficult to reconstruct which troops were located in specific spray locations. Millions of Vietnamese were also likely to have been exposed during these operations.\(^10\)

Dioxin-related health concerns are based in part on the chemical’s stability in the environment (primarily in soil) and also in human tissues following absorption. In fact, all Americans are exposed during their lifetime to at least trace levels of dioxins coming from a range of sources.\(^12\) According to one review, sunlight can be expected to break down only a small portion of dioxins, meaning that contamination from previous herbicide application can lead to persistence in the environment and lasting health concerns.\(^12\) Similarly, the average half-life of absorbed dioxin in the body is estimated to be 7 to 12 years.\(^12\)

Moreover, attempts to directly measure dioxin levels in Vietnam veterans have been unable to distinguish exposed from nonexposed individuals. A 1987 CDC study of serum dioxin levels in Vietnam veterans who served in a heavily sprayed region around Saigon, during 1967 and 1968, compared to Vietnam-era veterans (who did not serve in Vietnam) was unable to distinguish between the two groups.\(^13\) Median dioxin levels in Vietnam veterans were an unremarkable 4 parts per trillion, and the distributions of these measurements were nearly identical to those for the control group of Vietnam-era veterans.\(^13\) As a group, Vietnam veterans apparently experienced lower dioxin exposures compared to subjects evaluated after occupational or accidental exposures that have been the basis for the epidemiologic evidence of dioxin health effects.\(^7\) However, 1987 serum dioxin levels among Operation Ranch Hand veterans, who had been directly involved in Vietnam spray operations, were able to distinguish among groups of these veterans, based on their military duties.\(^7\)

These results are singularly unhelpful in evaluating potential exposure for individual veterans of the Vietnam War. For one thing, failure to detect mean differences does not necessarily indicate that there were no differences in past exposure.\(^7\) Similarly, the interval between the exposure in Vietnam and the actual blood level measurements was at least 2 decades, potentially obscuring a modest exposure, even with dioxin’s long tissue half-life.

Probably, the average dioxin exposure among the approximately 2.8 million U.S. Vietnam War veterans was not remarkable. However, some veterans were potentially exposed to levels significantly greater than their nondeployed peers. The problem, of course, is that today we cannot tell the difference between these groups of veterans. The failure of studies of Vietnam War veterans to provide a link between health effects and herbicide exposure remains difficult for nonscientists to understand. Even recently, policy makers have made renewed calls for basing compensation on exposure magnitude of individual veterans.\(^2,3\) Recent efforts to estimate “exposure opportunities” for Vietnam War veterans might be an answer to missing exposure data. However, as we shall see, policy makers in the meantime have moved on to new approaches that avoid the problem of limited exposure data.

**VA DISABILITY COMPENSATION**

Current Agent Orange policy is shaped in part by overall VA veteran disability compensation policies. The VA provides a wide range of federal benefits, including disability compensation, to about 23 million American veterans and their families.\(^14\) By law, disability compensation means monetary benefits paid each month to a veteran determined to be disabled by an injury or a disease that was caused, suffered, or
aggravated during active military service.\textsuperscript{15} Payment amounts are established by Congress and are based on the degree of the service-connected disability in 10% increments (10%, 20%, etc.), as determined by VA disability rating specialists.\textsuperscript{15} Currently, a veteran with a 10% service-connected disability receives $123 per month, while a veteran with a 100% service-connected disability receives $2,673 monthly.\textsuperscript{16}

VA disability compensation for most veterans covers injuries that can be readily assessed through a "direct service connection" approach. In these cases, a simple review of the veteran’s acute disease or injury, for example, a bullet or shrapnel wound, becomes the basis for establishing a direct service connection.

Establishing direct service connection for an environmental exposure can be more challenging. VA regulations establish what is known as the "reasonable doubt" or "benefit of the doubt" doctrine. In practice, VA adjudicates a veteran’s direct service claim relative to an environmental or occupational injury or illness for most veterans. An individual claim can be more challenging. VA regulations establish what is known as the "reasonable doubt" or "benefit of the doubt" doctrine. In practice, VA adjudicates a veteran’s direct service claim relative to an environmental or occupational injury or illness for most veterans. A veteran must demonstrate all 4 of the items listed in Table I.

Veterans often face significant difficulties establishing these 4 points in cases involving latent diseases allegedly associated with exposures occurring years or decades earlier. Thus, evidence demonstrating only a minimal, short-term, or commonplace exposure might support the possibility of an association with an illness or injury, but fail to cross the statutory threshold requiring it be at least as likely as not to have been the cause when compared to all other possible causes.

For example, a veteran who served 2 years in the military and then is diagnosed with leukemia at age 50 could have had as much as 30 years of postmilitary exposure to benzene (a component of gasoline) as a civilian. Further, benzene is only a single and probably relatively minor cause of leukemia, which is not an uncommon disease. Thus, to demonstrate that exposure to benzene during military service was more likely than not to be the cause of his/her leukemia would require the veteran to prove some sort of unusually large military benzene exposure. Despite the significant challenges facing such a claim by an individual veteran, disability claims related to environmental or occupational injury or illness for most veterans are based upon this direct service connection approach.

Nevertheless, VA has the authority to bypass 1 or even all of the 4 key categories of evidence (Table I) by establishing a “presumptive” or automatic service connection. For example, by law VA recognizes some relatively common chronic diseases among all veterans, including arthritis, leukemia, and Type II diabetes, as presumptively service connected, when they appear within a certain period (typically 1 year) after separation from military service, even if available evidence is not sufficient to support a direct service connection.\textsuperscript{15} In practice, this gives veterans the benefit of the doubt with poorly understood illnesses manifesting within a defined period. VA can consider evidence in rebuttal of a specific presumptive service connection claim.\textsuperscript{15} Presumptive service connections are useful for implementing disability compensation policy when scientific certainty cannot be achieved in a time frame necessary to address veterans’ health care issues and when the conventional direct service connection route is inadequate to the task.\textsuperscript{17} They are also useful when it is impractical for a veteran to develop a direct service claim, for example, when a veteran is diagnosed with an illness of unclear or unknown cause within a short period following separation from military service. Such presumption service connection policies have arguably helped veterans and their families in numerous cases, and are likely to continue to be an important part of the veterans’ benefits system for the foreseeable future.\textsuperscript{17}

\textbf{THE CURRENT APPROACH} \n
In 1991, Congress responded to the apparent impasse resulting from the demonstrated lack of usable exposure and troop location data by enacting Public Law 102-4, the “Agent Orange Act of 1991.” This broke the log-jam by stipulating that all Vietnam War veterans would be presumed to have been exposed to Agent Orange, and by establishing a new independent scientific review process for herbicide health effects.\textsuperscript{15} The 1991 law stated that, to establish service connection for herbicide exposure, a veteran who served in the Republic of Vietnam from January 9, 1962, to May 7, 1975, shall be presumed to have been exposed to herbicides containing dioxin unless there is clear evidence establishing the veteran was not so exposed.\textsuperscript{15} This declaration circumvented the lack of exposure data by setting a standard for disability determination that did not rely on establishing the level of herbicide or dioxin exposure or the probable corresponding health effect of that exposure for any individual veteran.

The law also acknowledged that studies of Vietnam veterans were apparently inadequate for providing useful data on herbicide health effects, and required therefore that policy

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\textbf{TABLE I.} Four Key Items a Veteran Must Demonstrate to Establish \textit{Direct Service Connection} Between a Current Disease and a Claimed Environmental or Occupational Exposure.\textsuperscript{15} A Presumption of Service Connection May, in Effect, Waive Some or All of These Requirements
\hline
1. \textit{Credible Scientific or Medical Evidence That the Exposure Involved Is Scientifically Accepted As Being Associated With Their Specific Illness or Injury}
2. \textit{Evidence That the Relevant Environmental or Occupational Exposure Occurred During Active Military Duty}
3. \textit{The Illness or Injury Was Initiated or Was Exacerbated During Active Military Duty}
4. \textit{Evidence of an Unusually Large or Prolonged Exposure Indicating It Was at Least As Likely As Not to Be the Cause of the Illness or Injury}
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Establishing Equitable Agent Orange Disability Compensation Policy

makers must consider all relevant available science, including studies of nonveterans. Veterans could thus benefit from all scientific findings in any exposed human population and at any exposure level. In fact, inclusion of studies of nonveteran subjects has been quite helpful because they almost always involve relatively much better exposure data with significantly larger and longer exposures.

The law further acknowledged that an independent and broad review by mainstream scientists was essential for any scientific conclusions to gain acceptance from veterans and their supporters. Earlier efforts by the VA to conduct its own scientific reviews on herbicide health effects were viewed by many veterans as lacking credibility and independence. Thus, the Agent Orange Act directed VA to contract with the National Academy of Sciences (NAS) to establish independent committees to conduct a comprehensive review of all relevant scientific and medical literature and for new independent NAS committees to update this review every 2 years, based upon new and evolving scientific evidence. In fact, the breadth and thoroughness of this required review process coupled with the NAS’s reputation for independence and scientific excellence have proved crucial to the success of this approach.

A critical point is that the Agent Orange Act did not give the NAS authority for actually establishing Agent Orange compensation policy. The Secretary of VA retained a clear legal responsibility for translating the NAS’s scientific conclusions into veteran compensation policy. Specifically, the law states: “Whenever the Secretary determines, on the basis of sound medical and scientific evidence, that a positive association exists between . . . the exposure of humans to an herbicide agent, and . . . the occurrence of a disease in humans, the Secretary shall prescribe regulations providing that a presumption of service connection is warranted for that disease . . . . In making determinations . . . the Secretary shall take into account . . . reports received by the Secretary from the National Academy of Sciences . . . and . . . all other sound medical and scientific information and analyses available to the Secretary. In evaluating any study for the purpose of making such determinations, the Secretary shall take into consideration whether the results are statistically significant, are capable of replication, and withstand peer review.” Further, “[a]n association between the occurrence of a disease in humans and exposure to an herbicide agent shall be considered to be positive . . . if the credible evidence for the association is equal to or outweighs the credible evidence against the association.”

The language and legislative history of this act make it clear that it did not require evidence of a causal association, but only credible evidence that herbicide exposure was associated with the disease. In practice, in response to each NAS committee report, VA assembles an internal task force of scientists, medical doctors, attorneys, and compensation experts to evaluate and recommend policy options to VA’s Secretary. This task force carefully reviews all the scientific evidence presented in each NAS committee report, including the herbicide exposure disease association assessed independently of other risk factors. Finally, VA is required to publish its full reasoning for establishing or not establishing any new presumptive service connections. The law does not provide for any consideration of potential costs of new regulations, essentially identifying fair compensation for affected veterans as an implied cost of military deployment.

The initial 1994 NAS committee report—an exhaustive and thorough review of all published literature on health effects from exposure to these agents—established the pattern for all future reports. Not surprisingly, most of the many hundreds of reviewed scientific reports came from scientific studies of civilians exposed via industrial accidents or in the workplace.

In reporting their findings, the NAS committee developed a hierarchy of scientific evidence associating herbicide or dioxin exposure with specific health effects, ranging from “limited or suggestive evidence of an association” (their weakest positive association category) through “sufficient evidence of an association” (their highest positive association). The default “null” category is “inadequate or insufficient evidence to determine association.” Importantly, the Agent Orange Act gives VA significant flexibility in how to respond to these different levels of evidence, and VA has on occasion declined, at least initially, to develop new service connections for illnesses in the weakest category of positive association.

No NAS “Agent Orange and Vietnam Veteran” report has ever reported an actual causal association between a disease and an herbicide exposure. However, the value of the process is that the Agent Orange act gives VA the authority to establish presumptive service connections even in the face of less than clear-cut scientific data. Thus, based upon findings contained in the initial and subsequent biennial NAS committee updates through 2008, VA has established new presumptions of service connection for veterans who served in Vietnam and are diagnosed with the illnesses and diseases shown in Table II.

In effect, the Agent Orange Act means that an eligible veteran needs only show that he/she is a Vietnam veteran diagnosed with one of these diseases, and service connection becomes automatic. Importantly, without these presumptive

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<th>TABLE II. Illnesses and Diseases Presumptively Linked to Herbicide and Dioxin Exposure Among Vietnam War Veterans</th>
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<tr>
<td>1. Soft Tissue Sarcoma</td>
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<td>2. Non-Hodgkin’s Lymphoma</td>
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<td>3. Chronic Lymphocytic Leukemia</td>
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<td>4. Hodgkin’s Disease</td>
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<td>5. Chloracne</td>
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<td>6. Respiratory Cancers</td>
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<td>7. Prostate Cancer</td>
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<td>8. Multiple Myeloma</td>
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<td>9. Early-onset Transient Peripheral Neuropathy</td>
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<td>10. Porphyria Cutanea Tarda</td>
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<td>11. Type 2 Diabetes</td>
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<td>12. Spina Bifida in the Children of Vietnam War Veterans</td>
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<td>13. Parkinson’s Disease</td>
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<td>14. Hairy Cell Leukemia</td>
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<td>15. Ischemic Heart Disease</td>
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service connections, Vietnam veterans would generally be unable to establish service connection for any illness related to herbicide exposure because they would be unable to show some or all of the 4 items required for direct service connection (Table I).

This part legislative, part scientific, and part administrative approach to determining eligibility for disability is still used today. Congress has also appreciated its value, renewing VA’s authority to use it through 2015.

CURRENT CONCERNS
The economic implications of the Agent Orange Act may not have been fully anticipated at the time of its passage into law in 1991. For example, based on new scientific evidence, a 2000 NAS committee report associated herbicide exposure with Type II diabetes. VA’s subsequent decision giving presumptive service connection for this disease among Vietnam veterans carried significant economic implications. VA estimated that about 9% (about 252,000) of approximately 2.8 million Vietnam veterans would develop Type II diabetes based solely upon their age and other demographics. Estimated disability and treatment costs ran to several billion dollars over the first 5 years—a significant portion of the VA’s total disability compensation budget for all veterans.

VA’s response in this case was driven solely by policy considerations. Epidemiological studies have not been able to detect an increase in diabetes mortality among Vietnam veterans, suggesting that there may be only a small, if any, excess of cases of this disease in this population because of military herbicide exposure. In fact, epidemiological studies of Vietnam veterans in general do not show that this group has higher mortality or morbidity for many of the diseases currently presumptively connected to herbicide exposure, possibly the result of poor exposure data. (An excellent summary of mortality and morbidity research on Vietnam veterans compared to their nondeployed peers is available in “Vietnam Veterans and Agent Orange Independent Study Course.”) 

However, as described earlier, few, if any, diabetes cases among Vietnam War veterans would likely be granted service connection via direct service connection. In effect, VA made a policy decision to compensate a large number of Vietnam veterans who would have been diagnosed with Type II diabetes regardless of their military service in order to ensure coverage of the few veterans who may have contracted the disease because of it.

CONCLUSIONS—WHERE TO GO
The 1991 Agent Orange Act remains a compromise between the desire for scientific certainty and the need to address the legitimate and immediate health concerns of veterans. It intentionally established an evidentiary threshold lower than certainty or actual causation, meaning that presumptions can be developed to the benefit of veterans and their families in cases where there is sound yet not conclusive scientific evidence. This aspect of the law represents a commitment by Congress and the U.S. public to move forward with providing Vietnam Veterans appropriate compensation for possible herbicide-related health effects. Without this policy and the presumptive service connections it has generated, Vietnam veterans would find it difficult or impossible to receive any such compensation.

Yet costs and related concerns will likely continue to be a focus for Congress and others. Can we adjust the process to make it more scientific and more equitable? Several decades of experience show that ongoing suggestions that NAS committees be required to estimate the actual number of Vietnam veterans affected by an illness tied to herbicide exposure are not practical because the required data simply are not available. Experience has also shown us that, if average herbicide exposure levels result in any increased health risk for all veterans taken together, then that risk is small and often undetectable. However, poor exposure and individual troop location data mean that we generally cannot tell which veterans experienced significantly larger exposures and are therefore potentially at greater risk. Experience has also shown that this conundrum does not relieve policy makers from the responsibility for implementing clear-cut disability policy for individual veterans whose health may have been affected by herbicide exposure. Further, calls to wait for more definitive science may be disingenuous since it is unlikely that any future study will ever definitively link a specific health effect among Vietnam veterans to herbicide exposure.

Finally, the Agent Orange Act has clearly resulted in a narrow focus on herbicides as the key factor in explaining all the health problems of Vietnam veterans, ignoring other important risk factors such as widespread endemic tropical diseases, psychological and physiological impacts of war and drug use. Quite likely, the majority of deployment-related health problems among Vietnam veterans today are not related to herbicide exposure. Congressional leaders recently pointed out that we might benefit by turning more toward research on Vietnam veteran health in the aggregate, in effect casting a wider net for the relationship between current veteran health status and service in Vietnam. Thus, new studies comparing all health problems of Vietnam veterans, regardless of possible cause to their nondeployed peers, could improve future presumptive service connection decisions and put them on a more firm scientific basis. One such study might be a replication of the Centers for Disease Control’s Vietnam Experience Study of the 1980s.

REFERENCES


Jeffrey S. Kirkpatrick, MS

ABSTRACT Deployments of U.S. Forces to the Persian Gulf (1991), Bosnia and Herzegovina (1995), and Kosovo (1999) were associated with diverse, potential environmental exposures. Health effects possibly associated with these exposures were cause for concern among service members, veterans, and military and civilian leaders. A need for the military to effectively respond to these exposures, and more importantly, to assess and mitigate exposures before deployments and to conduct environmental surveillance during deployments was identified. The Department of Defense encountered many obstacles in dealing with the exposures of 1991. Even though these obstacles were being identified, and in some cases, addressed, responses to historical exposure concerns continued to be reactive. In 1996, efforts were intensified to improve policy and doctrine, field sampling equipment, risk assessment processes, geographic information systems, and other tools needed to effectively identify and reduce the impact of exposures before troops deploy and to conduct environmental surveillance while deployed. Success in these efforts resulted in a comprehensive, planned approach being implemented to address environmental health concerns during the 1999 Kosovo deployment.

INTRODUCTION
The U.S. Department of Defense (Health Affairs; DoD[HA]) and the U.S. Army Institute for Public Health, Aberdeen Proving Ground, Maryland, (part of the U.S. Army Public Health Command; and formerly the U.S. Army Center for Health Promotion and Preventive Medicine [USACHPPM]) have been focal organizations for identifying and assessing potentially hazardous exposures in deployed U.S. Forces and determining possibly related health effects. During 1991–2000, multiple deployments with diverse exposures created interest among service members and veterans, and elsewhere within the U.S. Government, with regard to possible associated health consequences. These deployments included:

(1) Operation Desert Storm (ODS), Kuwait 1991;
(2) Operation Joint Endeavor, Bosnia and Herzegovina 1995; and

The DoD[HA] recognized the need for a capability to quickly respond to unexpected exposures and an ongoing requirement for planning and implementing meaningful environmental health surveillance programs for deployed U.S. Forces anywhere in the world. As a result, the USACHPPM was made the DoD Executive Agent for deployment environmental health surveillance and the associated development of databases and data analyses. In response, the USACHPPM formed the Deployment Environmental Surveillance Program (DESP) in 1996 to carry out its responsibilities as the DoD Executive Agent. During 1991–2000, in addition to the formation of the DESP, the USACHPPM and the DoD[HA] were involved with other innovations in support of deployment environmental surveillance. These included developing policy and doctrine, obtaining access to previously classified data, increasing the use of geographic information systems (GISs), improving risk assessment methodology, identifying industrial sites and industrial chemical contamination before deployments, development of chemical military exposure guidelines (MEGs), and acquiring improved sampling devices for field use. These events and their relevance to military environmental health surveillance are reviewed.

BACKGROUND
During ODS, Iraqi troops began destroying Kuwaiti oil wells in February 1991. On March 10, 1991, soldiers destroyed an Iraqi weapons bunker that contained sarin chemical nerve agent. For both these events, estimating possible exposures for U.S. service members and determining the possible associated risks would take many years.

The Dayton Peace Agreement/Peace Accords was initiated by the Republic of Bosnia and Herzegovina, the Republic of Croatia, and the Federal Republic of Yugoslavia on November 21, 1995, and signed on December 14, 1995. The agreement was the framework for peace in Bosnia and Herzegovina. In December 1995, about 20,000 U.S. Forces entered Bosnia as Task Force Eagle. The Task Force was part of the North Atlantic Treaty Organization (NATO) Operation Joint Endeavor, which had responsibility for keeping the peace. In January 1996, the USACHPPM was tasked by the U.S. Army Europe, the parent command of Task Force Eagle, to assess and document ambient air quality at camp Lukavac Base, in the Tuzla Valley, Bosnia and Herzegovina. Lukavac Base was situated beside a major coke plant, which was not operating but had a coal bin that was operational. Being very close to the coke plant and the coal bin, ground forces at Lukavac encountered a large...
amount of airborne soot and brown snowfall. USACHPPM personnel deployed to the Tuzla Valley in February 1996 and conducted extensive air and soil sampling to assess and document the situation.9

Following the NATO bombing of the former Yugoslavia (Operation Allied Force), U.S. Forces entered Kosovo in June 1999 as part of the NATO-led Kosovo Force. NATO’s actions included promoting regional stability, cooperation, and security in support of the international community; to allow safe return of refugees and displaced persons; to help alleviate human suffering; and to achieve a peace settlement in Kosovo.10 In the Kosovo response, improvements in the tools needed for planning and conducting environmental health assessments and surveillance that DoD(HA), USACHPPM, and others had worked on for almost a decade, resulted in a carefully constructed and executed plan that effectively identified, assessed, and communicated environmental health risks. The DESP created by the USACHPPM in 1996 captured and implemented the deployment environmental surveillance lessons that had been learned since the beginning of the 1991 Gulf War and archived pertinent data, reports, and assessments for study and future use.11

**POLICY AND DOCTRINE**

The DESP focused on the three military operations described above to identify strengths and weaknesses in policies and doctrine. Working with the Army Medical Department Center and School, Fort Sam Houston, Texas; DoD(HA); U.S. Army Training and Doctrine Command, Fort Monroe, Virginia; and the Office of the Special Assistant for Gulf War Illnesses (OSAGWI), existing policies and doctrine were identified and evaluated for completeness, currency, and applicability.

The Department of the Army applied the DoD Joint Capabilities Integration Development System (JCIDS), which was used to identify gaps and solutions for doctrine, organization, training, materiel, leadership, personnel, and facilities (DOTMLPF) to the process of environmental assessment and surveillance of deployed forces.12,13 The JCIDS analysis included a functional area analysis, with a prioritized list of tasks necessary to achieving objectives, a functional needs analysis, with a list of capability gaps with timelines for solutions, and a functional solutions analysis. For the policy and doctrine element of the JCIDS, two important DoD documents on deployment surveillance were published in August 1997. DoD Directive 6490.2, Comprehensive Health Surveillance, August 30, 1997, established that the DoD and Services would develop and execute health surveillance, which included environmental surveillance.14 The second, DoD Instruction 6490.3, Deployment Health, August 7, 1997, provided guidance for the DoD and Services to implement deployment health surveillance activities.15 Additionally, the Chairman of the Joint Chiefs of Staff published a memorandum in December 1998 (Deployment Health Surveillance and Readiness), which directed the Combatant Commands to implement deployment health surveillance in their geographic areas of responsibility.16,17 These three publications formed the foundation and justification for developing and implementing health surveillance where U.S. Forces are or may be deployed, to include environmental health surveillance. The Department of the Army began developing an implementation letter on force health protection and occupational/environmental health threats that would be published in 2001.18

**DECLASSIFIED DATA AND INFORMATION**

Large quantities of sensitive/classified data, reports, and assessments for ODS were maintained within the DoD. However, initial assessment efforts were directed at using only unclassified data and reports from the 1991 Kuwait oil well fires and Khamisiyah nerve agent incidents. Daily troop unit locations were needed to define the geographic relationships of service members to the oil fires super plume boundary and exposure perimeters for Khamisiyah. The unclassified documents provided the needed troop location information, at best, only 45% of the time.

The DoD, through the OSAGWI, undertook efforts to review and declassify records and data relating to health.19,20 In March 1995, the DoD ordered an expansion of declassification efforts to identify all DoD records in the operational, medical, and intelligence communities that could relate to the possible causes of health problems being experienced by 1991 Gulf War veterans. The Secretary of the Army was designated Executive Agent for declassifying operational records, the Assistant Secretary of Defense for Health Affairs for medical records, and the Director of the Defense Intelligence Agency for intelligence records. Declassified records were released on GulfLINK.19

The OSAGWI also assembled a high level staff conference where operational commanders and other operational people from ODS worked for over 1 year to review all daily troop unit location data and fill in missing data.20 The OSAGWI, in conjunction with the Department of the Army, brought operational officers from the XVIII Airborne Corps, whose area of responsibility included Khamisiyah during March 10–13, 1991, to the U.S. Armed Services Center for Unit Records Research (CURR; Springfield, Virginia) to review, refine, and enhance their units’ location information. In July 1997, these operations officers reviewed the existing location registry information and, using modeling tools, determined that the Khamisiyah potential hazard area extended beyond the original estimate of a 50-km radius. This effort continued through June 1998 and significantly enhanced the CURR database and helped reduce the uncertainties associated with locating U.S. units both around Khamisiyah during the demolitions and in the vicinity of the Kuwait oil well fires. From these efforts, the percent data capture for daily troop unit locations in the Kuwait Theater of Operations exceeded 90%.
GEOGRAPHIC INFORMATION SYSTEMS
The requirement to produce daily troop unit locations in relation to the Kuwait oil fires and the Khamisiyah nerve agent plumes boundaries led the USACHPPM to use GIS technologies.21,22 Imagery data, vector data, and geographic coordinate referenced data (e.g., for troop unit locations and base camps) were produced, assessed, and archived. To assist with the use, production, dissemination, and archiving of numerous disparate datasets with geographic attributes, the USACHPPM incorporated GIS technologies and relational database solutions. For the ODS efforts on environmental exposures (to include the oil well fires and the Khamisiyah nerve agent incident), the Troop Exposure Assessment Model (TEAM) was developed and used Intergraph Corporation GIS technology (Intergraph Corporation, Huntsville, Alabama) and the Informix relational database management system (IBM, New York). The TEAM has continued to be operational for over a decade, providing individual health risk assessments for the Kuwait oil well fires.23 In 1998, the USACHPPM contracted with the United States Military Academy, West Point, New York, to produce a White Paper on the continued use and integration of GIS technologies at the USACHPPM. The White Paper recommended the use of the Environmental Systems Research Institute (San Diego, California) GIS solution ArcView.24 The USACHPPM established a GIS program in 1999 to provide formal geospatial assistance.

IDENTIFYING INDUSTRIAL SITES
The environmental exposure concerns identified during 1991–2000 were military chemical threat agents, unconventional military use of chemicals (oil well smoke), and industrial chemicals from operating or formerly operating industrial sites. Operating industrial sites, closed industrial sites, and environmental contamination from industrial chemicals were significant concerns in deployments of U.S. Forces to the former Yugoslavia. To better deal with these industrial exposures, the DESP worked with the Armed Forces Medical Intelligence Center (AFMIC; now the National Center for Medical Intelligence), Fort Detrick, Maryland, to develop measures for identifying and assessing deployment hazards associated with industrial chemicals. These measures assisted AFMIC in producing intelligence assessments for specific locations and in defining toxicological and physical hazards associated with the chemicals. These assessments were extremely valuable in the predeployment process in identifying areas of concern and developing plans to address these areas. In addition, AFMIC worked with the Johns Hopkins University, Baltimore, Maryland, to develop frameworks for evaluating deployment environmental health risks, both catastrophic or near-term risks (Tier I) and noncatastrophic exposure risks (Tier II).25,26

The USACHPPM integrated data from AFMIC into a predeployment industrial hazards assessment for Operation Allied Force (OAF) in Kosovo.27 This assessment geographically identified industrial facilities during the Kosovo air war. As OAF bombing came to a close and ground operations began, the USACHPPM produced an interim health assessment that geographically mapped and assessed the Kosovo industrial facilities relative to proposed U.S. troop locations and base camps. This effort integrated operational data, medical intelligence data, and information and remote-sensed imagery, and established preventive medicine measures as part of a comprehensive assessment. The assessment communicated the known and potential deployment environmental hazards to U.S. Army personnel moving to occupy major base camps in the U.S. sector in southeast Kosovo.28 The product was provided to medical planners and operational personnel to support informed decisions that promoted force health protection while minimizing adverse health outcomes to military personnel.

RISK ASSESSMENT PROCESS AND EXPOSURE GUIDELINES
Assessments of health risks for environmental exposures to the Kuwait oil well fires and industrial chemicals in Bosnia were reported using the U.S. Environmental Protection Agency (EPA) process for predicting excess cancer and noncancer values.21,29 The reporting and documentation of these exposures were complex and not fully representative of military operational readiness. Communication of this information to line Commanders was difficult. The USACHPPM identified an Army Field Manual (FM 100-14; Operational Risk Management [ORM]) that incorporated a framework to make risk management a routine part of military operations and allow soldiers to operate with maximum initiative, flexibility, and adaptability.30 The primary process used hazard severity (i.e., degree of injury/illness) and probability (i.e., frequency of event occurrence). These can be used for force health protection risk assessment in military operations and easily communicated to Commanders to make informed decisions.

Exposures to chemicals during deployments may occur in varying concentrations and for variable periods of time. Chemicals may be present for only a short time, but at high enough levels so that exposures could immediately impact individual health or even degrade the mission. In other situations, continuous but lower levels of chemicals in the environment could put military personnel at increased risk of delayed, permanent health problems. The need to develop exposure-based chemical guidelines for military deployments was identified. The guidelines were needed by military preventive medicine officers, environmental staff officers, industrial hygienists, and health risk assessors to consistently characterize chemical exposure risks using a standardized process that was both scientifically supportable and militarily feasible. This work resulted in the publication of Technical Guide 230 (TG230) in 1999.31 TG230 provided short-term MEGs for chemicals in air, water, and soil for use during deployments.31 In May 2003, TG230 was updated to include exposure
concentrations for both short- and long-term exposures with specific information on the type and severity of health effects resulting from exposures to varying chemical concentrations, the primary organs and systems affected, and odor and taste threshold data.\textsuperscript{31} TG230 provided guidance on how the MEGs could be applied to characterize the health and mission risks associated with identified or anticipated exposures to chemicals, consistent with the existing military ORM paradigm.

A gap in the ORM process focused on how the health-based exposure guidelines for military deployments would be used. Hazard severity and probability of an event occurring were developed in the process, but dealing with varying concentrations in the air, water, and soil proved problematic. A means for integrating the MEGs into the ORM was needed. To ensure standardization in training and reporting with regard to the exposure guidelines and the ORM, Technical Guide (TG248) was developed and published in 2001 to address these areas.\textsuperscript{32} TG248 introduced the processes and tools to be used to make appropriate decisions based on the medical threat. Its primary focus was to assist preventive medicine and other staff personnel assigned the task of providing health risk assessments to commanders, primarily at the Corps-Joint Task Force medical staff level, and to provide guidance for: (a) documentation of environmental hazards and exposures to the force; (b) characterization of the risks associated with the hazards during all phases of deployment; (c) communication of the risks in understandable terms to the commander and operational planners; and (d) supporting the commander’s staff in developing courses of action to minimize risks to the force.

FIELD SAMPLING
During the Kuwait oil fires and Bosnia evaluations, it became apparent that available environmental surveillance equipment for air, water, and soil were complex, bulky, and expensive. In 1997, the USACHPPM initiated efforts to improve environmental sampling equipment for military applications by obtaining available, commercial off-the-shelf (COTS) sampling systems.\textsuperscript{33} Efforts to make existing (garrison-based) equipment and sampling media lighter, smaller, simpler to operate, and more rugged were completed. One successful example of from this effort was the deployment water sampling kit where the volume of field water needed for analysis was reduced over 75%, to less than 1 L; shipment required only a 0.2 cubic foot cooler; and full chemical analyses, comparable to EPA analytical methods approved for drinking water, could be provided.\textsuperscript{34} Battery operated, portable COTS sampling equipment were implemented for air sampling. Soil samples were collected using Teflon (E.I. DuPont; Wilmington, Delaware) jars with reduced quantity.

In November 2001, the USACHPPM published technical guide (TG251) on environmental and occupational health field sampling during military deployments.\textsuperscript{35} TG251 established standard procedures for environmental and occupational health (OEH) sampling during deployment and was a compilation of sampling methods and techniques used to characterize the environment. It provided the necessary information for trained personnel on the selection and operation of environmental field sampling equipment to: (1) characterize hazards that pose an immediate threat to personnel; (2) conduct a baseline assessment of an area to determine if a wide range of environmental contaminants are present; and (3) establish and operate a long-term OEH sampling effort. Data from these field sampling efforts could be used to develop ORM decisions based on health risk and general epidemiological analyses. TG251 was updated in February 2009 to focus efforts on sampling related to occupational and environmental health site assessments.

CONCLUSIONS
From 1991–2000, DoD(HA) and the USACHPPM worked to elevate environmental health surveillance measures from a reactive mode, as occurred with the Kuwait oil fires and the Bosnia deployment, to proactive support. ODS environmental exposures had limited preventive medicine documentation, and locating military units and personnel on the ground was difficult. Lessons learned from ODS were documented, but environmental surveillance support for the Bosnia deployment was still reactive. Pressure from concerns about Gulf War Illness stimulated DoD(HA) and the USACHPPM to increase efforts to proactively assess environmental health conditions before deployment and at sites where base camps were planned. In 1996, these efforts were intensified. The resulting improvements were highlighted and successful when U.S. Forces deployed to Kosovo and continued to benefit deployed U.S. troops.

REFERENCES
The Impact of U.S. Military Operations on Environmental Health Surveillance


ABSTRACT  During Operation Desert Storm (ODS), in late February 1991, Iraqi troops began the demolition of oil wells in Kuwait. Out of a total of 854 well heads, 605 were ignited, 108 were damaged, 46 were gushing, and 95 were left intact. The individual plumes of burning oil wells merged to form a massive super plume of particulate and gaseous air pollutants. Although the plume touched ground on occasion, most of the time the base of the super plume was 10,000 to 12,000 ft above ground and the top of the plume reached as high as 30,000 ft. The super plume traveled hundreds of miles downwind as its components dispersed and settled out until the super plume literally disappeared. The super plume was easily observed from orbiting satellites. The general direction of the plume was from the northwest to the southeast, traveling down the Saudi Arabian Coast. Besides the particulate and gaseous pollutants from the combustion of the crude oil, oil that was not burnt settled on the desert sand, frequently generating large ponds that posed various hazards including the release of light volatile compounds. The total volume of crude oil that collected in ponds was estimated at 25 to 40 billion barrels.  

The combustion pollutants were estimated from the known composition of Kuwaiti crude oil. Virtually all of these pollutants, to include SO$_2$, NO$_x$, H$_2$S, CO, suspended particulates, inorganic acids, metals, polycyclic aromatic hydrocarbons, and volatile organic compounds, carried short-term or long-term health risks, or both. In the vicinity of the oil well fires the degree of human risk depended on the pollutant concentrations in the breathing zones of exposed persons. Those concentrations could be determined through direct measurements. Consequently, groups from the United States, Saudi Arabia, Kuwait, Great Britain, France, Norway, and other countries launched a variety of air pollution monitoring efforts ranging from ground measurements of pollutants to measurements of pollutant concentrations directly within the super plume. These early efforts were focused on assessing potential acute health effects. The initial environmental monitoring reports concluded that pollution coming from the oil wells was at levels that would not cause severe short-term (acute) health problems. However, the groups conducting the monitoring (U.S. Environmental Protection Agency [USEPA], French and Norwegian scientists, and the Kuwait Environmental Department) emphasized that long-term or chronic health effects in exposed individuals could not be evaluated because of insufficient data.

THE U.S. MILITARY MEDICAL RESPONSE  Concern about a potential long-term impact on U.S. Department of Defense (DoD) military and civilian personnel prompted the DoD to initiate a study of long-term health effects. The Office of the Assistant Secretary of Defense (Health Affairs) [OASD (HA)], asked the U.S. Army Office of The Surgeon General to chair a Tri-Service medical working group to evaluate all potential health effects from the oil smoke on DoD personnel. The group consisted of medical personnel from each military service, in addition to representatives from the Department of Veterans Affairs, OASD (HA), and the Office of the Deputy Assistant Secretary of Defense for Environment. Additionally, the Deputy Assistant Secretary of Defense for Environment dispatched a team from the U.S. Army Environmental Hygiene Agency (AEHA), renamed the U.S. Army Center for Health Promotion and Preventive Medicine [CHPPM] on May 1, 1991, and currently part of the

INTRODUCTION  During Operation Desert Storm (ODS), in late February 1991, Iraqi troops began burning Kuwaiti oil wells. Almost immediately there was concern about possible adverse health effects in U.S. personnel exposed to crude oil combustion products. Combustions products were predicted from the known composition of Kuwaiti crude oil. Monitoring sites were established in Saudi Arabia and Kuwait; about 5,000 environmental samples were studied. Data collected were used to develop health risk assessments for the geographic areas sampled. This initial approach to assessing risk had to be greatly expanded when Congress passed Public Law 102-190, requiring development of means to calculate environmental exposures for individual U.S. service members. To estimate daily exposure levels for the entire area over 10 months for all U.S. troops, air dispersion modeling was used in conjunction with satellite imagery and geographic information system technology. This methodology made it possible to separate the risk caused by oil fire smoke from the total risk from all sources for each service member. The U.S. military responses to health concerns related to the oil well fires and to Public Law 102-190 were reviewed. Consideration was given to changes in technology, practices, and policies over the last two decades that might impact a similar contemporary response.
U.S. Army Public Health Command) to collect environmental samples and monitor health effects in U.S. personnel in South West Asia, and prepare a health risk assessment (HRA). The HRA was to look at the theater-wide risks associated with oil fire smoke, industrial pollution (which was difficult to separate from oil smoke contaminants), and natural background pollution for specific troop units.

Permanent ambient air monitoring stations were established at four locations in Saudi Arabia and six locations in Kuwait, although two in Kuwait were quickly abandoned as a result of logistical difficulties (Fig. 1). The locations were selected because they were the major sites where DoD troops were to be stationed long term. Approximately 5,000 samples (air, 4000; surface soil, 200; industrial hygiene, 600; and radiological, 200) were collected at these locations. With 558 oil wells on fire, the environmental monitoring effort by the AEHA began on May 5, 1991 and continued until December 3, 1991. The fires were all extinguished by approximately November 6, 1991 but monitoring continued to obtain about 1 month of background data. The background data would assist AEHA scientists in differentiating contaminants that occurred naturally, those that came from the oil well fires and possible industrial contamination. The environmental exposure data were then used to support a typical USEPA “Superfund” HRA.6 The HRA characterized general cancer and noncancer risks for the 10 monitoring sites where samples were collected. There was no attempt to characterize risk on an individual basis because of a lack of knowledge about exact troop movements and locations relative to the monitoring sites, and when and for how long individuals were at each site. This situation changed with the passage of Public Law (PL) 102-190, Section 734, which required a means to calculate exposures to the Kuwait oil well fires for DoD personnel deployed in ODS, to include, length of time exposed (number of days) and intensity of exposure (concentrations of oil well fire smoke emissions and risk).


POLLUTANTS, PERSONNEL EXPOSURES AND DATA LINKAGE

Pollutants were estimated from the known composition of Kuwaiti crude oil, and air concentrations were obtained from ground-based measurements and measurements from aircraft flying in the plume. For sampled data, the concentrations of measured contaminants in air and soil were used to calculate exposure point concentrations for HRA. The area occupied by troops during their stay in the Gulf Region was extensive. Therefore, initial sample-based risk assessments were conducted for all monitoring sites where DoD personnel were located and exposed to oil fire emissions. Eight sites had sufficient data to do this. Determining individual service member exposures to oil fire emissions for all service members, as mandated by PL 102-190, required much more innovative techniques. Nearly 700,000 mobile U.S. troops occupied a region of approximately 880,000 square miles within Kuwait, Saudi Arabia, and Iraq. Daily troop locations were not consistently documented and existing records were not readily available.

Also, the environmental samples collected had limitations. First, AEHA scientists used only static sampling locations (10 stations), but troops moved throughout the region. Second, the sampling period had a 3-month gap. Samples were collected starting in May, yet the oil well fires began in February. Third, the 5,000 environmental and industrial hygiene samples did not distinguish between pollutants originating from oil fires and those originating from other sources, such as industrial sources and natural background material. Therefore, AEHA personnel enlisted the aid of the National Oceanic and Atmospheric Administration/Air Resources Laboratory (NOAA/ARL) and obtained geographic information system (GIS) software. The NOAA/ARL had been involved since 1991 with the Department of Commerce Arabian Gulf Program Office in an international effort to determine the atmospheric effects of the Kuwait oil well fires.

To determine daily exposure levels for the entire area over 10 months for all troops, air dispersion modeling was used in conjunction with satellite imagery. The combined set of modeled and sampled exposure data was then applied temporally and spatially to the approximately 700,000 deployed personnel. In augmenting the fixed location sampling data, the NOAA/ARL models predicted daily pollutant concentrations at geographic locations impacted by the oil well fires. The first NOAA/ARL model simulations of the Kuwait oil fires were run for the AEHA in 1993 and used data from the NOAA/National Center for Environmental Predictions Medium-Range Forecast global spectral model. These simulations included archived fields that defined meteorological transport winds and boundary layer turbulence parameters.7–9 The meteorological fields were then used in the NOAA/ARL Hybrid Single-Particle Lagrangian Integrated Trajectories (HYSPLIT) dispersion model to derive daily super plume boundaries from the Kuwait oil fires for February 2 to October 31, 1991.10 AEHA scientists consulted with NOAA/ARL scientists in 1996 to reproduce the daily, modeled derived
super plume boundaries for February 2 to May 15, 1991, using high-resolution reanalysis meteorological fields from the European Center for Medium-Range Weather Forecasting. AEHA personnel coordinated with NOAA/ARL scientists to provide 24-hour predicted unit emission concentration values on a 15-× 15-km grid encompassing the extensive ODS Theater of Operations.

To comply with the public law, additional data on the locations of the deployed personnel and their respective time in the Theater of Operations were needed. The U.S. Armed Services Center for Unit Records Research (CURR), Alexandria, Virginia, developed a database that contained daily troop unit geographic locations for the Theater of Operations. To construct the database, the CURR gathered all 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 800,000-unit grid coordinates were created. With the CURR troop unit movement database, AEHA scientists were able to locate daily company level unit identification code locations. The AEHA, now the USACHPPM, scientists also obtained a copy of the Defense Manpower Data Center Desert Shield/Desert Storm Personnel File. These data provided the USACHPPM personnel the dates when each deployed person entered and exited the theater of operations and their unit of assignment.

Six primary data sets were gathered and loaded for use in the GIS. The data sets were spatially and temporally associated to derive daily exposure estimates of the troop units in theater. The first set of data was the sampled concentration data gathered from the 10 sites in Kuwait and Saudi Arabia. These sites sampled ambient air and soil media during May 5 to December 3, 1991 and represented primary troop staging locations. The second data set was the model simulations of the fire emissions generated by NOAA/ARL scientists. The model output was used to determine the location, extent, and concentration of the oil fire smoke. The output also supplemented the sampling data, as the sampling effort missed the first 3 months of the fires. The third set of data contained the satellite images of the oil fires combined smoke plumes (i.e., super plumes), obtained from the National Center for Atmospheric Research. The images were captured using the NOAA Advanced Very High Resolution Radiometer and were used to supplement and validate the spatial aspect of the NOAA/ARL model results. The fourth set of data was the troop unit locations provided by the CURR. These data provided the daily locations of company-sized units (about 75–150 people) in theater. The fifth set of data was the personnel data from the Defense Manpower Data Center, which provided service members’ units during their time in theater and the dates they entered and exited the theater. The final data set was obtained from standard USEPA data sources and included the toxicity values used to determine health effects possibly associated with oil well fire exposures.

For each day the fires were burning, daily grid locations (over 40,000) of the smoke were created with the GIS software. Each daily grid set was then used to digitize the outermost boundary of the smoke for that day (Fig. 2). Each modeled grid point contained data regarding the composition of the oil fire smoke. HYSPLIT predicted the concentrations and composition of each grid point by factoring in the oil fire’s extinguishment rate, emission rates, plume transects, and ground data. Similarly, the satellite images of the oil well fires “super plume” were georeferenced to the Theater of Operations and the outermost boundary of the satellite super plume boundary was also manually digitized (Fig. 3). Then, the GIS software merged the modeled and satellite boundaries together creating the outermost union of the two boundaries. The software then added a 15 km buffer around the merged boundary to help compensate for any user digitizing errors.
and to have a more conservative estimate of the super plume on each day (Fig. 4).

Once a daily boundary was created, troop unit locations provided by CURR were placed at their geolocations within the theater to determine if they were within the super plume boundary (Fig. 5). Units within a daily super plume boundary were run through a custom program generating exposure levels. A unit’s associated exposure level was determined from the closest modeled grid point on that day. Each grid point contained the concentrations of the smoke compounds at the breathing zone (2-m height). The identified compounds and concentrations were used to derive associated health risk factors. This routine continued for the unit’s entire duration in the theater. The program was complete when every unit in theater had been evaluated to see if it was within the super plume boundary and those that were, had a daily health risk factor assigned. Another program assigned risk levels to individual personnel. That program assigned risk to a service member based upon the risk identified for their unit identification code. The program also factored in the service member’s theater entrance and exit dates so their risk was generated only for their time in the theater.

The oil well fire exposure and risk generating methodology made it possible to separate the risk caused by oil fire smoke from the risk from all sources, as required by PL 102-190. Table I shows an example of the exposure to particulate matter caused by oil well fire smoke (modeled) vs. all source particulate exposure (measured from oil fire smoke, sand, and industrial pollution).

CRITIQUE AND SUMMARY
Planning started in December 1990 when intelligence reports suggested Iraqi forces might ignite Kuwaiti oil wells as a means of unconventional warfare. As a result of this early threat recognition, there was sufficient time to plan this project, train the people who deployed to carry out the mission, and obtain the sampling equipment. Due to the large scale of the project, much of the air sampling equipment had to be borrowed from the USEPA.

The methods used for sampling and analysis were the USEPA “gold standard” methods for the time. There were no methods developed specifically for use in deployment. The risk assessment method selected to analyze the sample data and present the risk was conservative to be protective of our forces, and again USEPA “gold standard” methods at the time were used.

Over 5000 environmental samples were collected and analyzed from 10 sites dispersed around the theater. Samples were analyzed for over 50 different pollutants, including particulates, metals, inorganics, acid gases, criteria pollutants, volatile organic compounds, and polycyclic aromatic hydrocarbons.

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<tr>
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<td>232.0</td>
<td>232.0</td>
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<tr>
<td>June 13</td>
<td>0.0</td>
<td>445.1</td>
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</table>
hydrocarbons. The contaminants sampled and analyzed comprised a very long list selected from the known constituents of the Kuwaiti crude oil, and data collected from earlier international sampling efforts, including sampling in the smoke plume. Sampling went on for 9 months to insure a representative data set was collected as the fires were extinguished. Despite these extensive efforts, many scientists would have preferred having more acid gas and criteria pollutant samples.

Before and during the study other U.S. agencies were contacted for help, advice, equipment, and guidance. USEPA provided significant equipment and advice on risk assessment and analytical methodologies. NOAA/ARL provided significant help with atmospheric dispersion modeling and satellite imagery.

The process for review and approval of reports was very extensive and involved numerous Federal agencies. The following reviewed the study: USEPA, U.S. Department of Health and Human Services, NOAA/ARL, National Institute of Environmental Health and Science, Agency for Toxic Substances and Disease Registry, National Science Foundation, Department of Veterans Affairs, Centers for Disease Control and Prevention, National Institute of Standards and Technology, National Research Council, and DoD. The following organizations reviewed and concurred with the oil fire HRA: National Academy of Science—Institute of Medicine, Presidential Advisory Committee on Gulf War Veterans’ Illnesses, DoD Science Board Investigating Persian Gulf Mystery Illnesses, NIH Technology Assessment Workshop on the Persian Gulf Experience and Health, Government Accounting Office, and Office of Technology Assessment. The data, information and reports generated by this study were made available to all interested parties. Numerous national presentations were made to a variety of audiences and the data collected were provided to many national and international scientific groups. Over the 20 years since the study was initiated, the results and data contained within the reports have been shared with many researchers and used in numerous publications.12-14

ODS veterans have developed many health problems over the last 2 decades and many attribute these to ODS exposures. The exposures include: oil well fire smoke or petrochemicals, chemical or biological warfare agents, pesticides, vaccines, depleted uranium, nerve agent pre-exposure treatment, particulate matter, insect repellants, and emissions from tent heaters. Unlike many of the other exposures of concern, oil well fire exposures and associated risks were characterized using a considerable amount of collected field data. The soil and air samples collected as part of the oil well fires study were used to assist with assessment of depleted uranium and pesticide exposures.

Reviews of the oil well fire exposure studies have identified some areas where the study could have been improved: deploying earlier, right after the ground war ended in late February; identifying areas of interest where U.S. forces had been located before sampling was initiated and testing these sites even though U.S. forces were no longer there; and collecting more acid gas and criteria pollutant samples.

**CHANGES IN DEPLOYMENT ENVIRONMENTAL SURVEILLANCE SINCE 1991**

There have been numerous changes in the tools used for deployment environmental surveillance and the policies and practices that support environmental surveillance since the 1991 oil well fires study. These include improvements in: equipment, sampling and analytical methods, training, specialized military units, risk assessment methods, troop tracking systems, routine health surveillance, data archiving, and military policy and doctrine. Equipment has become smaller, lighter, battery powered, and more rugged. DoD personnel have worked with commercial vendors to modify commercial equipment to suit DoD needs. Getting new equipment through the military bureaucracy to be available in timely fashion is an ongoing challenge, but military staff members are constantly working to place the best available tools in the military sets that accompany deployed units. Sampling methods have been modified to require less sample volume for easier transport. Environmental surveillance training is being conducted in military schools and equipped, trained personnel have been and are being assigned to specialized units in all the services to carry out deployment surveillance. The Army has had Area Medical Laboratories; the Navy has used field Forward Deployed Preventive Medicine Units; and the Air Force has deployed Preventive Medicine Teams-Air Force.

Risk assessment methods have undergone refinement and are now supported by Military Exposure Guidelines that have been developed for air, water, and soil, different exposure time frames, and thousands of chemicals. The Military Exposure Guidelines were developed by DoD with other Federal agencies using standard toxicological data and military specific exposure factors. They have been peer reviewed by the National Academies of Science.15

Troop tracking systems to monitor individual troop locations on a daily basis continue to improve and undergo refinement. Currently, a useful system for medical investigations is the Defense Theater Accountability Software, which is available in the Central Command Area of Responsibility. Social security number and location (latitude and longitude) are entered every day for each individual. The system contains basic demographic data and military specific information, including occupational specialty. A limitation on use is the security classification of the system.

Routine environmental surveillance is now carried out at most deployment sites, to include the Central Command Area of Responsibility. Requirements and guidance for conducting the surveillance are in DoD directives and instructions, Joint Chiefs of Staff memoranda and service specific documents. The data collected are archived in a document called the Periodic Occupational and Environmental Monitoring Summary, the standard DoD document for archiving...
Defining Troop Exposures and Determining Health Risks

environmental exposures. Additionally, most environmental exposure data and preventive medicine documents, surveys, and information relating to deployments are also archived in a system called the Defense Occupation Environmental Health Readiness System. The Defense Occupation Environmental Health Readiness System can be accessed over the internet.

CONCLUSION
Since the 1991 Kuwait Oil Fire HRA was developed, the DoD has made great strides in the area of deployment surveillance. There are trained and equipped units in all the services and trained individuals imbedded with deployed combat units. This infrastructure is intended to respond to an environmental catastrophe like the oil well fires or to smaller episodes like a fire or accident at an industrial facility, and to conduct routine surveillance. The DoD response to the 1991 Oil Well Fires required considerable resources, a great deal of time, and considerable consultation and collaboration with many U.S. Government agencies. The intent of the improvements within the DoD described above was to prevent or limit the consequences of environmental catastrophes and smaller accidents through preventive assessments and rapid, capable responses and to provide rapid, reliable, and actionable HRAs. The oil well fire exposure and risk generating methodology made it possible to separate the risk caused by oil fire smoke from the risk from all sources, as required by PL 102-190. The table shows an example of the exposure to particulate matter caused by oil well fire smoke (modeled) vs. all source particulate exposure (measured from oil fire smoke, sand, and industrial pollution).

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The Kuwait Oil Fire Health Risk Assessment Biological Surveillance Initiative

COL David P. Deeter, MC USA (Ret.)

ABSTRACT  An important environmental concern during the first Gulf War (Operation Desert Storm) was assessing exposures and potential health effects in U.S. forces exposed to the Kuwait oil fires. With only 3 weeks for planning, a Biological Surveillance Initiative (BSI) was developed and implemented for a U.S. Army unit. The BSI included blood and urine collections, questionnaire administration, and other elements during the predeployment, deployment, and postdeployment phases. Many BSI objectives were accomplished. Difficulties encountered included planning failures, loss of data and information, and difficulty in interpreting laboratory results. In order for biological surveillance initiatives to provide useful information for future deployments where environmental exposures may be a concern, meaningful, detailed, and realistic planning and preparation must occur long before the deployment is initiated.

INTRODUCTION  During the first Gulf War, Operation Desert Storm, Iraqi troops began burning 605 oil wells in Kuwait in February 1991.¹ The need to assess exposures and potential health effects in U.S. forces was quickly recognized and efforts were initiated to develop the Kuwait Oil Fire Health Risk Assessment (HRA).² One of the unique features of the Kuwait Oil Fire HRA was the inclusion of what was termed the “Biological Surveillance Initiative” or BSI as an appendix.² The BSI was considered a unique addition to the HRA because environmental HRAs usually were constrained by containing only assumptions about the extent to which a population had been exposed to environmental pollutants.

The BSI was conceived after military Occupational Medicine physicians at the U.S. Army Environmental Hygiene Agency (USAHEA, later the U.S. Army Center for Health Promotion and Preventive Medicine and, currently, part of the U.S. Army Public Health Command [Provisional]), Aberdeen Proving Ground, MD, learned that an element of the 11th Armored Cavalry Regiment (ACR), home-based in and around Fulda, West Germany, was going to be deployed to Kuwait for several months and then return to Germany. They viewed this as an opportunity to measure the doses of pollutants individuals in an exposed population were actually receiving at the same time environmental levels of the pollutants were being measured. It was also an opportunity to assess acute health effects in those exposed to the smoke from the oil well fires. The results of the BSI were not intended to replace the HRA exposure assumptions, but rather to help refine and corroborate, or perhaps refute them. This was an opportunity to collect biological and health effect information in a relatively large population simultaneously with the collection of environmental data.

Another important feature of the BSI was that the soldiers of the 11th ACR had not yet been exposed to the oil fire smoke. An HRA was usually conducted in response to an environmental event that had already started. If biological sampling was done in conjunction with these assessments, the biological sampling usually took place while subjects were already being exposed or after their exposure, sometimes long after, as with Agent Orange exposure in Vietnam.³ In these cases, assumptions had to be made about the exposed subjects’ baseline values before their exposures.

The BSI had two major objectives:

(1) To quantify exposure to oil well fire pollutants by measuring markers of internal dose.
(2) To identify and measure health and biological events possibly related to exposure to the oil well fire pollutants; and

We hoped to use the BSI to help answer three questions:

(1) How much of the measured environmental pollutants were actually getting into the exposed population?
(2) Could biological and genetic effects that might be related to the exposure be detected?
(3) Were soldiers experiencing acute health effects that might be related to the exposure?

CONDUCTING THE BIOLOGICAL SURVEILLANCE INITIATIVE  The BSI had several subjective and objective components, including evaluation of medical Treatment Facility (MTF) logs of soldier complaints, soldier diaries documenting their personal experiences, health status questionnaires, and pulmonary function test results. Direct measures of exposure included testing for urine 1-hydroxypyrene, blood
volatile organic compounds (VOCs), and blood and urine metals. Indirect measures of exposure were also used and included testing for sister chromatid exchanges (SCEs) and DNA-polycyclic aromatic hydrocarbon (DNA-PAH) adducts. Questionnaires were administered and blood and urine samples were collected for three time periods: predeployment in Germany, during deployment in Kuwait, and postdeployment after return to Germany.

For the questionnaires, a total of 3440 soldiers were interviewed at least once: 884 were questioned before leaving Germany and upon returning; 170 were questioned before leaving Germany, while in Kuwait, and upon returning. Blood and urine metal levels were tested for 203 soldiers, with 113 providing specimens for all three periods. A cohort of 25 soldiers gave blood all three periods for the VOCs assay. For SCE assays, a nonspecific indicator of genetic stress, 26 soldiers had samples collected for all three periods; 50 predeployment and during deployment; and 35 predeployment and postdeployment. The cohort for the DNA-PAH adduct assay was smaller. Detailed descriptions of the methods used and the results obtained are published in Appendix F of the “Final Report, Kuwait Oil Fire Health Risk Assessment” and several other publications. 2,4–6

Unfortunately, three sets of data and information that could have been quite valuable were not included in the published BSI results. We were unable to obtain valid baseline pulmonary function tests in Germany, so the pulmonary function data were never fully evaluated. We had little time to develop a plan for the BSI and believed ourselves fortunate to find a manufacturer who could quickly send three new, state-of-the-art, portable spirometers to Germany. Unfortunately, the members of the surveillance team who would be conducting the spirometry testing had no opportunity to learn how to program the new spirometers. Not making proper adjustments for such factors as race, ambient temperature, and humidity produced invalid results. The MTF logs may have provided the health complaints for which the 11th ACR soldiers sought medical care during their deployment to Kuwait. However, a large explosion and fire near the main MTF destroyed the logs. Finally, blank diaries were given to 25 Army Medical Corpsman volunteers, who were requested to record their daily observations of the weather, their proximity to the oil well fires, their activities, and how they felt. Only one of the diaries contained enough information to be of any value.

ASSESSING THE BIOLOGICAL SURVEILLANCE INITIATIVE

The BSI had two major purposes. The first was to measure the internal dose of environmental pollutants produced by the oil well fires and correlate these measurements with the air sampling results. Measurement of the internal dose of pollutants was accomplished in that we were able to obtain and analyze pre-, mid-, and post-exposure blood and urine levels for a broad range of metals and VOCs. These tests were highly sensitive (some VOCs results were in the parts per trillion range) and highly specific. The results of the BSI and the environmental sampling could not be directly correlated. Detailed environmental exposure data were not available for specific BSI subjects at the time the analyses were done.

The second purpose was to identify potential health and biological effects that might be associated with exposure to the oil well fire pollutants. Actually, the best that we could have done was to discern potential effects associated with being deployed to Kuwait while the oil well fires were burning. Dr. Petruccelli, in his article reporting on the survey results, pointed out that two major confounders could in themselves be the basis for any changes in health seen in soldiers deployed to Kuwait: the health stressors associated with being in the desert environment (especially during the summer months) and the nature of the soldiers’ jobs when deployed. 4

Interpretation of the results of the indirect measures of exposure, the DNA-PAH adducts and SCEs, was problematic. The specificity of these tests, in terms of being able to identify what may have caused any observed genetic change, was low. The DNA-PAH adducts are so highly sensitive that results could have been influenced by a variety of exposures, to include the soldiers’ diets, for example, consuming grilled meat at a unit barbeque. Similarly, the SCEs could have been influenced by the cosmic radiation associated with the flights between Germany and Kuwait. Having obtained serial, matched samples for both these tests enhanced the investigators’ ability to conclude that significant excess genetic damage did not appear to be associated with exposure to the oil well fire pollutants. By including the DNA-PAH adducts and SCEs in the BSI project, we contributed to a pool of knowledge and gained experience in their use, but the value of these tests as surveillance tools is certainly open to question. In the final analysis, the BSI results did support the overall conclusion of the HRA, which was that any short-term and long-term human health effects associated with exposure to oil well fire smoke were probably low risk events.

Looking back 19 years, it is appropriate to ask if we learned enough from the BSI to make the project worth our efforts. The oil well fire smoke was a potential health threat to fighting U.S. forces, and the threat had to be assessed using the best methods and tools available. When an opportunity to conduct the BSI was identified, the leadership of the Army Medical Department supported the initiative because of the potential value of the data and information that might be obtained. Additionally, the experience of quickly initiating a complex surveillance initiative using sophisticated laboratory tests and many U.S. Government and non-U.S. Government agencies was considered important. Some potentially valuable information was lost, and this was not unexpected since work was being done under significant time pressure and in a war zone. Much of the data and information collected were evaluated and included in reports that could be accessed easily to
assist in determining possible associations between exposure and health outcomes in veterans. Additionally, the BSI was documented and could be used as a teaching exercise for members of the military who might face a similar situation.

In examining the lessons learned that might help improve the quality of future biological surveillance efforts, two areas come to mind as requiring emphasis:

1. Time. Environmental disasters, whether natural or man-made, usually come with little or no warning. If a risk assessment is going to include biological monitoring that begins before initial exposure, extraordinary foresight and preparation must occur. For the BSI, we fortunately had 3 weeks before the soldiers from the 11th ACR deployed to develop the surveillance program, get it coordinated and approved, and execute the predeployment phase. At the time, we felt that we had very little time. In retrospect, the 3 weeks were a luxury that others should not expect to have. The lesson learned from this situation is the value of anticipating events and seriously conducting preplanning to the greatest extent possible. There are some components of field surveillance that can be expected to be essential and present in almost every field surveillance project. These would include funding, interinstitutional agreements, human use committee processes, informed consent, equipment, and health assessment and exposure questionnaires. The more preplanning that can be completed for these generic items, the more likely it is that biological and other medical surveillance can begin early in an environmental event. When Operation Desert Storm started, the Walter Reed Army Institute of Research (WRAIR), Washington, DC, was the parent organization for the U.S. Army Epidemiological Consultation (EPICON) Service, a Service that had 2 decades of experience in rapidly responding to outbreaks of all types around the world.7,8 The WRAIR was a BSI collaborating U.S. Government organization, and the EPICON Service personnel provided valuable advice and assistance in quickly developing, coordinating, obtaining approval for, and implementing the BSI.7,8

2. Institutional Cooperation and Human Subjects Concerns. BSI team members came from several U.S. Government and non-U.S. Government institutions. Although this was important for many reasons, such as funding, logistics, and release of publications, by far, the one issue for which the involvement of multiple institutions was a major factor was the question of the use of human subjects. A majority of the team members were researchers and were responsible to their home institutions’ human use committees to obtain approval for their work. The principal institution for the BSI was AEHA, which was not a research institution; AEHA had no human use committee. Many of us maintained that as public health surveillance the BSI was not human use research and, therefore, would not need committee approval. Even so, each involved institution’s committee would have to concur if its employees were to remain involved in the BSI work. We could not accomplish this in the 3 weeks available. In the end, this was resolved by submitting our plan through the WRAIR human subjects review committee. Even though the BSI was determined to be public health surveillance, the BSI project plan did include informed consent and provisions for protection of personal data.

CONCLUSIONS

The deployment of the 11th ACR presented a unique opportunity to validate the Kuwaiti oil fire HRA results using human biological surveillance data. Our final conclusion was that the BSI results did support the HRA results. Although we were reasonably confident that the health of our deployed soldiers was not significantly impacted by exposure to the oil well fire environment, it is possible that the BSI project was not adequate to detect an association.

Many lessons were learned. Time is a very important factor. Actions to plan for things that we know are going to have to be addressed in future projects like the BSI must be completed. Templates for a surveillance plan, interinstitutional agreements, emergency budget requests, human subjects committee approval, informed consent, and exposure and health assessment questionnaires must be developed and on the shelves, ready to go for the next environmental disaster. The organizations that would probably be involved and the agency that should be in charge of the project should be identified. Responsible military and other government medical planners should identify the organizations, military units, and locations that will supply the people to do the work and the equipment they will need. The biological and environmental samples that will need to be collected, specimen storage and transport requirements, the laboratory tests to be done, the laboratories doing the tests, the costs involved, and the organization that will pay the bill can also be identified before an actual event.

Given a situation similar to that in 1991, what should we do differently? If new equipment is to be used, such as new spirometers, consider how training for use and maintenance will be accomplished. Identify specific individuals who will be responsible for accomplishing specific tasks. All things considered, if a member of our surveillance team could have stayed on the ground at critical places with the 11th ACR during the predeployment, deployment, and postdeployment phases of this project, many problems and shortcomings could have probably been avoided or at least mitigated to some degree.

Finally, when one lacks personal experience in dealing with unusual and difficult situations, careful study of the experiences of others may be a valuable alternative. It is our hope that review of our experiences during the BSI for the
Kuwait oil fire exposure will serve as a teaching and learning tool for others.

ACKNOWLEDGMENTS
The contributions of the soldiers of the 11th Armored Cavalry Regiment who participated in the Kuwait Oil Fire Health Risk Assessment Biological Surveillance Initiative are gratefully acknowledged.

REFERENCES
Linking Exposures and Health Outcomes to a Large Population-Based Longitudinal Study: The Millennium Cohort Study

Tyler C. Smith, MS, PhD; for the Millennium Cohort Study Team

ABSTRACT  Objective: To describe current efforts and future potential for understanding long-term health of military service members by linking the Millennium Cohort Study data to exposures and health outcomes. Methods: The Millennium Cohort Study launched in 2001, before September 11 and the start of combat operations in Afghanistan and Iraq. Other substantial Department of Defense (DoD) health, personnel, and exposure databases are maintained in electronic form and may be linked by personal identifiers. Results: More than 150,000 consenting members comprise the Millennium Cohort from all services, and include active duty, Reserve, and National Guard current and past members, and represent demographic, occupational, military, and health characteristics of the U.S. military. These prospective data offer symptom assessment, behavioral health, and self-reported exposures that may complement and fill gaps in capability presented by other DoD electronic health and exposure data. Conclusions: In conjunction with Millennium Cohort survey data, prospective individual-level exposure and health outcome assessment is crucial to understand and quantify any long-term health outcomes potentially associated with unique military occupational exposures.

INTRODUCTION
The 1991 Gulf War was one of the shortest large-scale conflicts in military history. Although morbidity rates during the war because of combat as well as disease and nonbattle injuries were lower than in previous major conflicts,1 soon after the war many veterans began reporting symptoms and illnesses they attributed to exposures during the war.2–4 The 1990s were clouded with health concerns over environmental exposures stemming from the war prompting the Department of Veterans Affairs (DVA) to initiate the Gulf War Registry Health Examination on November 4, 1992, and the Department of Defense (DoD) to initiate the Comprehensive Clinical Evaluation Program on June 7, 1994.5–11 These health registries gave systematic medical evaluations to over 100,000 of the 697,000 U.S. military personnel who served in the Gulf;12 Nearly 1 billion dollars would be spent conducting research over the next decade trying to understand and answer veteran concerns.

Many studies attempted to retrospectively assess exposure and health outcomes through self-report.13–19 These cross-sectional and retrospective self-report assessments reported concurrently with health outcomes were limited by self-selection to participate and recall of exposures and outcomes and reporting of these simultaneously. Misclassification of exposure and disease was an inescapable bias, and it was often difficult to ascertain if there were a differential or nondifferential impact on the study results. A nondifferential bias would reduce effect sizes toward the null and determine no association when one truly existed, whereas differential misclassification would affect the effect size in either direction, possibly establishing a statistically significant association when one did not truly exist. These limitations further eroded confidence in the research findings that were being reported.

In an attempt to understand exposure in an objective and prospective way, the U.S. Army Center for Health Promotion and Preventive Medicine (now the U.S. Army Public Health Command) launched a monumental exposure assessment effort soon after the end of the 1991 Gulf War. The effort was conducted to document the potential exposure of service personnel to smoke resulting from the Kuwait oil well fires set ablaze by retreating Iraqi forces.20–22 Another objective exposure assessment, similarly as difficult, was the retrospective assessment of possible exposure to nerve agents inadvertently destroyed at the sprawling weapons depot at Khamisiyah, Iraq.23,24 These exposure assessment efforts were large and unique in that they leveraged meteorological modeling, plume dispersion science, and troop unit location data with Geographic Information System technology to estimate potential exposure and dose at the unit level. Though they represented quite an advance in population exposure assessment, these data lacked a key element that would allow the understanding of exposure at the individual level.

Studies conducted in the 1990s utilized innovative new approaches including leveraging advanced statistical and survey methods, newly available electronic hospitalization data, and never-before conducted exposure assessment; however, significant limitations to the inferential capability of these studies remained. First and foremost, the lack of baseline health data was a significant hurdle that none of the studies could overcome. Additional gaps included a lack of hospitalization studies to assess health outcomes in Reserve and National Guard members or those members separated from military service where access to the military health care...
system was not possible; an inability to control for important health-related behaviors such as tobacco and alcohol use; exposure data were not at the individual level and were limited to Khamisiyah and the Kuwaiti oil well fire smoke assessments; electronic vaccination, pharmaceutical, and outpatient data were limited; and the survey data were limited by assessment of exposures and health outcomes many years after the war. The DoD, recognizing many of the limitations to this research, initiated a series of efforts in an attempt to establish accessible data that would be capable of answering future concerns of military members.

By the end of the 1990s, tri-service inpatient and outpatient data (both at military treatment facilities and care billed to the DoD from private providers) were being aggregated in large electronic databases; the DoD Birth and Infant Health Registry was established; the DoD Serum Repository (DoDSR) was available for linkage and research; personnel data, including demographic and occupational characteristics, were available; and routine collection of vaccination data began with the anthrax vaccination efforts. Highlights of the first decade of the new millennium included a database to track DoD pharmacy transactions, a more robust contingency tracking system, initiation of Pre- and Post-Deployment Health Assessment (DHA) screening, and the launch of the largest prospective cohort study in military history, the Millennium Cohort. This article briefly describes existing DoD data sources and summarizes the Millennium Cohort Study and the potential for linking these data.

**DoD DATABASES**

**Defense Enrollment Eligibility Reporting System (DEERS)**

DEERS is the central source for personnel information that includes determination of medical benefits eligibility, dates of service, demographics, and military occupation and location variables. In addition, DEERS includes the military’s central immunization database.

**Standard Inpatient Data Record (SIDR)**

The SIDR contains 1 record for each inpatient encounter for care at all DoD hospitals worldwide, with up to 20 International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) discharge diagnoses. These files contain historical data dating from October 1988.

**Standard Outpatient Data Record (SADR)**

The SADR contains 1 record for each outpatient encounter for care at all DoD hospitals and clinics, with up to 4 ICD-9-CM diagnoses. These files contain historical data from November 1996.

**TRICARE Encounter Data (TED)**

Previously known as the Health Care Service Record, TED (institutional and noninstitutional) contains 1 record for each health care encounter (inpatient or outpatient) from civilian providers; care is covered by the DoD insurance system, TRICARE. These files contain historical data from October 1993.

**Pharmacy Data**

Mandatory reporting began in 2000 and resulted in a DoD centralized electronic pharmaceutical dispensing database from the Pharmacy Data Transaction Service. This database captures mandatory reported data from all military medical treatment facilities worldwide, civilian retail pharmacy networks, and the TRICARE Mail Order Pharmacy network.

**DoD Birth and Infant Health Registry**

The DoD Birth and Infant Health Registry captures comprehensive health care data to define live births and infant health outcomes among more than 90,000 infants born to military families each year. With nearly 1 million infants in this registry, there is considerable power to conduct robust research, even on the rarest birth outcomes.

**Pre- and Post-Deployment Health Assessments**

In response to Public Law 105-85 enacted by the U.S. Congress, the DoD established routine pre- and postdata collection on all service members before deployment and upon their return. Pre-DHA and Post-DHA questionnaires, also known as Department of Defense Forms 2795 and 2796, have been used to gather these data since 1998. The Post-Deployment Health Reassessment was initiated in 2006 to conduct a reassessment 6 to 9 months after returning from deployment.

**Recruit Assessment Program**

The Recruit Assessment Program, launched in June 2001 at the Marine Corps Recruit Depot in San Diego, California, was designed to collect survey-based health and behavioral data from west coast Marine recruits at the time of service entrance.

**DoD Serum Repository**

The DoDSR is a central archive of sera drawn from service members for medical surveillance purposes. To date, there are over 50 million specimens that date back to the 1980s from more than 9 million service personnel included in the repository.

**Defense Medical Surveillance System (DMSS)**

The Armed Forces Health Surveillance Center (AFHSC) was established by the Deputy Secretary of Defense in 2008 to provide a central repository of DoD health surveillance data sets and programs including the DoD Global Emerging Infections Surveillance and Response System (GEIS) and the DMSS. The AFHSC produces a Medical Surveillance Monthly Report (MSMR) allowing the efficient dissemination of medical
surveillance information of interest to the military public health community.

**Immunization Data**

Beginning in 1998 with the tri-service Anthrax Vaccine Immunization Program, vaccination data have been maintained by DoD. Data include dates and location of vaccines given to military members, number of doses in the primary series, and annual booster dose information.

**Deployment Data**

The Defense Manpower Data Center maintains a database for all contingency-related deployments and includes information regarding country location code, and start and end dates for each deployment. Service members are identified as having deployed by being reported directly from personnel offices of the service branches or based on having received imminent danger pay, hardship duty pay, or combat zone tax exclusion benefits.

**The Millennium Cohort Study**

The Millennium Cohort Study was designed in the late 1990s in response to gaps in research conducted in an attempt to answer veteran and public concern regarding the 1991 Gulf War. The population-based Cohort was envisioned to collect self-reported data to complement the growing number of electronic DoD health and personnel databases. In addition, this Cohort was established to fill known gaps in research capabilities such as collecting data on Reserve and National Guard members, service members separated from military, baseline predeployment health, and behavioral health such as smoking and alcohol use that may influence health outcomes.

The Cohort was constructed to prospectively assess long-term health in all branches of the U.S. Armed Forces and include active duty, Reserve, and National Guard members, and follow Cohort members while in and even after separation from military service. All participants enrolled in the study are followed up and surveyed at 3-year interval periods. Currently, the Cohort is composed of approximately 150,000 members who will be resurveyed again in 2010–2011 (and every 3 years afterwards through 2021) and will include an additional enrollment panel of approximately 60,000 members and 10,000 spouses. More information on the design and conduct of this Cohort study is available in previously published articles.

With nearly a decade of research conducted with this Cohort, deployment-related investigations of mental and physical health conditions have been completed, including major depression, anxiety disorders, post-traumatic stress disorder (PTSD), eating disorders and weight change, alcohol misuse, cigarette smoking, hypertension, respiratory conditions, diabetes, sleep, and mortality. Unique to these efforts is the ability to conduct this research at a population level while including all services, active duty, Reserve, and National Guard members while serving as well as after military service.

Multiple standardized instruments are included in the questionnaire: the PTSD Checklist-Civilian Version to assess PTSD symptoms; the Patient Health Questionnaire to assess depression, panic, other anxiety, eating disorders, and alcohol-related problems; the Medical Outcomes Study Short Form 36-Item Health Survey for Veterans to assess perceived functional health (mental and physical); and potential alcohol dependence assessed using the CAGE questionnaire. Standardized instruments included in the questionnaire have been found to be internally consistent and reliable using Cronbach’s alpha and thus indicating an appropriate measurement tool for this population.

Exposure assessment is an important component of the Millennium Cohort Study and allows for hypothesis testing as well as controlling for confounding that may distort research conclusions. In addition to medical outcome and mental health metrics, the questionnaire assesses alcohol use, tobacco use, complementary and alternative therapies, body mass index, physical activity, sleep, and dietary supplement use. Personal and family stressors are assessed including changes in residence or job, suffering sexual or physical assaults, and death or severe illness of family members, among others. Through a modest assessment of the continuum of potential occupational exposures, the questionnaire also assesses: service and post-service occupations; occupational exposures including assessment of jobs requiring protective equipment, routine skin contact with paint and/or solvents, microwaves, and pesticides (Table I); military-unique occupational exposures, including witnessing a

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**Table I.** Self-Reported Occupational Exposures Assessment Included in the Millennium Cohort Study

<table>
<thead>
<tr>
<th>Exposures in the Last 3 Years</th>
<th>No</th>
<th>Don’t Know</th>
<th>Yes</th>
<th>If Yes, List Most Recent Year of Exposure</th>
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</thead>
<tbody>
<tr>
<td>Occupational Hazards Requiring Protective Equipment, such as Respirators or Hearing Protection</td>
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<tr>
<td>Routine Skin Contact With Paint and/or Solvent and/or Substances</td>
<td></td>
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<td></td>
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<tr>
<td>Depleted Uranium (DU)</td>
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<td></td>
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<tr>
<td>Microwaves (Excluding Small Microwave Ovens)</td>
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<tr>
<td>Pesticides, including Creams, Sprays, or Uniform Treatments</td>
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<tr>
<td>Pesticides Applied in the Environment or Around Living Facilities</td>
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<td></td>
<td></td>
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<tr>
<td>Any Exposure, Physical or Psychological, During a Military Deployment that had a Significant Impact on your Health? Please Specify:</td>
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person’s death because of war, disaster, or tragic event, witnessing instances of physical abuse, seeing dead or decomposing bodies or prisoners of war, or being exposed to or provided with countermeasures for chemical/biological/radiological warfare agents or depleted uranium (Table II); and deployment dates and locations (Table III). On the most recent instruments, questions that ascertain specific military deployment-related exposures have been added including feeling in danger of being killed, being attacked or ambushed, receiving small-arms fire, clearing homes or buildings, having an improvised explosive device explode nearby, being wounded or injured, seeing or handling human remains, knowing someone seriously injured or killed, having members in one’s unit seriously injured or killed, and being directly responsible for the death of noncombatants or enemy combatants (Table IV).

Though the Cohort began with approximately 1 person enrolling for every 3 contacted,\textsuperscript{35,37} Cohort members stay engaged. Approximately 80% of participants who enrolled as part of the first 2 enrollment cycles have completed at least 1 follow-up survey. Representativeness of the Cohort to the entire military population has been investigated and suggests a reliable reporting Cohort that is reasonably generalizable.\textsuperscript{31,35,37,39,44,60–66}

**Linking Data**

Large DoD populations with centralized data repositories allow for efficient and cost effective research approaches along with the samples sizes necessary to test study hypotheses. However, access to these data is not achieved readily as DoD data are protected because of the sensitive nature and often including Personally Identifiable Information (PII) and Protected Health Information (PHI). The actual linking of these large and complex data sets is in general, easily accomplished by linking individual identifiers across data platforms. The real-time constraints involve securing approvals for acquiring these data and linking is secondary to necessary human use and ethics approvals. Data Use Agreements, Memoranda of Understanding, and Joint Research Agreements are just a few of the potential agreements necessary to be in place before data linking. Often, researchers may save considerable time by requesting de-identified data sets, though this may not be practical in all settings.

Data available on military populations offer unique challenges but also significant opportunity to answer questions of concern to veterans and DoD. Used individually, examples of how these data sets may allow questions to be answered include: healthcare utilization by region, medical treatment facility, or clinic; utilization by medical diagnostic coding; utilization of prescription drugs\textsuperscript{67}; administration of vaccines; and demographic and occupational characteristics in the military over time. In isolation, these data sources are useful, when joined they become invaluable. When combined, these data allow construction of denominators and identification of control populations critical to conduct research of exposures and outcomes. Examples of linking and leveraging these centralized data include: investigating hospitalizations postdeployment (linking inpatient, personnel, and deployment data),\textsuperscript{58–71} vaccine safety as measured by health care utilization postvaccination (linking vaccine, inpatient, personnel, and deployment data),\textsuperscript{28–30,72} birth outcomes potentially associated with vaccine or deployment (linking the birth and infant health registry, vaccine, and/or deployment data),\textsuperscript{65,73–75} hepatitis E seroprevalence and seroconversion among U.S. military service personnel deployed to endemic countries such as Afghanistan (linking personnel, deployment, and DoDSR data),\textsuperscript{76} and other important health concerns potentially linked to military

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<th>Table II. Self-Reported Stressful Occupational Exposures Assessment Included in the Millennium Cohort Study</th>
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<td><strong>Personal Exposures in the Last 3 Years (Not Including TV, Video, Movies, Computer, or Theater)</strong></td>
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<tr>
<td>Witnessing a Person’s Death because of War, Disaster, or Tragic Event</td>
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<td>Witnessing Instances of Physical Abuse (Torture, Beating, Rape)</td>
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<td>Dead and/or Decomposing Bodies</td>
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<td>Maimed Soldiers or Civilians</td>
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<td>Alarms Necessitating Wearing of Chemical or Biological Warfare Protective Gear</td>
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<th>Table III. Self-Reported Deployment Country and Imminent Danger Pay Assessment Included in the Millennium Cohort Study</th>
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<td><strong>Country Code or Sea Code Where Imminent Danger Pay, Hardship Duty Pay, or Combat Zone Tax Exclusion Benefits was Received, Within the Last 3 Years</strong></td>
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occupational experiences. Importantly, although these data are robust in answering many questions, limitations do exist and include: unequal ascertainment by component status where Reserve and National Guard are often not represented completely in military health system data; unequal ascertainment by separation from service status where those separated often no longer have access to health care and would not be visible to researchers; potential for over estimation of cases because of rule-out diagnoses if scanning for certain diagnostic codes or categories; and differential access to care and reporting in forward deployment theaters. Early Millennium Cohort data linkages focused on testing the reliability of self-reporting by linking to DoD electronic vaccine, healthcare, deployment, and occupation data while also linking to demographic and other occupational data to highlight differences in population reporting reliability. Linking to mortality data allowed for investigation of mortality ascertainment between the National Death Index, Social Security Administration Death Master File, DoD Medical Mortality Registry, and DVA mortality data sets, and is facilitating a unique effort to investigate an 8-year prospective study of suicide in this large cohort during a period of high operational tempo. Prospective Cohort data have been linked to demographic, deployment, and occupation data to understand potential short-term effects of deployment and reported symptoms. Follow-up of reported increases in hypertension and respiratory symptoms after deployment will allow for understanding transient or long-term implications of symptoms. Follow-up of increased reporting of mental health symptoms in subsets of deploying forces will allow for understanding of persistent, chronic, or episodic nature of the symptoms. Linking of the many available DoD data sets to the Millennium Cohort allows for understanding of health implications of combat deployments that has not been possible before. Currently, analyses are underway to link military health system data, deployment to bases with known open air burn pits, and Millennium Cohort Study data. This effort will be the first to investigate self-reported and ICD-9 assessed health outcomes and symptoms among service members deployed to several large bases with known burn pits while controlling for baseline health and behaviors. **DETERMINATION OF SUCCESS** The way forward for successful occupational and environmental research investigations will include real-time monitoring of service members’ exposures in deployment environments that will facilitate quick identification and prevention of exposure while not limiting or hindering the military mission. Advances in biomonitoring technology will allow postexposure assessment of whether contact with the hazard or exposure resulted in significant markers of exposure or health effects and will allow for monitoring health outcomes potentially linked to the exposure. This approach requires a small logistical footprint, command support for monitoring in operational settings, and funding for personnel and equipment. The exposure monitoring equipment will have to be issued, the data collected, and the data downloaded to the DOEHRS database. Retrospective self-reported assessment of exposure is a viable option if designed in a way such that exposures and health outcomes are not collected simultaneously. New efforts should investigate the possibility of a standard exposure assessment tool that is responsive to the potentially unique set of occupational settings and exposures that the U.S. Armed Forces may encounter. This tool may be constructed to be service specific though designed with the ability to crosswalk exposure assessment across service branches. Yearly assessment and/or postdeployment assessment should be considered, and systematic data flow to a central DoD data repository should be considered. In this way, prospective and historical prospective investigations of exposure and subsequent health outcomes may be conducted while limiting simultaneous exposure and health outcome assessment. Determining success may only be practical in retrospective assessment of what we have done collectively as a
community toward understanding the health of our service members. However, a plan for objectives to be met and priority setting should be conducted at high levels of the DoD and DVA, and those needs and priorities should be presented to DoD and DVA researchers in organized and systematic approaches. Organizational integration both between the DoD and DVA and within departments should be encouraged to more efficiently assess and leverage existing capabilities and to identify gaps. The balance of focus on short- and long-term goals should be weighed and efforts to address both should be coordinated at high levels of the DoD and DVA to effectively address prioritized objectives across the continuum of health outcomes during and after military service. It is through insightful vision of where we need to progress to, and collegiate collaboration between service branches, academia, private industry, and between the DoD and DVA that research of environmental exposures will advance to the level of offering credible answers to our service personnel.

ACKNOWLEDGMENTS

We are indebted to the Millennium Cohort Study participants, without whom these analyses would not be possible. In addition to the authors, the Millennium Cohort Study Team includes Paul J. Amoroso, MD, MPH, from the Army Research Institute of Environmental Medicine, Natick, MA; Edward J. Boyko, MD, MPH, from the Seattle Epidemiologic Research Center, Veterans Affairs Puget Sound Health Care System, Seattle, WA; Gary D. Gackstetter, DVM, MPH, PhD, from Analytic Services, Inc. (ANSER), Arlington, VA; Gregory C. Gray, MD, MPH, Environmental and Global Health, University of Florida, Gainesville, FL; Tomoko I. Hooper, MD, MPH, from the Department of Preventive Medicine and Biometrics, Uniformed Services University of the Health Sciences, Bethesda, MD; James R. Riddle, DVM, MPH, from the Air Force Research Laboratory, Wright-Patterson Air Force Base, OH; Timothy S. Wells, DVM, MPH, PhD, from the Air Force Research Laboratory, Wright-Patterson Air Force Base, OH; Margaret A. K. Ryan, MD, MPH, Naval Hospital Camp Pendleton, Occupational Health Department, Oceanside, CA; Melissa Bagnell, MPH; Nisara Granado, MPH, PhD; Jaime Horton; Isabel Jacobson, MPH; Kelly Jones; Cynthia LeardMann, MPH; Travis Leleu; Jamie McGrew; Amanda Pietrucha, MPH; Teresa Powell, MS; Bessa Smith, MPH, PhD; Donald Sandweiss, MD; Amber Seelig, MD; Katherine Snell; Steven Speigel; Kari Sausedo, MA; Martin White, MPH; James Whitmer, and Charlene Wong, MPH, from the Department of Deployment Health Research, Naval Health Research Center, San Diego, CA. We thank Scott L. Seggerman from the Management Information Division, Defense Manpower Data Center, Seaside, CA. Additionally, we thank Michelle Stoia from the Naval Health Research Center for technical review. We also thank all the professionals from the U.S. Army Medical Research and Materiel Command, especially those from the Military Operational Medicine Research Program, Fort Detrick, MD. We appreciate the support of the Henry M. Jackson Foundation for the Advancement of Military Medicine, Rockville, MD.

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INTRODUCTION

Although the Gulf War (Operations Desert Shield and Desert Storm) was a short conflict with very few battle casualties, many of the 697,000 service members who were deployed reported illnesses after their return. In the years immediately following the conflict, multiple expert panels reviewed aspects of the illnesses or programs developed by Department of Defense (DoD) or the Department of Veterans Affairs (DVA) in response to the illnesses. In 1996, Deputy Secretary of Defense John White met with leadership of the National Research Council and the Institute of Medicine to explore the idea of an independent, proactive effort to learn from lessons of the Gulf War and the deployments to Haiti, Somalia, Bosnia, and Kosovo that had followed it. DoD sought an external and unbiased evaluation of its efforts regarding the protection of deployed U.S. forces in four areas: (1) assessment of health risks, (2) technologies and methods for detection and tracking of exposures, (3) physical protection and decontamination, and (4) medical protection, health consequences and treatment, and medical record keeping. The project was to address the problem of limited and variable data in the past, and the development of a strategy for improved handling of health and exposure issues in future deployments.

This article describes, in abbreviated form, many of the recommendations from the report on topic 4, which was published in 1999 as Strategies to Protect the Health of Deployed U.S. Forces: Medical Surveillance, Record Keeping, and Risk Reduction, and the strategies presented in the final report of the project, Protecting Those Who Serve: Strategies to Protect

METHODS AND EMPHASIS

Report on Medical Surveillance, Risk Reduction, and Medical Record Keeping

The study charge for the project on medical protection, health consequences and treatment, and medical record keeping was to address the following:

— Prevention of adverse health outcomes that could result from exposures to threats and risks including chemical warfare and biological warfare, infectious disease, psychological stress, and injuries;
— Requirements for compliance with active duty retention standards;
— Predeployment screening, physical evaluation, and risk education;
— Vaccines and other prophylactic agents;
— Improvements in risk communication with military personnel;
— Improvements in the reintegration of all troops to the home environment;
— Treatment of the health consequences of prevention failures, including battle injuries, disease and non-battle injury (DNBI), acute management, and long-term follow-up;
— Surveillance for short- and long-term outcomes, to include adverse reproductive outcomes; and
— Improvement in keeping medical records... in documenting exposures, treatment, tracking of individuals through the medical evacuation system, and health/ administrative outcomes.

The study was led by two principal investigators: a retired military infectious disease specialist and a psychiatrist. To
provide additional breadth of expertise, a panel of advisors was convened with expertise in the fields of medical record keeping, epidemiology, reproductive health, toxicology, infectious diseases and vaccines, psychology, psychiatry, chemical warfare agents, risk communication, biomedical ethics, and neurobiology (Appendix A).

The principal investigators and advisors (the study team) gathered information through several means. Four public workshops and a discussion meeting were held at which members of the military services, DoD, and representatives of other relevant agencies as well as civilian experts provided briefings and participated in discussions. Commissioned papers, journal articles, DoD documents, and other relevant documents supplemented information from the workshops.

Within the breadth of the study charge, the study team chose to emphasize areas in which the greatest needs were evident from the lessons learned from the Gulf War and other recent deployments and to treat other areas (where the study team believed that it had little to offer the military) less thoroughly. Since an important motivating force for the study was the health concerns of veterans after the Gulf War, the study team focused on the major challenges for prevention and data needs indicated by the health problems widely reported by deployed forces after the Gulf War and the efforts to better understand them.

What were the lessons of the Gulf War? Briefly, one of the lessons was that even in the absence of widespread acute casualties from battle, war takes its toll on human health and well-being long after the shooting or bombing stops. Although military preventive medicine programs had developed reasonably effective countermeasures against many of the discrete DNBI hazards of deployment, they had not yet systematically addressed the medically unexplained symptoms seen not only after the Gulf War but also after other major wars. The health problems reported by veterans after the Gulf War also brought out two other major and interrelated needs. One is for a health surveillance system with documentation so that health events in the field are noted and responded to. Closely allied is the need for an automated medical record that can provide information about a service member’s health events over his or her service career and into civilian life after military service. These three topics of medially unexplained symptoms, medical surveillance, and medical record keeping formed the critical areas of emphasis of the report.

The postdeployment period appeared to be a time when, in particular, additional effort could be crucial in attending to the health of the deployed forces. The report discusses needs and opportunities for improved surveillance, special focused health care, and assistance with reintegration into the home environment during this time.

Another major issue concerned providing the National Guard and Reserve components with the preparation and health surveillance afforded the active duty component. The reserves play an increasingly important role in military deployments. Yet, their lack of access to the military health care system while they are inactive places serious limitations on the routine health care that they receive and the ability to monitor their health status after a deployment. This problem for the reserves highlights a challenge for many active duty service members after they separate from military service. To the extent that they receive their health care in the civilian sector and not through the VA, the capture of any data on their health care is problematic, as is the concept of a true lifetime medical record as promised by President Clinton in 1997.

**Final Strategies Report**

The study charge for the third year effort was for a newly formed committee to use the reports developed by the four study teams as a starting point to synthesize a final report. In it, the committee was to emphasize and extend those findings and recommendations from the interim reports considered to be most important to a long-term strategy for health protection, as well as expand its review to broader, cross-cutting issues. The committee could examine policy, technology, and organizational issues as necessary in considering a strategy for the future.

The Committee on Strategies to Protect the Health of Deployed U.S. Forces was convened to carry out this charge. Its members brought military experience as well as expertise in disease surveillance and epidemiology, infectious disease, internal medicine, military preventive medicine, information management, psychiatry, risk assessment and modeling, and risk communication and management (Appendix B).

In its final report, the committee described six major strategies addressing areas that demand further emphasis and effort by DoD. The committee selected these strategies on the basis of the contents of the four reports, briefings by the principal investigators, and input from members of the military and other experts.

**RESULTS**

The study on medical surveillance, recordkeeping, and risk reduction resulted in over three dozen findings and recommendations, falling into six categories reviewed here. The reader is referred to the full report for the entirety of the findings and recommendations.

**Medically Unexplained Symptoms**

Medically unexplained symptoms are symptoms that are not clinically explained by a medical etiology and that lead to use of the health care system. They are increasingly recognized as prevalent and persistent problems among civilian populations, and are associated with high levels of subjective distress and functional impairment with extensive use of health care services. Similar medically unexplained symptom-based conditions have been observed in military populations after military conflicts dating back to the Civil War.

Clinicians and others working in medical surveillance must recognize that medically unexplained symptoms are just that;
there are no current explanations for them. Therefore, communicating the limits of modern medicine coupled with a compassionate approach is essential to the management of such patients. Although a program of primary prevention is not feasible given the current state of knowledge, enough is known to recommend the implementation of a secondary prevention strategy. Good clinical evidence indicates that medically unexplained symptoms are much harder to treat and ameliorate once they have become chronic. It is thus important to identify patients with medically unexplained symptoms early, when there may be a greater opportunity to restore them to a previous level of function. Providers with the clinical skills needed for medical management of these patients can work with them toward a mutually agreed upon set of therapeutic goals that include striving to cope with residual symptoms and rehabilitation in the absence of a definitive diagnosis. The study team recommended:

The DoD should develop an improved strategy to address medically unexplained symptoms, involving education, detection, evaluation, mitigation, and research.

— Undertake a program of continuing education for military primary care providers to improve their clinical ability to diagnose, treat, and communicate with patients with medically unexplained symptoms.
— Carry out a pilot program to identify service members in the early stages of development of medically unexplained symptoms through the use of routinely administered self-report questionnaires and through informed primary care providers.
— Evaluate the efficacy of the pilot secondary prevention and treatment program, including the ability of screening questionnaires to detect early stages of medically unexplained symptoms.
— Treat medically unexplained symptoms in the primary care setting whenever possible, with referral to more intensive programs as necessary.
— Carry out a research program with prospective studies to assess the role of predisposing, precipitating, and perpetuating factors in medically unexplained symptoms.

**Medical Surveillance**

The military launched many medical or health surveillance initiatives in response to the problems highlighted by the Gulf War illnesses. Pre- and postdeployment questionnaires and blood draws, periodic health assessments, baseline health surveys for recruits, and improved systems for the tracking of inpatient and ambulatory care visits during deployments were all planned or implemented.

The multiplicity of medical surveillance-related tools that were developed reflected a genuine effort on the part of DoD and the individual services to better track and document the health of deployed forces. However, with no central authority for military public health, the tools lacked coordination as part of an overall plan for achieving public health goals. The study team recommended that DoD:

— Clarify leadership authority and accountability for coordination of preventive medicine and environmental and health surveillance across the U.S. DoD and the individual services.

Part of the work of such a body would be to coordinate and potentially consolidate multiple surveillance tools. The study team made the following recommendations in considering these tools:

— The Recruit Assessment Program should be implemented to collect baseline health data from all recruits, and should be periodically reassessed and revised. Its data should be used prospectively to test hypotheses about predisposing factors for the development of disease, injury, and medically unexplained symptoms.
— Annually administer an improved Health Evaluation and Assessment Review (HEAR) to reserve as well as to active duty personnel to obtain baseline health information. Refine the HEAR by drawing on additional survey instrument and subject matter expertise.
— Reinforce the laboratory capability for public health surveillance within the military. Mandate central reporting of laboratory findings of reportable conditions.
— Discontinue pre- and postdeployment health (versus readiness) questionnaires unless they are warranted for military reasons other than gathering baseline and postdeployment health status information.
— As quickly as possible, implement a deployment DNBI surveillance system that is integrated with the patient care information system and that automatically reports information to a central medical command.
— Integrate the efforts of environmental surveillance, preventive medicine, clinical, and information technology personnel to ensure the inclusion of medically relevant environmental and other exposures in the individual medical record.

Based upon the experiences after the Vietnam and Gulf wars, the postdeployment period is crucial for carrying out medical surveillance and providing appropriate care for returning service members. The Veterans Benefits Improvement Act of 1998 (P.L. 105-368) provided that service members would be eligible for medical care for a period of 2 years after their return from service in a theater of combat operations. Provision of this care without the need to establish service-connection provided a valuable opportunity to ascertain the health needs of this population.

— Carry out studies to evaluate the data captured from the 2 years of care provided after a deployment.
— Annually administer the HEAR to a representative sample of service members who have been separated from the service for 2 to 5 years after a major deployment to
track health status and identify health concerns including medically unexplained symptoms.

- Avoid whenever possible the creation of deployment-specific registries. Depend, instead, on the data provided by routine medical care under the Veterans Benefits Improvement Act of 1998 (P.L. 105-368) and the annual HEAR.

**Postdeployment Reintegration**

The changing demographics of deployed forces, increased operational tempo, and increased reliance on the reserve component has heightened needs for support services for service members and their families both during and after deployments. It is crucial that service members returning from deployments have seamless access to health care and support services and be made aware of the resources available to them. After the Gulf War, the service components made progress in providing support services to service members and families during reintegration, but at the time of the report the programs had not been adequately evaluated.

- Include plans for supporting return and reintegration of service members in planning and operational documents for military deployments.
- Study postdeployment needs of service members and families, and use findings to evaluate programs and policies.

**Medical Record Keeping**

The study team and other health information experts considered the computer-based patient record (CPR) essential for DoD to meet the health care needs of service members before, during, and after deployments. To serve the military health system needs, the CPR system must meet several needs simultaneously:

1. Provide access to an individual’s health data anytime and anywhere that care is required,
2. Support record keeping for the administration of preventive health services,
3. Facilitate real-time medical surveillance of deployed forces and timely medical surveillance of the total force,
4. Provide comprehensive databases that support outcomes studies and epidemiological studies, and
5. Maintain longitudinal health records of service members beginning with recruitment and extending past the time of discharge from the military.

The study team heard briefings on several military health information system projects. In general, each need for health data had been addressed by a separate data-gathering activity at the individual service level. No central oversight authority common to all three services was apparent to ensure that independent efforts were coordinated or, better yet, consolidated into a single activity that served the needs of all three services. To the extent possible, the needs of all three services should be considered concurrently to maximize the reuse of data and software programs.

In addition to the development of technical plans for data integration, organizational plans needed to be developed to standardize policies and practices related to medical record keeping. As the report was written, guidelines for medical record documentation varied on the basis of the type of data involved (e.g., outpatient, inpatient, and immunization information), the location of the service member (e.g., garrison, deployed, and location of deployment), and the branch of service. The report recommended that policies, procedures, and practices be standardized to store consistent and comprehensive data in the CPR throughout the military.

- Clarify leadership authority and accountability for establishment of an integrated approach to the development, implementation, and evaluation of information system applications across the military services. Establish a top-level technical oversight committee responsible for approving all architectural decisions and ensuring that all application component selections meet architecture and data standards requirements.
- Coordinate the evaluation of information needs for maximum reuse of data elements, data-gathering instruments (e.g., surveys), and software systems across the military health system.
- Develop standard enterprise-wide policies and procedures for comprehensive medical record keeping that support the information needs of those involved with individual care, medical surveillance, and epidemiologic studies.
- Develop methods to gather and analyze retrievable, electronically stored health data on reservists.

There are many challenges to the development, implementation, and maintenance of a health information system to serve the diverse needs of the military. It is not surprising that there are separate activities in each of the services. In some cases, these separate activities are driven by immediate needs; and in other cases, they arise out of a lack of awareness of existing solutions or projects under way elsewhere. To meet the needs of U.S. forces deployed abroad, however, a unified CPR system is essential. The study team recommended that a comprehensive review of the military health information systems strategy be undertaken to enumerate the information needs; define an expedient process for development of an enterprise-wide technical architecture, common data model, and data standards; identify critical dependencies; establish realistic time lines; assess the adequacy of resources; and perform a realistic risk assessment with contingency plans.

With much at stake, the study team recommended that an external advisory board provide ongoing advice regarding the military health information systems strategy. This group
would provide synergy and potential leverage between the military and civilian sectors in information systems.

— Conduct an independent risk assessment of the military health information system’s strategy and implementation plan. Establish an external advisory board that reports to the Secretary of Defense and that is composed of members of academia, industry, and government organizations other than the DoD and the DVA to provide ongoing review and advice regarding the military health information system’s strategy and implementation.

**Risk Communication**

The study team believed that a clear commitment to improvements in risk communication is needed from DoD. Responsibility should be designated to attempt a change in the culture within DoD and the military services so that dialogue about risks is facilitated at all levels. Aspects of risk communication need to be incorporated into the training programs for line commanders and health care providers. Furthermore, discussion is needed within DoD and the services about what problems the tool of risk communication may be used to try to solve. Such a discussion can lead to goals for reducing those problems and means of evaluation and improvement.

Although responsibility for risk communication must permeate all levels of command, the U.S. DoD should designate and provide resources to a group within DoD that is given primary responsibility for developing and implementing a plan to achieve the risk communication goal articulated in Presidential Review Directive 5. Such a plan should

— Involve service members, their families, and outside experts in developing an explicit set of risk communication topics and goals. In other words, decide what information people need to know and when they need to know it.

— Consider how to deliver the information, including the intensity of communication needed for different types of risks. Some topics will necessitate full, ongoing dialogue between the involved parties, whereas others will require less extensive efforts. Incorporate procedures to evaluate the success of risk communication efforts and use these evaluations to revise the communication plan as needed.

— Include a response plan to anticipate the inevitable appearance of new risks or health concerns among deployed forces. The plan should include a process for gathering and disseminating information (both about the risks themselves and about the concerns of the troops) and for evaluating how communications about these issues are received and understood by service members and their families.

— Educate communicators, including line officers and physicians, in relevant aspects of risk communication.

— Carry out the interagency applied research program described in Presidential Review Directive 5, Strategy 5.1.2.

**Reserves**

Several of the most important components of a strategy to protect the health of deployed forces pose particular challenges for the reserve component because of their quasicianvian status and geographically dispersed situation. Although their special circumstances make it impossible to mandate a health protection strategy identical to that for the active duty forces, a coherent strategy should be developed to provide similar programs working toward the same ends that are provided with adequate resources.

— Include the reserves in the planning, coordination, and implementation of improved health surveillance, record keeping, and risk communication. Develop a strategy for the reserve forces that takes into consideration their limited access to the military health care system before and after deployments but that recognizes their particular needs for health protection and that provides adequate resources to meet those needs.

**Strategies Identified by the Third Year Committee**

The strategies selected by the study committee in the third year of the project emphasized several of the recommendations from the interim report described above, as well as recommendations for risk assessment and the collection of environmental and personnel location data discussed in the other strategies reports.

— Strategy 1. Use a systematic process to prospectively evaluate non-battle-related risks associated with the activities and settings of deployments.

— Strategy 2. Collect and manage environmental data and personnel location, biological samples, and activity data to facilitate analysis of deployment exposures and to support clinical care and public health activities.

— Strategy 3. Develop the risk assessment, risk management, and risk communication skills of military leaders at all levels.

— Strategy 4. Accelerate implementation of a health surveillance system that spans the service life cycle and that continues after separation from service.

— Strategy 5. Implement strategies to address medically unexplained symptoms in populations that have deployed.

— Strategy 6. Implement a joint computerized patient record and other automated record keeping that meets the information needs of those involved with individual care and military public health.

**DISCUSSION**

After the Gulf War, DoD demonstrated greater awareness of the importance of medical surveillance and record keeping
in protecting the health of its deployed forces. It launched or planned a variety of initiatives to address acknowledged shortcomings in these areas. These efforts suffered from a lack of the concerted planning required for efficient use of systems and resources. For medical surveillance, this might be addressed with leadership and coordination in the area of military public health. With medical record keeping, outside expert review is needed to provide ongoing input into the challenging effort of implementing a successful CPR for the military.

The medically unexplained symptoms reported by veterans after the Gulf War have motivated many of DoD’s constructive changes in medical surveillance and medical record keeping, but these initiatives cannot be anticipated to prevent them after future deployments. Indeed, it is not yet known how medically unexplained symptoms can be prevented. Better medical surveillance and record keeping can lay the foundation so that similar questions can be more readily answered in the future, however, and permit better insights into questions of etiology.

All told, many of the messages of the Institute of Medicine and National Research Council reports on Strategies to Protect the Health of the Deployed U.S. Forces remain valid and potentially useful today.


Principal Investigators

Samuel B. Guze, Spencer T. Olin Professor of Psychiatry, Washington University School of Medicine.

Philip K. Russell, Professor Emeritus, Department of International Health, Johns Hopkins School of Hygiene and Public Health.

Advisory Panel

Arthur J. Barsky III, Professor, Department of Psychiatry, Harvard Medical School, Brigham and Women’s Hospital.

Dan Blazer II, Dean of Medical Education and J.P. Gibbons Professor of Psychiatry, Duke University Medical Center.

Germaine M. Buck, Associate Professor, Department of Social and Preventive Medicine, University at Buffalo, State of New York.

Charles C. J. Carpenter, Professor of Medicine, The Miriam Hospital, Brown University.

John A. Fairbank*, Associate Professor, Department of Psychiatry and Behavioral Sciences, Duke University Medical Center.

Kenneth W. Goodman, Director, Forum for Bioethics and Philosophy, University of Miami.

Sanford S. Leffingwell, HLM Consultants, Atlanta, Georgia.

Bruce S. McEwen, Professor and Head, Harold and Margaret Milliken Hatch Laboratory of Neuroendocrinology, Rockefeller University.

G. Marie Swanson, Director, Cancer Center and Professor, Department of Family Practice and Medicine, Michigan State University.

Paul C. Tang, Medical Director, Clinical Informatics, Palo Alto Medical Foundation, and Vice President, Epic Research Institute.

Frank W. Weathers, Assistant Professor, Department of Psychology, Auburn University.

Neil D. Weinstein, Professor, Department of Human Ecology, Cook College, Rutgers University.


Committee on Strategies to Protect the Health of Deployed U.S. Forces

Jack H. Moxley (Chair), Managing Director, North American Health Care Division, Korn/Ferry International, Los Angeles.

Ruth L. Berkelman, Senior Advisor to the Director, Centers for Disease Control and Prevention, and Rollins School of Public Health, Emory University.

J. Cris Bisgard, Director, Health Services, Delta Air Lines, Atlanta.

Guy A. Laboa, Executive Director, Dailies Manufacturing, CIBA Vision, Duluth, Georgia.

Layton McCurdy, Dean and Vice President of Medical Affairs, Medical University of South Carolina.

Matthew L. Puglisi, Government Relations Manager, Optical Society of America, Washington, DC.

Lynn A. Streeter, Consultant, Knowledge Analysis Technologies, LLC, Boulder, Colorado.

Elaine Vaughan, Associate Professor, Department of Psychology and Social Behavior, University of California at Irvine.

Lauren Zeise, Chief, Reproductive and Cancer Hazard Assessment Section, California Environmental Protection Agency, Oakland.

REFERENCES


INTRODUCTION

The refinement of concepts and procedures used to protect troops during combat has been an enduring and challenging task of the U.S. armed services since the militia was formed in the 18th century. As time has passed, the nature of environmental threats to the Armed Forces has evolved and expanded along with changes in the conduct and scope of military actions. As a result, force protection has become more complicated from the points of view of prevention, interdiction, response, and control of casualties, to include potential exposure to toxicants. Chemical, radiological, and biological weapons have been readily available as part of military arsenals for over 60 years. Each has been used during military campaigns or individual combat actions. In specific incidences, radiological and chemical toxicants have been used as weapons by various countries against small and large segments of the general population. In addition to potential and actual exposure to hazardous materials within combat zones, there are a number of additional potential human exposure issues raised by the presence of hazardous materials during both combat and non-combat situations. Examples include the aftermath of catastrophes such as the September 11, 2001 (9/11/2001) World Trade Center (WTC) collapse, and the capture and protection of high value facilities and operations, e.g., chemical plants.

EXPOSURE SCIENCE

To provide a baseline for a discussion regarding toxicant exposures, one first needs to define exposure and the applied science that may provide technologies that can protect workers and the public health. Human exposure is defined as the existence of a person and a toxicant in the same place and time, and the occurrence of contact between them. The level of exposure is dependent upon the concentration and duration of contact. However, to be clinically meaningful, the exposure must also be coupled to a biologically relevant duration of contact, specific to a given disease.

The general field of Exposure Science is defined, as published in the Journal of Exposure Science and Environmental Epidemiology by Dana Barr, as follows: The study of human contact with chemical, physical or biological agents occurring in their environments, and advances in knowledge of the mechanisms and dynamics of events either causing or preventing adverse health outcomes.

The activities of exposure science link many components of the environmental health continuum, and these are illustrated in Figure 1.

MINIMIZATION OF DEPLOYED TROOP EXPOSURES

In the National Research Council (NRC) report entitled, “Protecting Those Who Serve: Strategies to Protect the Health of Deployed U.S. Forces,” six important strategies were presented, each based upon the content of previous reports. These are:

1. Use a systematic process to prospectively evaluate non-battle-related risks associated with the activities and settings of deployment.
2. Collect and manage environmental data and personnel location, biological samples, and activity data to facilitate analysis of deployment exposures and to support clinical care and public health activities.
3. Develop the risk assessment, risk management, and risk communication skills of military leaders at all levels.
4. Accelerate implementation of a health surveillance system that spans the service life cycle and that continues after separation from the service.
5. Implement strategies to address medically unexplained symptoms in populations that have deployed.
(6) Implement a joint computerized patient record and other automated record keeping that meets information needs of those involved with individual care and military public health.

Based upon the scope of this manuscript, strategy recommendations 1, 2, and 3 are the focus of the following discussion, but each of the above are necessary to improve the short-term and long-term healths of the deployed U.S. troops. Using the above strategies as a conceptual framework, the overall goal is minimization or prevention of contact with hazardous materials in a given situation. Further, as outlined above and in contrast to many formulations of community-based risk assessments, the first strategy indicates defining the activities and settings that may be encountered, above and beyond those related to battle. Thus, the strategy’s first goal is to accurately define situations that may lead to contact with toxicants. This is the correct approach to providing procedures and training that are focused on avoiding non-combat risk associated with toxicants exposure. Figure 1 illustrates specific locations along a continuum where each of the above strategies can be implemented to either reduce exposure or, at very least, understand the potential consequences of exposure.

The implementation of programs to achieve the goals of each strategy, however, is complicated by the nature, timing, and potential severity of each potential threat, both during and after combat. In the case of combat actions, threats are often direct (immediate) and may come without warning. Post-combat, in the protection of high value assets, for example, threats can be immediate or arise over time. A key to success in either case is the rapidity with which individuals, including exposure scientists and occupational hygienists, can identify the source(s) and agent(s) of concern, characterize exposure pathways, and implement controls. Thus, training in exposure science is a needed specialization within the Armed Forces.

In both combat and non-combat situations, current and as yet undeveloped detection and protection systems are required to reduce the possibilities of contact with a toxicant or to determine the magnitude of contamination before entry into or stabilizing a captured area. Currently, most toxicant detection systems are bulky. They can be deployed on a variety of platforms (e.g., ground vehicles and planes); however, the near-field exposure issues for various types of troop detachments, e.g., platoons of about 40 people, require miniaturized and continuous sensing devices. There is research on such devices, but more needs to be done to harden equipment against the extreme conditions encountered during and after battle. Once collected and validated, data can be stored, transmitted, and used to evaluate the severity of the problems associated with a particular situation.

One problem that may arise is providing criteria on how much data to store and for how long? The relevant question is this: How quickly can information be interpreted to minimize injury or death? In a direct impact situation, one cannot easily deploy monitoring systems during military action, often because of their weight, and the use of miniaturized units for the detection of multiple agents on a real time basis may not be possible. Mobile monitoring and analysis vans could be helpful, but they may be targets during an action. Drone monitoring systems capable of operating in the line of fire should be considered for development. In exposure situations encountered after the completion of an engagement in a war zone,
deployed units may have more time to assess the situation, but the need to react quickly and deploy monitors to prevent and characterize exposures remains.

As noted in the NRC report, post-event issues need much attention since the nature of the deployment often changes from one of aggression to one of protection and re-entry.\(^4\) For such situations, troops may be deployed specifically to guard a unit or a facility from further hostile actions, or contractors who may be completing non-combat-related activities. Since this is a primary mission of the troops, it is important to realize that basic issues of occupational and environmental health and safety need more attention, as a basic component of troop survival. Thus, it is essential to train deployed troops and pre-position exposure science and occupational health personnel for potential post-action toxicant exposure situations. This will increase the probability that adequate personal protection and administrative controls are made available to prevent exposures to toxicants. In each of the NRC reports in the series, there are well-defined steps and activities that provide an overview of major components of the issues.\(^4⁵⁶\) The question may arise as to whether or not such comprehensive steps are correct. They are. During the course of both combat and non-combat activities, troops may not be in a position to do large-scale planning, and will probably be confronted by surprises. The pre-positioning of tools and protocols for entry and sustainability in the aftermath of an engagement is essential for success. However, there are still examples where this has not occurred in a systematic fashion, including the hexavalent chromium piles at the Qarmat Ali Industrial Water Treatment Plant, Basra, Iraq (Review of the U.S. Army Center for Health Promotion and Preventive Medicine Assessment of Sodium Dichromate Exposure at Qarmat Ali Water Treatment Plant. Washington, DC, Defense Health Board. Available at http://www.health.mil/dhb/downloads/2008_DEC_1/05_%20Halperin_QARMAT%20ALI%20DHB%20MTG%2012-15-08.pdf, December 15, 2008; accessed January 21, 2011), and troop encampments that were downwind of the Balad burn pit (Kennedy K: Balad burn pit harmed troops living 1 mile away. Army Times, January 23, 2010. Available at http://www.burn pitlawsuit.com/media/ArmyTimes_Balad-burn-pit-harmed-troops-living-1-mile-away_1-23-10.pdf, accessed January 21, 2011). Each indicates the need for a thorough review of procedures and that the above strategies in noncombat situations.

including the military, and the private sector. The occupational and environmental exposure lessons derived from the events of 9/11/2001 were numerous, and could be evaluated in the context of the NRC Deployed Forces Strategies and implementation framework.\(^4\) They would be associated with NRC strategies 1, 2, and 3.\(^4\) From the WTC aftermath, lessons have been learned; some lessons still need to be implemented to protect the public, and especially response teams.\(^1⁰¹¹,1²,1³,2⁴,2⁵\) The following are major needs identified in the book that relate to exposure response.\(^8\) Included are the specific NRC non-combat deployed troop health protection strategies to which they relate:

1. Need for improved portable and flexible emergency response platform and personal monitors (strategy 2).
2. Need for strategies to ensure that chemical, physical, and biological samples can be quickly collected and analyzed, and sensor data quickly processed on toxicants (strategies 2 and 3).
3. Need for measurement and detection systems that can be quickly deployed on site or available in strategic locations (strategies 1 and 2).
4. Need for accurate information on the processes and toxicants stored at facilities and debris that is disposed of post-engagement (strategy 1).
5. Need for short-term exposure standards and associated methods for detection in the concentration ranges of concern (strategy 3).
6. Need for safe indoor and outdoor clean-up protocols (strategy 3).
7. Design and implementation of highly flexible respiratory protection equipment with communication capabilities and the availability of personal protective equipment for different routes of contact and exposure (strategies 2 and 3).
8. Need to have prepositional situational awareness of potential toxicant contacts and severity of outcomes for an inventory of possible situations (strategy 1).\(^4\)

Many of these lessons were outlined as points of information and need in the NRC 2000 Deployed U.S. Forces report, and should be followed up with detailed protocols and criteria.\(^4\) However, even the military components did not appear to deal effectively with these issues following the attack on the WTC. Possible reasons for this are the rarity of such catastrophic situations, especially on U.S. soil, and the difficulty in obtaining an overview of the major toxicant exposure and health issues in a very short period of time. Without accurate data on the materials that might have been of concern and the levels and duration of exposure during the events that followed the WTC collapse, it was not possible to obtain an informed understanding of the situation regarding acute exposures and health protection responses. Recognition of acute health effects occurred about 1 week after the WTC collapse, when the “WTC cough” was first observed among firefighters and others who arrived at the disaster site before and

THE WTC EXPERIENCE

In “Dust: The Inside Story of the September 11th Aftermath,” a number of points were discussed and examined regarding WTC exposures.\(^8\) Contained in the book is information garnered from government reports, scientific manuscripts, and observations.\(^8⁻²³\) The author’s conclusions were that the country was not well prepared to respond efficiently to the immediate environmental and occupational health issues that arose in the aftermath of the WTC collapse. There was no one particular group to fault, even though many agencies and organizations were involved from different branches of government, including the military, and the private sector. The occupational and environmental exposure lessons derived from the events of 9/11/2001 were numerous, and could be evaluated in the context of the NRC Deployed Forces Strategies and implementation framework.\(^4\) They would be associated with NRC strategies 1, 2, and 3.\(^4\) From the WTC aftermath, lessons have been learned; some lessons still need to be implemented to protect the public, and especially response teams.\(^1¹,1²,1³,2⁴,2⁵\) The following are major needs identified in the book that relate to exposure response.\(^8\) Included are the specific NRC non-combat deployed troop health protection strategies to which they relate:

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immediately after the attack. The identification of victims, in this case first responders, is a typical method for defining a common exposure, but it is not an optimal way to minimize the number of post-event casualties. It is usually indicative of a general lack of information regarding the nature of the toxicants being emitted during an evolving situation. In the case of the aftermath of a terrorist incident like the WTC attack, and in most instances of non-combat deployment, it is doubtful that we will ever have the resources on hand and readily available to definitively characterize the agent or agents of eventual concern immediately after an event. This would include exposures to toxicants during the first minutes to hours after their emission.

Most monitoring devices are expensive, and more importantly, require maintenance and periodic calibration to remain of value. There are systems that operate continuously, and some are currently deployed at strategic locations indoors and outdoors in major U.S. cities, and in mobile units. However, there is no simple way to predict the target of an attack. Further, having devices to detect biological, physical, and chemical agents on call in major cities, and other high target locations, is cost-prohibitive. The best that can be done is having personnel and monitoring platforms available at strategic locations across the country. The mission, then, is to respond as quickly as possible to an exposure event. However, information gathering could still range from minutes to many hours after an event, depending on the location of the event and the closest monitoring equipment and personnel. The full range of tools can be simple or complex in nature, but to achieve the goals of NRC Strategies 1 through 3, they need to address the components shown in Figure 2. Each tool or activity is needed for observation, measurement, and control of potential exposures.

**WTC LESSONS AND NRC’S TROOP PROTECTION STRATEGIES 1, 2, AND 3**

**Strategy 1**
The collapse and disintegration of the WTC towers into dust and the associated fires was an unanticipated aftermath of the terrorist attack. However, the earlier 1993 terrorist attack on the WTC did provide guidance for evacuation procedures, and those procedures likely saved lives. Further, the nature of the collapse, and disintegration of all building materials and contents into dust, was not even a remote consideration as potential components of human exposure. The lesson that has been learned is this: Do not assume anything other than the worst. The collapse of modern buildings yields complex exposure situations because of the nature of the construction and materials. The toxicant profile resulting from the collapse of modern buildings is, for example, very different from that of older buildings or of those in many developing countries. Therefore, if National Guard or other military units are to be deployed to guard such a site of destruction, there needs to be training as to the hazards for health and injury around such a location. Also, during intervention, the leadership must define what protective equipment needs to be worn before entry into the area. An inventory of exposure conditions was warranted but unavailable at the WTC. Thus, use of proper respiratory protection was not strictly enforced. A series of training exercises for situations such as the WTC collapse could identify gaps in knowledge and the types of protective gear needed at a site.

**Strategy 2**
The WTC collapse clearly illustrated that an integrated approach to the collection of data on dust and smoke was needed. Data were collected initially for the presence of radiation and selected hazardous substances. Furthermore, inventories of potential sources of toxic chemicals (e.g., chlorofluorocarbons) were made. The New York Fire Department (NYFD) also took biological samples from firefighters to examine levels of gases and other materials that may have been inhaled during activities at ground zero. The latter effort proved to be important in discounting the significance of mercury exposures at ground zero. Thus, management of two concerns for noncombatant situations had partial successes in the chaos.

Initial assessments of the potential hazards that may have led to exposure were crippled at the WTC because of the lack of instrumentation. Two of the most apparent reasons for this were the lack of portable devices to collect particles and gaseous material in dusty situations, and the lack of understanding that the immediate concern was short-term exposures to dust and not the potential long-term effects caused by asbestos exposure or fine particles. The mindset at the time was focused on low-level exposure and long-term disease outcomes. In fact, we have drifted back to that position over the past few years, even though the NRC has continued the important work of developing Acute Exposure Guidelines for highly toxic substances, which will be of benefit in non-combat deployed U.S. forces situations. These will also enhance the selection of the tools related to the capabilities highlighted in Figure 2 that are appropriate for a particular situation or suite of toxicants.

There have been improvements in the types of monitors that can be put on various platforms for use, but I still have not seen updated total particulate matter mass samplers which, in

![FIGURE 2.](image-url) Elements that must be considered in developing information gathering tools and exposure metrics for deployed U.S. Forces.
retrospect, would have been capable of quantifying a major issue of concern. Training in acute exposure intervention and prevention is still needed in civilian situations, and should be a priority for training of military personnel for combat and non-combat activities (NRC Recommendation 2 in Strategy 2). In non-combat and combat situations, leaders of deployed forces should follow the NYFD example. Biological markers may not be a comprehensive marker of exposure, but in an acute exposure situation they can give valuable information on exposure to a wide variety of potential toxicants. The corollary is an absolute need for a field laboratory to process these samples quickly. Biomarkers, however, cannot take the place of sensors for real time understanding of likely hazardous agents. Biological markers are useful only after exposure may have occurred.

Strategy 3
Risk management, assessment, and communication are valuable evaluation tools. The effectiveness of each is dependent upon the accuracy of information and the speed at which advice can be effectively transferred. Within the WTC aftermath, the initial messaging was at best confusing and many times conflicting in depth and level of accuracy. There were many reasons: providing reassurance with limited information, poor data on the hazards and time course of acute exposures, multiple entities being in charge, and an inability to say, “We do not know, yet.” All the above contributed to the initial chaos. In a military action or post-battle exposure event, there needs to be clear and effective lines of communication, members of a team that can interpret data, and officers who will understand the meaning of the interpreted data. Most important are the professionals who can provide guidance and recommendations on how to proceed. In the aftermath of the WTC collapse, the messaging improved over time.

DEPLOYED TROOP CONTACT WITH TOXICANTS
Theaters of action can yield a number of situations that involve direct troop encounters with toxicants. However, they will be finite in number, and there are specific types of materials that can be surmised or assumed to be highly likely toxicants of concern. Some toxicants and situations will demand data be collected immediately, whereas others will allow a reasonable time for assessment and implementation of protective measures. Concurrently, the location and number of military forces potentially in harm’s way will be finite, and there will be some documentation about their locations in space and time. Thus, single or multiple sampling and monitoring platforms can be pre-positioned and, if necessary, be made available to military units for use during a specific deployment. The response to an event or detection of an event can be faster based upon the availability of, and proximity of, monitoring equipment to deployed personnel. Future detection platforms should include drones with detection devices in the theater of operations during an engagement with an enemy.

A more difficult task for environmental and occupational exposure specialists is the post-action security tasks that may require troop deployment in areas such as oil fields, chemical plants, contraband destruction (incineration) sites, and power plants. Of further importance is the fact that not all countries have the same environmental and occupational regulations as the United States, and some may have virtually none. Thus, one may assume nothing regarding safety, and one must be alert for the need to wear personal protective equipment and enforce administrative controls to safely guard such facilities. Consequently, monitoring equipment needs to be available, and surveys conducted to characterize the potential exposures that may be encountered before establishing permanent security or conducting other similar activities. Subsequently, monitoring and surveillance need to be formalized for the deployed troops who guard contractors and others during the destruction of contraband and other operations relating to critical infrastructure and facilities. Thus, the protection of the deployed troops would include information required for achieving risk minimization to prevent contacts at the points along the continuum in Figure 1. In addition, it must be remembered that during the re-entry and restoration of a facility the nature of the hazards can change, which indicates the need for regular communication among the individual contractors and Armed Forces units to ensure protective measures are adequate for the conditions encountered as time passes and conditions change. In the articles by Lioy et al about the aftermath of the WTC disaster, it was shown that the nature of the exposures and those potentially exposed changed over time at and around ground zero. The evolving situation was one of many different issues that lead to the lack of information about what responders and others were being exposed to at various points in time and locations. This tended to confuse the interpretation of messages, and in some cases led to overinterpretation or misinterpretation of the potential acute and long-term health outcomes caused by exposures at various points in time. For situations involving deployed forces that are designated to guard a facility or area with identified or suspected hazards, it is essential to provide current information on the need for and the level of protective equipment or administrative controls during all phases of re-entry, restoration, and rehabilitation.

CONCLUSIONS
The NRC documents available on protecting our deployed troops provide a good management framework for protection of health and safety during actions and activities that can lead to contact with toxicants. This said, it is important to develop and test a series of protocols that can ensure that monitoring and analytical capabilities are in the field at critical times that provide real-time or quasi-real-time data and information on suspected or known toxicants. The platforms that should be available for use at a facility may include both personal sensors and portable monitors mounted in a vehicle. A variety of samplers should be tested, including those which measure physical, chemical, and biological materials. Thus,
as troops are deployed in an area, either during combat or after combat activity, there will be some reasonable probability that equipment is available to detect toxics, and that, if measured, strategies and personal protection devices are available to reduce casualties during or after the hostile action. There are some devices currently available, especially for use during hostile action, but these need to be systematically introduced as part of a series of practical protocols that one can use to minimize the reoccurrence of problems generated by materials like Agent Orange. However, such devices may not preclude situations like the Gulf War syndrome, which appeared to be a multiple chemical sensitivity among a fraction of the deployed troops. It remains to be determined how such low level contacts and exposures can be easily quantified on a battlefield or in a staging area, but the Acute Exposure Guidelines do provide a baseline for development of exposure monitors and entry protocols.

ACKNOWLEDGMENTS

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REFERENCES

Exposure Science in U.S. Military Operations: A Review

LT Nicholas J. Martin, MSC USN*; CPT Erin E. Richards, MS USA†; Jeffrey S. Kirkpatrick, MS‡

ABSTRACT Since 1991, the U.S. Department of Defense has conducted deployment occupational and environmental health surveillance activities in the geographic combatant commands for major conflicts, military exercises, and humanitarian and peace-building missions. The DoD has made significant improvements in documenting and assessing deployment environmental hazards and threats since 1991, illustrated by accomplishments in Bosnia, Kosovo, and Operations Noble Eagle (following the September 11, 2001 terrorist attacks); Enduring Freedom-Afghanistan; and Iraqi Freedom (2003–2010). Sampling is now recommended as part of the DoD Exposure Assessment Method, a dynamic process that is performed during all phases of military operations: I—Predeployment, II—Mobilization, III—Conflict, and IV—Postdeployment. From 2001 to 2009, deployed personnel collected over 24,500 air, water, soil, and bulk samples during operations. These efforts have lead to the creation of an environmental health surveillance database that has been used to investigate public health issues. However, gaps exist, especially in the assessment of individual exposures during deployment.

INTRODUCTION
Experience from the 1991 Gulf War indicated that preventive medicine and environmental health measures could have received greater emphasis during the predeployment and deployment phases. Efforts to address occupational and environmental exposures were greatly accelerated after the conflict (i.e., postdeployment) as concerns about the long-term effects of exposure of U.S. Forces to oil fire smoke became an issue. As concerns about new Gulf War illnesses surfaced with recent military conflicts, assessing all environmental exposures became critical. The U.S. Department of Defense (DoD) did not want to repeat the experiences of the 1991 Gulf War and Agent Orange in Vietnam. A program to understand environmental risks at locations of military interest where U.S. Forces might operate was developed.

Since 1991, the DoD has conducted deployment occupational and environmental health (OEH) surveillance activities in the six geographic combatant commands for major conflicts, military exercises, humanitarian missions, and peace-building activities. These deployment OEH surveillance efforts have included the collection, analysis, and reporting of results from over 24,500 air, water, soil, and other (e.g., bulk material) samples worldwide. Sample collection was accomplished by deployed Preventive Medicine, engineer, Civil Affairs, and contract personnel.

Deployment OEH surveillance samples have been collected routinely for installation, site and activity baseline, and periodic and closing assessments, as well as for incident responses. The results of sample analyses and associated health risk assessments have been reported through official documents, electronic means, and oral communications. A 2005–2007 U.S. Central Command Enhanced Particulate Matter Surveillance Study was evaluated in detail. Over 80% of the collected samples were determined to be valid when quality assurance and quality control measures were reviewed for field collection, transportation, and analysis. Table I outlines requirements for deployment OEH surveillance sampling, focusing on Force Health Protection and the need to document known or potential exposures during military operations. Deployment OEH surveillance measures are identified in DoD, Combatant Command (COCOM), Component Command, and services publications.

The objectives of OEH surveillance conducted by military environmental health professionals in deployed settings are very similar to the objectives of OEH sampling in the U.S. civilian sector. These include monitoring the health of people and the identification, characterization, and assessment of environmental exposures. The primary differences between military exposure assessments in deployed settings and civilian efforts are the underlying assumptions of the exposed populations (e.g., healthy, working military people who are mostly young adults vs. healthy and ill civilians of all ages), lengths of exposures, nature of exposures, and the limitations of collecting samples and data during military operations.

The ultimate goals of exposure science are to identify and evaluate risks, to assess potential disease associations, and to develop and implement control strategies using the data and information collected. Consideration must be given to food, water, air, and soil that may be contaminated with chemical, radiological, or biological agents. Military environmental health professionals collect air, water, soil, and bulk samples that most closely reflect the exposures of deployed personnel for risk assessments using the best practices possible. In this report, we review and discuss in detail the DoD methods.

*Uniformed Services University, 4301 Jones Bridge Road, Bethesda, MD 20814.
†421st Multifunctional Medical Battalion, CMR 467 Box 1457, APO AE 09096.
‡U.S. Army Public Health Command (Provisional), 5158 Blackhawk Road, ATTN: MCHB-IP-R, Aberdeen Proving Ground, MD 21010-5403.
Exposure Science in U.S. Military Operations: A Review

DoD AND USEPA METHODS

Table II lists basic assumptions used in the DoD and EPA methods.10,13–15 The EPA method is based on the National Research Council’s 1983 document entitled “Risk Assessment in the Federal Government: Managing the Process” and the EPA Risk Assessment Guidance for Superfund (RAGS).12,14 The model used by the EPA was developed with the assumption that anyone in the United States could be exposed during work, at home or accidentally at any time. This acknowledges that sensitive subpopulations, such as children and pregnant women, could be at risk of exposure. Age-dependent adjustment factors have been developed to account for increased sensitivity of younger exposed populations when using the EPA risk assessment process.14

TABLE I. Deployment Occupation and Environmental Health Surveillance Requirements2–6

<table>
<thead>
<tr>
<th>Required OEH Reports and/or Data Submissions</th>
<th>Combatant Command or Service Components Submit to the Deployment OEH Surveillance Data Portals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline OEH Assessments With Accompanying Data:</td>
<td>No Later Than 30 Days After Report Completion</td>
</tr>
<tr>
<td>— Preliminary Hazard Assessments and/or OEH Intelligence Preparation of the Battlefield Assessments</td>
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<tr>
<td>— Predeployment Site Surveys</td>
<td></td>
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<tr>
<td>— OEH Site Assessments</td>
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<tr>
<td>— Base Camp Assessment Team Reports</td>
<td></td>
</tr>
<tr>
<td>Routine OEH Surveillance Reports With Accompanying Data:</td>
<td>No Later Than 30 Days After Report Completion</td>
</tr>
<tr>
<td>— Environmental Sampling Reports</td>
<td></td>
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<tr>
<td>— Industrial Hygiene Surveys</td>
<td></td>
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<tr>
<td>— Preventive Medicine Unit and Situation Reports</td>
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<td>— Analytical Summaries</td>
<td></td>
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<tr>
<td>— Veterinary Service Food and Bottled Water Sanitation Audit Reports; Veterinary Laboratory Food, Bottled Water, and Zoonotic Disease Test Results; and Veterinary Medicine Zoonotic Disease Data</td>
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<tr>
<td>— Disease Vector Surveillance Reports</td>
<td></td>
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<tr>
<td>— DoD Form 1532-1, “Pest Management Record” (DoD Instruction 4150.7)</td>
<td></td>
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<tr>
<td>Incident Response Reports With Accompanying Data:</td>
<td>Initial Reports Shall Be Made No Later Than 7 Days After an Incident or Outbreak. Interim and Final Reports Shall Be Forwarded No Later Than 7 Days After Investigation and Report Completion. Combatant Command Will Forward Copies of Reports to the Deployment OEH Surveillance Data Portals for Archival</td>
</tr>
<tr>
<td>— OEH and Disease Outbreak Reports</td>
<td></td>
</tr>
<tr>
<td>— OEH Exposure Incident Reports (Severe or Unusual Occurrences) Including Rosters of Exposed or Potentially Exposed Personnel</td>
<td></td>
</tr>
<tr>
<td>— Chemical, Biological, Radiological, Nuclear (CBRN) Incident Reports (Including Acute and/or Catastrophic Exposures to Toxic Industrial Chemicals and Materials, and CBRN Warfare Agents)</td>
<td></td>
</tr>
<tr>
<td>All Raw OEH Surveillance Data and Other Reports:</td>
<td>No Later Than 30 Days After Redeployment of the Preventive Medicine, Bioenvironmental Engineering, Veterinary, and/or Environmental Health Unit Responsible for Sampling and Report Preparation</td>
</tr>
<tr>
<td>— On Redeployment, All Raw OEH Data: Air, Water, Soil, Toxic Industrial Chemicals and Materials, and Veterinary Public Health Including Food and Bottled Water Safety, and Zoonotic Diseases</td>
<td></td>
</tr>
<tr>
<td>— Any OEH Reports Not Previously Submitted</td>
<td></td>
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<tr>
<td>— All After-action Reports and Lessons Learned Reports</td>
<td></td>
</tr>
</tbody>
</table>

TABLE II. Assumptions for USEPA and USDoD Risk Assessment Methods10,13–15

<table>
<thead>
<tr>
<th>EPA Assumptions</th>
<th>DoD Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure Duration</td>
<td>— During Working Hours (8 Hours/Day, 5 Days/Week) for Commercial-industrial/Occupational Receptors</td>
</tr>
<tr>
<td>Exposed Population</td>
<td>— Up to Lifetime Exposure for Residential Receptors</td>
</tr>
<tr>
<td></td>
<td>— 1–2 Hours/Day for Less Than 100 Days/Year for Trespasser/Recreational Receptors</td>
</tr>
<tr>
<td></td>
<td>— Entire Spectrum of U.S. Populations, Including Sensitive Populations, Such As Children</td>
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<tr>
<td>Acceptable Risk</td>
<td>1 in 10^8–10^9 Increase in Excess Cancer</td>
</tr>
<tr>
<td></td>
<td>— “Healthy and Fit” 18–55 Year Old Service Members</td>
</tr>
<tr>
<td></td>
<td>— Exposed Individuals Are Assumed to Be 70 kg Spheres</td>
</tr>
<tr>
<td></td>
<td>1 in 10^8 Increase in Excess Cancer Risk</td>
</tr>
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</table>

for OEH surveillance and exposure assessments. U.S. Environmental Protection Agency (EPA) methods are also reviewed and contrasted with DoD methods.

TABLE II. Assumptions for USEPA and USDoD Risk Assessment Methods10,13–15

for OEH surveillance and exposure assessments. U.S. Environmental Protection Agency (EPA) methods are also reviewed and contrasted with DoD methods.

DoD EXPOSURE AND RISK ASSESSMENT

Figure 1 illustrates the timeline of events that resulted in the evolution of the DoD risk assessment model from its
inception in 1991 following Presidential Review Directive 5, which addressed future deployments and their impact on the health of military members and their families. From the lessons learned from the 1991 Gulf War, military operations in Serbia and Kosovo, and more recent global operations, the current exposure assessment methods were developed. The underlying assumptions regarding exposure vary for different military operations; deployed military personnel may be exposed to environmental stressors, such as heat, as well as chemicals in air through inhalation, water through ingestion, and soil through absorption, ingestion, or inhalation. These exposures are expected to be transient, lasting less than 7 days, or may persist up to 1 year. Deployed military personnel are assumed to be “healthy and fit” individuals (a healthy work force) between the ages of 18 and 55 years. The DoD risk assessment model places a greater emphasis on acute effects that may quickly impact military operations, rather than delayed health effects.

The DoD exposure assessment method is a dynamic process that is performed during the four defined phases of military operations, summarized in Figure 2: I—Predeployment, II—Mobilization, III—Deployment and conflict, and IV—Postdeployment. This review focuses on the deployment sampling efforts for Phases I, II, and III. Phase I (Predeployment) preliminary hazards assessments (PLHA) are conducted using the Global Threat Assessment Program developed by the U.S. Army Public Health Command–Provisional (USAPHC-Prov, formerly the U.S. Army Center for Health Promotion and Preventive Medicine, Aberdeen Proving Ground, Maryland). The Global Threat Assessment Program identifies potential health threats on the basis of information from previous military exposure assessments. The program produces Phase I OEH assessments that are disseminated via the secret internet protocol router network (SIPRNET). These documents are developed with input from and for the staffs of the COCOMs, Component Commands, Joint Task Forces, military services, and medical planners for global locations of interest.

Information is also obtained from the U.S. Intelligence Community, to include: the National Center for Medical Intelligence, Fort Detrick, Maryland; the National Geospatial-Intelligence Agency, Fort Belvoir, Virginia; and the National Ground Intelligence Center, Charlottesville, Virginia. The information obtained contributes to processes known as “Intelligence and information preparation of the environment” and “Intelligence preparation of the battlespace.” These services are provided for all branches of the U.S. military and the COCOMs. As the Phase I assessments are performed, equipment, sampling media, and training required for the Phase II and III missions are identified. Additionally, any unique hazards or threats that may require special surveillance or sampling methods are identified, and actions are taken to procure the special equipment and supplies that will be needed by the deployed environmental health personnel to identify and assess the hazards and threats. The PLHAs are used for the development of the composite risk management program for the mission.

During Phase II (Mobilization), environmental health personnel are equipped, supplied, and trained to assess the hazards identified in the PLHA. This training may include
USAPHC-Prov and personnel from other services performing tactical assistance visits in which the operational and technical aspects of the Deployment Occupational and Environmental Health Survey (OEHS) are reviewed and training is provided for deploying units.

Exposure assessments conducted during Phase III (Deployment) are usually done by forward deployed environmental health professionals with back-up support from USAPHC-Prov; the Navy and Marine Corps Public Health Center, Portsmouth, Virginia; and the U.S. Air Force School of Aerospace Medicine, Dayton, Ohio. The deployed environmental health personnel conducting the OEH assessments work from forward operating bases, contingency operating bases, and base camps. Environmental health resources may also be stationed at other locations identified by the COCOM, Component Command, or task force, or specified in Annex Q of the operation plans.

The actions above support a two-part process of sample collection and analysis. Deployed personnel collect information and samples in the field. Full sample analysis is not performed in the field; air, water, soil, and bulk samples are sent to fixed laboratory facilities in the United States and Europe. Public health facilities with laboratories, such as USAPHC-Prov, analyze the samples and generate risk assessment reports for the deployed locations. Deployed environmental health personnel use prepackaged sampling kits based on EPA methods to collect the water, soil, and air samples.

Deployed environmental health personnel are tasked with preparing an OEH site assessment within 30 days of the establishment of an operating site. Assessments incorporate results from the field inspections and sample analyses, to include vector surveys and testing results for air, water, and soil samples, along with information from the PLHA. These data and the information collected are used to create a conceptual site model (CSM). The CSM identifies complete and potentially complete exposure pathways for deployed personnel.

The DoD exposure methods rely on the collection of representative composite or point samples to evaluate exposure pathways for deployed personnel. This approach does not create exposure data for individuals; instead, this is inferred from the collection of representative samples. This can be validated by a subset of personal samples taken during deployment or postdeployment for biomarker testing. Sample analytical results are reported and archived by collection location in the Defense Occupational and Environmental Health Readiness System (DOEHRs)-environmental health module and the deployment OEHS data portals, which are maintained by USAPHC-Prov. These repositories, which are available for use but still under development, allow health providers to review possible deployment exposures at locations of interest and assess potential health outcomes.

EXAMPLES OF DEPLOYMENT SUPPORT

Completed Phase I assessments include the evaluation of storage tanks targeted in air campaigns during Operations Allied Force and Joint Guardian (Kosovo). The assessment was updated as conditions changed, with the initial exposure assessments for toxicant inhalation being updated to include...
absorption and ingestion routes due to changes in the field conditions as military operations progressed.

Historic exposure assessment data from the oil well sabotage efforts from the 1991 Gulf War (Operation Desert Storm) were reviewed and used in the preparation of a Phase I assessment for Iraq, as part of the more recent Operation Iraqi Freedom (OIF). Procedures for monitoring and responding to environmental conditions related to oil fires caused by sabotage were provided to the U.S. Central Command (CENTCOM) Surgeon. Specific information for air, soil, and water sampling methods and responses to contaminations were provided to the OIF operational planners in the event sabotage of the oil industry occurred.

Deployed personnel have collected over 24,500 air, water, soil, and bulk samples related to U.S. military during operations from 2001–2009. These samples included predeployment baseline samples, routine samples, and incident-specific samples that were used to build, document, and assess conceptual models for operating sites. These samples were collected in all six geographic COCOM areas of responsibilities in over ninety countries (Table III).

The ambient air sampling and surveillance conducted at Joint Base Balad, Iraq, in 2007 in response to concerns associated with solid waste burn pits is an example of how sampling and CSMs were used to identify and assess inhalation hazards. These air surveillance efforts provided enhanced data and information that helped to characterize the risk of possible acute and long-term health effects due to smoke exposure. Since service members may be affected by longer-term health effects, possibly due to combined exposures (such as sand, dust, industrial pollutants, tobacco, and other agents) and individual susceptibilities, study of the burn pit data and information continues.

LIMITATIONS
Extensive efforts and resources have been expended since 1991 to ensure applicable, appropriate sampling and documentation, reporting, and assessment of exposures. Advances in technology, use of commercial off-the-shelf sampling equipment, and novel information management and technology systems have enhanced these efforts for two decades. The DoD is far ahead of the deployment OEH surveillance efforts completed in 1991. However, the DoD still has gaps to address, to include: developing personal sampling devices that are feasible for use in hostile areas; being able to identify daily troop locations; and tracking health outcome from deployment to civilian veteran status.

There also remains the question of how much and what type of data should be collected for exposure assessments. Much of the data collected to date are environmental data that characterize a location, but do not include variations in personal exposure, such as occupational exposure, individual variations in susceptibility, and the use or absence of personal protective equipment. Wild discusses the need to collect personal exposure data and evaluate exposure biomarkers for individuals to formulate an “exposome,” a composite personal exposure history. The DoD has limited experience with biomarkers dating back to the Gulf War. Following the Gulf War, Army soldiers’ exposures to polycyclic aromatic hydrocarbons (PAHs) were evaluated using a DNA–PAH biomarker. In addition, as part of a biologic surveillance, initiative blood volatiles, blood and urine metals, and sister chromatid exchanges were also evaluated. The use of biomarkers to improve individual exposure assessment was incorporated into the Joint Task Force (JTF) 180 (Afghanistan) campaign plan for deployment OEH. In this plan, medical personnel were recommended to carefully consider implementing a program for using exposure biomarkers to identify and document exposure to selected OEH hazards. A biomarker decision criteria flow chart was developed to include an appendix on the use of state-of-the-art technologies with means and methods to assess and document both individual and unit exposures. Biomarkers were to be used in situations only when the test was reproducible, validated, and quantitatively relatable to the relevant range of exposures.

Although the use of biomarkers may help determine the identity and magnitude of exposure to military personnel, there are concerns related to how best to store and access the large amount of data generated for area and individual samples. The data management system demands are large, and a system that links location and individual exposure data to patient records in the military and Department of Veterans’ Affairs systems is not currently available. An additional concern is how this large amount of data would be analyzed and assessed in a timely and comprehensive manner for military planning. In 1997, MG Patrick Sculley (Ret.) stated “we know more about the environmental health conditions in Bosnia than in some cities in the USA.” However, the value of such data is limited if the link to human exposure cannot be made.

The successful completion of exposure assessments during military operations (III—Deployment and Conflict) is difficult because of numerous limitations related to military operations, logistics, technology, and sampling opportunities. During military operations, exposure assessments for deployed personnel are only one of the many factors used in planning. Military operations are ultimately planned by warfighters who must balance the mission requirements personnel

<table>
<thead>
<tr>
<th>TABLE III.</th>
<th>Phase I Assessments Completed During 1999–2009 by COCOM</th>
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<tbody>
<tr>
<td></td>
<td>No. Locations</td>
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<td>Central Command</td>
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<tr>
<td>Africa Command</td>
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<tr>
<td>Total</td>
<td>489</td>
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MILITARY MEDICINE, Vol. 176, July Supplement 2011 81
and logistical constraints with health concerns. Environmental exposure assessments usually are not a very high priority concern. Additionally, exposure assessment equipment and supplies must be transported to remote locations. During transport, acceptable storage conditions may not exist, time between sample collection and analysis may exceed method recommendations, and supplies may be delayed due to limited logistic capabilities. Most field sample collection and analysis equipment is not designed for the rigors of field work. With extreme temperatures, high ambient air particulate matter, varied power supply, and limited space for large equipment, military field conditions are not hospitable for most analytical gear. Even if sampling equipment and supplies are available, they may not be deployed due to operational constraints, such as lack of cargo space. Physical security considerations, insufficient time on site, and restricted access to sampling sites also hinder the efforts of environmental health personnel who are trying to collect representative samples.

Because of the limitations and difficulties associated with working in a deployment area, sampling efforts must be focused on evaluating completed exposure pathways identified during site assessments and CSMS. By identifying hazards with the greatest exposure risk, prioritized sampling plans can be prepared that maximize the use of environmental health assets.

CONCLUSIONS
The DoD has made significant improvements in documenting and assessing deployment environmental hazards and threats since 1991. Programs have been established in the military services to execute and report deployment OEH surveillance for all deployment phases. This has led to the creation of an OEH surveillance database that has been used for the investigation of public health issues. However, gaps exist in our ability to develop individual exposure assessments during deployment. The DoD Preventive Medicine community has responded to the need to identify and define hazards in Operation Enduring Freedom-Afghanistan, OIF, and other deployments with tools that did not exist in the last millennium. The DoD Initial Capabilities Document for Joint Force Health Protection identifies capability gaps and shortfalls and provides recommended solutions for the 2015–2025 time frame. Achieving accurate, real-time analyses of health threats, risks, and trends of interest with shared medical intelligence remains a significant goal. Achieving this goal should greatly facilitate risk management activities, the development and implementation of effective countermeasures, and effective risk communication.

REFERENCES

2. U.S. Department of Defense: Instruction 6490.03, Subject: Deployment Health (original publication date: August 7, 1997), August 11, 2006.
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The Basis for and Uses of Environmental Sampling to Assess Health Risk in Deployed Settings

Coleen Baird, MD, MPH

ABSTRACT The ultimate goals of environmental sampling are the protection of health, or barring that, the assessment of health impact to exposed populations. However, environmental samples collected for undefined or poorly defined reasons and that are not part of a feasible strategy of hazard identification, intervention, and follow-up will likely be of limited value. Military commanders and their advisors must be aware of the need to quickly identify potential hazards and to respond appropriately with a comprehensive plan that may include sampling. Before samples are collected, the following must be adequately addressed: (1) the reason for sampling, (2) the parameters to be measured, (3) the possible range of results that might be obtained, and (4) the actions that will be taken in response to various results. Additionally, communication of the risks to commanders and the potentially exposed population is important, particularly if the results are inconclusive.

INTRODUCTION
Following the first Gulf War, the Department of Defense (DoD) and the Department of Veterans Affairs faced basic questions of exposure, outcome, and association. The Presidential Advisory Committee on Gulf War Illness noted that potential exposures included pesticides, chemical warfare agents, biological warfare agents, vaccines, pyridostigmine bromide (a pretreatment for nerve agent exposure), infectious diseases, depleted uranium, oil well fires and smoke, and petroleum products. The Presidential Advisory Committee considered the investigation of possible exposures “superficial and inadequate.” The Institute of Medicine noted that very little personalized exposure information was available, and that defining relevant control groups and obtaining information for them was very difficult. It was noted that the lack of exposure data limited even the most expert and well-funded investigation to identify health outcomes likened to specific exposures or risk factors. Similarly, the Government Accounting Office noted that “while … epidemiological research will provide descriptive data on Veterans’ illnesses, methodological problems are likely to prevent the researchers from providing precise, accurate, and conclusive answers regarding the causes of the veterans’ illnesses. Without accurate exposure information, the investment of millions of dollars in further epidemiological research on risk factors or potential causes for veterans’ illnesses may result in little return.” The recommendations, however, lacked specificity regarding what constituted “accurate exposure information.” The Institute of Medicine suggested that “DoD should ensure that military medical preparedness for deployments includes detailed attempts to monitor natural and manmade environmental exposures and to prepare for rapid response, early investigation, and accurate data collection, when possible, on physical and natural environmental exposures that are known or possible in the specific theater of operations.” The phrase “when possible” acknowledges that there may be competing priorities or missions, and the range of suggested potential exposures is broad, including all that are “known or possible.” This data collection would presumably require a broadening of the concept of operational health support beyond prevention (where possible), recognition, and treatment of injury and disease as it occurs. Ideally, sampling results would be available real time or timely so that preventive measures to reduce exposure could be taken when warranted. However, also implied in the recommendations are broad anticipatory sampling and a longitudinal assessment of individual exposures and their potential health impacts, which would occur long after the samples have been collected, analyzed, and archived. Complexity arises because the longitudinal component extends beyond the mission of the Preventive Medicine assets in theater at a location, and crosses into the mission of the U.S. Army Medical Command (MEDCOM) post-deployment.

THE CONCEPTUAL BASIS OF SAMPLING
During the Bosnia/Kosovo operations, sampling of air, water, and soil was conducted to address these exposure concerns. The approach involved both focused and unfocused sampling. Unfocused sampling is used here to describe a sample taken without a clear concern or specific target analyte based on potential hazards. Soil without visible staining, dead vegetation, or other indicators of potential contamination can be analyzed largely as a screening measure. Gray water, nonpotable and used for shower or other purposes, can be sampled. General air samples can be evaluated for particulate matter...
(PM) levels and other potential airborne contaminants. Gas chromatography and mass spectroscopy allow for the detection of a staggering list of analytes from a sample. When a compound is detected, a peak and spectrum are identified and compared against a library of “knowns” and quantitative results are provided. Particularly for soil, the number of pesticides, metals, and other potentially detectable compounds is long. Yet, DoD Directive 6490.03 required that “all significant exposure data must be documented on an SF 600 or equivalent” and required that periodic monitoring summaries be documented on an SF 600. The SF 600 is a medical form for use in medical records. This directive’s intent was to implement a comprehensive deployment health program that effectively “anticipates, recognizes, controls, and mitigates health threats encountered during deployments.” However, it became clear that posting this information in the medical record would be problematic for a number of reasons—the exposure pathway for an individual is not necessarily complete, the concentrations would be unintelligible to most nonoccupational medicine providers, and the duration of exposure would be unknown. Additionally, identifying a “significant” exposure requires a comparison of a concentration against a guideline comparison value, and a consideration of the potential implication if that exposure occurred over an extended duration. This generally requires longitudinal sampling and the creation of an integrated exposure assessment for an individual. Isolated sample results typically have limited health implications, particularly for long-term/chronic conditions which are associated with extended exposure durations.

Focused sampling, based on a reasonably anticipated hazard in association with an operation or activity, is typical in the industrial hygiene (IH) model. The results are compared to the appropriate standard. When the result is below the standard, there may be no further action. When it is above the standard, several actions may follow to include reducing the exposure through appropriate controls, medical surveillance of individuals, or epidemiological studies on groups. Findings from sampling, surveillance, or epidemiology can serve to inform potential health implication assessments and workers compensation claims, if appropriate. If conditions change, additional sampling may be performed.

Although the broad environment does not easily lend itself to this model, some components are similar and some expectations of the process are the same. An industrial hygienist may anticipate the hazards based on the known operations, with subsequent reassessment. Occupational Safety and Health Administration guidance generally notes that if an operation changes, it should be reassessed. In a field environment setting, hazards may be identified during the Phase 1 assessment (an intelligence-based reassessment) or during the Occupational and Environmental Health Site Assessment. The Occupational and Environmental Health Site Assessment is an on-the-ground assessment of the location and includes identifying potential hazards. These may then be evaluated with focused sampling. However, in dynamic environments such as base camps potentially located near industry, with trash burning operations, and off-base burning by local nationals, ambient PM, and other potential concerns, it is difficult to characterize exposure, extrapolate beyond the period of sampling, and identify the population exposed. In the workplace/IH model, results are compared to a standard based on an 8-hour exposure, assuming that the results represent typical exposures. Environmental conditions, in contrast, are expected to vary. Potential hazards related to trash burning would vary with the volume, nature of items burned, moisture present, wind, and burn temperature, as would ambient PM. Therefore, it is difficult to know when sufficient sampling has been accomplished to adequately characterize an environment as opposed to a fixed operation. Additionally, in complex environments, samples may be analyzed for multiple potential hazards. PM is typically analyzed for particulate level in two size fractions and a variety of metals concentrations. Most ambient air samples are analyzed for a class of compounds such as volatile organics. Each of these compounds has a reference standard or guideline. To each result, the same questions should be posed—Is there an immediate health risk present? Does the measured level of contamination pose a health risk to currently exposed populations? Is there a health risk present to future populations if exposed to this level? If this exposure was ongoing, is there a concern for a chronic or delayed health outcome? If the time from sampling to analysis is delayed, is there any concern for populations exposed in the past? After the fact, is it possible to identify who was exposed? How will the results of multiple samples with multiple exposures be integrated? These questions limit the ability to use the traditional IH model. If the population at risk (exposed) is not defined, epidemiology will be limited by exposure classification. If the hazard is a complex mixture, this might impact the ability to generalize from available toxicology or to conduct adequate toxicology studies. The military Post-Deployment Health Assessment form and process allow for self-reported exposures, but there is evidence that Soldiers do not accurately report their exposures, even when a clear exposure incident has occurred. This limitation may significantly influence the ability to adequately predict and monitor for health outcomes of concern, which can impact the ability of the U.S. Department of Veterans Affairs to assess service connection.

Despite the intuitive appeal of data when the absence of data has been criticized, the lack of clear and specific questions directing the sampling undermines the utility of the findings. A laboratory sample with a field data sheet noting “burn pit,” which is analyzed for volatile organic compounds, could have been taken to answer the question, “Does the burn pit produce levels of volatile organics sufficient to cause irritation to people standing at the spot where it was collected?” However, if the sampling point represents the burn pit perimeter where there is no exposed population, then that question has no relevance. In current deployed operations, samples are taken by forward personnel, but often analyzed in the rear.
Unless clearly identified, the population at potential risk is not known. Rotating personnel and variable assets often mean that follow-on sampling will be performed by different personnel at a later date, and results may be returned to Preventive Medicine assets covering a broad geographic area.

PLANNING FOR RESULTS

There is an often cited phrase “Never order a test without a plan for the results.” Although this may seem obvious, it is often overlooked. Many a medical student has ordered a full panel of serum chemistries on a patient with no specific concerns, only to get back a result or two in the abnormal range. While there was no specific question asked, there is now an abnormality to be explained. The differential diagnosis must be considered and evaluated in this individual patient. Laboratory test request slips require an ordering physician’s name because the presumption is that a medical doctor wishes to know the specific answer to a specific question about a specific patient. Although the laboratory can discuss the parameters of the test, the result must be evaluated in the context of the individual patient and his/her history. Thus, the ordering physician is responsible for determining the relevance of the finding in his patient.

So it should be with environmental sampling. Sampling should be done when there is specific information needed, and a planned use for that information. For example, samples are taken of stack emissions to determine compliance with air quality standards and to ensure that filtration is effective. Criteria pollutants are monitored to assess air quality and inform the public or sensitive subpopulations to minimize outside physical activity when air quality might impact their health. Air samples should be taken to answer a question, not to fulfill a requirement. In deployed settings, the sample may be taken by someone with minimal training, who understands sample collection, but not interpretation. However, there is an implicit assumption that the sample collector does so under the direction or plan of someone else who is interested in the answer. In the current deployed setting, forward deployed Preventive Medicine assets collect these samples and understand what they represent far better than the laboratory doing the analysis. Commonly, however, sampling is viewed as a requirement, done on behalf of the supporting rear Service Surveillance Center, under the assumption that they will know why it is needed and what to do with the results.

SAMPLING AS A GUIDE FOR ACTION

A finding of an acute hazard, assuming that the result is available near real time, should prompt control of the exposure, documentation of the condition of those exposed, and treatment if appropriate. For example, if an improvised explosive device (IED) releases acutely toxic levels of chlorine, the only control possible might be removal from the location, followed by the evaluation and documentation in a medical record of acute findings, which are important if subsequent health outcomes occur. However, the finding of a measured level of a contaminant just above a guideline or reference without clear acute health implications will generally lead to recommendations for additional samples. A report may identify a potential risk and recommend additional sampling to identify the source, and determine if the finding persists, and thus represents a potential chronic exposure. Particularly in deployed settings, with rotating personnel, it is important that recommended follow-on sampling occur and be documented and assessed. Given the emphasis on chronic health risks in the current Joint Chiefs Memorandum on deployment health, one current approach advocated by the Central Command is the integration of individual sample results into periodic summaries for a location that provide an assessment of the long-term conditions at a location. These documents are being created by the Services in a consensus format to address the potential for chronic health outcomes, and risk, and to inform medical considerations post-deployment in the military health care system. Equally important is the follow-up of individuals with specific acute exposures, as appropriate. Current practice depends on the documentation of an acute exposure in the medical record at the time of the evaluation and would rely on the examining physician’s assessment and plan to suggest potential follow-up. For individual exposures to chemical warfare agents, the MEDCOM has policies for reporting and long-term follow-up. Additionally, depleted uranium exposures are assessed and followed per a specific MEDCOM policy. With these exceptions, there are few deployment-related exposures that are systematically evaluated and followed on a regular basis by policy.

POTENTIAL EPIDEMIOLOGICAL USES OF SAMPLING DATA

Early in Operation Enduring Freedom/Operation Iraqi Freedom, ambient sampling identified that PM levels were elevated compared to U.S. levels and were present at levels potentially associated with adverse health outcomes. Data from epidemiological studies based in the United States had identified a number of acute and chronic health concerns, but these effects were identified in study populations to include children, adults over age 65 years, and those who had chronic conditions and as such were a somewhat different population than deployed forces. Additionally, it was recognized that PM in Southwest Asia was likely different in composition than the PM in the United States. As a result, a more extensive, every sixth day sampling effort was initiated and supported by Central Command forward deployed Preventive Medicine assets. The samples were analyzed for concentrations and numerous other parameters, such as levels of metals. Following this effort, two epidemiological studies were conducted to evaluate potential associations with health outcomes. One attempted to correlate acute in-theater health events with days when PM levels were high. However, given the every sixth day sampling, events which occurred on days
without sampling data could not be evaluated. As a result of
this and the fact that the overall number of events was low,
this effort suffered from low power to detect an association.
The other study identified populations at the base camp loca-
tions where sampling was conducted and compared to post-
deployment health outcomes. To do so, a variable associated
with the PM exposure had to be created and a decision was
made to construct a time-weighted average based on the
every sixth day sampling. The PM levels were divided into
quartiles, and the assessment evaluated whether increasing
events occurred with increasing quartiles of exposure. While
this study also failed to identify a dose-response increase in
health effects, it was also noted that the every sixth day sam-
pling may have been insufficient to characterize the exposure,
and that the constructed exposure variable may not have been
sensitive (e.g., if peaks were more important).

The PM sampling had not been designed specifically to
support epidemiological studies, but was undertaken when
the sampling results were unclear as to potential health risk.
Therefore, the studies attempted to utilize the data, recogniz-
ing that there were data limitations. When health concerns are
raised in populations for which there is some exposure data,
there will often be some pressure to attempt to utilize the ex-
posure data to assess health outcomes. Historically, in the field of
occupational medicine, this approach was used to assess poten-
tial human health effects associated with occupational cohorts
for whom limited sampling existed. It was recognized that
questions arose concerning the generalizability of intermittent
sampling, and whether it represented peak or average expos-
ures. Many of these studies suffered from potential misclas-
sification, were too small to have sufficient statistical power
to detect elevated rates of significance, and lacked informa-
tion on confounding variables such as smoking. Given the cur-
rent availability of potentially large deployed populations and
their health outcome data, there will likely be attempts to use
somewhat insufficient exposure data to evaluate potentially
associated health outcomes. It should be recognized that the
lack of individual exposure data can result in misclassification
as a substantial limitation. Information on confounding vari-
ables is rarely available; relatively rare events are difficult to
assess reliably; and large sample sizes and testing of multiple
hypothesis and associations may lead to findings of statistical
significance based on chance.

COMMUNICATING SAMPLING RESULTS

Traditional preventive medicine support in deployments
assessed and controlled sanitation, pests, and vectors and
focused largely on infectious disease threats and recommen-
dations regarding exposure to heat and cold. The outcomes
likely to occur if such measures were not taken were largely
straightforward and known, and most often fairly immediate:
increased rates of diarrheal or other infectious diseases, or
environmental conditions such as heat stroke and frostbite.

Water evaluation and treatment largely focused on chlorine
disinfection. In contrast, current approaches include testing
water for a suite of metals, volatile organics, and other possi-
ble contaminants. This raises some interesting questions. What
is the appropriate level of detection or concern? Presidential
Review Directive 5 directed DoD to “identify and minimize
or eliminate the short and long-term health effects of mili-
tary service …When making decisions, commanders should
attempt to quantify long-term health effects that any action
may have on their troops.”

In a combat environment, it can be assumed that Com-
manders will be only vaguely interested in information that
does not guide their choice among courses of action. If the
road is flooded, another path would be chosen, if available and
without additional risks. If the road is contaminated because
of a chemical spill, a similar decision might be made. In the
second instance, a staff officer should provide the risk infor-
mation to the commander in a format similar to other risks.
For example, if the unit travels through the contaminated area,
50% will suffer eye and throat irritation sufficient to inter-
fere with vision, but lasting only 6 hours. A small percent-
age might suffer longer term complications, which would
impact the mission when the unit arrives at the location. If
the alternative is a road suspected to be littered with IEDs,
with a far greater operational impact, the choice of a course of
action considers the available competing risks. This analysis
would not be possible if the assessment of the contamination
required samples that would be sent back to a rear supporting
laboratory. Of the available Military Exposure Guidelines, the
most infrequently used are the acute, short-term air expo-
sure guidelines, because these levels are so rarely detected
and documented. These levels are identified by direct reading
equipment, often not available at the site of the unintended
exposure. In the example provided earlier of a chlorine release
in association with an IED, it would be unusual to have detec-
tion equipment on hand. In less-than-acute situations, even
if results were available immediately, most situations where
the concern is for longer term or chronic health outcomes
would require additional sampling over a longer time window
because chronic concerns are typically the result of long-term
exposure. Invariably, it is difficult to quickly gather suffi-
cient quantitative exposure information to inform immediate
decisions. This can be frustrating to the Preventive Medicine
asset asked to conduct additional sampling based on sampling
performed, and to Commanders who have to choose among
courses of action. The risk matrix for operational risk manage-
ment classifies risks in a table as yellow, red, and black as the
risk increases. Gray (unclear results) is not in the matrix.

ACKNOWLEDGING THE LIMITATIONS OF
SAMPLING TO ANSWER ALL QUESTIONS

When a large burn pit utilized for waste management at Joint
Base Balad, Iraq, was identified as a potential health con-
cern, sampling of the air for contaminants was conducted
and used in a health risk assessment. As some data limita-
tions were identified, additional sampling was considered.
Although media and Congressional interest in the question of
potential health effects related to burn pits created some urgency, it was difficult to obtain consensus on the plan for additional sampling. There was a wide range of objectives based on a variety of stakeholders, their interests, and areas of technical specialty. In the initial draft of the sampling plan, no less than eight objectives were identified, although many were not likely to be achievable. These ranged from characterizing ambient air at the perimeter of the burn pit to predicting health risk to potentially exposed populations and conducting epidemiological studies with the exposure data. Although all the objectives had value, and all addressed likely questions and concerns from a range of parties to include commanders, individual service members or providers, and Congress, some of these objectives exceeded the reasonable uses of planned data collection. For example, short-term, intermittent sampling would be unlikely to support long-term epidemiological studies.

WILL THE HAZARD BE RECOGNIZED?
It is an unproven assumption that deployed Preventive Medicine assets will recognize an environmental hazard when encountered and initiate an assessment to identify an acute or chronic risk. In 2003, a Special Medical Augmentation Response Team-Preventive Medicine was requested to assess a potential exposure to sodium dichromate at a looted water treatment plant. Looting had resulted in the dispersion of bags of sodium dichromate, an orange powder containing carcinogenic chromium VI. An extensive assessment of the site, remediation, and physical examinations of those at the site was conducted. Sometime later, concerns were raised about individuals not present at the time of the evaluation when levels may have been higher. Media coverage included individuals who described being covered in orange powder and large piles of orange dust. However, there is no indication that these individuals raised a concern near their time of alleged exposure, even though there is at least one report of acute health effects occurring. Ideally, the presence of a colored powder that was irritating to individuals who were in the vicinity would prompt a request for assistance to assess the potential implications. However, available information indicates that this did not occur until a new unit arrived in the area. Because some environmental hazards are not obviously identifiable and there is often limited information regarding the nature and degree of exposure, it is not uncommon for individuals to relate health outcomes to ill-defined past potential exposures (“post hoc ergo propter hoc”—after this, therefore/because of this). This often generates requests for sampling results or questions as to why sampling did not occur.

IF SAMPLING HAS LIMITATIONS, CAN OTHER METHODS ASSESS EXPOSURE?
An article discussing inadequate exposure assessment during the first Gulf War notes that “… we need methods to make risk management decisions in the field, which requires the identification and measurement of significant exposures … if an exposure which causes ill health is not accurately identified and measured for later research, any association and causal link may not be identified, especially if the association is only of weak to moderate strength.” Based on known incidents that have occurred in the current theater and that have been archived in the military Occupational and Environmental Health Surveillance Data Portal, when exposures of acute significance occur, they typically come to attention through the symptoms of those exposed. Direct-reading equipment to measure and document the exposure is rarely available at the exact location needed during short-lived events, but it is probably reasonable to assume that exposures, which result in acute symptoms will be evaluated medically, recognizing that health care seeking behavior may differ in deployed settings when compared to garrison situations.

However, the authors recognize that “… environmental hazards such as chemical, physical, or radiological hazards where the exposure pathways are less well defined, where there may be longer latency period and the connection between exposure and disease is not well established, exposure assessment becomes much more challenging.” Recognizing limitations to sampling and documentation of exposures, Glass summarized epidemiological studies relating to Gulf War Illness. Out of 29 studies, 21 utilized self-reported exposures. The authors discuss numerous problems and considerations with this approach, although self-reported exposures have long been utilized in occupational studies, particularly case-control studies. They also noted four studies where exposure was estimated from personal measurements, including biological monitoring data, notably for depleted uranium (DU). The DU long-term follow-up is a rare example of specific and regular individual assessments with a variety of diagnostic measures. The program is fully funded and serves as a prospective active registry to evaluate health outcomes associated with documented DU body burden, either due to imbedded fragments or due to inhalation exposure under specific circumstances. Another study mentioned polycyclic aromatic hydrocarbon DNA adducts in a group of soldiers potentially exposed to oil well fires. What is not mentioned related to this assessment is that this type of biomonitoring for DNA damage was rarely done and so interpretation of the prognostic significance was limited. The question of “what will the results mean and how will they be communicated?” had not been well explored.

Is there a risk to providing individuals with unclear or incomplete answers regarding potential environmental exposures? If sampling is conducted, but the findings are not generally available or communicated to the service members, how does this influence their perceptions? One author noted that belief in past exposure to chemical warfare agents due to alarms or other potential indicators that were not confirmed has been shown to correlate with current ill health. Additionally, in a longitudinal study, those Gulf War Veterans
who were sick tended to increase the number of exposures they reported over time.  

In the previously cited article on exposure assessment by Glass, the authors suggest that occupational exposure methodology can provide insights into the exposure assessment process. However, they also note that one of the major tools in occupational epidemiology studies involves job exposure matrices. The evidence from occupational studies suggests that between any two workers with the same job title, the actual mix of tasks and the time spent on each may vary and that between worker and within worker differences can lead to considerable differences in exposure even in those with the same job title. “This is particularly true in a war environment where troops may move between units and into several different environments over a short period of time.” It would seem that given different locations, duties, microclimates on a base camp, meteorological conditions, and other variables, constructing job exposure matrices would be insufficient, or at a minimum, difficult to validate as a useful measure of exposure. What is presumably needed is an “all exposure” matrix that addresses complicated microclimates of exposure and integrates changing exposures and multiple deployments over time. But how would this be constructed in the absence of detailed information and data?

WHY DO WE SAMPLE?

It is inevitable in the years following a major conflict that some individuals will become ill absent any exposure, but most individuals will consider the potential role of exposures when an unexpected health outcome occurs. When individuals raise potential health concerns, doing something seems appropriate. Sampling is something. Data are attractive. Almost universally, the data collection is not designed to support epidemiological studies. Reviewing epidemiological studies conducted around hazardous waste sites in the United States, the Committee on Toxicology of the National Academy of Sciences noted that attempts to use intermittent sampling data to assess the risk for long-term health outcomes invariably led to inconclusive results. They cited limitations to include lack of individual exposure data, low power, nonspecific health outcomes, recall bias, latency, and exposure misclassification. Many of these limitations stemmed from the use of available data that was not collected to support an epidemiological study.

Samples should be interpretable in their own right, or linked to a specific prospective follow-up study with specific questions. This would require that the samples are taken within the framework of the prospective cohort study, which is often not practical in a military theater. Establishing a prospective cohort study may be unrealistic when the priority is to assess the safety of a population in real time, not for follow up. The ultimate goal of sampling is the protection of health, or barring that, the assessment of health impact to exposed populations. However, in order for the latter to occur, sampling must be part of an overall strategy that identifies credible potential hazards, characterizes them, acts on the findings, and identifies and follows known exposed populations. This process continues long after the wind has changed direction and conditions have changed and the unit has packed up and returned home, to the time when concerns are raised and claims are filed. If the sampling cannot support the ultimate connection to human health, then the important question remains … “Why do we sample?”

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Panel 1: Medical Surveillance Prior to, During, and Following Potential Environmental Exposures

Kelley Brix, MD*; COL Francis L. O’Donnell, MC USA (Ret.)†

ABSTRACT This review assesses the Department of Defense approach to medical surveillance of environmental exposures during deployments. Seven steps in the process are reviewed: (1) exposure assessment, (2) identification of the target population, (3) surveillance for current exposures, (4) surveillance for long-term effects, (5) record keeping for environmental data, (6) analysis of surveillance data, and (7) communication of results. Exposures need to be evaluated as soon as they are recognized, and potentially exposed individuals should be identified at the time of the exposure. Long-term health surveillance relies primarily on electronic medical records. Department of Defense databases are powerful resources for surveillance for service members, up until the time of separation. The Millennium Cohort Study is tracking the health status of 150,000 service members for 21 years, including after separation. Risk communication principles should be incorporated when reporting surveillance results. Often, there are several interested audiences, in addition to military leaders and service members.

INTRODUCTION

The symposium on “Assessing Potentially Hazardous Environmental Exposures Among Military Populations” focused on the evaluation of potential health effects of environmental exposures during deployments. The symposium included five panels that discussed specific aspects of the Department of Defense (DoD) response to exposures. This review is the outcome of a panel that examined the current DoD approach to medical surveillance of environmental exposures, including identification of successes, problems, and possible solutions to these problems.

Medical surveillance during deployments was codified in 1997 in DoD Instruction 6490.3: Implementation and Application of Joint Medical Surveillance for Deployments. Several requirements in this Instruction resulted from lessons learned during the 1990–91 Gulf War. Several aspects of surveillance were updated and defined in more detail in 2006 in DoD Instruction 6490.03: Deployment Health. This review is directly relevant to many requirements in these two Instructions.

This review is divided into seven steps in the medical surveillance process, as follows:

1. Exposure assessment
2. Identification of the target population
3. Medical surveillance for current exposures
4. Medical surveillance for long-term health effects
5. Record keeping for environmental monitoring data and electronic medical records
6. Analysis and interpretation of medical surveillance data
7. Communication of results of medical surveillance to service members and their senior leaders

EXPOSURE ASSESSMENT

Occupational medicine surveillance encompasses the systematic collection, analysis, and dissemination of data on groups of workers and workplaces for the prevention of illness and injury. The symposium focused on service members as the “workers” and the operational theater as the “workplace.” Occupational medicine surveillance programs are usually tailored to the results of occupational or environmental sampling. Sampling for potential hazards in air, water, food, and soil in theater should be performed in near real time; that is, sampling and laboratory analysis should be performed during or soon after the time of a suspected exposure. Two of the four other symposium panels focused on environmental monitoring in theater.

In some situations, a concern about a potential environmental exposure leads to the establishment of a medical surveillance program, even though there are no recognized illnesses at the time. During the 1990–91 Gulf War, there were some individuals who had potential exposure to depleted uranium. The population who had the highest potential exposure was identified through an exhaustive investigation of all friendly fire incidents. First, the investigators identified military units involved in friendly fire; then, they identified the impacted...
vehicles and the individuals in the vehicles. DoD provided the names of individuals involved in friendly fire incidents to the Department of Veterans Affairs (VA) for long-term medical follow-up. Sixteen years after the exposure, some individuals with embedded depleted uranium fragments continue to excrete very high levels of uranium in their urine. However, there is little evidence of clinically significant health effects attributable to uranium. This surveillance program will continue indefinitely. 7

In some situations, illnesses in service members, which are possibly related to an exposure, prompt the initiation of a medical surveillance program. For example, in June 2003, a fire accidentally ignited at the Mishraq State Sulfur Mine in Iraq burned for almost a month. The smoke plume contained various contaminants including varying concentrations of sulfur dioxide and hydrogen sulfide. 8,9 A roster was prepared during the incident that included 191 firefighters and support personnel, such as medics. Some firefighters experienced irritation effects, minor burns, and blood-tinged nasal mucous, but no serious health effects were recorded at the time. Firefighters were evaluated with physical exams before they were released from duty at the site; and entries were made in their medical records documenting the exposure in response to the sulfur fire.

To plan for future medical surveillance programs, DoD could prioritize the most frequently encountered or the most serious environmental exposures. Some environmental exposures recur during different operations; therefore, a standardized medical surveillance program could be developed. This program could then be adapted and applied to specific environmental exposure incidents. For example, during the 1990-91 Gulf War and Operation Iraqi Freedom, exposures were documented for high concentrations of ambient particulate matter and combustion products (from oil well fires and burn pits). 10-14 DoD could develop a surveillance program for respiratory exposures that are frequently encountered in theater. Prioritization for developing model programs could be based on factors such as:

- frequency of exposures to specific chemicals or chemical mixtures (such as combustion products)
- potency of the chemicals
- likelihood of a substantial absorbed dosage
- likelihood of health effects, based on the potency and absorbed dosage
- severity of health effects (such as cancer)
- number of service members who could have potential exposure

**IDENTIFICATION OF THE TARGET POPULATION**

The target population must be identified for inclusion in a medical surveillance program. If the exposure is ongoing or recent, it is much easier to identify the potentially exposed population and to perform medical evaluation on the target group. There is no substitute for the development of a complete, accurate roster of exposed individuals, which is collected during or right after the time of the exposure. The roster must be developed and archived so that it can be retrieved easily at a later time.

If a specific roster is not possible, individuals can be classified into proposed exposure groups by military unit, workplace, or particular occupational specialty. Sometimes, the exposure groups can be estimated by using the geographic location of the exposure, relative to the known location of military units, during a particular time period. This spatial–temporal approach would be more effective for a more stable population in a fixed location, such as some Air Force units, compared to Army and Marine units that are very mobile in theater. In some cases, the need for medical surveillance is not recognized until long after the exposure occurred. Reconstruction of possible exposures to military units and individual service members is extremely difficult years after exposure. It is often difficult to identify the individuals who had the highest exposure, or even to differentiate the individuals who had some exposure from the individuals who had no exposure.

In some situations, environmental sampling indicates that particular individuals had had moderate- to high-level exposures. In addition, other individuals might have had low-level exposures, but they are frequently more difficult to identify. For example, during the Mishraq Sulfur fire, some firefighters had definite exposures to the smoke. However, the exposures were not solely limited to the immediate vicinity of the fire. At times, sulfur dioxide was detected at concentrations that could cause symptoms as far away as a U.S. base that was 25 km south of the fire. However, environmental sampling of the smoke plume was limited, beyond the immediate vicinity of the fire. In 2004, the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM), Aberdeen Proving Ground, MD, initiated a health study that focused on the firefighters. In 2006, USACHPPM expanded the study to include 6,341 service members who were within 50 km of the fire. 8,9 In situations like the sulfur fire, it is difficult to draw the line between a population with low exposure and a population with no exposure.

Occasionally, an astute clinician identifies a cluster or pattern of unusual diseases in deployed service members. If the disease is serious enough or rare enough, it could be identified before an exposure is recognized. In these situations, the pattern of disease drives the medical surveillance, rather than the results of environmental monitoring. For example, in Iraq in 2003, several cases of severe eosinophilic pneumonia were diagnosed in soldiers, who required respiratory support. These cases were thoroughly investigated, but a definitive link could not be made to an infectious etiology or to a specific environmental exposure that the cases had in common except new-onset smoking. 15,16

**MEDICAL SURVEILLANCE FOR CURRENT EXPOSURES**

Medical surveillance uses a variety of methods to assess health status, including questionnaires, physical examinations,
laboratory tests, and review of the electronic medical records. When service members return from deployments, two questionnaires are used, the Post Deployment Health Assessment (PDHA) and Post Deployment Health Reassessment (PDHRA). These assessments include general questions about symptoms and about environmental exposures. However, the questions do not yield adequate details on time of onset and severity of symptoms or on location and duration of exposures to be useful for medical surveillance. In addition, these questions rely on the ability of the service member to recognize potentially hazardous exposures and to recall them accurately for as long as several months later.

The PDHA and PDHRA were not designed for, nor should they be used in, epidemiological research. For example, in 2003, National Guard members who worked at Qarant Ali, Iraq, were potentially exposed to sodium dichromate. USACHPPM performed environmental monitoring and medical surveillance of these soldiers on site. USACHPPM personnel advised the soldiers to mention sodium dichromate exposure on their PDHA when they returned home. Despite this extra risk communication effort, only 24% of the soldiers reported the exposure. The USACHPPM personnel concluded: “The PDHA is a risk assessment and risk communication tool that has sources of misclassification, and results must be interpreted with caution when individual or population occupational and environmental risks resulting from deployment are assessed.”

In medical surveillance programs, biological monitoring and other laboratory testing are designed to detect early biological changes. Biological monitoring can demonstrate that exposure has led to absorption of a chemical, even if the concentrations are too low to cause disease or a change in organ function. Examples of biological monitoring tools used in the military include: lead concentrations in blood, uranium concentrations in urine, cholinesterase levels to detect exposure to nerve agents and organophosphate pesticides, and radiation dosimetry badges. The biological half-life of a chemical must be considered in a surveillance program. Often, a surveillance program is established months or years after exposure, so biological monitoring cannot be used.

DoD has archived serum samples since 1985, when the DoD Serum Repository was established to preserve serum that was collected for HIV testing. Starting in 1997, DoD has mandated the collection of a serum sample from each service member within 1 year prior to deployment, and a second sample within 30 days after return from deployment. Currently, the repository contains more than 50 million serum specimens. Paired sera for individuals, which were collected before and after deployment, have been used in a number of seroconversion studies of infectious diseases. In the future, paired sera from the repository could be used to evaluate serum concentrations of potential toxins or biological effects after deployments. These frozen specimens have advantages, in that they could be analyzed years after a deployment, and there would be less concern about the biological half-life of the chemical.

Laboratory tests can be used to evaluate the function of target organs that are impacted by environmental exposures. Relevant tests include pulmonary function tests (PFTs), chest X-rays, and blood tests for liver or kidney function. The tests should be selected to be as sensitive and specific to the particular exposure, as possible. However, there are always multiple, possible reasons for abnormal results on lab tests. For example, abnormal results on PFTs after a deployment could be due to high-level exposures to particulates in theater, proximity to burn pits, preexisting asthma, exposure to allergens at home, and/or cigarette smoking. Abnormalities on PFTs are not specific and could be due to many factors, which leads to difficulties in determination of causation.

Baseline testing is sometimes needed to assist in the interpretation of results of postexposure testing. This is particularly true for the interpretation of PFTs, because a baseline PFT is needed to detect changes in lung function over time. For example, the lung function could have declined substantially after a deployment in a particular individual, but the measurement could still be within the normal range. After the Mishraq sulfur fire, some potentially exposed individuals reported shortness of breath on exertion. Despite their symptoms, some of these individuals had normal results on their PFTs. Clinical interpretation of these apparently normal PFT results would have been more meaningful if changes in pulmonary function had been documented over time. However, predeployment PFTs were not available. In contrast to this military population, periodic PFTs were performed on firefighters and emergency response workers in New York City, before September 11, 2001. One year after inhalation exposure to debris from the clean-up of the World Trade Center, 12,781 of these workers demonstrated a significant decline in lung function. This decrement in lung function was persistent during the next 6 years. These changes over time could be documented because baseline PFTs were available before the clean-up, and periodic PFTs were performed afterward.

MEDICAL SURVEILLANCE FOR LONG-TERM HEALTH EFFECTS

Long-term medical surveillance is warranted for some environmental exposures, such as exposure to carcinogens or some respiratory hazards. Environmental exposures in Iraq and Afghanistan could possibly lead to long-term effects. The potential hazards include particulate matter and combustion products (smoke from burn pits, and smoke from oil well fires during the 1990–91 Gulf War). Multiple surveys demonstrated an increased rate of self-reported respiratory symptoms in veterans of the first Gulf War. Most Gulf War veterans were deployed for a few months. Some of them experienced substantial exposures to oil well fire smoke for short periods, which were documented by USACHPPM. Nonetheless, there was no increase in the rate of diagnosed respiratory diseases in veterans during the first 10 years after the Gulf War,
based on objective measures of disease, including medical exams and PFTs.\textsuperscript{21}

In the Millennium Cohort Study (MCS), 9,210 service members reported a significant increase in the rate of new-onset respiratory symptoms after deployment to Iraq or Afghanistan, compared to the rate of new-onset symptoms reported over time by 29,783 service members who did not deploy. The deployed group did not report an increase in the rates of new-onset asthma, chronic bronchitis, or emphysema after deployment, compared to the rates reported by the non-deployed group. These findings warrant longer-term follow-up in the MCS.\textsuperscript{22} At the time of the symposium in May 2010, the Armed Forces Health Surveillance Center, Silver Spring, MD, the Naval Health Research Center, San Diego, CA, and the U.S. Army Public Health Command, Provisional, (USAPHC, formerly the USACHPPM) were performing several analyses to determine if there were health effects associated with exposure to the burn pits in Iraq.

DoD inpatient and outpatient electronic databases are powerful resources for medical surveillance. To perform long-term surveillance, an accurate roster of exposed individuals is needed, as well as a method to track the location of individuals over time. DoD can track medical conditions in electronic records only up until the time of separation. This means that long-term surveillance is difficult for the great majority of service members if DoD databases are the only source. The MCS is the only long-term, prospective study that is evaluating the health of the active duty, Reserve, National Guard, and veterans who have separated. More than 25\% of the 150,000 participants in the MCS have already separated. The MCS is tracking the location of its participants from enrollment in 2001 to 2022 and is conducting health surveys every 3 years.\textsuperscript{23}

The VA maintains inpatient and outpatient databases that could be used for long-term surveillance. Currently, the VA provides 5 years of free medical care to all service members who have returned from a combat zone. Approximately 46\% of eligible combat veterans have enrolled in VA medical care in recent years. This means the current health status of about 46\% of recent combat veterans can be assessed using VA databases.\textsuperscript{24} However, substantial barriers exist to the sharing of medical data between DoD and VA. Currently, VA has little access to data or awareness of environmental exposures in the military. Also, VA does not share medical data of individual veterans with DoD unless those individuals have given informed consent. In general, only about 20\% of veterans of all eras use VA as their main source of health care over time. VA has conducted studies that demonstrated that these 20\% are not representative of all veterans. The 20\% who seek VA care have higher rates and severity of disease, higher rates of unemployment, and lower incomes, compared with veterans who do not seek VA care. Overall, the longer-term health status of 80\% of veterans cannot be assessed solely through the use of DoD and VA databases. The MCS will help address this deficiency because it is tracking a large, representative population over time.

RECORD KEEPING FOR ENVIRONMENTAL MONITORING DATA AND ELECTRONIC MEDICAL RECORDS

Record keeping of environmental data and the use of paper vs. electronic medical records present some challenges to long-term surveillance. One of the four other symposium panels focused on these topics in detail; therefore, only a few issues will be highlighted here.\textsuperscript{25} The USAPHC currently archives all environmental sampling results from theater, for all three services. The USAPHC has been improving its system of archiving these records to make retrieval of records easier and more complete. One challenge is environmental reports from theater often remain classified for years because of operational concerns. The USAPHC publishes fact sheets about unclassified environmental exposure incidents on its web site.\textsuperscript{8,10,14,18}

The services sometimes develop paper records of environmental exposures, which are placed into the service member’s theater medical record. For example, the Air Force develops paper reports called Environmental and Occupational Health Workplace Exposure Data summaries. In addition, the USAPHC is developing site-specific “deployment exposure summaries” for individual base camps, based on sampling data, which are called Periodic Occupational and Environmental Monitoring Summaries. These are intended to be used by service members and health care providers to aid in medical evaluation of potential exposures and related health effects.

In some cases, a very complete report on an environmental incident is written, but the report goes into the USAPHC archives, and not into the medical records. In general, paper records of exposures are not incorporated into the individual’s electronic medical record after returning home. Even if an environmental report is included in the individual’s paper medical record in theater, it will not be incorporated in the electronic medical record at home.

Electronic records of inpatient and outpatient visits in theater or of medical evacuations could be analyzed to look for short-term health effects. However, these records are incomplete because of the difficulties in achieving universal electronic medical records of all health care encounters in theater. In general, there is no way to flag or identify individuals who had a particular environmental exposure through the use of electronic medical records. For example, a search using the term “burn pit,” to identify exposed individuals, cannot be performed using electronic records.

ANALYSIS AND INTERPRETATION OF MEDICAL SURVEILLANCE DATA

DoD inpatient and outpatient databases have a number of advantages for surveillance. Capture of health care data for active duty members is relatively complete in the United States because of their universal health care coverage. No similar comprehensive system exists that can capture the breadth of health care data in the civilian population. These databases include millions of records; therefore, analyses based on these
databases can achieve high statistical power. In addition, these databases can be analyzed using standardized definitions of specific medical conditions. For example, DoD has adopted standard definitions for use in surveillance of Reportable Medical Events, which are primarily infectious diseases. This provides comparability of results of different studies over time. Recently, DoD also developed standardized definitions for surveillance of traumatic brain injuries and posttraumatic stress disorder.

Geographic or temporal trends in the rates of a disease could indicate a deleterious effect of an environmental exposure. However, this requires accurate determination of the specific population at risk, in terms of a relatively circumscribed geographic location and a limited period of time. In most situations, misclassification of exposure would reduce the likelihood of detecting an association between exposure and disease. This is a very real concern if there is no accurate way to identify the group of individuals who had high or moderate levels of exposure. For example, drawing a 50-km radius around the Mishraq sulfur fire would likely lead to the inclusion of a large number of service members who had little or no exposure to the smoke. Misclassification of exposure is one of the most common and most serious methodological problems in environmental epidemiology, in general.

COMMUNICATION OF RESULTS OF MEDICAL SURVEILLANCE

Communication of risk to the affected service members should be an integral part of conducting surveillance in response to environmental exposures. There should be a clear plan to present the results to leadership, to service members, and to other stakeholders. The findings should be framed in terms of actions that could be taken. Risk communication principles should be incorporated to prevent the creation of either unnecessary anxiety or a false sense of security. Study strengths and limitations must be clearly explained. One plenary presentation and one of the four other panel discussions focused on communications. Therefore, only a few issues will be highlighted here.

During or soon after an exposure, interested stakeholders would include active duty and Reserve members, unit leaders, senior military leaders, and military physicians, as well as other groups, such as family members. Years after an exposure, interested stakeholders could include veterans, family members, VA medical and disability benefits staff, veteran service organizations, Congress, Government Accountability Office, and the news media.

DoD is continually working to improve the credibility of its communications on environmental exposures. There are a number of methods that DoD uses to increase the public trust in its messages. DoD frequently requests evaluations of its scientific reports from expert panels. These include the Defense Health Board, the National Academy of Sciences, and the Institute of Medicine. Most of the panel experts work for universities and are not connected to DoD. For example, DoD requested the National Academy of Sciences to review the studies related to particulate matter exposure in Iraq and Afghanistan.

DoD often collaborates with other government agencies on health studies. For example, DoD collaborates with the Centers for Disease Control and Prevention, an agency that has high public trust and credibility. DoD also publishes its health studies in peer reviewed medical journals, which is essential to ensure scientific rigor and credibility within the scientific community. For example, DoD published its evaluations of particulate matter exposure in theater in a peer reviewed journal. Also, researchers who are conducting the MCS follow a policy of publishing their findings in peer reviewed journals, and they have published more than 30 journal articles, to date.

SUMMARY

This review of DoD’s approach to medical surveillance considered seven steps in the process. The first two steps are the most critical to success. Ideally, the exposure should be assessed in near real time to determine the types and concentrations of chemicals or other exposures (such as radiation), the geographic extent, and the duration. The service members who were potentially exposed need to be identified during or soon after the exposure. Years after an exposure, reconstruction of the extent of an exposure and the exposed group of individuals is extremely difficult. Medical surveillance for current or recent exposures relies on a variety of methods, including questionnaires, physical examinations, and laboratory tests. Generally, biological monitoring and other lab tests are most useful in evaluating current exposure and often cannot be used years after exposure.

Surveillance of long-term health effects usually relies on electronic medical records and questionnaires. DoD inpatient and outpatient databases are powerful resources for surveillance; however, DoD can only track service members using electronic records until the time of separation. The MCS is a 21-year study of 150,000 service members, which is tracking their health status after separation from the military. DoD is improving its record keeping for environmental data, which will reduce misclassification of exposure and enhance the ability to evaluate long-term effects. Risk communication principles should be considered when reporting the results of surveillance. Often, there are several audiences who are interested in these results, in addition to military leaders and service members. Continued improvement of DoD’s environmental monitoring, medical surveillance, and risk communication should be a major outcome of this symposium. These functions are the three critical components of assessment of environmental exposures during deployments.

REFERENCES

Panel 2: Anticipatory Risk Assessment: Identifying, Assessing, and Mitigating Exposure Risks Before They Occur

Tee L. Guidotti, MD, MPH*; LTC Laura Pacha, MC USA†

ABSTRACT Health threats place the military mission and deployed service members at risk. A commander’s focus is on preventing acute health risks, such as diarrhea, because these quickly compromise the mission. However, in recent conflicts chronic and long-term illness risks have emerged as concerns. Department of Defense and Joint Chiefs of Staff mandates require documentation of exposures and environmental conditions to reconstruct exposures and evaluate future health risks. Current processes for identifying and assessing hazards, including identification and assessment before deployment and in time to take action to prevent or reduce exposures, when followed, are generally adequate for known hazards. Identifying and addressing novel, unexpected risks remain challenges. Armed conflicts are associated with rapidly changing conditions, making ongoing hazard identification and assessment difficult. Therefore, surveillance of the environment for hazards and surveillance of personnel for morbidity must be practiced at all times. Communication of risk information to decision makers is critical but problematic. Preventive Medicine (PM) personnel should take responsibility for communicating this information to non-PM military medical people and to military commanders. Communication of risks identified and lessons learned between PM personnel of different military units is extremely important when one military unit replaces another in a deployed environment.

BACKGROUND

Protecting health entails shielding warriors from unnecessary risks. By reducing their vulnerability, the uncertainties of military operations and the risks that missions will be compromised are reduced. Threats to personnel and to mission success that could be prevented or reduced, but are not, create a breach of trust with the warrior. Such breaches create environments of distrust and skepticism involving enlisted military members, their leaders, and military medical personnel. These breaches could also spark public suspicions of cover-up and negate attempts to accurately and effectively communicate risks and associated scientific findings regarding exposures and health.

A commander’s initial focus is on immediate or acute health threats, such as diarrheal diseases, because these can quickly compromise the military mission. Although outbreaks of acute disease still occur, public health interventions have reduced acute disease-related concerns, compared to past military operations. Acute disease threats must continue to be identified and addressed. Additionally, hazards that may cause long-term health effects and chronic diseases must be considered. Identification and evaluation of these hazards and their associated long-term risks have been challenging. After the completion of deployments, concerns about associations of medically unexplained illnesses and multiple, different negative health outcomes with deployment exposures have been difficult to evaluate. Often, available data and information provide, at best, weak or equivocal support for or against a direct association.

Concern and uncertainty relating to health outcomes following military deployments have led to support for anticipatory risk assessment, a prospective method for dealing with potential health hazards related to military deployments that will facilitate the early identification, assessment, and mitigation of hazardous exposures. Since the 1990s, there have been Department of Defense and Joint Chiefs of Staff mandates, periodically updated, to document exposure and environmental conditions for the purpose of avoiding or mitigating risks, reconstructing exposure scenarios and evaluating personal risk should an adverse health outcome later be suspected. To be effective the mandates need to be executed in all phases of military operations, to include the predeployment period, during deployment and after deployment.

DEPLOYMENT RISK IDENTIFICATION AND ASSESSMENT

Overall, Panel participants felt that there are processes in place for conducting deployment risk assessments, but challenges remain. The processes include: premission identification of known and potential hazards and preparations for dealing with these; deployment of personnel and entire units with the equipment and ability to identify and rapidly assess and react to hazards; morbidity surveillance of military forces before, during, and after deployment; surveillance of the
The primary objective of Panel 2 members was to address anticipatory risk assessment relative to human health. However, Panel participants recognized that accurate and timely hazard identification, risk assessment, and risk reduction or mitigation can serve many useful purposes. Table I lists eight reasons identified by the Panel for conducting anticipatory risk assessment and ongoing surveillance of military forces and their environment in conjunction with deployment. However, Panel members noted that sharp distinctions should not be made between deployment scenarios, military training exercises, and fixed military facilities, such as installations in the United States, with regard to the processes implemented to protect health and address potentially hazardous exposures.

Panel members identified four general areas of concern for surveillance and monitoring, hazard identification, risk assessment, and risk elimination or reduction. These areas could relate to fixed military installations in the United States or deployments in hostile, foreign territories. As the emphasis of the Panel was on military deployments, examples from deployment scenarios were identified:

1. Ambient conditions, to include water, food, and air quality, soil contamination, and waste management. An example of a recent concern is the potential impact on health of air pollution from burn pits used for waste management in Iraq.7
2. Threatening, unanticipated situations, such as troops coming in contact with potentially hazardous sites that had not been identified as such and evaluated for health hazards. In 2003, during Operation Iraqi Freedom, U.S. Forces provided security for the Qarmat Ali Water Treatment Plant in Basrah, Iraq, a site that was contaminated by a hexavalent chromium compound.8
3. Emerging situations that can significantly change the exposure and risk profile for a given area, the Kuwaiti Oil Fires during the First Gulf War being an example.9
4. Environments of uncertainty, which would probably include most military deployments in hostile, foreign territories, but could also include any area, even in the United States, where industrial contamination of soil and water may have occurred, but thorough risk identification and assessment had never been done.

In all of the above scenarios, ongoing monitoring for exposures and ongoing assessments of health and disease must occur and be documented with data on times and places of possible exposure. These practices are necessary to quickly identify and deal with acute health threats and to provide detailed records that may elucidate relationships between exposures and symptoms or diseases that appear many years later. Detailed, accurate documentation could contribute to the diagnosis of medical conditions that appear later in life and enable appropriate compensation based on fact.

Detailed discussions occurred with regard to anticipatory risk assessment activities that should occur before the deployment and during the deployment. Emphasis was also placed on the need for improved communication. Key points from discussions of these topics are summarized below.

**PREDEPLOYMENT PREPARATION**

Premission preparation of the deployment area or battle space can be partly accomplished through utilization of data, information and analyses from the National Center for Medical Intelligence, Fort Detrick, Maryland (available at https://www.intelink.gov/ncmi/ ; accessed January 18, 2011). The U.S. Army Public Health Command-Provisional, Aberdeen Proving Ground, Maryland (available at http://phc.amedd.army.mil/Pages/default.aspx; accessed January 18, 2011) also offers assistance with predeployment environmental surveillance, operational risk management, and health threat assessments.

Predeployment preparations are based upon descriptions of planned activities in specified geographic areas. The effectiveness of these preparations will be related to the completeness and accuracy of the descriptions of the planned activities and the geographic areas, and the availability of relevant data and information on the areas of interest. Unfortunately, predeployment preparation is often based on limited and uncertain operational information that may, and often does, change.

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**TABLE I.** Reasons to Conduct Anticipatory Risk Assessment, to Include Occupational and Environmental Health Surveillance, in the Deployed Setting

<table>
<thead>
<tr>
<th></th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Support the mission (to maintain the capability to meet the mission objectives)</td>
</tr>
<tr>
<td>2</td>
<td>Protect the individual</td>
</tr>
<tr>
<td>3</td>
<td>Document conditions to address perception and reality in the event of future known or suspected disease outbreaks</td>
</tr>
<tr>
<td>4</td>
<td>Foster distributive justice, so that compensation for meritorious claims can be based on documented exposures</td>
</tr>
<tr>
<td>5</td>
<td>Learning for the purpose of mitigation and prevention, to become proactive rather than reactive</td>
</tr>
<tr>
<td>6</td>
<td>Inform risk communication that is accurate, clear, and as certain as possible under the circumstances</td>
</tr>
<tr>
<td>7</td>
<td>Educate personnel on occupational and environmental assessment and mitigation; to comply with laws and mandates</td>
</tr>
<tr>
<td>8</td>
<td>Ensure that we are held accountable for only those international deployment legacy environmental problems we actually create and not contamination from other causes</td>
</tr>
</tbody>
</table>
Once military forces are on the ground. Nevertheless, predeployment preparations should be directed to provide the best possible risk identification and assessment information and the communication of this information to military decision makers who should use it to reduce hazardous exposures while accomplishing their mission. If predeployment assessments are integrated with other predeployment planning and effectively communicated to military decision makers, the decision makers may develop plans that will result in mission completion with avoidance of hazardous areas. Additionally, this predeployment information should direct efforts to educate military members about risk identification and avoidance and the implementation of protective measures. Such information also provides the basis for formulating meaningful morbidity surveillance and environmental sampling and surveillance plans for the deployment.

**SURVEILLANCE WHILE DEPLOYED**

Troops may be required to take positions in locations that were not identified before deployment, or they may encounter previously unrecognized hazards, such as abandoned industrial facilities, or they may find themselves coping with the contaminants from a military operation, such as an exploding enemy special weapons bunker.\(^ {10,11} \) Health risk assessments for exposures occurring in these unusual and sometimes unique situations are based upon joint military risk management doctrine.\(^ {12-14} \)

Outside the battlefield and other less-than-friendly deployment areas, these situations are addressed using various technologies (environmental monitoring, industrial hygiene monitoring, and hazardous materials evaluations) and methods, to include passive dosimetry. Threats and risks are assessed by standards and guidelines developed by the U.S. Environmental Protection Agency (available at [http://www.epa.gov/](http://www.epa.gov/); accessed January 19, 2011, Acute Exposure Guideline Levels and the Integrated Risk Information System), the Occupational Safety and Health Administration (available at [http://www.osha.gov/](http://www.osha.gov/); accessed January 19, 2011), and the National Research Council (NRC, available at [http://sites.nationalacademies.org/NRC/index.htm](http://sites.nationalacademies.org/NRC/index.htm); accessed January 19, 2011).

However, Panel participants recommended treating potentially hazardous situations similarly throughout the global military community, regardless of the type of operation. For example, consistent hazard evaluations should be followed and sampling equipment, supplies, and procedures should at least be similar, if not identical, or versatile and adaptable to different environments. If this consistency were to be achieved, the people who perform hazard identification, assessment, and communication would have little new knowledge to acquire about their equipment and sampling protocols as they moved from one type of environment to another.

For efficiency and effectiveness, environmental assessments should be standardized and coordinated across military theaters of operation. Panel participants viewed these assessments as currently fragmented. Joint service and combined service operations are becoming common, but training, skills, equipment, and procedures for environmental assessments and surveillance still differ among the services. An exercise to compare and contrast procedures among the services may be useful to identify best practices and opportunities for achieving consistency and interoperability without sacrificing mission-specific efficiency.

In general, the panel agreed that the currently available monitoring technology is adequate. Surveillance equipment, media, and kits are generally portable, lightweight, and reasonably complete and easy to use. However, technological improvements are needed and should be encouraged, to include making the instruments highly reliable even when these are being transported and used in the harsh environments in which the military operates. Additionally, the technology needs to be adaptable to identify new and unusual hazardous agents, not just those agents that are more commonly encountered. Unfortunately, as a result of the complexities of military acquisition systems and the bureaucracy of military training programs, instrument updates, acquiring new instruments and implementing the associated training currently take excessively long periods of time. New equipment does not reach the units that need it in timely fashion and the military schools are not training the operators of sampling equipment to use the current models.

The panel expressed concern that previously common problems such as drinking water quality are better controlled in today’s field situations such that prevention is nearly taken for granted at times, with a subsequent loss of focus on basic preventive medicine (PM) applications. The concern is that an unanticipated problem or a system breakdown may introduce unrecognized vulnerabilities that are not appreciated until morbidity occurs. One panel member recalled that a deployed unit that experienced a systems failure, resulting in an outbreak of diarrhea, was evaluated as having “successfully” managed the outbreak through education and hand washing. Although the intervention led to resolution of the outbreak, the episode actually represented a system failure because it should not have happened in the first place.

When unexpected potentially hazardous situations develop during deployments, an effective, rapid response must occur to identify and define the threat, develop recommended responses to the threat, and communicate this information to decision makers. Panel members thought that consolidation of the resources needed to perform these tasks in special units in the theaters of operation was not the appropriate response model. Panel participants generally felt that having trained, appropriately equipped, competent PM personnel stationed at lower level units would result in responses to concerns and threats. Additionally, these personnel and their capabilities should become known to the lower level unit leaders, which should increase the probability that they will be promptly notified if a potential hazard is identified, and their consultation would be more likely to be requested and considered by military decision makers.
COMMUNICATION

Risk communication is central to the work of military PM Officers and Environmental Science Officers. It is more than educating and persuading deployed personnel. Rather, risk communication is a basic skill set that is applied at different levels and includes effective peer-to-peer communication as well as informing superiors and subordinates. Military PM professionals and specialists must be able to articulate the relationship between occupational and environmental health and the military mission, clearly describe why health-related interventions are important, and provide meaningful justification for interventions using appropriate metrics and analyses. Risk communication training was viewed by the Panel as highly desirable, not only in the traditional dimensions of risk perception and clarity of communication, but also in terms of cultural awareness. Cultural sensitivity is obviously critical for transcultural communications within communities. It is just as important across the different cultures that constitute the U.S. military, to include the different uniformed services and various types of units, and their commanders. Unless commanders are convinced of the importance of acquiring and using hazard identification and mitigation information, and this process is seen as supporting the mission, opportunities to educate or train military personnel will be limited. It is therefore essential that commanding officers have clear understanding of the goals of occupational and environmental health, the relationship of occupational and environmental health to the mission, the interventions being proposed and how they might impact the mission, and the assets required to achieve mitigation of the hazardous risk. Lacking that understanding, military occupational and environmental health management will become marginalized.

Communication is especially important and often very difficult during periods when military units change over. During the replacement of one military unit by another, exchange of information relating to hazards and risks is imperative but often neglected. Information regarding the risk-related priorities that were established, the lessons that were learned, and the risks, particularly the novel risks, that were identified and assessed is critical to the incoming unit.

CONCLUSIONS

Armed conflicts are associated with rapidly changing conditions subject to uncertainty. These circumstances make it difficult to identify and evaluate exposure-related events. Therefore, planning, preparation, and vigilance during predeployment and deployment stages are essential. The identification and assessment of potential environmental exposures must be linked to scientific data relating to the hazardous substance, the circumstances of exposure, and actual health risks. Effective communication of the hazards and the risks to decision makers must occur if hazards are to be avoided or their risk mitigated. Post-deployment morbidity surveillance was recognized by the Panel as also being important, but was beyond the scope of the area of consideration assigned to the Panel.

REFERENCES

Panel 3: Conducting Environmental Surveillance Sampling to Identify Exposures

LTC Robert Batts, MS USA*; CPT Diana Parzik, MS USA†

ABSTRACT  Environmental sampling technology has improved significantly since Operations Desert Shield and Storm (Gulf War I, August 6, 1990–February 27, 1991). Deployment of U.S. Forces overseas and Joint Service operations have increased, and large numbers of troops are currently deployed for long periods of time. Concerns of adverse health effects from environmental exposures, similar to the concerns about exposures to oil well fires in Gulf War I, continue to occur today. Although progress has been made in developing Joint Service policies for training and conducting environmental sampling, the military doctrine that drives this training and allows for the purchase of updated sampling equipment has been slow to respond to changes, thus resulting in conflicts between current technology and assets available in the field. The military needs to remain flexible to new technology and new requirements, and must standardize doctrine and training across the services, and acquire standardized, state-of-the-art sampling equipment to improve field assets.

INTRODUCTION

Panel 3 participants addressed environmental surveillance sampling that is currently conducted by Department of Defense (DoD) personnel to protect Soldiers, Sailors, Airmen, and Marines, predominantly in a deployed environment. Environmental surveillance sampling is conducted during contingency operations to help identify or quantify potential hazards to which personnel may be exposed. Sampling is typically based on doctrinal or situational considerations, and the current conduct of such sampling varies widely for a number of reasons. Doctrinal sampling includes collection of baseline screening samples to identify the possible presence of hazards at a newly established base camp. This may include routine sample collection per policy, instruction, or other guidance, or directed sampling dictated by higher authority. Situational sampling occurs when preventive medicine (PM) assets identify a potential hazard for which environmental samples may be useful in determining the magnitude of the hazard or establishing an exposure pathway. Through a combination of training, command emphasis, and the development of sample collection methods and devices more amenable to contingency operations, the military PM community has greatly improved sample collection. To date, nearly 20,000 samples have been collected and sent to laboratories for analyses during Operation Enduring Freedom (OEF) (Afghanistan) and Operation Iraqi Freedom (OIF); (OEF began on October 7, 2001 and OIF started on March 20, 2003). However, much remains to be accomplished.

CURRENT PRACTICES

The military PM community has a large breadth of expertise and education levels ranging from high school graduates to people with doctoral training in a variety of fields including public health, entomology, industrial hygiene, and environmental engineering. The military PM unit may contain active duty, reserve, or National Guard personnel. Training levels within PM units can vary widely, with some personnel possessing little practical sampling experience and others being licensed professionals who were actively conducting sampling operations before deployment. During contingency operations, chains of command and traditional PM roles are mixed; e.g., Navy PM personnel may be performing an Army PM mission and reporting to a Marine commander. Also, equipment sets and predeployment training vary between services and between individual units. Training sets used before deployment may differ from sampling sets used during deployment.

Doctrinal samples with defined requirements, like drinking water surveillance samples and mosquito collections, are routinely acquired in most situations. Other sample collections, such as air samples for particulate matter, have become a routine practice at some locations. In the absence of objective oversight, some military PM people will routinely collect samples they are comfortable in collecting, whereas others will collect samples only when faced with a possible hazard concern. The collection of any sample or sample set is often a function of the inclinations of an individual PM person or a unit concern and tends to be leadership driven. Samples may also be collected as a matter of opportunity. For example, if a PM unit only gets to a base camp every other month, they will probably collect any samples they can reasonably collect.
on each trip. Situational sampling is highly dependent on individual personalities and abilities, and leadership interests.

The current best practice is for PM units to complete an occupational and environmental health site assessment (OEHSA) to document potential hazards (e.g., air, water, soil, noise, heat, radiation, and disease), potential pathways of exposure, and personnel who may be exposed at a specific site, and then identify means to mitigate the exposure hazards. The completed OEHSA should be used to develop an ongoing site sampling plan. Ongoing situational sampling efforts are determined by observations by PM personnel, complaints from troops regarding health or unusual events, review of historic site documents, and consultation with backup military surveillance units. Additionally, situational sampling may be directed by higher headquarters. Health concerns raised by service members who have returned home, concerns raised by families of deployed personnel, congressional questions, public concerns about situations raised anecdotally, requests for data to support epidemiological studies, and other issues can lead to command-directed, targeted sampling.

The results from sampling efforts are primarily assessed using risk-based models. These can be objective (e.g., potable water criteria are applied in a pass or fail manner) or subjective (e.g., evaluation of severity and frequency of exposure to determine the operational risk) processes. Samples analyzed in the field are typically used to assist in making immediate decisions (e.g., Can a water source be used for drinking water?). Because the time from sample collection to final results being available can be lengthy as a result of logistical issues, samples sent to a laboratory are commonly used only to document environmental conditions and to identify possible long-term health risks. Sample results may also be used to justify interventions, such as installation of water treatment equipment, and to determine the frequency and type of samples collected in the future.

Sucesses
The PM services of the U.S. military have initiated several strategies to improve the conduct of environmental surveillance sampling for U.S. service members during deployments, and this was successful in some areas. The services have worked to develop policies and doctrine to support environmental surveillance and facilitate PM units completing their environmental surveillance missions. Additionally, PM units from the Air Force, Army, and Navy have worked to integrate environmental sampling training as part of routine mission training for Airmen, Soldiers, and Sailors. Finally, deployable sampling equipment has been developed with reduced size, weight, and power requirements to facilitate sample collection at remote sites. Despite these initiatives and improvements, many significant problems and gaps persist.

ProblemS and Gaps
Pursuant to DoD Instruction 6490.03 and Presidential Review Directive 5, the U.S. military is required to assess exposures to environmental contaminants. To successfully complete this mission, military units need appropriate sampling equipment and adequately trained and available personnel. The panel discussed four categories of sampling and surveillance gaps that are highlighted below: (1) equipment and personnel, (2) education, (3) data management, and (4) doctrine.

Equipment and Personnel
Technology is constantly changing in environmental sampling equipment. Great strides have been made in recent years; however, the organic equipment that is currently fielded with most PM units is based on older technology, which often requires additional training and supplies. Additionally, the results obtained may be less accurate or precise than that which updated technology can provide. The equipment that is fielded with PM units is typically a predefined set, which may be inadequate or inappropriate for the sampling mission at hand.

The various services are operating more heavily in a joint environment; however, equipment and related training is not the same among services. There are vast differences between the equipment fielded by an Army PM detachment, a Navy Forward Deployed Preventive Medicine Unit (FDPMU), and an Air Force Bio-Environmental Engineering unit. Gaps in sampling equipment capabilities are often filled by the U.S. Army Public Health Command (Provisional) (USAPHC [Prov]), Aberdeen Proving Ground, MD, formerly known as the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM). These differences in equipment have led to inconsistent sampling and analysis capabilities within the theater of operations. Civilian sampling equipment is sometimes used, but usually is not designed to stand up to the harsh environments or rough handling found in a deployed setting. When civilian equipment is used in a military deployed environment, the lack of durability often leads to unreliable performance, to include problems with maintaining calibration.

Often, military PM personnel are not utilized appropriately within combat units and are assigned to other primary jobs, with PM tasks serving as a secondary focus. Stateside installations of environmental sampling functions are commonly conducted by civilians. Consequently, military PM individuals do not have a primary sampling function in garrison. This lack of garrison responsibility has fostered the assigning of additional duties to military PM personnel, which often become their primary responsibilities. When the unit deploys, the PM personnel are then expected to continue to function primarily in their additional duty, with PM tasks receiving little or no emphasis.

Education
Field commanders often are not aware of the function of their PM assets. This lack of understanding has led to the idea that PM is not an essential part of the military mission. The PM
community has exacerbated the problem by working primarily behind the scenes and not being an integral, visible, part of the operational and sustainment team.

Currently, there is not a doctrinal requirement for sustainment training in PM. Because of the rapidly changing field of sampling, military PM personnel are often not maintaining the knowledge base needed to meet sampling requirements on the modern battlefield. Standard institutional training, such as the Army’s Advanced Individual Training and Principles of Military Preventive Medicine course (6A-F5), is inadequate to keep up with the rapidly changing advances in sampling and analysis.

Army PM personnel are often trained as generalists and do not have a specialty in the PM realm. Because many of the PM domains have very specific skill sets (e.g., industrial hygiene, hazardous waste, water and wastewater management), specific specialization is an essential element needed in PM training. This is especially true in the officer corps. Unfortunately, those individuals who have a specialty in a specific PM domain cannot be easily identified because current skill identifiers are not associated with PM specialties.

Data Management

Because of the distance between the theater of operations and the continental United States, where specimens must often be sent for analyses, it is difficult to receive the results of sampling in a timely manner. This delay leads to data that is not actionable and is useful primarily for historical documentation and archiving. The data and recommendations that are generated are often met with skepticism by the general population and civilian scientific community because military reports tend to be DoD-centric and are not typically subjected to peer review.

The process for management of theater-derived data is often not adequate enough to ensure proper archiving. The lack of a comprehensive and enforced data reporting and archival process results in data gaps that are difficult to be filled because historical data is often lost when units rotate out of theater. Identification of specimen collection sites is also a problem since bases in theater often have had several names throughout their existence. This lack of continuity leads to fragmented data sets and data that cannot be paired to an existing base. The issue is compounded when different services have different names for the same base.

Some sampling results and risk assessments are classified and often must be archived in a secure system. This makes accessing historical data exceedingly difficult, particularly for company level personnel without access to a secure computer system. Often requests are received for data that are classified, and the reports must undergo a lengthy declassification process before the data are released.

Doctrine

Doctrine must be standardized throughout each service and across services, and should cover personnel, equipment, training, and communication. Examples of where doctrine is needed or is inadequate are dispersed throughout this report. Panel participants also provided an important example where attention must be given to the need for PM support doctrine in an operational setting. Each Army Brigade Combat Team (BCT) is allocated to PM resources. This is not true for all military units. When the BCT role is filled by another type of unit, such as a Fires Brigade, there are no PM resources. This lack of PM assets creates a capability gap that must be filled by another unit with PM assets or by a higher headquarters.

SOLUTIONS

Near-term Solutions

The first and foremost near-term solution is better education. This should be multilevel and targeted at operational line officers, physicians, combat medics, corpsmen, and technicians to gain a better understanding of the concepts at hand. An example might be a teaching module for officer and non-commissioned officer staff schools which addresses the role of PM assets in achieving success in military operations, as well as the proper utilization and deployment of PM assets. Emphasis on education is especially needed at tri-service medical and medical service corps officer basic and advanced courses.

Special Operations, engineering assets, and scout units are often deployed near military PM units. These units cover large areas as part of their mission and obtain considerable information, information that may help in locating and assessing environmental hazards. There are historical examples of these units providing early and accurate warning of potential environmental hazards. Frequent communication between PM and other military units that may have important information must be encouraged.

The Navy FDPMU and Army Area Medical Laboratory (AML) are outfitted with equipment that is not typically found in the lower echelon military PM units. This equipment may provide additional analytical capabilities to enhance the turnaround times from sample collection to the delivery of actionable data. The FDPMU and AML may also be a source of additional PM personnel should additional resources be required in-theater. All military PM personnel must be knowledgeable about the presence of FDPMU and AML units in their areas and the capabilities of these units, and they must establish effective lines of communication with them.

As technologies for sampling advance, the military PM community can capitalize on many of the advantages found in modern sampling techniques. For example, passive air sampling techniques have proven to be a valuable alternative to the traditional active sampling using air pumps and tubes. These newer techniques can provide validated results and their simplicity may encourage military PM personnel to employ air sampling techniques despite not having a high degree of training.
**Long-term Solutions**

Long-term solutions were identified in the following categories: equipment, training, communication, personnel, and doctrine. Differences in equipment and capabilities between services and between different units, charged with the same mission, must be addressed through a comprehensive system to continually evaluate new equipment and make recommendations to DoD for acquisition within a reasonable amount of time. Training programs and supply channels will require additional flexibility to more rapidly integrate new equipment.

Environmental hazard identification and assessment training should be integrated in general military training for nonmedical personnel, and provided in depth for military environmental health professionals. The importance of PM must be stressed to leaders in all the military services. Integrating PM principles into all aspects of training can create a culture of hazard recognition, assessment, and prevention similar to efforts made for training service members on how to deal with potential chemical weapon attacks. Increasing the acceptance of using PM assets to identify and assess hazards and estimate risk will result in better informed leaders who can make sound decisions in austere conditions. Providing a standardized approach to environmental surveillance and sampling across the DoD will aid military PM professionals in accomplishing their mission of effectively communicating hazards and risks to unit commanders.

Even though training will improve the ability of PM professionals to design sampling plans and interpret results to formulate hazard and risk assessments, these efforts will be lost if they are not properly communicated to decision makers and nongovernment peers. By educating all service members on the importance of PM and providing training on risk communication for PM professionals, the communication of risk and hazards should be improved throughout the DoD. Additionally, military PM professionals must make a concerted effort to communicate new methods, findings, and results to non-DoD PM professionals in peer-reviewed journals. This effort needs to be promoted by the military PM leadership. Service members must be encouraged and assisted in preparing scholarly manuscripts. By publishing in peer-reviewed journals, military PM professionals will gain greater acceptance and credibility in the global PM community.

The last long-term solution to be addressed is the issue that likely must be addressed first. Changes in doctrine will need to precede changes in equipment, training, and communication. The doctrine that is the basis for training and equipment purchases must be flexible and updated to meet changing technology and changing needs. Doctrinal changes in equipment evaluation, procurement, integration, and training should be made to increase service and unit interoperability. Policy makers must balance the need to remain flexible for situations that cannot be anticipated with the need for detailed guidelines for the training and equipping of a unified DoD PM professional corps. This corps must be capable of meeting exposure assessment and risk communication needs in austere and rapidly changing conditions.

**SUMMARY**

Sampling equipment, personnel, and methodologies vary widely between services and between units. These disparities often lead to a patchwork of PM capabilities within the theater of operations. Although standardizing capabilities throughout the spectrum of the entire PM community, both between services and within the echelons of PM services, may help to curb some discrepancies, this may not be enough to fully synthesize environmental surveillance sampling. Doctrinal changes that emphasize training, education, and equipment procurement need to be implemented across services in order to realize a unified DoD PM effort that will benefit the warfighter and serve as a force multiplier.

**REFERENCES**


INTRODUCTION

In 2000, the Institute of Medicine (IOM) published a report, Protecting Those Who Serve: Strategies to Protect the Health of Deployed U.S. Forces, reviewing the problems associated with identification, mitigation, and tracking of chronic health consequences associated with deployments. In this report, six strategies were recommended to the Department of Defense (DoD) pertaining to: prospective evaluation of nonbattle-related risks associated with deployment; collection, management, and analysis of environmental data, personnel locations, predeployment and post-deployment biological samples, and activity data; development of risk assessment, management, and communication by military leaders; acceleration of health surveillance spanning the service lifecycle (to include post-separation); addressing medically unexplained symptoms; and implementation of a joint computerized patient record to support individual care and military public health needs.

To discuss progress made toward implementation of strategies to address similar issues in current combat operations around the globe, the Armed Forces Health Surveillance Center (AFHSC) and Uniformed Services University of the Health Sciences sponsored an educational symposium on Assessing Potentially Hazardous Environmental Exposures Among Military Populations. The meeting provided an opportunity for stakeholders and policy makers to review key historical information in areas related to this subject, discuss current policy, and identify future initiatives. In small group sessions, one area of focus centered on linking individual service members and environmental exposure data to assess health risk. Discussion included describing the current Department of Defense approach to this issue, successes, problems, gaps, near future solutions to overcome gaps, and identification of those problems and gaps for which there are no easy, foreseeable, or near term solutions available. A summary of the discussion and determinations from this focus group is provided.

ABSTRACT

On May 19 to 21, 2010, the Armed Forces Health Surveillance Center and Uniformed Services University of the Health Sciences cosponsored an educational symposium on Assessing Potentially Hazardous Environmental Exposures among Military Populations. The meeting provided an opportunity for stakeholders and policy makers to review key historical information in areas related to this subject, discuss current policy, and identify future initiatives. In small group sessions, one area of focus centered on linking individual service members and environmental exposure data to assess health risk. Discussion included describing the current Department of Defense approach to this issue, successes, problems, gaps, near future solutions to overcome gaps, and identification of those problems and gaps for which there are no easy, foreseeable, or near term solutions available. A summary of the discussion and determinations from this focus group is provided.


CDR Mark Riddle, MC USN*; CAPT Mark Lyles, DC USN†

*Naval Medical Research Center, 503 Robert Grant Avenue, Silver Spring, MD 20910.
†U.S. Naval War College, 686 Cushing Road, Newport, RI 02841-1207.
Panel 4 Leaders: CDR Mark Riddle, MC USN; CAPT Mark Lyles, MC USN

Panel 4 Participants: Col Michael Butel, USAF BSC; COL Joel Gaydos, MC USA (Ret.); Jack Heller, PhD; Tomoko Hooper, MD, MPH; Mary Paxton, PhD, MSc; MAJ Christopher Perdue, MC USA; Susan Proctor, ScD; Christopher Rennix, CIH, ScD; Besa Smith, MPH, PhD; Tyler Smith, MS, PhD; Kevin Ulmes, BS, PE; Lt Col Jay Vietas, USAF MC; MAJ Duval White, MS USA; CPT Sarah Barbo, MS USA; MAJ Chanda Maneval, MS USA

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assess current deployment-related exposure at the individual by place (longitude and latitude) and time, our ability to perform epidemiological analyses to investigate associations between specific deployment-related exposures and potential health outcomes. To critically evaluate this data linkage strategy, a fundamental understanding of relevant data systems and their accessibility is necessary.

Personnel tracking is both service and unit specific; there is variability in the ability to precisely locate an individual at any given time. Past and current epidemiologic research efforts have been limited by problems with deployment tracking related to location accuracy, completeness of data, and access issues as a result of the classified nature of these data. Data on country location are unclassified, but more specific data on individual and daily unit location are available as classified information only. Troop location data differ slightly by Service and are based on either longitude and latitude, 6-digit map grid coordinate, or camp and base to which an individual is assigned. Accessing these data for research purposes through ongoing deployments is a significant hurdle for researchers; furthermore, detailed daily individual location data within the theater is unknown as some personnel assigned to a camp leave the camp on daily missions whereas others rarely leave at all.

Beyond the ability to precisely identify location of an individual by place (longitude and latitude) and time, our ability to assess current deployment-related exposure at the individual level was explored by the group. Environmental monitoring and self-reported exposure data were considered. Self-report data has been used widely in the past; current ongoing self-report surveillance of both exposures and health outcomes is conducted through the Post-Deployment Health Assessment and Post-Deployment Reassessment surveys (PDHA and PDHRA/DD 2975 and 2976), obtained from each service member returning from a deployment, and the triennial surveys of Millennium Cohort Study (MCS) participants.

Deployment-related environmental exposure data can be categorized as routine surveillance (e.g., for assessment of unknown exposures), or incident or event response (e.g., “known” exposure of interest); the strategies, policies, and practices associated with each of these activities are very different. Currently, environmental monitoring data collection (e.g., soil, air, and water) varies among Services and deployment settings with respect to sampling uniformity, sampling protocols, laboratory protocols, equipment, personnel training, and database access. However, the assessment of exposure risk is conducted consistently throughout the DoD, and encompasses possible exposure pathway, exposure route (inhalation, ingestion or absorption), and potential dose. In addition to these ongoing surveillance efforts, ad hoc exposure data collection efforts occur in response to hazardous incidents or events, and provide valuable exposure data (e.g. Kuwaiti oil well fires, burn pits, and dust exposures). Currently, environmental sampling during deployments is conducted at the population level only. The lack of personal environmental monitoring allows for a great deal of misclassification at the individual level.

Health outcome data for active duty service members are obtained from several sources including electronic medical encounter data from the Defense Medical Surveillance System (DMSS) and the Theater Medical Data Store (TMDS), self-report through PDHAs and PDHRAs (PDHRAs/DD 2900), MCS questionnaires for participants, and disease registries. Although each of these resources provides valuable information, they also have their own limitations and present different challenges with respect to exposure and outcome misclassification when used for research purposes.

Military environmental epidemiology not only attempts to close the link between exposure data and health outcomes, but also attempts to do this for deployed troops, making the task even more difficult. Exposure assessment is a major limitation in determining causality. This problem extends through all of epidemiologic research but is an even greater obstacle in environmental epidemiology, in which measuring environmental exposures at the individual level is always challenging. Using population-level environmental sampling data as a proxy for individual exposure, the ability to link service members’ personal health information to multiple platforms of personnel, demographic, occupational, and exposure data is currently possible through the use of Social Security number as the unique identifier. Although not perfect, this capability provides DoD researchers the ability to conduct timely and efficient investigations based on previously collected data to...
address questions important to active duty military members and veterans.

**SUCCESSES OF CURRENT METHODOLOGY**

There have been several past successes in the DoD’s ability to link individual service members’ health and personnel data to deployment exposures in the determination of health risk. These include the DoD response to potential exposures relate to the 1991 Gulf War oil wells fires and the Khamisiyyah munitions demolition. During these instances, potentially hazardous exposures were identified through routine environmental sampling; once the hazard was identified, steps were taken to retrospectively identify a representative sampling of potentially exposed service members and to ascertain the level of exposure. These situationally-dependant steps included quantifying the exposure through additional sampling, physical exams, collection of blood and urine samples to determine level of exposure via biomarkers, review of electronic medical encounters, and geographic assessment of exposure.

One particular success that was mentioned in the course of discussion that deserves further discussion is the MCS. This is a 21-year prospective cohort study designed specifically to investigate how military service, particularly deployment, may affect the long-term health of U.S. service members. Over 150,000 participants have been enrolled since 2001 in this large, population-based cohort of individuals representing all military service branches and including regular active duty, Reserve, and National Guard personnel. A detailed description of the methodology is further described elsewhere; briefly, MCS subjects complete a baseline survey at enrollment and are subsequently contacted at scheduled 3-year intervals to complete a follow-up survey (planned to continue through 2022). The questionnaires include specific questions on diagnosed medical conditions, symptoms, psychosocial factors, physical and functional status, sleep patterns, tobacco and alcohol use, deployment experience, military exposures and occupations, and basic demographics. Many MCS survey questions are from standardized survey instruments, such as the Medical Outcomes Study Short Form 36-item Questionnaire for Veterans (SF-36V), the Patient Health Questionnaire (PHQ), and the Posttraumatic Stress Disorder Checklist-Civilian Version (PCL-C). These standardized instruments included in the questionnaire have been shown to be internally consistent and reliable. Additionally, one of the unique aspects of the MCS is that exposure and health outcome assessments (self-reported) continue to be ascertained even after service members leave active duty.

Other notable successes are the establishment of the AFHSC and the DoD Serum Repository (DoDSR). The AFHSC is the central epidemiological resource for the U.S. Armed Forces and provides routine and ad hoc analyses, including interpretation and dissemination of information regarding the status, trends, and determinants of the health and fitness for U.S. military populations. The DoDSR was established in 1989 and is maintained by the AFHSC for the purpose of storing serum specimens following mandatory HIV testing within the active and reserve components of the Army, Navy, and Marines. This inventory of over 50 million specimens is the largest of its kind in the world and is a rich resource for clinical- and sero-epidemiologic investigations.

Personnel tracking systems during deployment has also improved dramatically since the first Gulf War. The Defense Manpower Data Center (DMDC) is the central DoD repository for tracking personnel involved in contingency operations; the continually evolving system receives data from Defense Theater Accountability System–Army (DTAS), Secure Personnel Accountability–Marines (SPA), Deliberate and Crisis Action Planning and Execution Segments (DCAPES), Joint Personnel Accountability Reconciliation and Reporting (JPARR), and other tracking systems developed for government civilian personnel and contractors.

**IDENTIFIED PROBLEMS AND GAPS**

While significant progress has been made in initiating and maintaining the broad range of data systems required to link multiple platforms for health outcome and exposure assessment, a number of limitations remain with respect to the DoD’s ability to adequately link data on individual service members to currently available exposure assessments for the purpose of scientific research. These limitations were noted throughout the symposium and were further elucidated within the focus group. Improvements in these critical gaps are vital to the appropriate investigation of the relationship between potential environmental hazards during deployment and their possible health outcomes.

Exposure-related gaps noted were the inability to easily capture personal exposure data and lack of real-time exposure assessments. Currently, environmental monitoring data used for research is linked to place and time at the population level; environmental data come from multiple sources, does not provide information on individual dose, and allows for a great deal of misclassification. One of the most promising developments in improving individual exposure assessment is the exploration of exposure biomarkers and the availability of data in the DoDSR. Through the gradual inclusion of the latest biotechnologies, a more precise determination of exposure and internalized dose will be permitted, at least in cases for which there are known exposure biomarkers. The group also noted that routine urine sampling for major deployments for which there is an anticipated threat of chemical exposures has not been implemented as recommended by the IOM (Fig. 1, recommendation 2.3).

Health outcome-related gaps included assessment of long-term health outcomes for those who have separated from the military and among Reserve and National Guard members; ascertainment of baseline health status of deploying personnel outside of the predeployment health assessments and MCS are positioned to help fill these gaps.
Several gaps pertaining to current DoD structure and policy were noted. The lack of standardization across Services in core environmental and occupational activities, e.g., environmental sampling, and the need for more adequately trained and experienced environmental and occupational health personnel were both cited as major deficiencies. Reliable risk assessments often require trained personnel on site who can recognize potential health hazards and have the requisite skills, abilities, and resources to initiate appropriate exposure hazard assessments in the deployed setting. It was thought that there was an overall lack in both DoD subject matter experts to recognize potentially hazardous exposures and possible health consequences. A doctrinal deficiency cited was the inadequacy of funding for research and technology development programs. It was mentioned that there is no defined Research, Development, Technology and Evaluation (RDT&E) program for environmental health research, similar to those for other deployment-related health threats, such as combat casualty care and infectious diseases. A prime example of this research need is the development and fielding of technology to support individual exposure assessments, to include individual chemical dosimeters for toxic industrial chemicals and the development of a suite of validated exposure biomarkers. Though research collaborations in this area between DoD, academia, non-DoD governmental agencies, and other organizations are ongoing, further improvement can be made to expand scientific capabilities and credibility.

Another current limitation is the gap between expectations and results. Many external partners and stakeholders, including politicians, special interest groups, and leadership within the DoD have expectations that cannot reasonably be achieved with the available resources, technologies, and current access to data. Using current technologies a high level of precision in measuring chemical, physical, and biologic agents is possible in the ambient environment. However, causally linking potential exposures to specific environmental hazards to short-term and long-term health outcomes, whereas also considering other nonenvironmental exposures (e.g., stress) and accounting for these exposures over multiple deployments is very challenging. The expectation that valid, definitive answers should be readily available is impractical now and in the near future. The severe limitations in quantifying individual exposure levels present a great deal of uncertainty surrounding who is exposed and what the actual internalized dose is, and this preclude any definitive determination of potential health risks for populations and individuals.

IDENTIFIED SOLUTIONS

The group attempted to address each identified limitation with a solution, with the feasibility of solutions categorized as (1) foreseeable in the near future (2–3 years) and (2) no foreseeable solution or taking many years to resolve.

To address the need for personal exposure data, the group agreed that feasibility studies of exposure biomarkers should be initiated in the near future (for infectious diseases and long-lived stable chemicals, such as dioxins and furans); these studies could be conducted on existing samples in the DoDSR and a DoD wide survey study similar to the National Health and Nutrition Evaluation Survey (NHANES) biomonitoring of chemical exposures could be developed. There was clear agreement that better assessments of individual exposure could be obtained through these types of technologies and studies, and that agencies within the DoD could conduct this type of study if funding were provided. An example of progress in this area is a deployable real-time dosimeter for naphthalene that has been developed over the past few years. This rugged, wearable dosimeter is intended to measure individuals’ exposures to naphthalene, a toxic component of jet fuel propellant 8 (JP8); JP8 currently represents the single largest source of chemical exposure to DoD personnel. A field validation test of a prototype is planned for the near future.

To address health outcome-related gaps, it was agreed that mutual data sharing between DoD and Veterans Affairs health systems should be continually encouraged in order to better understand chronic health problems among service members that have separated from active duty. Study-specific efforts are underway to pave the way for a more formalized and efficient data sharing arrangement between these government agencies.

Additional proposed short-term solutions included the following: increasing training and education of personnel in the area of environmental and occupational health, exposure assessment, and epidemiology; leveraging continued efforts to reduce negative health behaviors such as tobacco smoking and alcohol misuse; instituting objective PDHA/PDHRA for select health conditions; standardized documentation of deployment-related environmental and occupational exposures within medical records (link digital exposure information to PDHAs and PDHRAs); development of a DoD-wide consensus for sampling and analysis (through the existing Joint Environmental Surveillance Working Group); partnering with experts and organizations outside the DoD to develop advanced strategies; and improving communication and exchange within DoD and among its partners through multiple venues, such as this symposium.

Lastly, successful collaborations between DoD scientists and external experts in academia and other governmental agencies were identified. Examples of successful past collaborations that have led to enhanced scientific research capabilities include the U.S. Geological Survey and the U.S. Army Corps of Engineers, Health Affairs and the National Institutes for Environmental Health Sciences, and the U.S. Army Public Health Command and the Centers for Disease Control and Prevention (CDC).

Although several short-term solutions were identified, it was also recognized that many of these were difficult to implement. Theater-wide individual exposure data, electronic personnel tracking systems in theater, technology solutions for tracking individual personnel locations, and direct-reading
CONCLUSION

The problems related to linking individual service members and environmental data to determine health risk will continue to be a major concern as long as service members are exposed to new and potentially hazardous environments. While difficult problems continue to face researchers in this area, significant progress has been made in the last 20 years and since the publication of the 2000 IOM report. Major advancement in this area depends on the continual development of environmental sampling methodology, exposure biomarker assays, troop location and activity databases, electronic medical record, and other relevant databases that can be linked together. Although much of the required data is classified, the concept of linking via electronic databases is in many ways already achievable through the use of Social Security numbers. The next step is to provide information in an unclassified environment that allows for rapid and efficient database linkages and assessment of potential health hazards to allow questions of concern to military service members and veterans to be answered quickly and reliably.

Despite progress, the integration of expertise in the nuclear, biological, chemical, and environmental health sciences for efficient environmental monitoring for short- and long-term health risks has not been widely incorporated by the Services, nor has a joint system for recording, archiving, and retrieving troop location information. While the DoDSR could potentially provide a significant amount of data, our scientific capacity to measure individual internal dose related to environmental exposures through serum assays is currently limited.

It is hoped that the result of this symposium and deliberations of this focus group will result in or strengthen further partnerships between DoD and other federal agencies, as well as academic institutions, in order to enhance routine health surveillance, incident response, and hazardous exposure assessment. There is a clear need for strong policy changes within the DoD to improve in-theater tracking of personnel location, documentation of individual level exposures, and short- and long-term health outcomes. There is a great deal of future work in terms of application of current knowledge, research, and development of novel technologies; this can only be accomplished by increasing the number of trained personnel with requisite skills and knowledge in relevant environmental and occupational disciplines. It is hoped that the deliberations described herein may serve as a record of progress made to date and benchmark, describing where we’ve been, where we are now, and where we need to go in the future to better serve those in harm’s way.

REFERENCES

Panel 5: Educating Leaders on Identifying and Mitigating Environmental Exposure Risks

MAJ Joseph J. Hout, MS USA*; Col Alvin L. Young, USAF (Ret.)†

ABSTRACT Rapidly identifying and appropriately reacting to potentially hazardous environmental exposures could result in the mitigation of adverse health effects, accurate documentation of the exposures leading to reliable assessments of the risks associated with the exposures, and records of those actually exposed and the extent and duration of their exposures. As a panel, we addressed the questions of who should be educated, why they should be educated, what their education should consist of, and when the educational activities should occur. Our panel concluded that within the Department of Defense global community, education on potentially hazardous environmental exposures must start with and be grounded in the military Preventive Medicine (PM) professional community. Members of the military PM professional community must develop the skills needed to educate military non-PM medical and non-medical leaders, and they must actively assume their roles as educators. Panel 5 participants identified computer-based education as a means of disseminating teaching materials on environmental risks among military members as they move through the different phases of their careers.

INTRODUCTION
During May 19 to 21, 2010, Panel 5 participants addressed the issue of how best to educate military and civilian leaders whose decisions impact military forces on identifying and mitigating environmental exposure risks. Studies have been conducted on the quality and quantity of policy makers scientific literacy in the United States. These studies showed that many leaders frequently have only a limited understanding of the processes or methods of science, and an equally limited vocabulary of scientific and technical terms and concepts, especially concepts related to environmental risks. Our military and civilian government leadership must have this basic understanding if there is to be a sustained and meaningful dialogue on scientific and technical issues, and to understand the potential impact of environmental exposure risks on military populations. However, it is clear that when science is used as the basis for policy decisions, it invariably becomes entwined with social considerations. This is because policy-relevant scientific data are often produced under extraordinary constraints of time, money, and politics, especially when it involves military populations that are at risk during military operations. Nevertheless, it is also crucial that military populations trust their leaders to protect their health and their common economic well-being.

The Panel members identified four questions relevant to our topic:

1. Whom should we educate on identifying and mitigating environmental exposure risks?
2. Why should we educate leaders on identifying and mitigating environmental exposure risks?
3. What message do we convey to leaders about identifying and mitigating environmental exposure risks?
4. When should we educate leaders on identifying and mitigating environmental exposure risks?

WHOM SHOULD WE EDUCATE?
In a perfect world, all service members and civilians would be educated in the art of identifying and mitigating environmental exposure risks. However, we are currently faced with the challenge of communicating environmental risks to leaders who do not fully understand the public health implications associated with many environmental exposures. The panel concluded that two target audiences, military Preventive Medicine (PM) professionals and non-PM leaders must be educated on the subject if we are to effect change.

Education must start with PM professionals, who are often responsible for communicating risks and mitigation strategies to personnel who are not well versed in the science behind environmental exposures. This military PM audience includes Army Environmental Science and Engineering Officers (ESEOs), Air Force Bioenvironmental Engineers (BEEs) and Public Health (PH) Officers, Navy Environmental Health Officers (EHOs), PM health care providers, Army PM Technicians, Air Force BEE and PH technicians, and Navy Corpsmen. It is imperative that these professionals are properly trained to convey clear, concise, and consistent messages...
that can be applied in a joint service environment. Without providing a unified, tri-service response on how to identify and mitigate environmental exposures, we face the reality of conflicting information that will result in confusion on a joint battlefield. Once this level of training has occurred, PM professionals should have the tools necessary to educate our second target audience, the non-PM leaders.

Many times it is non-PM leaders that are charged with making the ultimate risk decision in both the garrison (installation) and field environments. These leaders, consisting of officers, noncommissioned officers, and civilian counterparts, make decisions based upon the impact on mission accomplishment and the risk of human disease and injury. It is critical that they are educated by our PM professionals to understand environmental exposure risks, the associated health outcomes, and how these outcomes can affect not only the mission, but the lives of their personnel in future years.

WHY SHOULD WE EDUCATE LEADERS?

It is important that we educate leaders on the identification and mitigation of environmental hazards for four reasons. The first is to prevent risk decisions that unintentionally jeopardize human health. Most leaders are well trained to make decisions based upon future exposures to chemical, biological, radiological, and nuclear (CBRN) agents. However, the majority of military training does not provide our non-PM leaders with the consequences associated with unique exposures to toxic industrial chemicals and materials. Another reason for educating leaders relates to understanding the complexities of exposure science. Outcomes of exposures to agents can result in a range of responses, from no observed effect to death or incapacitation of an entire unit. Leaders must appreciate the nature, magnitude, and potential adverse outcomes associated with the risk posed by environmental exposures. Third, leaders must realize that the identification and mitigation of environmental hazards will not only reduce exposure and expenditures of money, equipment, and time, but will also, and very importantly, enhance mission accomplishment. The fourth reason for educating leaders on environmental hazards relates to legal issues. Leaders must recognize that there is a legal requirement to maintain the health and well-being of the men and women under their command.

WHAT MESSAGES DO WE CONVEY?

Non-PM leaders are accustomed to making risk decisions based upon the given risks impact mission accomplishment or readiness. Therefore, PM professionals must be able to translate environmental exposure hazards into something meaningful, the probability of mission success or failure. The U.S. Army Public Health Command (Provisional), (USAPHC-P, formerly the U.S. Army Center for Health Promotion and Preventive Medicine), Aberdeen Proving Ground, MD, published Technical Guide 230, Short-Term Chemical Exposure Guidelines for Deployed Military Personnel, which helps translate environmental exposures into meaningful risk assessments that can be understood by leaders.

In conjunction with conveying the risk, PM professionals must also be able to provide leaders with feasible, suitable, and acceptable methods to mitigate risks associated with environmental exposures. This includes informing leaders of assets they have at their disposal to develop mitigation strategies. These assets include: the USAPHC-P; the Navy and Marine Corps Public Health Center, Portsmouth, VA; the U.S. Air Force School of Aerospace Medicine, currently at Brooks City-Base, TX, but relocating to Wright-Patterson Air Force Base, OH; the National Center for Medical Intelligence, Fort Detrick, MD; the Centers for Disease Control and Prevention, Atlanta, GA; the Deployment Health Clinical Center, Washington, DC; Navy Environmental Preventive Medicine Units in Pearl Harbor, HI, San Diego, CA, and Norfolk, VA; Army PM detachments; Army medical laboratories; and other organic military PM assets.

WHEN SHOULD WE EDUCATE LEADERS?

The panel agreed that education must start at the institutional level (e.g., basic combat training, the basic officer leadership course, and professional development schools) and continue throughout a military member’s career. The concept of identifying and mitigating environmental exposures must be engrained in a service member’s mind early in their career, before they are charged with making decisions that impact the health of their troops. From the above military training institutions, educational responsibilities could be delegated to unit level training programs, such as Noncommissioned Officer Professional Development and Officer Professional Development programs. It could further be reinforced through quarterly briefings and annual common task training. For units requiring additional training, USAPHC-P offers Technical Assistance Visits, where they deploy a team of PM professionals to train units on environmental exposures and risk mitigation. Additional training on how to identify and mitigate expected exposure risks could be included in the required country specific health threat briefing given to all deploying personnel.

Feedback from institutional and unit training, and from deployments, is essential to create a product that can evolve as we face new and unexpected exposures. The method of training delivery could be determined by the specific topics to be covered and learning objectives, and could include a combination of didactic and hands-on training exercises that highlight the impact of environmental exposures on both the individual and the military unit.

Computer-based education (CBE) provides a technology for training delivery that can occur in a variety of settings. CBE is often based on PowerPoint presentation, a computer program widely available in military commands. Educational topics for environmental CBE could originate from existing programs, such as the USAPHC-P Global Threat Assessment.
Program to identify and assess deployment and environmental health hazards world-wide. Small CBE modules could focus on specific need-to-know information for deployed units or more general information for quarterly briefings or annual training. CBE modules would facilitate rapid electronic distribution of environmental risk information at all stages in a military member’s career.

CONCLUSIONS
Mitigating the effects of potentially hazardous environmental exposures requires leaders who recognize these exposures and their threats and take appropriate action. Panel members uniformly agreed that (1) education is the foremost step in ensuring environmental exposure risks are completely understood, and that (2) environmental risk education is not the exclusive domain of the PM community. Ultimately military PM professionals must be able to convey concepts about environmental exposure and risk communication to each other and non-PM leaders. Assigning this task to the PM community should help to ensure that non-PM leaders will have the appropriate background knowledge to make well-informed, risk-based decisions because PM professionals will have the responsibility to keep them informed.

Education in recognizing and mitigating environmental hazards is needed in all services, for all military specialties, and at all levels in a service member’s career. The most effective training would begin early in a service member’s career and be maintained throughout that career. Effective leader training would appropriately relate environmental exposures to the mission and focus on safe mission accomplishment. The Panel agreed that the environmental risk recognition and assessment capabilities of PM personnel in all uniformed services must be promoted and emphasized. Making military leaders aware of military PM professionals and units and their capabilities should facilitate their effective use. CBE using PowerPoint presentations and web-based software are examples of technology that can deliver focused and timely PM messages to a wide audience in a variety of military scenarios. Overall, the educational messages delivered must be consistent and presented in such a way as to demonstrate that, as always, a leader’s concern is both mission accomplishment and the health and welfare of everyone involved.

REFERENCES